Impacts of paludiculture on the natural environment: a scoping report

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Broadleaf cattail *Typha latifolia*, a potential paludiculture crop (Travis Juntara, Flickr, CC BY 2.0); Drainage sluice, Newborough Fen, Peterborough (Rodney Burton, geograph.org, CC BY-SA 2.0); Marsh warbler *Acrocephalus palustris* (Pierre-Marie Epiney, Flickr, CC BY-SA 2.0); *Sphagnum papillosum* in cultivation at Universität Greifswald, Germany (Leonhard Lenz, Wikimedia Commons, CC0); Paludiculture trial site in Norfolk, England, with celery growing in the foreground (Nigel Taylor, CC BY-ND 4.0).

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Disclaimer

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Executive summary

Paludiculture – the productive land use of wet and rewetted peatlands – is gaining attention in England as a land use option that can extend the commercial life of drained lowland peatlands whilst simultaneously reducing greenhouse gas emissions. However, there is relatively little consideration given to the impacts of paludiculture on other aspects of the natural environment.

This report provides an overview of (a) observed and potential impacts of paludiculture on the **natural environment**, specifically soils, hydrology, water quality, biodiversity, and landscape character and heritage, (b) management options to minimise negative and maximise positive impacts, (c) open research questions and knowledge gaps related to these impacts, and (d) strengths, weaknesses, opportunities and threats related to paludiculture and its impacts on the natural environment. The focus is on English lowland peat landscapes. As a **scoping report**, it provides a range of ideas and options, but these are not comprehensive and are not to be taken as recommendations (without further research).

Paludiculture is likely to have **mixed effects** on the natural environment, depending on the **outcome considered** and precisely **how it is implemented**. Many intrinsic features of paludiculture could lead to desirable or undesirable impacts, depending on the context. Outcomes on different aspects of the natural environment are inherently linked. Some major impacts include:

- A **high water table**, within paludiculture sites and across landscapes, could contribute to peat preservation and even formation. It could generate new wetland habitats, but flood existing dry habitats. Wet paludiculture sites could hydrologically buffer existing wetlands, improve connectivity between them, and contribute to landscape cooling. A high water table can preserve historical artefacts, but *re*wetting can potentially damage them. The impacts of rewetting on soil and water chemistry are heavily dependent on how it is carried out, site history, and the time horizon.
- Paludiculture sites and associated infrastructure can contribute to **landscape water management**, mediating floods and droughts in other habitats and diluting pollution events. However, paludiculture will compete for water with natural ecosystems. It may increase or decrease groundwater salinity. Water management infrastructure will create new aquatic habitats, but these may be bridgeheads for invasive alien species, and barriers (e.g. weirs) may limit native species movements.
- The introduction of **new paludiculture crops**, or areas thereof, in the landscape can contribute to habitat and resource diversity, and remediate pollution. The impact on landscape character may be positive (e.g. improved soundscapes) or negative (e.g. altered views). Crops such as willow and reed present an opportunity to maintain or revive cultural values of lowland peat landscapes.
- **Vegetation harvesting** will maintain open, early successional habitats and create transient ones. Pollutants can be removed in harvested biomass. However, harvesting can have direct negative impacts on soils and biota. Harvest regimes for production and nature are not necessarily aligned.
- **Livestock** can damage peat through their grazing and trampling. They can degrade soil and water quality by introducing bioavailable nutrients and veterinary chemicals in their waste products. However, livestock can maintain open, early successional habitats, and introduce new habitat types (e.g. buffalo wallows) and resources (e.g. dung).
- Paludiculture in England's lowland peat landscapes will have **telecoupled impacts**, particularly through displacement of food production and increased domestic production of certain crops.

There are numerous elements in the wider environment that could modulate the impacts of paludiculture on the natural environment. Many of these could be **opportunities or threats**, depending on how we engage with them. For example, payment schemes could effectively compensate farmers for the benefits paludiculture offers to the natural environment, but could also be toothless or encourage degradation of the natural environment if not financially adequate or framed with paludiculture in mind. Similarly, limited water supplies may restrict the realisation of paludiculture benefits, but government commitments to secure a plentiful water supply could help build the necessary water-management infrastructure for climate-resilient paludiculture.

A **landscape mosaic or portfolio approach** – in which different types of paludiculture, and paludiculture and other land uses, are interspersed in space and time – stands out as a way to potentially balance many positive and negative impacts of paludiculture on the natural environment. There is also a clear need for **adaptive management**: monitoring impacts of paludiculture on the natural environment and responding appropriately.

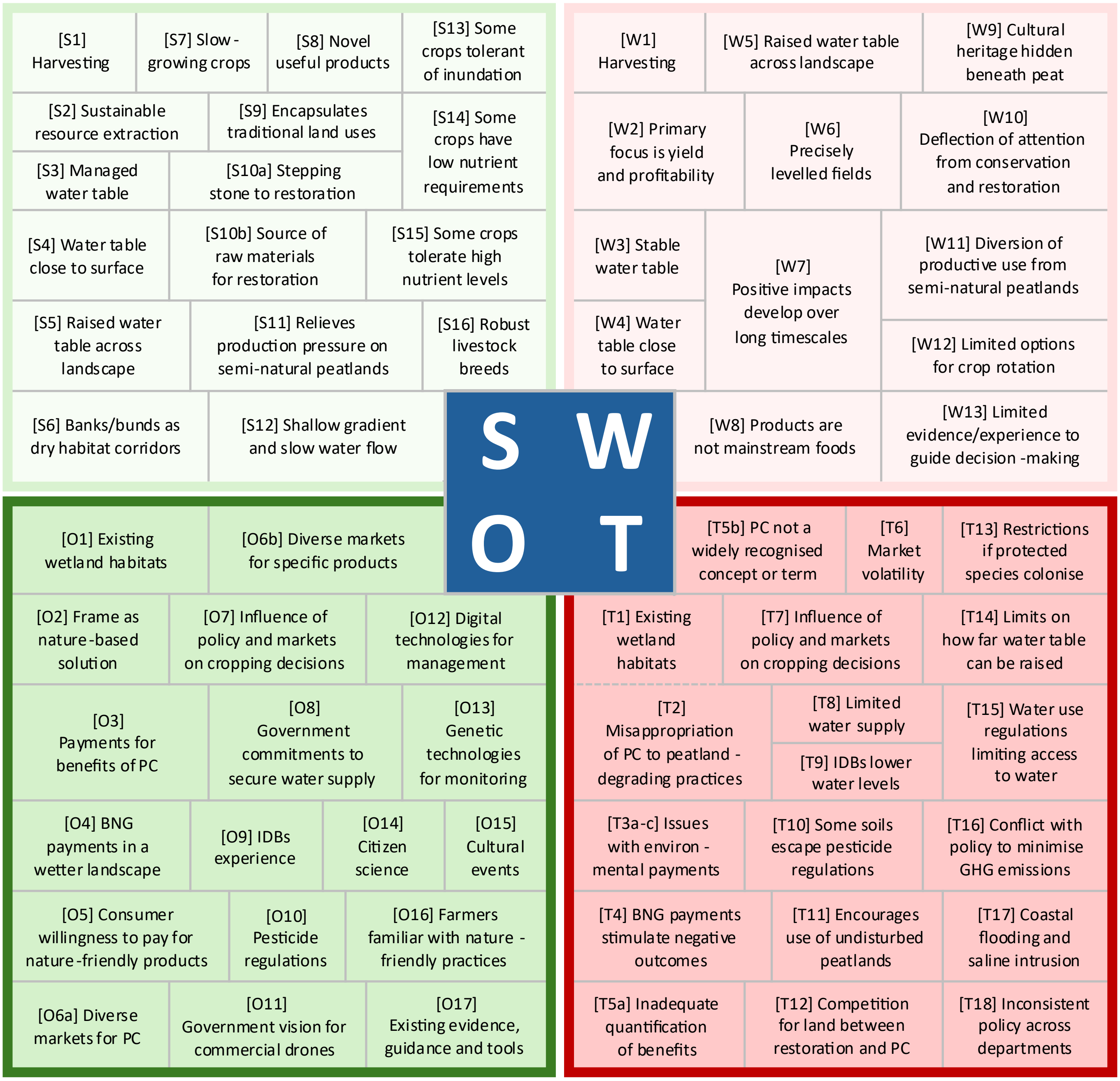


Figure S1 Summary of Strengths, Weaknesses, Opportunities and Threats with respect to lowland paludiculture and its impacts on the natural environment. Codes in square brackets link to more detailed explanations in Section 8 of the main report. BNG – biodiversity net gain; GHGs – greenhouse gases; IDBs – Internal Drainage Boards; PC – paludiculture.

1. Introduction

1.1 Context

There are approximately 465,000 ha of lowland peatland in England (CEH, 2024): roughly three times the size of Greater London. Most of this – up to 90% – has been drained for agricultural use, exploiting the highly fertile soils to grow high-value crops such as salad and cereals (CEH, 2024; Rhymes et al., 2023).

One major problem with farming on drained peat is that it has a limited lifespan (Caudwell, 2023). Much of the peatland in the Fens, for example, has a remaining productive life of <50 years (Morris et al., 2010). Drained peat is exposed to oxygen, meaning organic materials are broken down and the peat degrades and subsides (Figure 1.1; Dawson et al., 2010; Lindsay et al., 2014b). Dry peat is also susceptible to erosion, especially from the wind (Figure 1.1; Cumming, 2018). It is estimated that draining and farming lowland peatlands results in a loss of 10–30 mm of peat per year (Morris et al., 2010). Together, degradation and erosion increase the dominance of mineral over organic material, reducing overall fertility. Lower land is also more susceptible to freshwater flooding or saltwater intrusion (Ikkala et al., 2021; Moodie, 2023), neither of which are conducive to growing dryland crops. There is a 'vicious cycle' of peatland degradation, whereby subsidence necessitates deepening of drainage ditches, in turn increasing subsidence (Kuntze, 1982).

Another major problem with farming on drained peat is that oxidation of the peat is associated with substantial emissions of greenhouse gases, particularly carbon dioxide. Whereas wet peatlands are more or less carbon neutral, drained peatlands are carbon sources. Lowland peatlands drained for agriculture generate 85% of peatland greenhouse gas emissions in England (Brown et al., 2023). This contributes to climate change and its resulting ecological, social and economic challenges, whilst reducing our ability to meet associated international obligations (Dinesen et al., 2021).

Figure 1.1 **Left** – Rows of celery growing in black peat soil near Upware, Cambridgeshire. Credit: Richard Humphrey (geograph.org.uk, CC BY-SA 2.0). **Centre** – A "fen blow" near Yaxley, Cambridgeshire. Following a particularly dry spell, loose peat is blown away. Credit: Michael Trolove (geograph.org.uk, CC BY-SA 2.0). **Right** – Post at Holme Fen, Cambridgeshire, illustrating peat degradation. The post rests on a clay layer beneath the peat. The top was flush with the peat surface in 1851. Four metres of peat have been lost since. Credit: Rodney Burton (geograph.org.uk, CC BY-SA 2.0).

Paludiculture is the productive land use of wet and rewetted peatlands (EU Peatlands & CAP Network, 2021). This is of course not a new idea: plants have been harvested from peatlands, and livestock grazed in them, for centuries (Al-Mudaffar Fawzi et al., 2016; Biró et al., 2019; GMC, 2022). However, paludiculture has recently come into focus as a potential land use option that can address both problems introduced above: reducing greenhouse gas emissions and extending the commercial life of lowland peatlands to support the rural communities dependent on their production (Caudwell, 2023; EU

Peatlands & CAP Network, 2021; HM Government, 2021a, 2023c; Wichmann & Nordt, 2024; Ziegler et al., 2021).

Paludiculture is explicitly mentioned as a sustainable land use option in policy and initiatives at various scales: from local (e.g. Wildlife Trust BCN, 2024a) to national (e.g. HM Government, 2021a, 2021b, 2023d) and international (e.g. FAO, 2014; IPCC, 2023; Ramsar Convention on Wetlands, 2018). Further, the UK Land Use Consultation 2025 recognises "responsible management of peat" as a component of future agricultural land management for environmental benefits (HM Government, 2025a). Over the past 20 years, modern paludiculture research has been pioneered in Continental Europe (Wichtmann & Joosten, 2007). In 2023, the UK government pledged £5 million to paludiculture projects through the Paludiculture Exploration Fund (HM Government, 2023c).

Contemporary paludiculture work largely focuses on greenhouse gas emissions, agronomic issues, and financial and market aspects. There remain many questions to be answered in these areas and they may present barriers to widespread commercial adoption of paludiculture (Freeman et al., 2022; Geurts et al., 2019; Ross, 2025). However, we are also aware that there has been far less consideration given to the impacts of paludiculture on other aspects of the natural environment. It is important to understand the direction and magnitude of these impacts to inform discussion and decisions about the role of paludiculture in the future of England's lowland peat landscapes.

1.2 Aims

This report outlines:

a) Observed or potential impacts of paludiculture on the natural environment.

b) Management options that could avoid or minimise negative impacts of paludiculture on the natural environment, or generate or maximise positive impacts.

c) Open research questions and knowledge gaps related to the impacts of paludiculture on the natural environment. Answers may be generated by primary studies or secondary synthesis.

d) Strengths, weaknesses, opportunities and threats related to paludiculture and its impacts on the natural environment.

1.3 Scope

This is a **scoping report**, meaning we have tried to capture a diverse range of ideas but have not examined the evidence for each in detail. As such, **impacts should not be considered as guaranteed to occur in any context, and management options should not be read as recommendations**. Further detailed analyses are desirable, especially for topics with major potential consequences (Kahneman, 2011). These should include diverse types of evidence, include participation from land managers and other stakeholders, and consider a range of factors including effectiveness, cost, feasibility and acceptability. We have tried to comprehensively address the above aims (Section 1.2), but in the absence of a systematic evidence review, we do not claim to have been exhaustive.

Geographically, we have focused on **lowland peat landscapes in England** (Figure 1.2). Following Caudwell (2023), this excludes any areas with peat soils above and within 2 km of the moorland line. The most substantial peat deposits are in the east (East Anglian Fens and Norfolk Broads), south west (Somerset Levels), north west (Lancashire Mosses) and north east (Humberhead Levels), but there are many other patchy peat deposits across the country. Most of this peat would have been formed in **raised bogs** (domed wet peatlands, where the water source is primarily precipitation and the peat tends to be acidic and low in nutrients) or **fens** (wet peatlands, where the water source is primarily groundwater and the peat tends to be less acidic and higher in nutrients than in bogs) (Rydin & Jeglum, 2013). Despite this geographic focus, we drew on lessons from peatland landscapes and paludiculture elsewhere in the world where they could transfer to English lowland peatlands.

Figure 1.2 Lowland peat extent in England. Map generated using deep peat and shallow peat areas at least 2 km below the moorland line. Hexagons are 10 km wide.

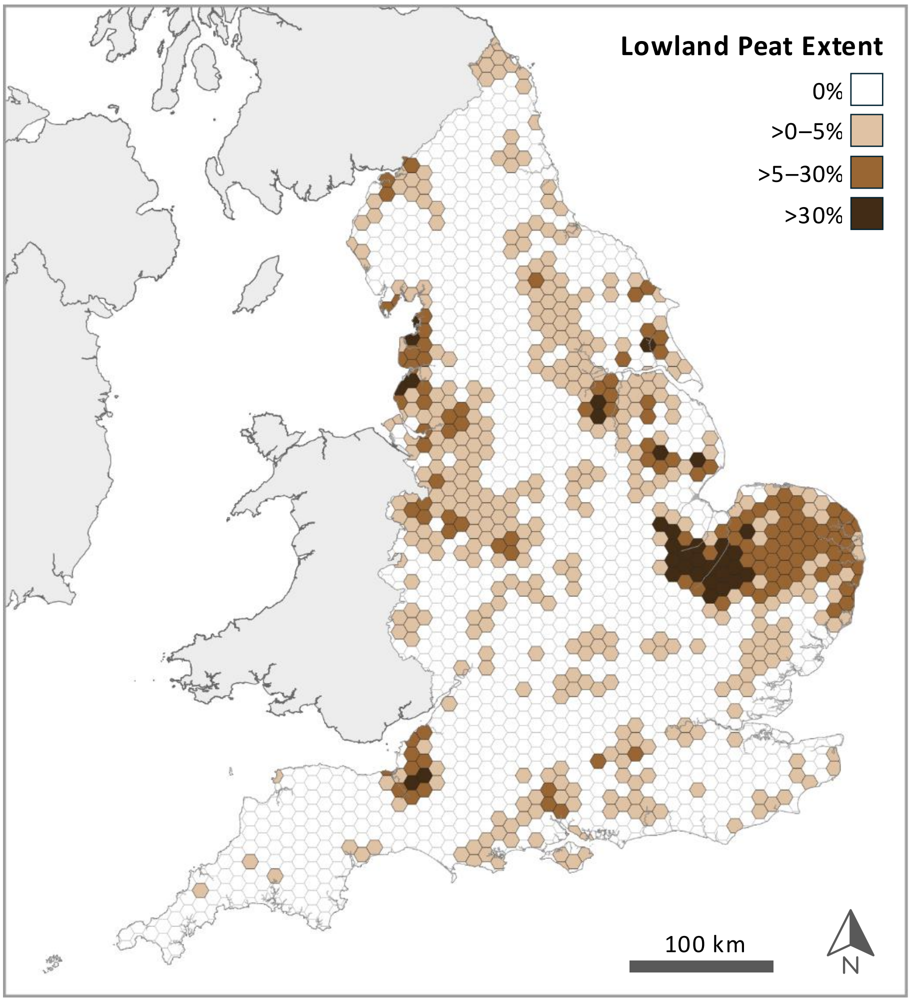
Peat data: Natural England Peaty Soils Location (England). Used under a Non-Commercial Government License, with acknowledgement to British Geological Survey (BGS), Cranfield University (NSRI) and Ordnance Survey (OS).

Moorland line data: Less Favoured Areas (LFA) and Moorland Lines Layer. Used under the Open Government License v3.0.

UK borders: Office for National Statistics (ONS) Countries (December 2021) Boundaries UK BUC. Used under the Open Government License v3.0. Contains OS data © Crown copyright and database right (2023).

Other country borders: geoBoundaries (Rufola et al., 2020). Used under a Creative Commons License (CC BY 4.0).

Projection: British National Grid (OSGB36).



We have focused on five main dimensions of the **natural environment: soils, hydrology, water quality, biodiversity, and landscape character and heritage**. These are fundamental topics related to aspects of Natural England's long-term goal: *to restore and enhance the health of our ecosystems and the natural beauty of our landscapes by increasing the area and improving the character, quality, resilience and connectivity of wildlife-rich places* (Natural England, 2024b). They are clearly interrelated (Figure 1.3), so many issues (e.g. livestock grazing) appear in multiple chapters. We consider the natural environment at **various scales**: within the paludiculture site, in the surrounding landscape, and across the globe. We have explicitly not considered issues related to greenhouse gas emissions because they have been addressed in detail elsewhere; we acknowledge that these will have fundamental implications for the local and global natural environment.

We define **paludiculture** as the productive land use of wet and rewetted peatlands (EU Peatlands & CAP Network, 2021). We assume that the water table will generally be held 10–30 cm below the ground surface (Stockdale & Bellett, 2023). Based on current evidence, this is optimal for minimising greenhouse gas emissions and preserving the peat soil (Evans et al., 2021; Freeman et al., 2022). There is the potential for higher or lower water tables, including flooding, depending on the product and season (Abel & Kallweit, 2022; Wichtmann & Joosten, 2007), but any system with a groundwater level consistently >40 cm below the ground surface is not considered to be paludiculture (Stockdale & Bellett, 2023). We include paludiculture involving plants or animals, that cultivates or harvests, that is intensive or extensive, and which utilises deliberately introduced or spontaneously established organisms (Ziegler et al., 2021).

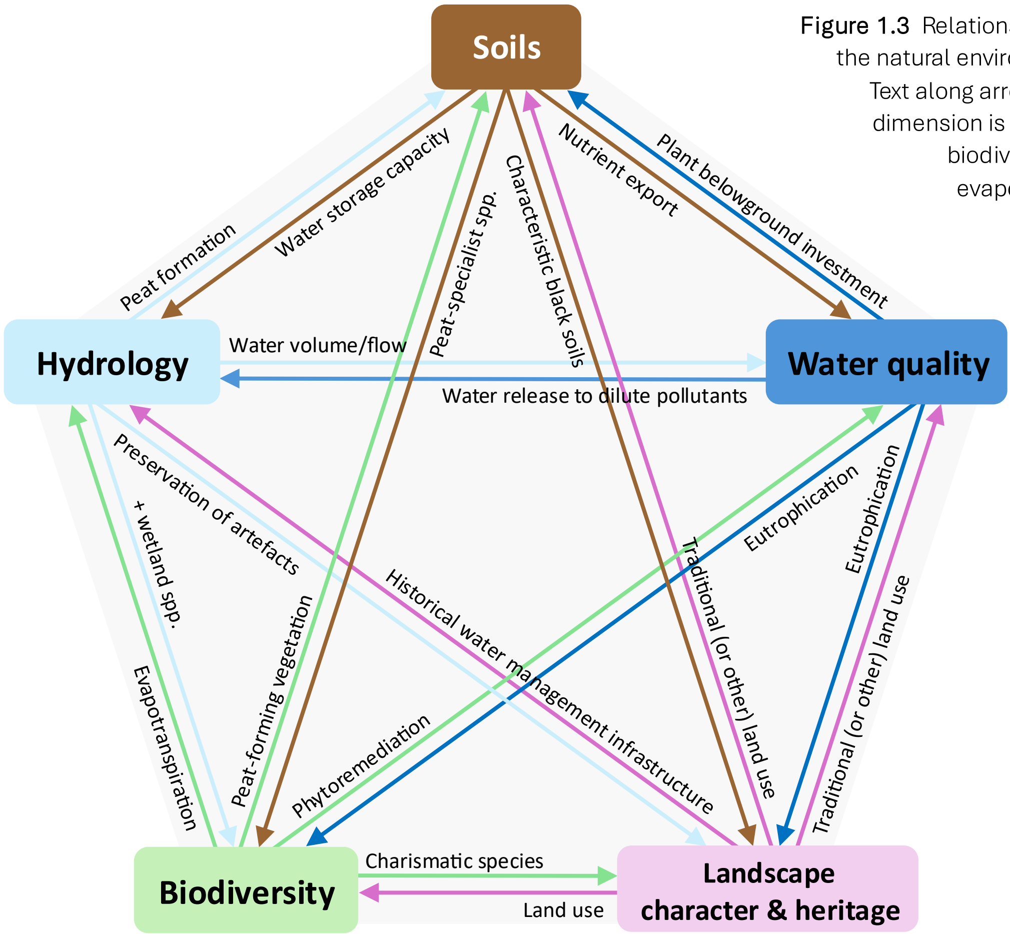


Figure 1.3 Relationships between five dimensions of the natural environment considered in this report. Text along arrows gives an example of how one dimension is related to or affects another (e.g. biodiversity can influence hydrology via evapotranspiration through vegetation present on a peatland).

Much of the report applies to paludiculture in general or across many of these dimensions. However, especially when giving examples, we focus on **crops and products of major current interest** (marked ● in Table 1.1). These are currently being grown or harvested in England, or likely to become major paludiculture types in England in the next 10–20 years based on cultivation experience and market demand.

1.4 Methods

We gathered ideas through literature searches, conference presentations and online resources, a workshop, and one-on-one conversations with relevant experts. We prioritised data and evidence specifically from paludiculture sites, but also drew upon the peatland restoration literature – given that this is better developed and given the similarities between certain aspects of restoration and paludiculture (e.g. the need to rewet peat), especially in the early stages.

- We carried out ad hoc searches of online sources of peer-reviewed scientific literature. Platforms used included Web of Science, Scopus and Google Scholar. Searches generally involved a combination of a term related to paludiculture (e.g. paludicultur*, wet* farm*, *Sphagnum*, *Phragmites*, cattail, wetland grazing) and a relevant outcome variable (e.g. natural environment, soil health, water quality, pollution, biodiversity, nature, species richness). We carried out searches between October 2024 and April 2025.

Table 1.1 Examples of products that could be cultivated, reared or harvested on England's lowland peat (Abel & Kallweit, 2022; Joosten et al., 2016; Lloyd, 2024; Ross, 2025; Stuart et al., 2023). ● indicates products of major current interest. The rest of this report generally uses common names for species.

	Scientific name	Common name	Example uses
	Agrostis stolonifera	Creeping bentgrass	Forage
●	*Alnus glutinosa*	Alder	Furniture, decorative homewares, bioenergy
	Angelica archangelica	Angelica	Flavouring, medicinal
	Apium graveolens	Celery	Food
●	*Bos taurus*	Cattle	Food (meat, dairy)
●	*Bubalus bubalis*	Water buffalo	Food (meat, dairy)
	Carex spp.	Sedge	Forage/fodder, packaging, decorative homewares, bioenergy
	Cladium mariscus	Saw sedge	Construction, bioenergy
	Drosera spp.	Sundew	Medicinal
	Eupatorium cannabinum	Hemp agrimony	Medicinal, ornamental
	Mentha aquatica	Water mint	Flavourings, tea
	Myrica gale	Bog myrtle	Insect repellent, flavouring, medicinal
	Phalaris arundinacea	Reed canarygrass	Packaging, forage/fodder, bioenergy
●	*Phragmites australis*	Common reed	Construction, bioenergy, industrial chemicals, packaging
●	*Salix* spp.	Willow	Furniture, decorative homewares, bioenergy
	Schoenoplectus lacustris	Common club rush	Food, medicinal, decorative homewares, ornamental
●	*Sphagnum* spp.	*Sphagnum* moss	Growing media, material for peatland restoration, biomedical
●	*Typha* spp.	Cattail	Construction, bioenergy, filling material, packaging, fodder
●	*Vaccinium macrocarpon*	American cranberry	Food
●	*Vaccinium myrtillus*	Bilberry	Food, flavouring
●	*Vaccinium oxycoccus*	Small cranberry	Food

- To capture ongoing projects and grey literature, we attended (or watched recordings of/read notes from) various paludiculture and lowland peat conferences held between October 2021 and April 2025. We screened relevant online resources, including the www.paludiculture.org.uk website, the paludiculture newsletter of the Greifswald Mire Centre (www.greifswaldmoor.de/paludiculture-newsletter.html), the document database of the International Peatland Society (www.peatlands.org), and the directory of Open Access Theses and Dissertations (www.oatd.org). We checked the Conservation Evidence database (www.conservationevidence.com), which includes evidence on the effects of conservation interventions on various relevant target habitats and species, e.g. peatland vegetation, marsh vegetation (including reedbeds and cattail marshes), farmland biodiversity, butterflies, amphibians, and mammals.
- In October 2024, we held a two-hour online workshop specifically addressing our research aims (Section 1.2). An open invitation was posted on www.paludiculture.org.uk. We also sent out targeted invitations to individuals working on our five focal topic areas and/or on paludiculture generally. Sixteen individuals participated. Most were affiliated with government agencies (Natural England, Defra, Environment Agency; 7 participants) or universities (4 participants). Most (14) participants were based in the UK; one was based in the Netherlands and one was based in Latvia. Participants contributed to two breakout groups arranged around the focal topic areas, and a general group discussion.

- Twelve individuals contributed ideas through one-on-one discussions: either face-to-face, in an online video call, or via email exchanges. Conversations lasted 5–90 minutes. Each individual discussed at least one of the aims posed above (Section 1.2), according to their expertise.

Below, our findings are presented according to the five major dimensions of the natural environment: soils, hydrology, water quality, biodiversity, landscape character and heritage. We also include a section assessing some general issues that cut across multiple dimensions. We end with a SWOT analysis related to paludiculture and its impacts on the natural environment.

1.5 Key to symbols and codes

✅	Impacts of paludiculture that are likely to be perceived as positive (desirable), should they occur
❌	Impacts of paludiculture that are likely to be perceived as negative (undesirable), should they occur
❓	Impacts of paludiculture that could be positive (desirable), negative (undesirable) or neutral (no meaningful effect), depending on the local context and/or how the paludiculture system is managed
[WS]	Ideas originating from our workshop (see Section 1.4)
❗ *GHG emissions*	Management options that may cause substantial increase in greenhouse gas (GHG) emissions. These effects are not the focus of this report, but reviewers of draft versions found it useful to highlight this potential conflict between different environmental goals.

2. Soils

2.1 Paludiculture impacts and management options

Impacts are not guaranteed: many are context dependent. Management options are some ideas to consider: they are not necessarily effective or feasible in all contexts, so should not be read as recommendations.

a) Peat quantity

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **Preservation of peat due to high water table**. Peat that is kept or made wet, for paludiculture, is less susceptible to degradation, subsidence and loss than drained peat. When peat is drained, oxygen can penetrate the peat and reacts with the carbon it contains. Matter is lost from the peat as carbon dioxide, so it shrinks and subsides (Dawson et al., 2010; Lindsay et al., 2014b; van Hardeveld et al., 2020). Oxygen also facilitates aerobic decomposition of peat by microbes, which is 50 times faster than anaerobic decomposition (Clymo, 1983). Chemical reactions in general are faster in warmer drained soils. Finally, the dry surface layer of drained peat is susceptible to wind erosion (Cumming, 2018). When peat is degraded or lost, the dominance of mineral materials in the soil increases.	→ **Keep water table high (not >10 cm below peat surface) in summer**, when the peat will be warmest and microbial activity greatest (Nordt et al., 2022).
✔ **Protection of peat by vegetation**. Bare peat is susceptible to erosion from rainsplash, water flows, peat slippage, and wind blows (Godwin & Conway, 1939; Li et al., 2018; Page et al., 2020). It is also susceptible to needle ice weathering, due to the strong thermal gradient in the peat profile (Outcalt, 1971). Vegetation cover in paludicultures can protect against erosion and weathering, for example by intercepting rain, slowing water flows, reducing thermal gradients, and reducing wind exposure (Li et al., 2018; Newman, 2022). There is, of course, potential for peat loss during post-harvest or fallow periods, especially for annual crops.	→ Where there is a choice, **grow perennial rather than annual crops** (Abel & Kallweit, 2022). → **Utilise existing peatland vegetation**, for low-intensity harvesting or grazing. → **Grow cover crops** during any period when peat would otherwise be bare (Badr, 2024).
✖ **Peat degradation due to soil disturbance**. Tillage to prepare a seed bed or planting site, or to control weeds, can introduce oxygen to the peat and mobilise nutrients, stimulating peat decomposition by microbial activity (Abel et al., 2016). This will be a particular problem for annual or short-lived plants that require regular soil preparation.	→ **Minimise soil disturbance**: utilise existing peatland vegetation for low-intensity harvesting or grazing, use no-till farming methods; grow perennial rather than annual crops (Abel et al., 2016; Närmann et al., 2021).
✖ **Peat degradation due to nutrient inputs from livestock**. Livestock can add bioavailable nutrients to peatlands in their urine and faeces (Cid-Rodríguez et al., 2024; Lindsay et al., 2014a). These nutrients can stimulate peat decomposition by microbial activity (Rydin & Jeglum, 2013). Nitrogen addition is of particular concern, given that it is often the key limiting nutrient for microbial activity in peatlands (Rydin & Jeglum, 2013) but is highly concentrated, in bioavailable forms like urea, in livestock excreta (Angelidis et al., 2021).	→ **Reduce livestock density** to reduce nutrient inputs.

Export of peat stuck to crops. This is a known issue in dryland systems, especially for root and tuber crops (Panagos et al., 2019; Ruysschaert et al., 2006). It is also a possibility in paludiculture systems (Page et al., 2020) [WS], especially for plants where underground organs are harvested (e.g. sweet flag *Acorus calamus*, marshmallow *Althaea officinalis*, great burnet *Sanguisorba officinalis*; Abel & Kallweit, 2022). However, for most crops currently being considered for mainstream paludiculture in the UK (e.g. cattails, common reed, *Sphagnum* mosses, alder, many fruits and vegetables), only above-ground parts would be harvested so this would not be an issue.

- **Prioritise crops for which only the above-ground biomass is harvested**.
- **Wash harvested plants on site to retain peat soil** [WS].

Formation of new peat, as long as some biomass is left in place and water levels are kept consistently high. The limit for peat formation in temperate peatlands is a geometric mean summer water table 10–20 cm below the surface: a suitable level for many paludiculture crops (Abel & Kallweit, 2022). Paludiculture tends to make use of above-ground biomass, whether it is harvested or grazed, leaving below-ground biomass that can form peat (EU Peatlands & CAP Network, 2021; Gaudig et al., 2014). Rewetting can also restore microbial communities important for peat formation (Emsens et al., 2020; see also BIODIVERSITY). It has been suggested that up to 90% of net primary production can be harvested from temperate grassy or woody peatlands without harming peat formation (Wichtmann & Joosten, 2007). Recent trials in Germany and the Netherlands have shown that peat can form in *Sphagnum* paludiculture sites – although these were not harvested for at least 3.5 years (Temmink et al., 2024; van de Riet et al., 2018).

- **Prioritise plants for which only the above-ground biomass is harvested**.
- **Ensure some biomass is left in place post-harvest to facilitate peat formation**.
- **Incorporate peat-forming vegetation into crop rotation or intercropping system** (e.g. *Sphagnum* moss rotated/intercropped with cranberries; Casperd, 2024).

Impacts of wheeled or tracked vehicles on peat formation. Vehicles may be used in paludiculture systems for several tasks, including groundworks, soil preparation, sowing/planting, pesticide or fertiliser application, harvesting, and livestock management. The rate of peat formation may *increase* if peat is compressed and therefore is less aerated. The rate of peat formation may *decrease* if the reduced porosity of the compressed peat is associated with a more variable water table and thus increased decomposition (Schröder et al., 2015; Worrall et al., 2024). Impacts on peat formation are a particular concern if harvesting semi-natural sites, but could also apply to cultivated sites since they can form peat (see above).

- Where infrastructure exists, **control water table to reduce fluctuations** (Schröder et al., 2015).

Impacts of livestock, especially at high densities, on peat formation. Compaction of surface peat associated with trampling (Cid-Rodríguez et al., 2024; Duncan et al., 2021) could increase or decrease the rate of peat formation, depending on water table management (Schröder et al., 2015; see above). Through grazing, livestock can reduce the amount of vegetation biomass present that might otherwise form peat. Grazing can also alter the vegetation composition, potentially favouring species more or less prone to decomposition and therefore more or less likely to form peat (Lamers et al., 2015; Lindsay et al., 2014a). However, livestock might have a relatively small effect on peat formation compared to other factors such as productivity, water table depth and nutrient availability (Lamers et al., 2015).

- Where infrastructure exists, **control water table to reduce fluctuations** (Schröder et al., 2015).
- **Change livestock density**. For example, lower densities will reduce the impact of trampling and the biomass of vegetation consumed (Lindsay et al., 2014a; Taylor et al., 2018) [WS].
- **Change livestock type**. Smaller/lighter species or breeds will generate less pressure on the peat, reducing impacts from trampling (McBride et al., 2011).

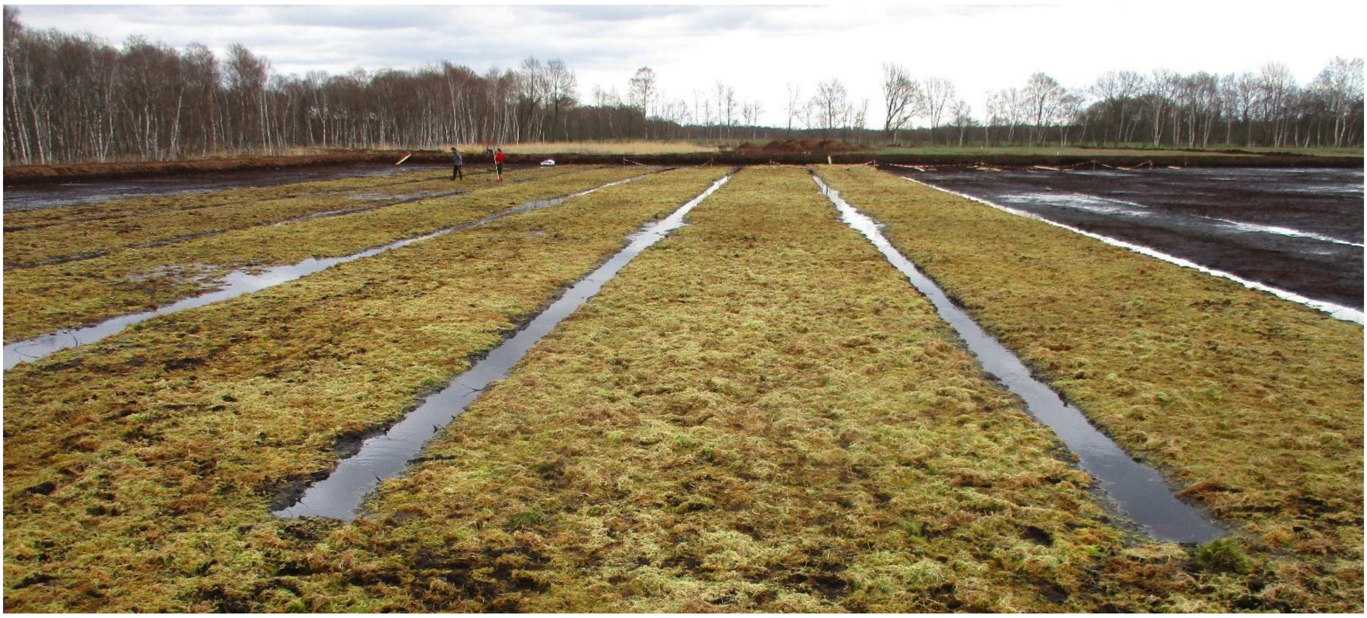


Figure 2.1 *Sphagnum* paludiculture demonstration site on Barver Moor, Germany. Irrigation trenches allow the water level to be held approximately 5 cm below the peat surface. The high water table should preserve the existing peat, and any *Sphagnum* biomass left after harvest should contribute to formation of new peat. Credit: CANAPE (2023) (CC BY-SA 4.0).

b) Peat structure

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **Preservation of peat structure under high water table conditions**. Natural, wet peatlands have a low bulk density (dry mass per unit volume) with large pores and high organic matter content (Rydin & Jeglum, 2013). Physical and chemical changes in drained peat increase the bulk density, reduce the pore size and reduce the organic matter content. Keeping peatlands wet for paludiculture *prevents* these changes. Rewetting for paludiculture can *slow or reverse* these changes (Ahmad et al., 2020; Lundin et al., 2017) – but often not to the level of near-natural peatlands for several years, or even decades (Kreyling et al., 2021).	
✖ **Damage to peat structure from vehicles**. Vehicles may be used in paludiculture systems for several tasks (see PEAT QUANTITY). Damage may be caused by the ground pressure of the vehicle compressing the peat and/or creating ruts, tearing of the sward (the upper layer of topsoil held together by the roots of plants) if the machinery sinks below the ground surface, and shear stresses during turning (Schröder et al., 2015) [WS]. Rewetted peats are particularly sensitive to damage from vehicles, because they have low penetration resistance, cohesion and shear strength due to structural degradation while drained and high water content once rewetted (Nordt et al., 2022).	➔ **Use specialised vehicles**, e.g. with extra/balloon wheels or tracks, or hovercraft (Dubowski et al., 2013; Nordt et al., 2022; Schröder et al., 2015). ➔ **Use fleets of small vehicles instead of single large ones** (Nordt et al., 2022). ➔ **Plan harvest logistics**, e.g. to avoid sharp turns and repeated crossings of an area, and to confine vehicles to few permanent traffic lanes (Niab, 2024; Schröder et al., 2015) [WS]. ➔ **Temporarily lower water table during harvest to allow vehicle access** (Stuart et al., 2023). ⚠ *GHG emissions*

- **Reduce harvest frequency** to allow the sward to regenerate between harvests (Schröder et al., 2016).
- **Create appropriate infrastructure**, e.g. raised bunds or reinforced tracks on which vehicles can drive (Lancashire Wildlife Trust, 2023). ⚠ *GHG emissions if bunds are made from peat*
- **Train vehicle operators** on how to work in wet peat (Schröder et al., 2015).
- **Avoid using vehicles**, e.g. use drones or robots for sowing, spraying, weeding, pest/disease detection (Fountas et al., 2020); water drift for sowing (Nordt et al., 2022); air pipelines or ropes to remove harvested material (Broads Authority, 2004; Nordt et al., 2022).
- **Provide opportunities to share or borrow specialist equipment** (Blue Marble Research, 2024).

✖ **Flattening of peat surface by vehicles**. Vehicles may be used in paludiculture systems for several tasks (see PEAT QUANTITY). Vehicles push tussocks and hummocks into the peat, reducing microhabitat variability (Banaszuk et al., 2016; Kotowski et al., 2013). This can reduce overall species richness due to the loss of rare species that depend on certain microhabitats (Kotowski et al., 2013; Peach & Zedler, 2006). This may be a particular problem when using or harvesting semi-natural peatlands.

- **Create appropriate infrastructure on which vehicles can drive** (see above).
- **Avoid using vehicles** (see above).
- **Provide opportunities to share or borrow specialist equipment** (Blue Marble Research, 2024).

✖ **Damage to peat structure from livestock movements [WS]**. Livestock have a small hoof size for their body weight, meaning they exert considerable pressure on the peat (ca. 14 psi for a standing 500 kg pony; Broads Authority, 2004). Treading on peat will lead to compaction and compression, especially at the surface, reducing its water content and potentially increasing the decomposition rate (Cid-Rodríguez et al., 2024; Duncan et al., 2021). Treading can also cause poaching (slurry-like conditions) and pugging (deep hoof imprints), especially around crossing points, rest spots or supplementary feeding points (Drewry et al., 2008; McBride et al., 2011) [WS]. Soils with a high water content, such as wet peats, are particularly susceptible to such damage.

- **Change livestock density**. Lower densities will consume less vegetation and generate less overall trampling pressure (Lindsay et al., 2014a) [WS].
- **Change livestock type**. Smaller or lighter species/breeds will generate less hoof pressure (McBride et al., 2011).
- **Control water table to reduce fluctuations** (Schröder et al., 2015).
- **Keep livestock off paludiculture site during particularly wet periods**.
- **Keep livestock out of particularly wet areas**, which are most susceptible to damage. GPS-based "virtual fences" can delimit small and dynamic areas (Issimdar, 2025; VIPNL, 2024).
- **Locate pinch-points, such as gates or supplementary feeding stations, on higher or drier ground**. This may be within the paludiculture site, or in a separate area (McBride et al., 2011).

Figure 2.2 Peat is an organic material, formed from plant and animal remains accumulating under more or less water-saturated conditions. Exclusion of oxygen and the chemical characteristic of the remains are among the key factors facilitating peat formation. Credit: Nigel Taylor (CC BY-ND 4.0).

c) *Peat chemistry*

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✓ **Mitigation of drainage-induced pollution of soil water** [WS]. When peat is drained, air can enter the pore spaces. This stimulates breakdown of organic matter by aerobic micro-organisms (also known as mineralisation) and an increase in pH (e.g. due to oxidation of organic acids or sulphur). These changes can release *nutrients*, especially nitrogen and phosphorous, into more mobile or bioavailable forms (Rydin & Jeglum, 2013). They can also release *heavy metals* from complexes with organic matter (Tipping et al., 2003). The mobilised nutrients and metals can then accumulate in soil pore water (Prévost et al., 1999; Tipping et al., 2003). Keeping peatlands wet prevents these chemical changes. Rewetting can slow or reverse these processes over the long term (compare below), for example by locking up nutrients in stable complexes.	➔ **Retain intact (undrained) peatlands wherever possible**, to minimise pollutant release associated with drainage.
✗ **Mobilisation of nutrients by rewetting, increasing their concentration in the peat** [WS]. Rewetting leads to chemical changes that can release nutrients into more mobile or bioavailable forms (Smolders et al., 2006; Zak & Gelbrecht, 2007). Mobilised nutrients can accumulate in pore water, reaching levels up to three orders of magnitude greater in rewetted than pristine peatlands (van de Riet et al., 2013; Zak et al., 2010; Zak & Gelbrecht, 2007). This can be a particular problem in historically fertilised fields, where nutrients have accumulated, mostly in unavailable forms, in the surface peat (van der Laan et al., 2024). Phosphorous and potassium are likely to be the main problems; nitrogen is actually likely to be lost from the peat, as nitrogen gas via denitrification, under anaerobic conditions (Comber et al., 2023). Effects of rewetting on soil nutrients will generally be transient: nutrient levels should decrease over multi-year to decadal timescales as they are leached from the peat or taken up by vegetation (Comber et al., 2023; see also below) or as new peat forms (Reddy & DeLaune, 2008; see also PEAT QUANTITY).	➔ **Retain intact (undrained) peatlands wherever possible**, to minimise nutrient release associated with rewetting. ➔ **Grow crops that can take up and store nutrients.** Many paludiculture crops can sequester nutrients, which can be removed from site at harvest (see below). ➔ **Remove degraded/nutrient-enriched surface peat before rewetting.** This can reduce the amount of nutrients present in the system (van den Berg et al., 2024; Zak et al., 2017). However, removing surface peat is expensive (Klimkowska et al., 2010) and can generate ! *GHG emissions*. ➔ **Rewet surface peat gradually, rather than instantaneously.** This involves raising the water table only slightly at first, or allowing the surface peat to dry out periodically. It can limit phosphate mobilisation in particular (Lucassen et al., 2005; Zak & McInnes, 2022).

Mobilisation of heavy metals by rewetting, increasing their concentration in the peat [WS]. Chemical changes associated with rewetting, especially linked to the reduction in oxygen availability, can release heavy metals from bound complexes into more mobile or bioavailable forms (Blodau et al., 2008; Tipping et al., 2003). The increase within the peat should be transient, as ongoing heavy metal deposition is unlikely to keep pace with leaching losses (Tipping et al., 2003; see also WATER QUALITY).

- **Retain intact (undrained) peatlands wherever possible**, to minimise metal release associated with rewetting.
- **Grow crops that can take up and store heavy metals**. Many paludiculture crops can sequester metals, which can be removed from site at harvest (see below).
- **Remove metal-enriched surface peat before rewetting**. But note cost and *GHG emissions* (see above).

Mobilisation of dissolved organic carbon (DOC) by rewetting, increasing its concentration in the peat. Chemical changes associated with rewetting can increase the porewater DOC concentration (Cabezas et al., 2013; Zak et al., 2010; Zak & Gelbrecht, 2007). DOC is highly mobile and reactive, forming strong complexes with nutrients and heavy metals, affecting various chemical properties of the soil (James & Harrison, 2023; van den Berg et al., 2012). It also provides a carbon and energy source for soil organisms (James & Harrison, 2023). DOC increases in surface peat may be temporary, as DOC can readily leach into deeper peat layers or be exported out of the soil profile (James & Harrison, 2023; Zak & Gelbrecht, 2007; see also WATER QUALITY).

- **Retain intact (undrained) peatlands wherever possible**, to minimise DOC production associated with rewetting.
- **Remove degraded surface peat before rewetting**. DOC mobilisation following rewetting can be highest in degraded peats (Cabezas et al., 2013; Zak & Gelbrecht, 2007). But note cost and *GHG emissions* (see above).

Reduced nutrient and heavy metal concentrations in soils due to removal by paludiculture plants. Paludiculture plants such as common reed, cattail, sedges, *Sphagnum*, cranberries, poplars *Populus* spp. and willows can remove pollutants from wetland soils, reducing their concentration in the soil pore water. This applies to both nutrients (Bentley, 2023; Brix, 1994; DeMoranville, 2010; Geurts et al., 2020; Hänel et al., 2022; Hinzke et al., 2021; Münzer, 2001; Temmink et al., 2024; van den Berg et al., 2024; Vroom et al., 2020) and heavy metals (Chitimus et al., 2023; Demırezen & Aksoy, 2004). For example, the plant biomass in a *Sphagnum* paludiculture in Germany sequestered 46 kg N, 5 kg P and 15 kg K/ha/yr over 2.5 years (Vroom et al., 2020).

Chemicals may be removed from a system when biomass is harvested. Paludiculture sites can therefore act as nutrient sinks and remediate chemical legacies (e.g. from historical agriculture), perhaps as an intermediate step towards restoration of near-natural wetland habitats (Comber et al., 2023; Fritz et al., 2014).

Note that nutrients and heavy metals may be concentrated in roots and rhizomes rather than shoots, so harvesting above-ground biomass may only have a minor influence on their concentration in the ecosystem (Maddison et al., 2009).

- **Select crops that sequester the most target chemicals in their removable parts**. Tissue concentrations vary between crop species and chemical type (Geurts et al., 2020).
- **Time harvest to maximise removal of chemicals from site**. For example, the nutrient content of common reed and cattails is higher in summer than in winter, since nutrients are transported to the rhizomes for winter storage (Gessner, 2001; Geurts et al., 2020).
- **Situate crops with high chemical removal potential in the most enriched or polluted parts of the landscape**.

Impacts of paludiculture water source on peat chemistry. Lowland peatlands are either fed primarily by groundwater (minerotrophic peatlands, aka fens) or precipitation (ombrotrophic peatlands, aka bogs). The source of water affects the chemistry of the peatland: adding surface water to fens can make them more acidic and reduce nutrient levels, whereas increasing the influence of groundwater in bogs can make them less acidic and increase nutrient levels (Rydin & Jeglum, 2013).

- **Match water source** (ground- or surface water) **to the desired peat chemistry**.

These changes to the existing chemistry will probably be seen as detrimental, although the choice of water could also be used to modify chemistry in desirable ways (e.g. to support particular rare species).

Impacts of livestock on local nutrient budgets. Livestock can add bioavailable nutrients to peatlands in their urine and faeces (Cid-Rodríguez et al., 2024; Lindsay et al., 2014a). If livestock also graze outside of a paludiculture site, or are given supplementary food, they could be net importers of nutrients to the site and contribute to soil nutrient enrichment (Duncan et al., 2021; Middleton et al., 2006). However, if livestock graze exclusively in a paludiculture site, they can generate a net nutrient deficit as nutrients are removed in animal products (Duncan et al., 2021).

- **Avoid providing livestock with supplementary food** (e.g. silage) if there are concerns over nutrient enrichment in a paludiculture site where they will subsequently graze.

Pollution from harvesting machinery, for example due to oil leaks. Just 1 cm^3 of mineral oil spilled in a wetland can contaminate five litres of water (Dubowski et al., 2013).

- **Ensure machinery is well maintained** to reduce risk of breakdowns and leaks.
- **Use biodegradable oils** (e.g. derived from plants) rather than mineral oils (derived from petroleum) (Dubowski et al., 2013).
- **Use oils low in (or ideally free from) heavy metals.**

2.2 Research questions / knowledge gaps

Sources: Own work, Workshop, A. Kowalski (pers. comm.), K. Ross (pers. comm.).

- How does paludiculture affect peat formation? How much vegetation can be harvested without noticeably impacting the rate of peat formation? How does peat formation vary between paludiculture systems, e.g. depending on the crop, water level and peatland type?
- How much peat is exported on unwashed paludiculture crops? Is this agronomically or ecologically significant?
- How is the load-bearing capacity of peat affected by rewetting and repeated harvesting in paludiculture systems?
- (How) can drones be used to harvest vegetation in paludicultures?
- How do additives focused on managing greenhouse gases (e.g. biochar to incorporate carbon into the soil and gypsum to manage methane emissions) affect soil properties (e.g. peat structure and chemistry)?
- How does the microbial diversity, both taxonomic and functional, in paludiculture sites influence nutrient availability?
- How does remediation performance vary between paludiculture plants? Which plants sequester the most chemicals in removable tissues, both overall and for specific chemicals?
- How does the remediation performance of paludiculture plants vary over time, especially in several years of monoculture?
- How is product quality affected by the use of paludiculture plants to remediate pollution, and the resulting incorporation of pollutants into plant tissues? Does this restrict potential uses of the end product?
- How do low- or no-till paludiculture methods affect peat degradation and crop yield? How practical are these methods in paludiculture systems?

- How do the impacts of paludiculture on soils differ between deep peat (>100 cm depth), shallow peat (40–100 cm depth) and wasted or skirt peats (<40 cm depth, and typically containing a mixture of peat and mineral soils)?

- More data on chemical changes in drained and rewetted (lowland) peats, including the contextual factors that affect pollutant mobilisation.

3. Hydrology

Definition: The movement, distribution and management of water, within sites and across the landscape.

3.1 Paludiculture impacts and management options

Impacts are not guaranteed: many are context dependent. Management options are some ideas to consider: they are not necessarily effective or feasible in all contexts, so should not be read as recommendations.

a) Site hydrology

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **Increased water storage capacity associated with peat formation**. Paludiculture can contribute to peat preservation and even formation by keeping or making the peat wet (see SOILS). A larger volume of peat will be able to store more water (Ahmad et al., 2020; Mulholland et al., 2020). This is particularly useful in winter to buffer extreme rainfall events.	➜ **Facilitate peat formation** (see SOILS for specific actions).
✔ **Preservation of peat hydraulic properties, and thus peatland hydrological function, under high water table conditions**. For example, wet, undecomposed peat has larger pores than dry, degraded peat (see SOILS; Karimi et al., 2024; Whittington & Price, 2006). This is associated with increased hydraulic conductivity, meaning water can move through the peat more easily and water table fluctuations are less extreme. Their high porosity also means wet peatlands are better able to buffer extreme rainfall events, mediating extreme flows downstream (Ahmad et al., 2020; Karimi et al., 2024). Keeping peatlands wet can maintain these hydraulic properties. Rewetting drained peatlands can at least partially restore them (Ahmad et al., 2020; Karimi et al., 2024). However, some changes are irreversible (Whittington & Price, 2006) and hydrological functioning of rewetted peatlands generally remains below that of near-natural peatlands (Kreyling et al., 2021).	➜ **Retain intact (undrained) peatlands wherever possible**, to minimise hydraulic changes associated with drainage.
✖ **Altered peat hydraulic properties due to impacts of livestock or vehicles**. Livestock grazing on wet peat, and vehicles driving on it (e.g. for sowing/planting, harvesting, agrochemical application and livestock management), exert forces that can alter peat structure and consequently its hydraulic properties (see also SOILS). In particular, compacted peat has a higher bulk density, lower porosity and lower hydraulic conductivity, meaning it can hold less water and is a less effective hydrological buffer (Cid-Rodríguez et al., 2024; Drewry et al., 2008). For example, compressed peat is less able to absorb water during extreme rainfall events, and is subject to greater variation in water table depth (Cid-Rodríguez et al., 2024; Schröder et al., 2015).	➜ **Reduce forces on peat exerted by livestock or vehicles** (see SOILS for specific actions).

❌ **Flattening of the peat surface by vehicles.** Vehicles may drive over paludiculture sites to carry out various tasks (see above). Vehicles can reduce microtopographic and microhydrological variation by crushing tussocks and hummocks, which are normally slightly drier than adjacent hollows (Kotowski et al., 2013; Schröder et al., 2015). The rough surface formed by hummocks and hollows can also slow surface runoff, tempering flood peaks in adjacent streams and rivers (IUCN, 2024b). Impacts of vehicles on microtopography may be a particular concern when harvesting semi-natural peatlands.	➔ **Create appropriate infrastructure** on which vehicles can drive (see SOILS). ➔ **Avoid using vehicles** (see SOILS). ➔ **Provide opportunities to share or borrow specialist equipment** (Blue Marble Research, 2024).

Figure 3.1 Water tables in paludiculture sites. **Left** – Preparation of cells for cattail paludiculture on Chat Moss, Lancashire. Credit: Nigel Taylor (CC BY-ND 4.0). **Right** – Water table around 20 cm below peat surface, under a celery crop at a paludiculture trial in Norfolk. Credit: Nigel Taylor (CC BY-ND 4.0).

b) Landscape hydrology

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
❓ **High water table across the landscape.** Just as peatland drainage alters the hydrological function of entire landscapes (Temmink et al., 2023), rewetting for paludiculture will typically have broad hydrological impacts. Practical and financial considerations favour raising water levels across landscapes or hydrological units rather than isolated fields (Freeman et al., 2022; Nordt et al., 2022; Ozola et al., 2023). Higher and stabilised water tables would provide hydrological security for existing wetlands, link up remnant "wet islands" in the landscape, and create opportunities for wetland creation or restoration at a variety of scales (Anon, 2021c; IUCN, 2023) [WS]. For example, ponds or lakes may form in low-lying parts of the landscape. More specifically, The Cranberry Company in the Netherlands allocated only half of its rewetted area to cranberry production with the rest being restored to semi-natural wetland habitats (Casperd, 2024).	➔ **Keep water out of important dry sites with bunds, sheeting or ditches.** Clearly there are practical, economic, and environmental factors to consider here, including ⚠ *GHG emissions*. ➔ **Increased monitoring of water table across landscape**, e.g. with increased density of (automated) monitoring devices, to enable dynamic responses to changes in water table depth. ➔ **Involve all relevant stakeholders in water management decisions**, with consultations, forums, workshops. For example, the *Future Fens: Integrated Adaptation* project is using collaborative, multi-stakeholder visioning and

However, flooding of existing habitats may be undesirable in some cases, especially when they are important for protected species like water voles *Arvicola amphibius* [WS]. Flooding of low-lying farmland could displace food production to areas themselves important for nature (see CROSS-CUTTING POINTS).

- Involve all relevant stakeholders in mapping exercises to define future landscape water management in the Fens (Anon, 2021a).
- **Exploit the opportunities for habitat restoration or creation** that arise due to a higher water table.

Hydrological buffering of existing wetlands. Paludiculture around existing wetlands could reduce the hydrological gradient between wetland and non-wetland sites (IUCN, 2023; Temmink et al., 2023). If the gradient is large, wetlands will lose water to the surrounding landscape. Drainage of surrounding land has a marked influence on the hydrology of patchy or isolated peatlands, such as the raised bogs in the Manchester Mosslands (Walker, 2008). In the Fens, several nature reserves are perched above drained and degraded peat, and there are substantial management costs associated with maintaining the appropriate wetland hydrology (Anon, 2021c).

- Where there is a choice, **situate paludiculture strategically, around existing wetlands**.

Contribution of paludiculture systems to landscape water management. English lowland peat landscapes currently struggle with excess water in the winter and water shortages in the summer. Paludiculture systems – both fields/plots and associated infrastructure – could be used as temporary water *storage* areas in times of water excess, reducing flood risk for other natural habitats (Anon, 2021b; Labadz et al., 2010; Mulholland et al., 2020). Water could be *released* from paludiculture systems to the wider landscape during drought, keeping wetlands wet and rivers flowing (Karimi et al., 2024). In this way, natural habitats could be buffered from excessive hydrological fluctuations.

Generally, paludiculture could improve regional hydrology by keeping water longer in the landscape (Wichtmann & Joosten, 2007) and improve overall landscape resilience to fluctuating water availability (Stockdale & Bellett, 2023). The water storage capacity of paludiculture sites greatly exceeds that of conventional agriculture (on drained peat; Liu et al., 2023).

However, the capacity for paludiculture to support such management will depend on the crop (e.g. tolerance of temporary water level fluctuations without reductions in yield or quality) and existing hydrological regime (e.g. a saturated *Sphagnum* field will not be able to absorb any additional water; Labadz et al., 2010).

- **Involve all relevant stakeholders in water management decisions** (see above).
- **Widen ditches to increase water storage capacity** (Anon, 2023). But note potential ! *GHG emissions*.

Artificialisation of water systems. Widespread adoption of paludiculture could generate highly artificial and managed water systems, at odds with natural ecosystem function [WS]. This could reduce the likelihood of nature recovery at the landscape scale. However, the hydrology of English lowland peatlands such as the Fens and Somerset Levels is already highly artificial, being managed with pumps, drains, and sluices. There are 17,000 flood risk and water level management assets in the Fens alone (Environment Agency, 2023a).

Modification of hydrology by tracks and roads. Paludiculture sites will need to be supported by transport infrastructure (Nordt et al., 2022). Sites may need tracks within fields to allow vehicles to access the crop, and roads across the wider landscape to link harvested material to processing facilities or markets. Potential hydrological impacts of tracks and roads include: reduced infiltration into peat (where road surface is impermeable); changes to surface and subsurface flows (due to compression of peat, and especially in peatlands on slopes), segregating the peatland into hydrologically isolated units and producing wetter upslope and drier downslope patches; and development of waterlogged areas associated with subsidence (Lindsay et al., 2016; Partington et al., 2016; Williams-Mounsey et al., 2021).

- **Build tracks/roads parallel rather than perpendicular to any slope**.
- **Install structures under tracks/roads to allow water flow**, e.g. culverts, log bundles, aggregate seams (Partington et al., 2016). But note that these structures can concentrate flows and therefore contribute to erosion, and are unlikely to completely restore hydrology (Lindsay et al., 2016).
- **Use temporary tracks/roads**, e.g. made of wood or plastic, especially for very short and infrequently used spans.

Competition for water with other land uses. Paludiculture requires water inputs to maintain a high water table. This high water table may also, in turn, lead to high water loss via evapotranspiration (Mulholland et al., 2020; Wahren et al., 2016; Worrall et al., 2019). However, many other land uses rely on ground and/or surface water inputs including, of particular relevance to this report, wetland nature reserves (e.g. Lady Fen, Norfolk; Wicken Fen, Cambridgeshire; RSPB Greylake, Somerset). Paludiculture could lead to pressure on water resources in water-scarce regions such as Eastern England (Anon, 2021b), and particularly during drought periods. At Lady Fen, for example, there is already insufficient water available in dry years to keep the site fully wet (L. Marshall pers. comm.). Climate change (Met Office, 2022) and a growing population (Jenkins et al., 2024; Somerset Council, 2024) will add further pressure on water resources.

Note that some paludiculture plants like common reed, cattail, marshmallow *Althaea officinalis* and switchgrass *Panicum virgatum* can at least tolerate brackish conditions (Abel & Kallweit, 2022). They could thus temporarily be irrigated with brackish water, reducing competition for fresh water with other land uses.

- **Expand reservoir capacity**, through construction of few large and/or several small reservoirs. Consider catchment-scale impacts (e.g. on BIODIVERSITY and LANDSCAPE CHARACTER & HERITAGE).
- **Increase water supply in other ways**, e.g. water transfers, desalination, water recycling (Environment Agency, 2024).
- **Match paludiculture species to local water demand** [WS]. Crops that can tolerate prolonged flooding (e.g. cattails) may be better suited to wetter western areas. Crops that can tolerate drought (e.g. reed canarygrass) may be better suited to drier eastern areas (Abel & Kallweit, 2022).
- **Add mulch to reduce water loss**, especially during dry periods (Price et al., 1998) [WS].
- **Adjust crop spacing to manage evapotranspiration** [WS]. Crop spacing affects various factors related to evapotranspiration, e.g. area of exposed peat, air movement through crop canopy, and number of transpiring plants per unit area (Allen et al., 1998).
- **Tolerate some drier periods in paludiculture sites**. Many paludiculture plants can grow under temporarily drier conditions as long as competition from weeds is managed (Anon, 2021b). There may be trade-offs between crop yield/quality, impacts on the wider natural environment, and ! *GHG emissions*.

Impact of reservoirs on landscape hydrology. Reservoirs may be constructed to provide sufficient water year-round to manage water levels in paludiculture systems (see above). In replacing terrestrial surfaces with open water surfaces, reservoirs can affect the rate, and spatial and temporal patterns, of hydrological parameters such as evaporation, infiltration and runoff (Sang et al., 2023). Storing water in the catchment will likely affect downstream hydrology too, reducing both average and peak river flows (Nathan & Lowe, 2012; Perin et al., 2024) and affecting the timing of the latter (Carluer et al., 2016). Although individual reservoirs may be small, the cumulative impact of multiple reservoirs could be substantial (Carluer et al., 2016; Perin et al., 2024).

- **Regulate the construction of new reservoirs**.
- **Require or engineer water releases to the natural environment during drought periods** (Nathan & Lowe, 2012). This could be achieved with legislation and/or by installing physical bypasses.
- **Cover/shelter reservoirs to reduce evaporative losses**. Options include photovoltaic panels, floating shade cloth or shade balls, trees/vegetation to block sunlight and act as windbreaks.

Reduced risk of flooding and, in coastal areas, consequent soil salinisation. Peatlands that are kept wet, with fresh water, will suffer from less subsidence (see SOILS). Peatlands that maintain their elevation will be flooded less often, and for a shorter duration, than drained and subsided peatlands (Moodie, 2023; Page et al., 2020; White & Kaplan, 2017). Maintaining the elevation of coastal peatlands can protect them from seawater flooding and resulting soil salinisation: a growing risk as sea levels rise and the frequency of storm surges increases (Anon, 2020; Gould et al., 2021; Moodie, 2023). Given that paludiculture will likely raise the water table across broad peatland landscapes (see above), these benefits should extend to other habitats beyond the paludiculture site itself.

Flood protection is important for dry near-natural habitats (e.g. grasslands) and the organisms within them (e.g. breeding birds), for which prolonged, mistimed or saline flooding can be devastating. It is also important for maintaining the viability of conventional dry farmland, where flooding (especially by salt water) could displace food production and its associated environmental impacts to other areas (Page et al., 2020; see CROSS-CUTTING POINTS).

- **Prioritise paludiculture in coastal areas**. The impacts of flooding are potentially more severe here than inland. Maintaining coastal peatland elevation could also protect areas further inland.

Impact of coastal paludiculture on groundwater salinity. Paludiculture in coastal peatlands could affect the salinity of groundwater, although the direction is not clear and is likely to depend on local water levels and geology. Some coastal peatlands, such as those in the Fens, are underlain by a wedge of saline groundwater (Moulds et al., 2023). Increasing the amount of fresh groundwater in a landscape should increase pressure on the saline groundwater, pushing the saline front downwards (Gould et al., 2021; Moulds et al., 2023). However, diverting and storing surface water in reservoirs could reduce the downward pressure of fresh water and cause the saline front to rise, leading to salinisation of inland ecosystems (Stofberg et al., 2017). This can be difficult to manage once it occurs, and is often irreversible (Greene et al., 2016).

- **Release water held in paludiculture systems (e.g. reservoirs) to the wider landscape** when there is little natural water input.
- **Carefully manage water abstraction**, for paludiculture or other purposes.

3.2 Research questions / knowledge gaps

Sources: Own work, Workshop, Holman (2024), Lindsay et al. (2016), Stuart et al. (2023), Tan et al. (2021).

- What is the water storage and discharge capacity of paludiculture sites? How does this differ between sites that have remained wet vs those that have been rewetted? How does it differ from restored peatlands that are not used for paludiculture?
- How do different crop spacings/densities affect evapotranspiration from paludiculture sites?
- How does the growth and harvest of different paludiculture plants affect hydrology?
- How does adding paludiculture, and its associated infrastructure, into lowland peat landscapes affect the overall catchment or landscape water balance?
- How resilient are paludiculture systems and wetter landscapes to extreme rainfall events? How will they cope with prolonged or intense rainfall, and what happens if they can't?
- Where is the existing hydrological infrastructure in lowland peat landscapes, and how would paludiculture interact with this?
- What are the long-term hydrological impacts of paludiculture tracks and roads in lowland peat landscapes?
- How does adding paludiculture, and its associated infrastructure, into lowland peat landscapes affect groundwater availability and quality (e.g. salinity)?

- Better understanding of in-field water table variation, and associated tools to predict water tables under different scenarios to inform local decision making.
- Better understanding (e.g. models) of how raising the water table in a paludiculture site affects the surrounding landscape.

4. Water quality

Definition: The chemical, physical and biological characteristics of water, and particularly the presence of pollutants and contaminants.

4.1 Paludiculture impacts and management options

Impacts are not guaranteed: many are context dependent. Management options are some ideas to consider: they are not necessarily effective or feasible in all contexts, so should not be read as recommendations.

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **Mitigation of drainage-induced pollution of surface waters** [WS]. Several pollutants can accumulate in drained peat soils and then leach into surface waters (e.g. after rainfall). These include: • *Nutrients* (Aldous et al., 2005; Tiemeyer & Kahle, 2014; Zak et al., 2017), *dissolved organic carbon* (Evans et al., 2016; Tiemeyer & Kahle, 2014) and *heavy metals* (Evans et al., 2005; Tipping et al., 2003). See SOILS for details of soil chemical processes, and see below for water quality impacts. • *Sulphate*, formed by oxidation of sulphide or organically bound sulphur. Sulphates in surface waters can affect biogeochemical cycles and the fitness of organisms (Bottrell et al., 2004; Tipping et al., 2003; Zak et al., 2021). • *Ochre*, or ferric hydroxide, which is released when iron-rich peats are oxidised. Ochre is an orange solid that can reduce light availability and smother plant and animal life (Dewi, 1985; Madsen, 2005). Keeping peatlands wet for paludiculture can prevent these chemical changes. Rewetting can be a long-term solution to continued release of pollutants (Aldous et al., 2005; Evans et al., 2016). However, it may cause short-term pollution of surface waters (see below).	➔ **Retain intact (undrained) peatlands wherever possible**, to minimise chemical changes associated with drainage.
✖ **Mobilisation of chemicals by rewetting, leading to pollution of surface waters**. Chemical changes associated with rewetting can release chemicals that are bound in drained peat soils (see SOILS for details). If these leach into surface waters, they can have negative environmental impacts, including breaching of ecological and drinking water quality standards (HM Government, 2025b). More specifically: • *Nutrients* released from rewetted peat (Aldous et al., 2005; Rupp et al., 2004; Shenker et al., 2005; van de Riet et al., 2013) can cause eutrophication. The associated algal blooms can kill aquatic organisms (see BIODIVERSITY) and affect scenic quality (see LANDSCAPE CHARACTER & HERITAGE).	➔ **Retain intact (undrained) peatlands wherever possible**, to minimise nutrient release associated with rewetting. ➔ **Remove degraded surface peat before rewetting**. This can mitigate the release of nutrients into water bodies (Harpenslager et al., 2015; van den Berg et al., 2024; Zak et al., 2017, 2018). However, removing surface peat is expensive (Klimkowska et al., 2010) and can generate ⓘ *GHG emissions*.

- *Heavy metals* released from rewetted peat (Nieminen et al., 2020; Tipping et al., 2003) can have various lethal or sublethal effects on aquatic organisms. Toxic effects may be most dramatic in higher trophic levels due to bioaccumulation (Sharma et al., 2025).
- *Dissolved organic carbon* flushed from rewetted peat (Evans et al., 2005; Nieminen et al., 2020) can increase acidity, reduce light penetration through the water column via changes in turbidity and colour, and increase metal concentrations due to the transport of attached metal ions (Evans et al., 2005).

Note that pollutant export to surface waters may be a short-term effect while legacy chemicals or accumulated pollutants are expelled from the peat (Comber et al., 2023; Evans et al., 2016; Negassa et al., 2020; Tipping et al., 2003). Note also that pollutant release to surface waters may be limited by local soil properties (e.g. nutrient release can be limited by high iron or aluminium levels; Florea et al., 2024; Zak et al., 2004).

- **Rewet surface peat gradually, rather than instantaneously**. This involves raising the water table only slightly at first, or allowing the surface peat to dry out periodically. It can limit phosphate mobilisation in particular (Lucassen et al., 2005; Zak & McInnes, 2022).
- **Construct water treatment facilities** (e.g. artificial wetlands) **downstream of nutrient source**.
- **Maintain high water levels in water bodies** adjacent to nutrient-enriched peatlands (e.g. ditches), to minimise the translocation of nutrients from the peat into the water (Comber et al., 2023).
- **Manage external nitrogen inputs** to counter phosphorous enrichment. Even under phosphorous enrichment, some nuisance plant growth can be limited by keeping nitrogen levels low – although this will not be effective for nitrogen-fixing taxa like *Azolla* spp. (Comber et al., 2023).

Figure 4.1 An excess of nutrients in surface waters (eutrophication) can cause blooms of micro-organisms, such as algae in this ditch in the Fens, Cambridgeshire. Further consequences include death of aquatic animals, reduced diversity, altered species interactions (see BIODIVERSITY) and diminished scenic quality (see LANDSCAPE CHARACTER & HERITAGE). Credit: Richard Humphrey (geograph.org.uk, CC BY-SA 2.0).

Removal of pollutants from the landscape by slowing the flow of water. Paludicultures will be areas of relatively slow water flow, due to the presence of vegetation and flat topography. This will facilitate settlement of solid pollutants and allow time for chemical and biological transformation (breakdown) of pollutants (Caudwell, 2023; UN-HABITAT, 2008). Furthermore, paludiculture plants provide a large total surface area, and can increase oxygen levels in the water, both of which can favour chemical reactions that transform pollutants. Reed paludiculture is being trialled at Horsey in the Norfolk Broads, in part to manage ochre (ferric hydroxide) pollution. Slow flows in the reedbeds allow the ochre to settle out of the water column

- **Retain intact (undrained) peatlands wherever possible**, to act as natural water filters within the landscape, and as buffers between agricultural land and surface waters (Walton et al., 2020).
- **Manage pollution at source to reduce the work paludiculture sites need to do** (Russell et al., 2021). For example, if paludiculture input water is being contaminated by poor agricultural practices upstream, work with farmers to improve these practices.

before it reaches Horsey Mere, a nationally and internationally designated nature reserve (Anon, 2022; Madsen, 2005).

- **Consider system design to maximise benefits** (Stuart et al., 2023) [WS]. For example, in a system involving multiple crop species, cattails could be planted upstream to treat nutrient-rich input water and *Sphagnum* moss planted downstream in the resulting nutrient-poor water (Anon, n.d.). Similarly, cattail crops could be planted down-stream of a grazed plot to remove nutrients added via urine and faeces.

Removal of pollutants from site and landscape by paludi-culture plants. Paludiculture plants can remove nutrients and heavy metals from wetland soils (see SOILS) or directly from surface waters (Bennicelli et al., 2004; Vroom et al., 2020, 2024). For example, a study in Italy showed that nitrogen and phosphorous uptake of grass paludicultures (common reed, giant reed *Arundo donax*, miscanthus *Miscanthus* × *giganteus*) matched or exceeded that of a conventional maize crop. However, uptake in short rotation coppice paludicultures (Canadian poplar *Populus* × *canadensis*, white willow *Salix alba*) was generally lower than the conventional maize crop (Giannini et al., 2017). Nutrients and heavy metals can be removed in plant biomass when it is harvested, reducing concentrations in surface waters (Vroom et al., 2018).

- **Time harvest to maximise removal of chemicals from site**. For example, the nutrient content of common reed is higher in the summer than in the winter, because nutrients are transported down to the rhizomes for winter storage (Gessner, 2001).
- **Consider system design to maximise benefits** (see above).

Short-term reductions in surface water quality associated with harvesting. For example, harvesting vehicles can introduce crushed or cut biomass into surface water (across a whole flooded paludiculture site, in natural hollows, or in depressions generated by the vehicles themselves). This can increase nutrient availability (Banaszuk et al., 2016). If reed is cut in spring or early summer, the cut shoot will pump nutrients into surface water (Huhta, 2009). Finally, bare peat exposed post-harvest is vulnerable to erosion from rainsplash, water flows, slippage and (if it dries out) wind, especially on slopes of raised bogs (Godwin & Conway, 1939; Li et al., 2018). Eroding peat can add pollutants such as particles and heavy metals to surface waters (Garcés-Pastor et al., 2023; Shuttleworth et al., 2015). However, note that commercial harvesting offers a reason to export vegetation from site and reduce local pollution loads (see above).

- **Avoid using wheeled or tracked vehicles for harvesting**. Hovercraft or drones may offer alternative solutions (e.g. www.seadartists.com), if currently expensive and/or unproven.
- **Time harvest to prevent plants acting as chemical pumps**, e.g. avoid cutting just before site will be flooded.
- **Harvest at low intensity**, e.g. harvest fewer individuals, a smaller area, or to a shallower depth (Silvan, 2019; Silvan et al., 2012).
- **Ensure harvested material is re-moved from site**, rather than piled up or burned on site, for example.

Impacts on pollution from use of agrochemicals. To maintain a commercially viable crop, paludicultures may apply fertilisers or pesticides (Abel & Kallweit, 2022; Lloyd, 2024; Madel, 2020).

- *Fertilisers* may be needed to compensate for shallow, limited root systems that develop above the water table (Ward, 2024; M. Hammond pers. comm.), compensate for reduced nutrient availability due to reduced mineralisation in wetter peat (see SOILS) or nutrient removal in crop rotations [WS], or to balance nutrient ratios [WS]. Fertilisers are also important for crops such as cranberries grown in nutrient-poor sand perched on top of peat (Casperd, 2024).

- **Employ non-chemical pest control methods**. For example, weeds can be controlled by mowing (Wichmann et al., 2020), flooding (Crouwers, 2021), or growing cover crops (Badr, 2024). Insect pests can be killed with lasers (Gaetani et al., 2021). Field/ditch margins could be managed to support natural enemy populations (Marshall & Moonen, 2002).

- *Pesticides* may be needed to control a range of problematic species including plants, insects, fungi and bacteria. The pest burden in paludiculture crops can be substantial, for example if there is a dense weed seed bank present in the early years of crop establishment (Casperd, 2024; Stockdale et al., 2024). Long-term monocultures of paludiculture crops may be particularly susceptible to pest problems and thus require agrochemical inputs (Casperd, 2024; Ward, 2024).

Runoff, leaching or drift of agrochemicals can lead to surface water pollution [WS]. In the Netherlands, for example, application of manure to cattail plots has led to water quality problems (Caudwell, 2023).

However, note that many paludiculture sites will need low or no agrochemical inputs, especially in comparison to conventional agriculture on drained peat. For instance, fertiliser may be unnecessary in sites that are initially eutrophic or subject to atmospheric deposition, or where crops with low nutrient requirements, like *Sphagnum*, are grown (Eversham & Stanier, 2022; Temmink et al., 2024). Also note that currently, there are no pesticides listed as suitable for use on paludiculture crops in the UK (Stockdale et al., 2024).

- **Control pests before crop establishment, reducing the need for long-term chemical intervention** (Stockdale et al., 2024).
- **Use nutrient-rich water to feed paludicultures, rather than adding fertiliser**. In this way, paludiculture can also contribute to water purification (see above).
- **Use foliar rather than soil fertilisation** to reduce nutrient run-off (K. Evans pers. comm.).
- **Use precision agriculture techniques,** applying chemicals exactly when and where needed. Potential to use artificial intelligence and 'Internet of Things' to monitor sites or automate actions (Rowan et al., 2022; Zakaria et al., 2024).
- **Include buffer zones between water bodies and pollution sources**. This is a legal requirement for areas of chemical application (Bayer, 2018) and can substantially reduce pollutant inputs to water bodies (Norris, 1993).
- **Install artificial water treatment wetlands at polluted outflows**.
- **Match crops to conditions available at a site**, e.g. grow nutrient-demanding crops like cattail in eutrophic sites and nutrient-intolerant crops like *Sphagnum* in oligotrophic sites (Nordt et al., 2022). Note potential change in nutrient status over time as crop is removed from site. Crop choice will also depend on economic and practical factors [WS].
- **Consider system design to maximise benefits** (see above).

✖ **Pollution from harvesting machinery**, for example due to oil leaks. Just 1 cm^3 of mineral oil spilled in a wetland can contaminate five litres of water (Dubowski et al., 2013).

- **Ensure machinery is well maintained** to reduce risk of breakdowns and leaks.
- **Use biodegradable oils** (e.g. derived from plants), not mineral oils (derived from petroleum) (Dubowski et al., 2013).
- **Use oils free from heavy metals**.

✖ **Pollution from livestock urine and faecal inputs**. These can add bioavailable nutrients to the local ecosystem (see SOILS). If livestock also graze outside of a paludiculture site, or are given supplementary food, they could be net importers of nutrients to the site and its connected waters (Duncan et al., 2021; Middleton et al., 2006). Nutrient pollution from livestock is likely

- **Include buffer zones between water bodies and grazed areas**. Buffer zones can substantially reduce pollutant inputs to water bodies (Norris, 1993).
- **Consider system design to maximise benefits** (see above).

to be a particular problem in coastal systems, because livestock excreta are rich sources of nitrogen (Angelidis et al., 2021) which is generally the key limiting nutrient for microorganisms in coastal waters (Smith & Schindler, 2009). An additional problem is that worming treatments, excreted in faeces and urine, can end up in surface waters where they can have toxic effects on aquatic organisms (Wagil et al., 2015).

- **Avoid giving prophylactic worming drugs to livestock** grazing in paludiculture systems.

Figure 4.2 In a trial in Norfolk, celery grown in paludiculture (left) developed shallower and thinner roots than celery grown conventionally in drained peat (right). Such paludiculture crops, with poorly developed root systems, might require additional fertilisation to maintain yield and/or quality. Credit: Nigel Taylor (CC BY-ND 4.0).

✖ **Pollution linked to soil amendments**. There is interest in adding materials such as biochar and gypsum to paludiculture soils to maximise their benefits with respect to greenhouse gas emissions. Biochar can contribute to long-term carbon storage, and gypsum can reduce methane production. However, initial studies suggest these amendments may increase concentrations of nitrate, ammonia and sulphate in the peat (Barry & Rhymes, 2025). Release of these chemicals into surface waters could breach ecological and drinking water quality standards (HM Government, 2025b).

- **Avoid using soil amendments in paludiculture systems** until the water quality implications are understood, and mitigation measures are developed (Barry & Rhymes, 2025).

✖ **Pollution from inundation of wastewater infrastructure**. Raised water levels across a landscape (see HYDROLOGY) could flood infrastructure such as septic tank systems and cesspits. This could cause pollution of the surrounding environment, and particularly water bodies. For example, flooding of onsite drainage from septic tank systems can generate polluted surface or subsurface runoff (Withers et al., 2014).

- **Ensure all wastewater infrastructure is identified before raising water levels in an area**.
- **Take appropriate mitigating action**, such as installing local water treatment systems.

✖ **Increased pollutant concentrations due to reduced flows downstream of paludiculture systems**. Diversion of water into paludiculture systems could take water out of existing water bodies, meaning there is less water to dilute any pollutants (L. Crockford pers. comm.).

- **Monitor downstream flows and ensure they are sufficient, especially during droughts**. Flows could be maintained by releasing water from reservoirs or lowering weir heights, for example.

- **Mitigation of acute pollution using water held in paludiculture systems**. Well-designed paludiculture systems will increase the landscape water holding capacity (see HYDROLOGY). Water could be released strategically, from paludiculture plots or associated infrastructure like reservoirs, to dilute or flush away sudden pollution events (DeSmet, 2014).

- **Real-time monitoring of pollution events to allow rapid response**.

4.2 Research questions / knowledge gaps

Sources: Own work, Workshop, Barry & Rhymes (2025), Comber et al. (2023), Lundin et al. (2017), Stuart et al. (2023).

- How does agrochemical loss to the wider environment (e.g. drift, runoff) vary between different methods of application in paludiculture systems?
- What are the implications of cycling the water level (e.g. to allow machinery access) on nutrient losses?
- How effective are different paludiculture plants at removing pollutants – including pharmaceutical and medical chemicals, which are becoming more prevalent in aquatic environments?
- How exactly do rewetting and cultivation of paludiculture crops affect nutrients in surface waters? How do these effects vary between contexts (e.g. land use history, surrounding landscape land use, crop species, duration of paludiculture) and over long timescales (multi-year or decadal)?
- How does preparation of paludiculture sites impact surrounding and downstream water quality?
- How does harvesting of vegetation from paludiculture sites impact surrounding and downstream water quality?
- What is the optimal design of paludiculture systems (e.g. crop types and landscape configuration) to deliver improved water quality?
- How is product quality affected by the use of paludiculture plants to remediate pollution, and the resulting incorporation of pollutants into plant tissues? Does this restrict potential uses of the end product?
- How do impacts of soil amendments, such as biochar and gypsum, on porewater chemistry translate to impacts on surface water quality? How can any negative impacts be mitigated?

5. Biodiversity

Definition: The number and types of living things that exist in a site, region, or on Earth. Includes ecological scales from genes through individuals, populations, species, communities, and ecosystems.

5.1 Paludiculture impacts and management options

Impacts are not guaranteed: many are context dependent. Management options are some ideas to consider: they are not necessarily effective or feasible in all contexts, so should not be read as recommendations.

a) Landscapes

	Observed or potential impacts of paludiculture		Options to minimise negative / maximise positive impacts
✔	**Increased diversity of habitat types in the landscape**. In particular, paludiculture would restore *wetlands* to landscapes that have been historically drained. Less than 1% of the original wetland habitat in the Fens remains, for example (Fens for the Future, 2024). *Tall* graminoid and woody crops can add structural diversity to generally flat and open landscapes. Increased habitat diversity should lead to increased species diversity across the landscape (Walz & Syrbe, 2013). Furthermore, many individual species rely on a *mosaic* of different habitats. For example, marsh harriers *Circus aeruginosus* nest in reedbeds but hunt over arable land (Underhill-Day, 1984).	➔	Across a landscape, **maintain a mosaic of paludiculture and other land uses**. ➔ **Engage early with reserve managers or conservation specialists** to inform landscape planning (Nordt et al., 2022).
✔	**Benefits to biodiversity from landscape water management** (see HYDROLOGY). Water from paludiculture systems could be used to supplement natural wetland sites during droughts. Equally, paludiculture systems could store water in times of excess, mitigating impacts on biodiversity (e.g. spring flooding on the Ouse Washes that is driving declines in black-tailed godwits *Limosa limosa*; Ratcliffe et al., 2005; RSPB, 2024).	➔	**Consider how paludiculture systems can support biodiversity in landscape water management plans or budgets**.
✖	**Damage to existing habitats and their biodiversity, across landscapes, due to a higher water table** (see HYDROLOGY). This applies to both existing dry habitats and wetland habitats For example, there is concern that MG5 grasslands, a key SSSI feature on the Somerset Levels and Moors, will be degraded if continually saturated as part of landscape rewetting (Comber et al., 2023). Similarly, species that rely on temporary wetlands, such as the diving beetle *Agabus uliginosus*, may suffer from more permanent inundation (Foster, 2010). Raised water levels could also damage key habitat features such as water vole *Arvicola amphibius* burrows [WS].	➔	**Manage water levels to maintain appropriate hydrology for drier habitats**. ➔ **Ensure remaining sites are adequately conserved**. ➔ **Restore/create lost habitat, or its key features, nearby** – particularly if the impacted species are protected. ➔ **Translocate rare or specialist species** out of lost habitats. Follow latest guidance (HM Government, 2024b).
?	**Increased connectivity of wetland habitats via paludiculture sites**. Paludiculture sites could act as wet corridors or stepping stones between existing isolated wetland habitats (Gorokhova, 2023). This could benefit native species, increasing connectivity and gene flow between populations, facilitating migration between	➔	**Monitoring and rapid eradication** of any invasive species detected in the landscape, especially those prone to dispersing along corridors.

transient habitats, improving landscape-scale resilience to population fluctuations, and facilitating adaptation to longer term climatic challenges. However, there is a risk that increased connectivity will allow invasive species to spread (Havel et al., 2005).

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
? **Increased connectivity of aquatic habitats via water management infrastructure**. For example, ditches could act as corridors, and on-farm reservoirs could act as stepping stones between existing aquatic habitats. This could benefit native species (as above). However, increased connectivity could also facilitate the spread of invasive species (Havel et al., 2005).	**Good biosecurity practice** to prevent introductions of invasive species to water management infrastructure. **Monitoring and rapid eradication** of any invasive species detected in water management infrastructure.
? **Impacts on biodiversity via water quality**. Paludiculture could have mixed effects on biodiversity via water quality. For example, it could reduce the risk of eutrophication where *nutrients* are exported in harvested vegetation, or increase the risk when degraded peat is rewetted (see WATER QUALITY). Eutrophication leads to increased abundance of phytoplankton and floating plants which block out light, killing submerged vegetation (Janse & van Puijenbroek, 1998) and aquatic animals (Chislock et al., 2013). It can also cause more subtle changes in species interactions, food web structure, and temporal community turnover (Cook et al., 2018; van der Lee et al., 2021). Paludiculture could also increase or reduce *dissolved organic carbon (DOC)* concentrations in water bodies, depending on the site history and time since rewetting (see WATER QUALITY). DOC can affect aquatic biota via chemical and physical mechanisms (e.g. increasing nutrient availability, reducing visibility, offering UV protection; Evans et al., 2005; Kritzberg et al., 2020). Restrictions on *pesticide* use in paludiculture crops should limit the pollution risk (Stockdale et al., 2024), but any future regulatory concessions could increase it. Pesticide pollution can impact sensitive aquatic species (Wagil et al., 2015) and ecosystem functions such as leaf-litter breakdown (Schäfer et al., 2007).	**Implement measures to improve water quality** (see WATER QUALITY).
✓ **Benefits to biodiversity via landscape cooling**. The high water table associated with paludiculture can cool the landscape via evapotranspiration (Wahren et al., 2016). Worrall et al. (2019) demonstrated that peatland restoration (revegetation and re-wetting) reduced air temperatures by 1.7°C compared to drained agricultural land. Cool microclimates in paludiculture sites may help wild species cope with climate change (Suggitt et al., 2018).	**Grow crops with high albedo** (ability to reflect solar radiation) **and low 'surface roughness'** (complexity). These factors can modulate the cooling effect (Worrall et al., 2020). Accordingly, *Sphagnum* mosses, for example, might offer greater cooling than berry shrubs.

b) Habitats

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✓ **Paludicultures can support wetland-specialist species, as analogues for rare or declining wetland habitats**. Paludiculture crops are likely to mimic aspects of natural wetland habitats – to a greater or lesser extent, and perhaps only at certain points in the cropping cycle. Generally, rewetting lowland	**Tolerate some 'weeds'**. Many of these will be wetland or peatland specialists (Wichtmann & Joosten, 2007). Some have notable national or global conservation status (Table 5.1).

peatlands is followed by an increase in richness, diversity and/or abundance of wetland animal and plant species, i.e. species characteristic of wetlands or peatlands in general, or of particular wetland habitats (Tanneberger et al., 2022; Taylor et al., 2018). Several such species have been found specifically in paludiculture crops (e.g. Table 5.1; Casperd, 2024; Martens et al., 2023; Zoch & Reich, 2022). Specialist species may also be introduced with wild-sourced donor material (Grobe, 2023).

Note that the presence of habitat-characteristic species and metrics of community composition are typically better indicators of peatland and wetland habitat quality than metrics like overall species richness, since these habitats can be species-poor even in a pristine state.

- **Situate paludiculture close to other wetland habitats** (existing, restored or created), so that wetland species can reach and use paludiculture sites (Gaudig & Krebs, 2016). But beware of paludicultures becoming ecological traps.
- **Maintain sufficient area of habitat in landscape for target species**. The probability of occurrence of habitat-specialist species in a landscape can be strongly related to the proportional area of that habitat (Mortelliti et al., 2012).
- **Translocate wild species to sites with suitable wetland/peatland habitat** but outside their dispersal range. Follow guidance (HM Government, 2024b).

Paludicultures do not exactly replicate natural habitats, so may support different species and communities. For example:

- *Small isolated habitat patches* may be unsuitable for species that have large home ranges (Gilbert et al., 2005) or require a high proportion of a habitat type in the landscape (Mortelliti et al., 2012).
- Where paludiculture sites are levelled, to standardise water table depth, they will lack *variation in microhabitats* that is important for diversity.
- The presence of *open water* in wetland habitats is critical for some species, including birds (Gilbert et al., 2005; Morganti et al., 2019) and invertebrates (Hardman et al., 2012). Yet flooding of paludicultures may be undesirable in terms of greenhouse gas emissions, farming processes (e.g. sowing, harvesting) and/or productivity (Abel & Kallweit, 2022; Evans et al., 2021; Hudson, 2024).

Generally, paludiculture sites support biological communities intermediate between conventional agricultural sites (on drained peat) and pristine peatlands; there are more mixed results for species richness and diversity (Table 5.2). Paludiculture sites may lack individual wetland- or peatland-characteristic species present in nearby habitats (Zoch & Reich, 2022). Even rewetting peatlands primarily for nature conservation can create novel ecosystems with different communities to natural peatlands – for several years, or even decades, after rewetting (Kreyling et al., 2021; Renou-Wilson et al., 2019; Strobl et al., 2020; Taylor et al., 2018; Utseth, 2021).

- **Incorporate or tolerate some variation in site topography to** generate micro-habitat variation.
- **Seasonally raise the water table, perhaps even flooding the paludiculture site, to support target species.** Note that this can have negative effects on some species depending on timing (see ORGANISMS). ! *GHG emissions*
- **Incorporate habitat features necessary for focal species**, e.g. open pools amongst reedbeds for bitterns (Gilbert et al., 2005).
- **Restore or create near-natural wetlands elsewhere**, either on farm or across the landscape.

Indirect impacts on biodiversity via habitat provision for predatory species. For example, marsh harriers *Circus aeruginosus* could nest in reed paludicultures and prey on surrounding late-nesting waders of conservation concern (Upcott et al., 2024). However, paludiculture sites may also provide less cover (e.g. trees) for predators than drained agricultural landscapes, which could reduce predation pressure on species like ground-nesting birds [WS].

- **Monitor prey species and carry out conservation action where necessary**, e.g. predator diversion, predator exclusion, or headstarting for waders (Williams et al., 2012).

Figure 5.1 Some wetland-characteristic species that have been recorded in paludiculture crops. **Left** – Marsh warbler *Acrocephalus palustris*, Reference: Graf (2014), Credit: Pierre-Marie Epiney (Flickr, CC BY-SA 2.0). **Centre left** – Spider *Pirata piscatorius*, Reference: Martens et al. (2023), Credit: hanjohan (iNaturalist, CC BY 4.0). **Centre right** – Round-leaved sundew *Drosera rotundifolia*, Reference: Grobe (2023), Credit: Chris Parker (Flickr, CC BY-ND 2.0). **Right** – Natterjack toad *Epidalea calamita*, Reference: Graf (2014), Credit: Bernard Dupont (Flickr, CC BY-SA 2.0).

- **Replacement of drained farmland habitats by paludiculture, and loss of species dependent on them** [WS]. For example. Finch et al. (2023) modelled scenarios for future UK land use to 2050. Scenarios that involve converting lowland arable fields, grassland, and forests on peat to a mixture of paludiculture and restored peatlands are associated with a 17–21% reduction in habitat availability for farmland specialist birds.
  - **Restore/create lost habitat, or its key features, nearby** – particularly if the impacted species are protected.

- **Use of near-natural or semi-natural habitats for paludiculture, with impacts on dependent species**. With sufficient economic incentives (e.g. markets and/or subsidies), land managers may be encouraged to use near-natural or semi-natural habitats for paludiculture (Ward, 2024). This could involve full conversion of habitats to paludiculture crops, or more intensive harvesting or grazing. This would probably have negative impacts overall on biodiversity. Small pockets of wet peatland vegetation across the English lowlands are particularly important as refugia for peatland species; many of these would be damaged by productive use (IUCN, 2023). A recent survey, with responses mainly from Europe, found that 49% of paludiculture initiatives were being carried out on at least some protected land (Ziegler et al., 2021).
  - **Ensure regulations prevent unplanned conversion, or unsustainable use, of near- or semi-natural sites** with high biodiversity value.
  - **Incentivise retention of near- or semi-natural sites** with high biodiversity value, for example with payments for ecosystem services.
  - **Restore/create lost habitat, or its key features, nearby** – particularly if the impacted species are protected.

- **Habitat provision by water management infrastructure** associated with paludiculture [WS]. *Ditches and reservoirs* can be important sites for biodiversity. A study of ditches in Lincolnshire found that they supported diverse aquatic macroinvertebrate communities at both the site and landscape scales, and that some supported communities of high conservation value owing to their richness and rarity of constituent species (Hill et al., 2016). Regular clearing of ditches to maintain their capacity for water management, as would be needed in a paludiculture system, can actually increase their biodiversity and conservation interest (Graham & Hammond, 2015). Farm reservoirs can provide habitats for various taxa (Littlefair et al., 2024b) and hold distinct assemblages of species compared to other aquatic habitats (Brainwood & Burgin, 2009). *Water treatment wetlands*, used to clean input water for crops such as *Sphagnum* moss (Eversham & Stanier, 2022), could also increase habitat and species diversity (Worrall et al., 1997; Zhang et al., 2020).
  - **Manage ditches for biodiversity**. For example, reducing shading can increase aquatic plant species richness (Shaw et al., 2015). Water depths of 50–60 cm can maximise richness of aquatic invertebrates (Shaw et al., 2015) and plants (Twisk, 2003).
  - **Manage reservoirs for biodiversity** [WS]. For example, fencing the site to exclude livestock can increase vegetation cover (Littlefair et al., 2024a). Lining reservoirs with clay rather than plastic facilitates better colonisation by fauna and flora (Suffolk Coast and Heaths AONB, 2022).

Table 5.1 Notable species recorded in temperate lowland paludicultures (or paludiculture crops, not necessarily on peat). These species are listed in selected international biodiversity agreements, UK legislation or country lists, or have notable conservation status. Statuses are derived from the IUCN Red List (IUCN, 2024c) and the JNCC UK Collation (JNCC, 2023). For Red List status, only threatened categories (CR, EN, VU) are listed. National Red List statuses are generally for Great Britain, except for plants which are for England. For birds, the two National Red List statuses refer to breeding / non-breeding periods; non-threatened categories are listed when the species is threatened in only one period. Note: (1) Presence may be related to specific geographical, habitat or management conditions in each study; (2) Species in this list do not necessarily *benefit* from paludiculture, and may *perform better* in uncultivated habitats; (3) This is not an exhaustive list of species or studies. Abbreviations: CR – Critically Endangered; EN – Endangered; LC – Least Concern; NT – Near Threatened; PE – Possibly Extinct; VU – Vulnerable.

Taxon	Species	Global Red List (Threatened)	National Red List (Threatened)	Bern Convention	Birds Directive (Annex 1)	Convention on Migratory Species	Habitats Directive	Rare and Scarce Species	England Biodiversity List (NERC)	Wildlife and Countryside Act	Habitat Regulations	References
Common reed												
Amphibians	Natterjack toad *Epidalea calamita*			●			●		●	●	●	1
Birds	Moustached warbler *Acrocephalus melanopogon*				●							2
	Aquatic warbler *Acrocephalus paludicola*	**VU**			●	●			●			3
	Purple heron *Ardea purpurea*			●	●	●				●		4
	Eurasian bittern *Botaurus stellaris*		**NT / VU**	●	●	●			●	●		5
	Reed bunting *Emberiza schoeniclus*			●					●			2,6
	Red-backed shrike *Lanius collurio*		**CR / –**	●	●					●		2,7
	Bluethroat *Luscinia svecica*			●	●					●		6
	White wagtail *Motacilla alba*			●								2
	Yellow wagtail *Motacilla flava*			●								6
	Whinchat *Saxicola rubetra*			●								7
Insects	carabid beetle *Acupalpus exiguus*							●				8
	carabid beetle *Amara lucida*							●				9
	carabid beetle *Badister collaris*							●				8
	carabid beetle *Badister dilatatus*							●				8
	carabid beetle *Badister peltatus*							●				8
	carabid beetle *Bembidion fumigatum*							●				8
	carabid beetle *Blethisa multipunctata*							●				8,9
	carabid beetle *Carabus clatratus*							●				9
	carabid beetle *Demetrias monostigma*							●				8
	carabid beetle *Elaphrus uliginosus*							●				8
	dytiscid beetle *Graphoderus zonatus*		**CR**						●	●		9
	carabid beetle *Odacantha melanura*							●				8,9
	carabid beetle *Oodes helopioides*							●				8
	carabid beetle *Pterostichus gracilis*							●				8
Plants	Holy grass *Hierochloe odorata*		**VU**									10
	Frogbit *Hydrocharis morsus-ranae*		**VU**									10
	Tufted loosestrife *Lysimachia thyrsiflora*		**CR**									10
	Greater water parsnip *Sium latifolium*		**EN**						●			10
	Lesser bladderwort *Utricularia minor*		**VU**									10
Cattail												
Amphibians	Natterjack toad *Epidalea calamita*			●			●		●	●	●	11
	European common frog *Rana temporaria*			●			●			●		11
Birds	Marsh warbler *Acrocephalus palustris*		**CR / –**						●	●		11

Taxon	Species	Red List	National Red List	Bern	Birds A1	CMS	Hab. Dir.	RSS	NERC	WACA	Hab. Reg.	Refs
	Mallard *Anas platyrhynchos*					●						11,12
	Meadow pipit *Anthus pratensis*			●								12
	Grey heron *Ardea cinerea*					●						12
	Tufted duck *Aythya fuligula*					●						12
	Reed bunting *Emberiza schoeniclus*			●					●			11,12
	Eurasian coot *Fulica atra*					●						11,12
	Common snipe *Gallinago gallinago*					●						13
	Common moorhen *Gallinula chloropus*		**VU / –**			●						11,12
	Oystercatcher *Haematopus ostralegus*					●						11,12
	Black-tailed godwit *Limosa limosa*		**EN / LC**			●				●		12
	Savi's warbler *Locustella luscinioides*		**CR / –**						●	●		11
	Grasshopper warbler *Locustella naevia*								●			11
	Bluethroat *Luscinia svecica*			●	●					●		12
	Gadwall *Mareca strepera*					●						12
	Spotted crake *Porzana porzana*		**EN / –**	●	●	●				●		11
	Water rail *Rallus aquaticus*					●						11,12,13
	European stonechat *Saxicola rubicola*			●								12
	Northern shoveler *Spatula clypeata*					●						12
	Garganey *Spatula querquedula*		**CR / –**			●				●		12
	Little grebe *Tachybaptus ruficollis*					●						11
	Common redshank *Tringa totanus*		**VU / NT**			●						12
	Lapwing *Vanellus vanellus*		**EN / VU**			●			●			12,14
Arachnids	wolf spider *Pirata piscatorius*							●				14
Insects	Green-eyed hawker *Anaciaeschna isoceles*		**EN**						●	●		11
***Sphagnum* moss**												
Birds	Mallard *Anas platyrhynchos*					●						15
	Meadow pipit *Anthus pratensis*			●								16
	Grey heron *Ardea cinerea*					●						15
	Little ringed plover *Charadrius dubius*			●		●				●		16
	White stork *Ciconia ciconia*			●	●	●						15
	Common snipe *Gallinago gallinago*					●						15
	Oystercatcher *Haematopus ostralegus*					●						15
	White wagtail *Motacilla alba*			●								15
	Yellow wagtail *Motacilla flava*			●								16
	Green sandpiper *Tringa ochropus*		**EN / EN**	●		●				●		15
	Lapwing *Vanellus vanellus*		**EN / VU**			●			●			15,16
Arachnids	money spider *Araeoncus crassiceps*							●				17
	money spider *Bathyphantes setiger*							●				15,18
	money spider *Erigonella ignobilis*							●				15
	wolf spider *Hygrolycosa rubrofasciata*		**EN**					●				15
	wolf spider *Pirata piscatorius*							●				17
Insects	ground beetle *Acupalpus brunnipes*							●				19
	ground beetle *Acupalpus flavicollis*							●				19
	chrysomelid beetle *Chaetocnema sahlbergii*		**VU**					●				19
	dung beetle *Chilothorax distinctus*							●				19
	diving beetle *Hydroporus scalesianus*		**VU**									19
	staphylinid beetle *Ischnosoma longicorne*							●				19
	carabid beetle *Stenolophus teutonus*							●				19
Plants	Oblong-leaved sundew *Drosera intermedia*		**VU**									20
	Common cottongrass *Eriophorum angustifolium*		**VU**									20
	Pin cushion moss *Leucobryum glaucum*						●					20
	Lesser spearwort *Ranunculus flammula*		**VU**									21
	Greater yellow-rattle *Rhinanthus angustifolius*									●		21

Taxon	Species	Red List	National Red List	Bern	Birds A1	CMS	Hab. Dir.	RSS	NERC	WACA	Hab. Reg.	Refs
Harvested fen/raised bog												
Birds	Aquatic warbler *Acrocephalus paludicola*	**VU**			●	●			●			22
Arachnids	wolf spider *Aulonia albimana*		**CR**					●				23
	raft spider *Dolomedes fimbriatus*							●				23
	money spider *Donacochara speciosa*							●				23
	money spider *Erigonella ignobilis*							●				23
	jumping spider *Evarcha arcuata*							●				23
	money spider *Gonatium paradoxum*		**EN**					●				23
	money spider *Gongylidiellum murcidum*		**VU**					●				23
	Bog sun-jumper spider *Heliophanus dampfi*		**VU**					●				23
	money spider *Oryphantes angulatus*							●				23
	wolf spider *Pirata tenuitarsis*							●				23
	Diamond spider *Thanatus formicinus*		**CR(PE)**					●				23
	wolf spider *Trochosa spinipalpis*							●				23
	Double-banded crab spider *Xysticus bifasciatus*							●				23
Plants	Slender sedge *Carex lasiocarpa*		**VU**									23
	Bladder sedge *Carex vesicaria*		**VU**									23
	Common cottongrass *Eriophorum angustifolium*		**VU**									23
	Tufted loosestrife *Lysimachia thyrsiflora*		**CR**									23
	Grass of Parnassus *Parnassia palustris*		**VU**									23
	Common butterwort *Pinguicula vulgaris*		**VU**									23
	Lesser butterfly orchid *Platanthera bifolia*		**EN**						●			23
	Dwarf milkwort *Polygala amarella*		**EN**									23
	Whorled Solomon's seal *Polygonatum verticillatum*									●		23
	Lesser spearwort *Ranunculus flammula*		**VU**									23
	Cambridge milk parsley *Selinum carvifolia*		**EN**							●		23
Grazed fen/raised bog												
Amphibians	European common frog *Rana temporaria*			●			●			●		24
Arachnids	wolf spider *Aulonia albimana*		**CR**					●				23
	money spider *Allomengea vidua*							●				23
	raft spider *Dolomedes fimbriatus*							●				23
	money spider *Erigonella ignobilis*							●				23
	jumping spider *Evarcha arcuata*							●				23
	money spider *Gongylidiellum latebricola*							●				23
	money spider *Gongylidiellum murcidum*		**VU**					●				23
	Bog sun-jumper spider *Heliophanus dampfi*		**VU**					●				23
	money spider *Oryphantes angulatus*							●				23
	wolf spider *Pirata tenuitarsis*							●				23
	money spider *Taranucnus setosus*							●				23
	Diamond spider *Thanatus formicinus*		**CR(PE)**					●				23
	wolf spider *Trochosa spinipalpis*							●				23
	money spider *Walckenaeria alticeps*							●				23
	money spider *Walckenaeria kochi*							●				23
	Double-banded crab spider *Xysticus bifasciatus*							●				23
Molluscs	Desmoulin's whorl snail *Vertigo moulinsiana*	**VU**	**VU**				●	●	●			25
Plants	Creeping marshwort *Apium repens*		**EN**	●			●		●	●	●	26
	Common cottongrass *Eriophorum angustifolium*		**VU**									23,27
	Slender sedge *Carex lasiocarpa*		**VU**									23
	Bladder sedge *Carex vesicaria*		**VU**									23
	Fen orchid *Liparis loeselii*		**EN**	●			●		●	●	●	26
	Grass of Parnassus *Parnassia palustris*		**VU**									23
	Common butterwort *Pinguicula vulgaris*		**VU**									23
	Lesser spearwort *Ranunculus flammula*		**VU**									23

References: [1] A. van Weeren, pers. obs., [2] Vadász et al. (2008), [3] Tegetmeyer et al. (2007), [4] Barbraud & Mathevet (2000), [5] Poulin et al. (2009), [6] Zitzmann (2023), [7] Weerman et al. (2021), [8] Görn et al. (2014)*, [9] Andersen et al. (2024)*, [10] Andersen et al. (2021)*, [11] Graf (2014)**, [12] J. Copping & C. Waite, unpublished data from paludiculture sites in the Netherlands (2024), [13] DBU (2007), [14] Martens et al. (2023), [15] Gaudig & Krebs (2016), [16] Zoch & Reich (2022)**, [17] Muster et al. (2020), [18] Gaudig et al. (2014), [19] Zoch et al. (2024), [20] Grobe (2023), [21] van de Riet et al. (2018), [22] Kubacka et al. (2014), [23] Bucher et al. (2016), [24] Zahn & Herzog (2015), [25] Ausden et al. (2005), [26] Duncan et al. (2021), [27] Groome & Shaw (2015). * Only productive treatments and the most recent harvests are included in Table 5.1. ** Only species thought to be breeding are included in Table 5.1.

✖ **Loss of aquatic habitats as water management infrastructure is remodelled for paludiculture**. As paludiculture sites are established, existing drainage ditches and other water bodies may be filled, removed or remodelled (Nordt et al., 2022). Existing drainage ditch networks are generally designed to remove excess water and are not optimised for precise water table control (Freeman et al., 2022). The loss of older, late-successional aquatic habitats is a concern because they can harbour distinct communities and rare or specialised species (Fens for the Future, 2015; Herzon & Helenius, 2008).

➔ **Follow mitigation hierarchy to avoid, minimise, restore, or offset any impacts** to ecologically valuable water infrastructure.

➔ **Where possible, keep (some) existing ditches as part of water management infrastructure**. Drainage ditches could contribute to peatland rewetting if they are dammed or flooded, for example.

✖ **Loss of habitats due to the footprint of water management infrastructure**, especially on-farm reservoirs. Even if each reservoir is small, the cumulative effect could be substantial. Small agricultural excavations and engineering operations, on farms ≥5 ha, are generally exempt from planning permission.

➔ **Follow mitigation hierarchy to avoid, minimise, restore, or offset any impacts** to existing habitats.

➔ **Minimise footprint of individual water management infrastructure projects**.

? **Compatibility of water table management with species requirements**. Maintenance of *constant water tables* – to meet plant demands and/or qualify for subsidies (HM Government, 2024a; Nordt et al., 2022) – will exclude species that rely on fluctuating water levels. This includes the nationally endangered Cambridge milk parsley *Selinum carvifolia*, and milk parsley *Thysselinum palustre*, host plant of the swallowtail butterfly *Papilio machaon* (Fitter & Peat, 1994; Ward, 2024). Further, inter-annual variation in the frequency and magnitude of water table fluctuations is important for certain species and communities in natural peatlands (McBride et al., 2011).

Paludiculture sites may be seasonally *flooded* to support crops, control weeds, manage landscape flood risk, and/or benefit biodiversity. But flooding at the wrong time of year could harm some species, converting paludicultures into ecological traps. For example, the large copper butterfly *Lycaena dispar* can be drowned by floods just before or just after the winter hibernation period (Duffey, 1977). It is thought that floods contributed to the failure of recent reintroduction attempts (M. Hayes pers. comm.).

Paludiculture sites may be temporarily *drained*, for example to allow vehicle access. This can affect species with young that develop or hibernate in wet peat. In drained peat, invertebrate eggs and larvae can be killed by frosts in winter (Zeller & Bauchhenß, 2001) and desiccation in summer (Carroll et al., 2011). Cranefly abundance, for example, is positively associated with soil moisture and population declines have been observed following drought (Carroll et al., 2011). However, some species may benefit from seasonal drainage. The mud snail *Omphiscola glabra* is restricted to fen areas that dry out in summer (McBride et al., 2011).

➔ **Consider implications of water table management on local biodiversity and adjust schedule**. For example, draining in autumn rather than winter could allow animals to move to wetter parts of the landscape before they hibernate (Zeller & Bauchhenß, 2001).

➔ **Rotate crops in any given land parcel, such that the frequency and magnitude of water table fluctuations varies over time**. Even with a constant crop, consider varying water table management in fallow periods, or periods when the crop is less sensitive to fluctuations.

➔ **Vary topography across landscape to create habitats with varying moisture levels**, e.g. leave some fields slightly higher, create raised embankments, excavate pools.

Table 5.2 Example studies comparing overall biodiversity metrics in temperate lowland paludicultures (or paludiculture crops, not necessarily on peat) to counterfactuals (either conventional/drained agriculture, unmanaged, or near-natural habitats). Note that this list is far from exhaustive. Unless specified, data are averages from different treatments and statistical significance of differences was not assessed. Countries: DE – Germany; DK – Denmark; GB – Great Britain; HU – Hungary; NL – Netherlands.

Ref	Ctry	Comparison	Taxon	Metric	Findings
Common reed					
1	HU	Unharvested (≥20 years)	Birds	Abundance	Plots harvested in the preceding winter contained fewer individual birds during the breeding season than unharvested areas (29 vs 120 birds/100 m).
				Richness / diversity	Plots harvested in the preceding winter contained significantly fewer breeding bird species than unharvested areas (5 vs 8 species/100 m). The same was true for diversity (Shannon index: 1.31 vs 1.27).
2	DE	Unharvested (1–3 years)	Birds	Abundance	Plot harvested in preceding winter contained fewer individual breeding birds than unharvested plot (27 vs 57 pairs/10 ha).
				Richness	Plot harvested in preceding winter contained fewer breeding bird species than unharvested plot (6 vs 8 species).
3	DK	Unharvested (25 years)	Beetles	Biomass	Reedbed harvested during year of study contained significantly higher total beetle biomass than reedbed left unmanaged for 25 years (21 vs 6 g trapped/fortnight).
				Richness / diversity	Reedbed harvested during year of study contained significantly fewer beetle species than reedbed left unmanaged for 25 years (15 vs 20 species trapped/fortnight). The same was true for diversity (Shannon index: 5 vs 10; Simpson's index: 3 vs 6).
				Community composition	Overall beetle community in reedbed harvested during year of study differed from reedbed left unmanaged for 25 years.
4	DE	Unharvested (fallow)	Butterflies	Richness / diversity	Butterfly richness and diversity did not significantly differ between winter-harvested and unharvested reedbeds (richness: 1.6 vs 2.5 species/100 m; Shannon index: 0.3 vs 0.5).
			Grass-hoppers	Richness / diversity	Grasshopper richness and diversity did not significantly differ between winter-harvested and unharvested reedbeds (richness: 0.1 vs 0.3 species/100 m; Shannon index: both <0.1).
			Carabid beetles	Richness / diversity	Carabid richness and diversity did not significantly differ between winter-harvested and unharvested reedbeds (richness: 34 vs 29 species trapped; Shannon index: 2.6 vs 2.1).
5	DK	Unharvested (25 years)	Plants	Richness / diversity	Reedbeds harvested in the preceding winter had significantly higher plant richness in May than unharvested reedbeds (7.4 vs 6.3 species/79 m^2), but there was no significant difference in August (8.4 vs 6.8 species/79 m^2). Plant diversity did not significantly differ between harvested and unharvested reedbeds in either month (Shannon index: 0.5–0.8 vs 0.7; Pielou's index: 0.4–0.5 vs 0.5).
				Community composition	Overall plant community in reedbed harvested in preceding winter differed from reedbed unharvested for 25 years.
Cattail					
6	NL	Conventional agriculture	Birds	Abundance	Cattail fields contained more individual birds than nearby pasture grassland (31 vs 11 individuals/ha) and more wetland specialists (29 vs 7 individuals/ha), but a similar abundance of threatened species (4 vs 3 individuals/ha).
		Near-natural	Birds	Abundance	Cattail fields contained a similar number of birds to near-natural wetlands. This was true for all species (31 vs 32 individuals/ha), wetland specialist species (29 vs 27 individuals/ha) and threatened species (4 vs 4 individuals/ha).

Ref	Ctry	Comparison	Taxon	Metric	Findings
7	NL	Near-natural	Birds	Abundance	Bird abundance in paludicultures is similar to near-natural wetlands.
			Birds	Community composition	Overall bird community in paludicultures is noticeably different from near-natural wetlands.
8	NL	Conventional agriculture	Birds	Richness	Cattail fields contained fewer bird species than nature-friendly agricultural fields (18 vs 21 species), but some species were only found in the cattail fields.
			Insects	Richness	Cattail fields contained fewer insect species than nature-friendly agricultural fields (26 vs 81 species), but some species were only found in the cattail fields.
***Sphagnum* moss**					
9	DE	Near-natural	Spiders	Community composition	Overall spider community in paludiculture site, over the first seven years since establishment, remained distinct from adjacent near-natural habitats. Paludiculture site lacked some species characteristic of pristine bogs.
10	DE	Near-natural	Beetles	Abundance	Paludiculture sites contained fewer individual beetles than near-natural bog sites. This was true for both all species (80–158 vs 214–265 total beetles/site; 0.8–1.6 vs 2.1–2.7 beetles/sample) and bog-typical species (14–70 vs 89–136 total beetles/site; 0.1–0.7 vs 0.9–1.4 beetles/sample).
			Beetles	Richness	Paludiculture sites contained fewer beetle species than near-natural bog sites. This was true for both all species (23–36 vs 35–38 total species/site; 0.7–1.0 vs 1.4–1.5 species/sample) and bog-typical species (8–16 vs 15–19 total species/site; 0.1–0.4 vs 0.6–0.7 species/sample).
11	DE	Near-natural	Plants	Richness	Paludiculture sites contained fewer plant species in total than near-natural donor sites. This was true for all plants (49 vs 65 species/site), vascular plants, bryophytes, bog-typical and bog-tolerant species (see paper for data). Species richness at the 25 × 25 cm plot scale did not significantly differ between paludiculture and near-natural sites for all plants (6.0 vs 6.0 species/plot), vascular plants, non-*Sphagnum* bryophytes and bog-typical species (see paper for data).
Harvested fen/raised bog					
12	DE	Unharvested (rarely mown fallow)	Spiders	Abundance	Spider abundance did not significantly differ between annually mown fens and rarely mown fallows (359 vs 266 individuals/site).
				Richness	Spider richness did not significantly differ between annually mown fens and rarely mown fallows. This was true for all species (20 vs 23 species/site) and endangered species (2.1 vs 1.3 species/site).
				Community composition	Overall spider community in annually mown fens differed from rarely mown fallows.
			Leafhoppers	Abundance	Leafhopper abundance did not significantly differ between annually mown fens and rarely mown fallows (719 vs 701 individuals/site).
				Richness	Leafhopper richness did not significantly differ between annually mown fens and rarely mown fallows. This was true for all species (27 vs 34 species/site) and endangered species (8 vs 9 species/site).
				Community composition	Overall leafhopper community in annually mown fens differed from rarely mown fallows.
			Plants	Richness	Annually mown fens contained more plant species than rarely mown fallows (52 vs 33 species/site). There was no significant difference in the richness of endangered species (6 vs 1 species/site).

Ref	Ctry	Comparison	Taxon	Metric	Findings
				Community composition	Overall plant community in annually mown fens differed from rarely mown fallows.
13	GB	Unharvested (several years)	Plants	Richness	In three of four comparisons, harvested plots had statistically similar plant richness (6–17 species/100 m^2) to unharvested plots (7–16 species/100 m^2). Harvesting took place in spring 2012. In the other comparison, harvested plots contained more species than unharvested plots (11 vs 7 species/100 m^2). Vegetation was surveyed in summer 2012 and 2013.
14	DK	Unharvested (≥18 years)	Plants	Richness / diversity	A fen harvested twice each year contained significantly more plant species than a fen unharvested for ≥18 years (18–23 vs 5 species/0.25m^2; 39–45 vs 10–16 species/1.25m^2). The same was true for diversity (Pielou's index: 0.9–1.0 vs 0.6–0.9).
Grazed fen/raised bog					
12	DE	Ungrazed (rarely mown fallow)	Spiders	Abundance	Spider abundance did not significantly differ between summer-grazed fens and rarely mown fallows (241 vs 266 individuals/site).
				Richness	Spider richness did not significantly differ between summer-grazed fens and rarely mown fallows. This was true for all species (29 vs 23 species/site) and endangered species (2.3 vs 1.3 species/site).
				Community composition	Overall spider community in summer-grazed fens differed from rarely mown fallows.
			Leafhoppers	Abundance	Leafhopper abundance did not significantly differ between summer-grazed fens and rarely mown fallows (1,078 vs 701 individuals/site).
				Richness	Leafhopper richness did not significantly differ between summer-grazed fens and rarely mown fallows. This was true for all species (36 vs 34 species/site) and endangered species (6 vs 9 species/site).
				Community composition	Overall leafhopper community in summer-grazed fens differed from rarely mown fallows.
			Plants	Richness	Summer-grazed fens contained more plant species overall than rarely mown fallows (54 vs 33 species/site), but there was no significant difference in the richness of endangered species (1 vs 3 species/site).
				Community composition	Overall plant community in summer-grazed fens differed from rarely mown fallows.
15	GB	Ungrazed (2–4 years)	Molluscs	Richness	Plots grazed for four years contained significantly fewer mollusc species than ungrazed plots (2.5 vs 5.1 species/0.25 m2).
			Plants	Richness	In five of six comparisons, grazed plots had significantly higher plant richness (e.g. 10.6–11.1 species/m^2) than ungrazed plots (e.g. 8.6–8.8 species/m^2). In only two of six comparisons, grazed plots had significantly higher richness of fen-characteristic species (19.0–20.3 species/20 m^2) than ungrazed plots (15.7–16.7 species/20 m^2), but all other comparisons trended in the same direction.
16	GB	Ungrazed (>40 years)	Plants	Richness	Total plant species richness increased more, over nine years after reinstating cattle grazing, in grazed peatland areas than in ungrazed areas (data not reported).

References: [1] Vadász et al. (2008), [2] Zitzmann (2023), [3] Andersen et al. (2024), [4] Görn et al. (2014), [5] Andersen et al. (2021), [6] Copping et al. (2025), [7] A. van Weeren, pers. obs., [8] Weerman (2021), [9] Muster et al. (2020), [10] Zoch et al. (2024), [11] Grobe (2023), [12] Bucher et al. (2016), [13] Menichino et al. (2016), [14] Sand-Jensen et al. (2019), [15] Ausden et al. (2005), [16] Groome & Shaw (2015).

Impacts of paludiculture water source on habitats. Lowland peatlands are either fed primarily by groundwater (minerotrophic peatlands, aka fens) or precipitation (ombrotrophic peatlands, aka bogs). The source of water affects the chemistry of the peatland, in turn affecting the species that can grow there. Many *Sphagnum* moss species, for example, are adapted to the nutrient-poor and acidic conditions found in ombrotrophic peatlands (Rydin & Jeglum, 2013). Thus, biological communities could be altered by using surface water to hydrate fens, raising the groundwater level to hydrate bogs, or using paludiculture sites to hold flood waters (see HYDROLOGY). Changes to the existing community will probably be seen as detrimental, although the choice of water could also be used to modify communities in desirable ways.

Match water source (ground- or surface water) to the desired biological community.

Maintenance of open habitats by harvesting or grazing. Across the English lowlands, the structure and biodiversity of many peatland habitats has changed following abandonment of traditional management and subsequent vegetation succession (CaBA Biodiversity Group, 2018; Fojt & Harding, 1995; Menichino et al., 2016; Natural England, 2015b). Emerging markets or grants for paludiculture products could revitalise such management in the form of mowing or grazing (Joosten et al., 2016); Ausden et al. (2005) cite the lack of a market for fen vegetation as one barrier to regular cutting in the East Anglian Broadland.

Generally, regular harvesting or grazing will control scrub encroachment and favour small, slow-growing plant species that require the heat and light associated with more open, early-successional environments. However, larger, fast-growing, shade-tolerant species will suffer (Andersen et al., 2021; McBride et al., 2011; Närmann et al., 2021). Amongst some context-dependency, regular harvesting or grazing tends to increase overall vegetation richness/diversity. Harvesting also tends to increase the overall abundance of peatland-characteristic species (Hájková et al., 2022; Taylor et al., 2018, 2021).

Note that many animal species rely on adjacent habitats at different successional stages. For example, bearded reedlings *Panurus biarmicus* require young, open reedbeds for foraging near to old, dense reedbeds for nesting (Malzer, 2017).

Across a landscape, maintain a mosaic of disturbance frequencies or harvest ages [WS]. This could be achieved by harvesting plots within a field, or fields within a farm, in different years.

Generation of transient habitats by harvesting. For example, *bare or thinly vegetated wet peat* may be transiently present after harvest or while a crop is becoming established. These habitats can support waterbirds, specialist insects and annual or short-lived plants, many of which would naturally occur at the margins of peaty pools (Eversham & Stanier, 2022; Münzer, 2001). Snipe *Gallinago gallinago*, for example, like to feed in recently cut areas of reedbed where the soil is exposed (Sussex Wildlife Trust, 2025). Transient areas of bare peat could also help species cope with climate change: some birds sit on bare wet ground to cool themselves down during warm weather (Ryeland et al., 2021). However, creation of bare ground could provide ideal conditions for plant invasions (Foster et al., 2015).

Temporary patches of older vegetation, retained as part of a landscape mosaic but harvested on multiannual cycles, can

Across a landscape, maintain a mosaic of disturbance frequencies or harvest ages (see above).

provide refuge for invertebrates during harvest. They can also function as a wintering habitat for litter- or stem-dwelling invertebrates, in turn supporting their avian predators (Närmann et al., 2021; Schmidt et al., 2005).

Loss of habitat of a specific age, where this does not match production goals. For some paludiculture products, optimal harvest schedules for production and conservation goals may be aligned (e.g. three- to four-year harvest of saw sedge; Broads Authority, 2004). However, for many products, yield and quality will be maximised by regular harvest (e.g. annually for reeds; Thatch Advice Centre, 2024). This may conflict with species' habitat requirements. For example, *Archanara* sp. moths require old reed shoots, 20–40 cm above the ground or water level, for oviposition and larval overwintering (van der Toorn & Mook, 1982). Reed warblers *Acrocephalus scirpaceus* nest earlier, nest at higher densities, and suffer less predation in uncut reedbeds than in recently cut reedbeds (Graveland, 1999).

- **Adjust frequency of harvest**, e.g. harvesting every other year rather than every year.
- **Across a landscape, maintain a mosaic of disturbance frequencies or harvest ages** (see above). Spatial harvest mosaics can balance optimal harvest timing for product quality with biodiversity habitat needs (Poulin et al., 2009).

Figure 5.2 Neighboring patches of recently harvested and unharvested common reed, in the Norfolk Broads. The standing reeds and the bare wet peat each provide important resources for biodiversity (see main text). The juxtaposition of habitats at different successional stages is also important for some species. Credit: CANAPE (2023) (CC BY-SA 4.0).

Generation of diverse habitats and resources by livestock. Generally, low-intensity livestock grazing increases habitat structural diversity (compared to both no and high-intensity grazing), providing suitable microhabitats for a wider range of species (Duncan et al., 2021; Middleton et al., 2006; Zahn et al., 2007). More specifically, water buffalo can create wet tracks through vegetation, which may support fish movement and consequently improve feeding habitat for birds (Gulickx et al., 2007). They also form large wallows, which can support notable aquatic plant species like bladderwort *Utricularia vulgaris* (Duncan et al., 2021) and amphibians like the common frog *Rana temporaria* (Zahn & Herzog, 2015).

Dung is another novel resource: 20 species of dung beetle have been recorded in Konik horse dung on the Wicken Fen reserve (Tegala, 2024). Finally, frogs have been observed resting on

- **Modify density and type of livestock, and timing of grazing**, to benefit target species and avoid negative impacts. For example, higher intensity grazing will generate a more uniform habitat. If existing evidence on impacts is limited, consider adaptive management.
- **Avoid giving prophylactic worming drugs to livestock** grazing in paludiculture systems. These chemicals are toxic to invertebrates that would otherwise inhabit dung (McBride et al., 2011).

livestock themselves, perhaps using them as a platform for hunting flies and/or as a heat source (Zduniak et al., 2017).

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
Damage to peatland habitats by livestock grazing and trampling, especially at high densities (Lindsay et al., 2014a). Grazing will change the vegetation community composition. The relative abundance of palatable species will decline (Duncan et al., 2021; Taylor et al., 2018). Meanwhile, the relative abundance of species that can tolerate grazing and trampling, or exploit the niches they create, will increase (Arnesen, 1999; Duncan et al., 2021; Middleton et al., 2006). Impacts of trampling on vegetation may be direct (e.g. crushing or burial by hoof action) or indirect (e.g. via compaction of peat; see SOILS). When grazing and trampling affect functionally important plant species, there can be negative impacts on dependent animal species. In Belgium, for example, cattle grazing reduced the suitability of wet meadows for the bog fritillary butterfly *Proclossiana eunomia* by reducing the abundance of the host plant and destroying tussocks that the butterfly uses for sun basking (Schtickzelle et al., 2007). At the RSPB Mid Yare Reserve in Norfolk, cattle flattened dead reeds in search of food, with negative consequences for breeding birds and overwintering invertebrates (McBride et al., 2011).	**Modify density and type of livestock, and timing of grazing**, to avoid negative impacts. For example, a low density of lighter breeds will reduce trampling pressure. If there is limited existing evidence on impacts, consider adaptive management.

c) *Organisms*

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
Direct damage to, or disturbance of, organisms during construction [WS]. For example, earthworks to create paludiculture sites could directly damage water vole *Arvicola amphibius* habitat and disturb great crested newts *Triturus cristatus*. Noise and vibrations from vehicles could disturb breeding birds (Nordt et al., 2022).	**Carry out appropriate biodiversity surveys before construction**. **Follow mitigation hierarchy to avoid, minimise, restore or offset any impacts**. For example, adjust timing of construction and mitigation activities. Alternatively, displace or temporarily relocate species (Dean et al., 2016).
Direct damage to, or disturbance of, organisms during harvest [WS]. By definition, harvesting vegetation damages or kills the target plants. It can also cause collateral damage to animals, especially those living in the vegetation or close to the ground (Närmann et al., 2021). Paludicultures could therefore act as ecological traps.	**Increase cutting height to reduce risk of injury to ground-dwelling organisms**. Närmann et al. (2021) recommend a cutting height ≥8 cm. **Use oscillating rather than rotary cutting blades**. The former cause less damage to animals (Närmann et al., 2021; von Berg et al., 2023). **Harvest in direction of natural habitat or fallow areas** to allow animals to flee (Tyler et al., 1998). **Adjust timing of harvest, avoiding harvest during sensitive periods**, e.g. bird breeding [WS].

- If sensitive periods cannot be avoided, **maintain a zone of unharvested vegetation around sensitive locations**, e.g. bird nests (Broads Authority, 2024).
- **Adjust intensity of harvest**. Harvesting fewer individuals, a smaller area or to a shallower depth can reduce impacts and speed up recovery times (Diaz & Silva, 2012; Silvan et al., 2012; Whinam & Buxton, 1997).

Direct damage to, or disturbance of, organisms by livestock. Livestock can graze or trample rare or functionally important plant species (Schtickzelle et al., 2007). Summer grazing can prevent flowering and seeding of plant species of conservation interest (McBride et al., 2011). Livestock can also harm animals, for example by trampling bird nests (Pakanen et al., 2011) and ingesting or trampling snails (Ausden et al., 2005).

- Within constraints dictated by logistics and ground conditions (compare SOILS), **adjust timing of grazing to avoid sensitive periods**, e.g. plant flowering/ seeding or bird nesting.

Impact of drones on wildlife disturbance. Drones may be used in paludiculture as an alternative to ground-based machinery, addressing some problems of working in wet peat (see SOILS). There is a risk that drones will disturb animals such as nesting birds if proper protocols are not followed (Cantu de Leija et al., 2023). However, drones could also reduce disturbance from machinery or human presence otherwise needed to perform agricultural tasks.

- **Adopt flying protocols to minimise wildlife disturbance**. For example, avoid flying near nesting birds or colonies, near particularly sensitive species, and during nesting season. Avoid threatening approach trajectories and sporadic movements. Use equipment that allows drones to work as far from sensitive subjects as possible (Cantu de Leija et al., 2023; Hodgson & Koh, 2016).

Barriers to animal movements as part of water management systems [WS]. Paludiculture systems are likely to include structures and systems to control water levels (Nordt et al., 2022). Weirs, gates, dams, sluices and non-operational pumps can physically block movement of fish and other aquatic species. The moving parts of operational pumping stations can also cause substantial mortality (Evans et al., 2024; Solomon, 2010). These are clearly undesirable impacts if they affect species of conservation concern. The disappearance of eels *Anguilla anguilla* from parts of the Somerset Levels, for example, has been attributed to the presence of barriers and pumps, particularly those that separate the drainage system from the major rivers (Horton, 2023). However, barriers may be desirable where they could limit the spread of invasive species (Jones et al., 2021).

- **Minimise number and height of barriers**.
- **Modify design of barriers to allow animals to cross them**, e.g. by adding notches (NWRT, 2024).
- **Install structures that allow animals to cross or bypass barriers**, e.g. fish passes or climbing structures (Cutts et al., 2024; Solomon, 2010).
- **Install exclusion devices or other deterrents at pump intakes** (Cutts et al., 2024; Turnpenny & O'Keefe, 2005).
- **Modify operation of barriers**, e.g. open gates or switch on fish-friendly pumps during migration periods; leave barriers open by default, only closing them when needed (Cutts et al., 2024; Evans et al., 2024).
- **Capture animals and transport them around barriers**, especially in critical periods like migration (Solomon, 2010).
- **Use fish-friendly pumps**, e.g. with modified blade design (Solomon, 2010).

Alteration of wild animal movements by livestock fencing. Fencing may be necessary to contain livestock to parcels of land, reflecting land ownership, grazing rights or nature protection goals (see SOILS and WATER QUALITY) or to keep certain problematic species out of paludiculture sites (see below). Fences may completely block, slow or otherwise alter movement patterns of wild animals, with potential impacts on populations (Xu et al., 2021).

- **Modify fences to allow wild animal movement**, e.g. cutting holes at ground level, installing badger gates, creating "water pathways" (Gulickx et al., 2007; Natural England, 2011).
- **Use GPS-based "virtual fences"** (Issimdar, 2025; VIPNL, 2024).

Human-wildlife conflict due to herbivory or disturbance of paludiculture crops. For example, geese and swans will consume crops such as cattail, common reed and sweetgrass *Glyceria* sp. (Kjeller et al., 2024) and have been observed to damage paludiculture crops (Geurts & Fritz, 2018) [WS]. They consume green vegetative parts in summer and dig for rhizomes and tubers over winter. Wild boar can disturb paludiculture crops, especially young plants (Nordt et al., 2022). Deer and other large mammals graze cranberry crops in the USA (Casperd, 2024) and may be attracted to tall paludiculture crops as shelter [WS].

- **Oversowing**: sow some additional crop, accepting a portion will be lost to herbivory.
- **Non-lethal herbivore management** (e.g. fencing), considering implications across the wider landscape – and entire migration route for migratory species (Bauer et al., 2018).

Hybridisation of paludiculture crops with wild species. Several paludiculture crops can hybridise with native species, e.g. willows, poplars *Populus* spp., water mint *Mentha aquatica* (Abel & Kallweit, 2022; Armstrong et al., 2005; Schanzer et al., 2012). Hybridisation can introduce genes or alleles from crop populations into wild populations. This will generally be undesirable due to inherent alteration of wild species genetics, reductions in wild population fitness (e.g. through outbreeding depression), extinction of rare taxa through genetic swamping, or creation of weedy hybrids that can become invasive (Bohling, 2016; Ellstrand & Schierenbeck, 2000; Todesco et al., 2016).

- **Avoid planting paludiculture crop species near to important related wild populations** (Bohling, 2016).
- **Genetically modify crop plants to prevent them from reproducing with wild relatives** (Bohling, 2016).

Impact on resources for pollinators. Whether this impact is positive or negative will depend on many factors, including the crop type and pollinator species. For example, willows produce pollen and nectar early in the growing season, when many alternative floral resources are not available, and thus can be crucial for early-season pollinators (Ostaff et al., 2015). Generally, a greater diversity of vegetation types in the landscape (see above) could maintain the availability of floral resources throughout the year. In contrast, *Sphagnum* moss is a bryophyte so does not produce pollen, and common reed and cattail are wind-pollinated (Fitter & Peat, 1994). Note, however, that these plants may still provide resources for pollinators, e.g. as nest sites, for materials, or even pollen as a food source (Saunders, 2018).

- **Tolerate some flowering plants as 'weeds' within paludicultures**, to provide resources for pollinators.
- **Leave uncultivated margins within paludiculture plots**.
- **Plant nectar flower mixture along raised features** such as tracks or berms.
- Where feasible, **incorporate pollinator-friendly paludiculture crops into a landscape mosaic**.

Increased mosquito abundance associated with standing water. Mosquitoes require standing water to breed. Paludiculture may increase the availability of standing water in the landscape, for example if fields are flooded (even intermittently), in low-lying areas within paludiculture fields or in the surrounding rewetted landscape, or in water management infrastructure (e.g. ditches, reservoirs). Mosquitoes can transmit pathogens to humans and animals, and the UK is likely to become more suitable, over the next 40 years, for non-native disease vectors such as the tiger mosquito *Aedes albopictus* (Metelmann et al., 2019). However,

- **Install mosquito traps around settlements to minimise human-mosquito interactions** (Poulin et al., 2017).

mosquito adults, larvae and eggs are resources for various predators and parasites (Bonds et al., 2022; Medlock & Snow, 2008). Their increased abundance may benefit biodiversity, particularly opportunistic and generalist species (Bonds et al., 2022).

d) Microorganisms

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **Recovery of soil microbial communities, and associated biogeochemical functions, due to rewetting**. Drained and undrained peatlands support different microbial communities (Emsens et al., 2020; Kitson & Bell, 2020; Yang et al., 2025). Equally, rewetting drained peatlands can alter the microbial community composition and functional diversity (Andersen et al., 2013; Kitson & Bell, 2020; Weil et al., 2020). Recovery of the community towards that of undrained peatlands is possible, although this may depend on factors such as the aboveground vegetation composition and the amount of soil organic matter remaining (Andersen et al., 2013; Bardgett et al., 1998; Emsens et al., 2020).	➔ **Remove degraded/nutrient-enriched surface peat before rewetting**. This can alter the abundance and composition of microbial communities (Huth et al., 2020). But removing surface peat is expensive (Klimkowska et al., 2010) and can generate ! *GHG emissions*. ➔ **Manage vegetation to influence soil microbial communities**. This might include altering crop type, litter inputs, and the presence or length of fallow periods. If evidence on impacts of specific management options is limited, consider adaptive management. ➔ **Inoculate paludiculture sites with microorganisms from** adjacent near-natural peatlands (Peddle et al., 2024).
? **Impacts of livestock grazing on soil microorganisms**. The size and activity of the soil microbial community could be increased due to changes in plant carbon allocation and root exudation, or changes in root biomass and morphology, in response to grazing (Bardgett et al., 1998). Grazing can also affect the quality of plant litter inputs, in turn altering soil microbial communities in hard-to-predict ways (Bardgett et al., 1998). Where livestock increase soil nutrient levels (e.g. through faecal inputs; see SOILS), tolerant species will be favoured (Cid-Rodríguez et al., 2024).	➔ **Modify density and type of livestock, and timing of grazing**, to benefit target species and communities. If there is limited existing evidence on impacts, consider adaptive management.

e) Biological invasions

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✘ **Escape of invasive paludiculture crops into the wild**. Several potential paludiculture crops – such as common reed, cattail, American cranberries and water fern *Azolla filiculoides* – are known to form invasive populations. This means they can become established and spread in the wild (Blackburn et al., 2011; Matthews et al., 2015) with negative impacts on native habitats and species (Ciotir et al., 2017; Perrevoort, 2024; Pysek et al., 2019). Even native species can become invasive (Valéry et	➔ **Select plant genotypes with less vigorous growth and thus less likely to be invasive** (Ciotir et al., 2017; Pysek et al., 2019). Note trade off with yield. ➔ **Avoid planting hydrochorous plants** (that spread through dispersal of propagules in water) **next to streams and rivers** (Matthews et al., 2015).

al., 2009), although it is often particular genotypes that show this tendency (e.g. hybrid cattail; Ciotir et al., 2017). Wetlands and water infrastructure would be particularly vulnerable to invasion by paludiculture crops (Graham & Hammond, 2015). There remains much uncertainty about the potential for paludiculture crops to become invasive in any particular context (Matthews et al., 2015), but a precautionary approach would assume potential invasiveness in the absence of evidence otherwise.

- **Avoid planting crops near to sites of high conservation value that provide suitable conditions for escapees to establish** (Matthews et al., 2015).
- **Apply effective biosecurity measures around paludiculture site**, e.g. washing equipment before moving between farms.
- **Early detection and rapid eradication** of any introduced populations.

Introduction of new pests as hitchhikers with crops. Pests associated with paludiculture crops include:

- Asian longhorn beetle *Anoplophora glabripennis*, hosted by willows. This beetle was flagged in 2019 as a species highly likely to arrive, establish and affect biodiversity within Britain (Roy et al., 2019; Wentworth, 2011).
- The fungal pathogen *Hymenoscyphus pseudoalbidus*, carried by ash *Fraxinus* spp. This fungus is responsible for ash dieback, which has caused massive losses of wild ash trees across the UK and Europe (Gross et al., 2014).
- Water mould *Phytophthora* sp., carried on cranberries, but with the ability to infect and damage native plants (Casperd, 2024; Pscheidt, 2023).

Paludiculture may involve growing completely new crops in England, or growing existing crops in much larger volumes than at present. Larger volumes of imported material could increase the diversity of pest species and/or number of individuals introduced, both of which could increase invasion risk. Sourcing crops from new areas to meet demand could also expose England to a new pool of pest species or genotypes.

- **Source crop plants from pest- and disease-free areas**.
- **Apply effective biosecurity measures at UK border**, e.g. screening and quarantine of imported material.
- **Apply effective biosecurity measures between sites**, e.g. washing equipment before moving between farms.

Spread of invasive species by interbasin water transfers (Waine et al., 2024). The need for interbasin water transfers, to reduce pressures on the water supply system, is recognised in government policy (HM Government, 2023d) and local water resources plans (Water Resources East, 2023). Water transfers may be used to support paludicultures, even if only as an emergency measure (e.g. during droughts).

- **Prevent transfer of invasive species**, e.g. by avoiding water transfers during their breeding period (Zhu et al., 2023). Consider potential spread of all life stages (SEPA, 2022).
- **Early detection and rapid eradication** of any introduced populations.

Habitat provision for aquatic invasive species. Aquatic invasive species could inhabit paludiculture sites when flooded and/or water management infrastructure such as reservoirs (Carluer et al., 2016; Graham & Hammond, 2015; Stockdale et al., 2024). Therefore paludiculture could facilitate spread of these species across the landscape (if sites act as stepping stones) and/or local persistence (if sites act as spatial or temporal refuges). Aquatic invasive species of special concern that are already present in lowland England include the Chinese mitten crab *Eriocheir sinensis*, signal crayfish *Pacifastacus leniusculus*, North American bullfrog *Lithobates catesbeianus*, floating pennywort *Hydrocotyle ranunculoides* and parrot's feather *Myriophyllum aquaticum* (GBNNSS, 2024).

- **Rapidly establish native communities** (e.g. via planting) to increase resistance to invasions (Petruzzella et al., 2018).
- **Early detection and rapid eradication** of any new populations.

- **Control of invasive, dominant or otherwise undesirable vegetation by harvesting**. For example, a study in Sweden found that annual autumn mowing/harvesting reduced the cover of dominant graminoids (purple moor grass *Molinia caerulea* and brown bog rush *Schoenus ferrugineus*) in rewetted rich fens (Mälson et al., 2010). A study in Welsh fens found that a single spring cut reduced cover of the dominant graminoids (saw sedge *Cladium mariscus* and black bog rush *Schoenus nigricans*) and of ericoids/sub-shrubs, for up to two years (Menichino et al., 2016).

- **Modify timing of harvest** (e.g. season and frequency) to maximise control of undesirable species. If there is limited existing evidence on impacts, consider adaptive management.

- **Control invasive, dominant or otherwise undesirable vegetation by livestock**. For example, a study in Surrey found that cattle grazing moderated cover of purple moor grass *Molinia caerulea* (Groome & Shaw, 2015). A study in Spain found that after rewetting a fen at the same time as removing cattle, rushes grew over 80% of the fen (Peralta de Andrés et al., 2015). Water buffalo are controlling scrub and saw sedge at Chippenham Fen, Cambridgeshire (C. Hainsworth pers. comm.) and giant goldenrod *Solidago gigantea* at Csákvár Fen, Hungary (Fűrész et al., 2023).

- **Modify type of livestock, and perhaps their density and timing of grazing**, to maximise control of undesirable species. If there is limited existing evidence on impacts, consider adaptive management.

5.2 Research questions / knowledge gaps

Sources: Own work, Workshop, Andersen et al. (2013), Eversham & Stanier (2022), Littlefair et al. (2024b), Tanneberger et al. (2022), Wichmann (2012).

- How congruent is water table management for yield, greenhouse gas emissions and biodiversity? Are there opportunities to implement a biodiversity-friendly water regime without compromising yield or emissions?
- How do design and management of water infrastructure associated with paludiculture affect biodiversity?
- How are food webs structured in paludiculture systems?
- How does paludiculture affect invertebrates, both in the soil and in the vegetation? What are the implications for their predators? What management options can maintain populations of (key) invertebrate species?
- (How) do different paludiculture plants support pollinators?
- Do paludiculture sites function as ecological traps? If so, how can this be avoided?
- How does the use of drones in paludiculture systems affect biodiversity? How does disturbance from drones compare to counterfactuals, e.g. use of ground-based machinery for sowing or spraying?
- What are the key pests of paludiculture crops (especially insects and microbes)? How can these be managed with minimal impacts to the natural environment while maintaining product quality?
- How do soil microbial communities and functions vary between different paludiculture crop types?
- How readily can soil microbes recolonise rewetted peat?
- (How) does paludiculture benefit invasive non-native species? Does it provide a refuge or facilitate spread?
- What is the potential for paludiculture plants to become invasive? How does this differ between plant species and local contexts?

- More data on the effects of paludiculture and management options on taxa other than plants and birds, especially mammals, invertebrates and microorganisms.
- More data on biodiversity in paludiculture crops specifically, rather than natural analog communities
- Data on biodiversity in a wider variety of paludiculture crops, such as wood and berries.

Box 5.1 Biodiversity conservation actions in temperate lowland paludiculture systems

Some possible on-the-ground conservation actions for biodiversity in temperate lowland paludiculture systems. Listing of an action does not necessarily mean it is beneficial for biodiversity. Actions have been adapted from www.conservationevidence.com.

Harvest vegetation	Restore/create vegetated buffer strips around fields to manage pollution
Change season/timing of harvest	Leave uncultivated margins around fields
Change frequency of harvest	Excavate pools
Change intensity of harvest	Manage ditches to benefit wildlife
Modify harvest techniques to reduce animal mortality (e.g. raise mowing height)	Retain habitat corridors in farmed areas
Provide refuges during harvest	Increase proportion of semi-natural habitat in farmed landscape
Mark bird nests during harvest	Increase crop diversity
Grazing	Reduce field size (to increase heterogeneity)
Change season/timing of grazing	Increase field size (to meet minimum size requirements of some species)
Change intensity of grazing	Use non-lethal deterrents for crop pests
Change livestock type	Provide perches/nest boxes
Reduce agrochemical use	Design/modify fences to allow animal passage
Manage agrochemical use	Mark fences to reduce bird mortality
Sow 'weeds' of conservation interest	Use deterrents to keep wild species away from crops
Reduce tillage	

Some existing syntheses of the effects of biodiversity conservation actions that are relevant to temperate lowland paludiculture systems (e.g. including data from peatlands, wetlands or farmland)

Reference	Scale	Response taxa
Dicks et al. (2013) *Farmland Conservation: Evidence for the Effects of Interventions in Northern and Western Europe*. Synopses of Conservation Evidence Series, University of Cambridge.	Europe	Plants, Animals
Duncan et al. (2021). *La restauration et la gestion des milieux tourbeux alcalins – utilisation du pâturage*. Rapport de synthèse, projet LIFE 18NAT/FR/000906.	Global	Plants, Animals
Hájková et al. (2022) Conservation and restoration of Central European fens by mowing: a consensus from 20 years of experimental work. *Science of the Total Environment*, 846, 157293.	Europe	Plants
Littlewood et al. (2010) *Peatland Biodiversity*. Scientific Review for IUCN UK Peatland Programme.	UK	Plants, Animals
Middleton et al. (2006) Biodiversity management of fens and fen meadows by grazing, cutting and burning. *Applied Vegetation Science*, 9, 307–316.	Global	Plants
Natural England (2023) *The Impacts of Vegetation Cutting on Peatlands and Heathlands, A Review of Evidence*. Natural England Evidence Review NEER028.	UK	Plants, Animals
Rowland et al. (2021) Effectiveness of conservation interventions globally for degraded peatlands in cool-climate regions. *Biological Conservation*, 263, 109327.	Global	Plants, Animals
Taylor et al. (2018) *Peatland Conservation: Global Evidence for the Effects of Interventions to Conserve Peatland Vegetation*. Synopses of Conservation Evidence Series, University of Cambridge.	Global	Plants
Taylor et al. (2021) *Marsh and Swamp Conservation: Global Evidence for the Effects of Interventions to Conserve Marsh and Swamp Vegetation*. Conservation Evidence Series Synopses, University of Cambridge.	Global	Plants
Valkama et al. (2008) The impact of reed management on wildlife: a meta-analytical review of European studies. *Biological Conservation*, 141, 364–674.	Europe	Plants, Birds, Invertebrates

6. Landscape character and heritage

Definition: Based on Natural England's criteria for determining areas of outstanding natural beauty (Natural England, 2024a), we consider this section to include: **landscape quality** (overall), **scenic quality** (how the landscape looks), **relative wildness** (e.g. isolated from infrastructure such as roads or housing), **relative tranquillity** (i.e. limited anthropogenic noise; predominance of natural sounds such as flowing water or birdsong), **natural heritage features** (e.g. distinctive species, habitats, geology), and **cultural heritage** (including the built environment that makes an area unique, and archaeological features or remains).

6.1 Paludiculture impacts and management options

Impacts are not guaranteed: many are context dependent. Management options are some ideas to consider: they are not necessarily effective or feasible in all contexts, so should not be read as recommendations.

a) Landscapes, wildness, tranquillity and natural heritage

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **A return to wetter landscapes that reflect historical natural heritage**. England's lowland peat landscapes were historically much wetter, before large scale drainage (Irvine, 2016; Natural England, 2013). Paludiculture could at least partially restore wetter landscapes, and the characteristic species within them (see BIODIVERSITY), which some people will find desirable. For example, an RSPB volunteer, quoted in Irvine (2016), referred to wetlands as "the past and the future" of the Fens. Streatfeild (1884) wrote, "As we contemplate the never-ending fields of corn, and mustard, and potato… we can scarcely repress a sigh after the beds of osier and sedge, which were so much more natural, if far less profitable. We, perhaps, confess that things are better as they are; yet we cannot dissemble our regret at the change… We may… weep over the progress of the plough – an abomination of desolation unknown to the swans and ruffs and oyster-catchers of happier days." In the 1600s, the 'Fen Tigers' resisted drainage of the Fens, because their livelihoods were dependent on the wetlands. The Fen Tigers are represented on the modern-day Fenland flag. Similar paludi-positive sentiments are shared by some, but by no means all, contemporary stakeholders in lowland peat landscapes (Blue Marble Research, 2024; Rawlins & Morris, 2010; Reed et al., 2020; The Wildlife Trusts, 2025) [WS].	➜ **Exploit opportunities to restore or create natural wetlands** as part of paludiculture sites, or in the wider landscape. ➜ **Manage paludiculture sites to benefit biodiversity** (see BIODIVERSITY / Box 5.1).
✔ **Increased landscape quality associated with increased land use diversity**. Paludiculture, especially where it replaces conventional agriculture on drained peat, will introduce parcels of distinct vegetation to the landscape. This may generally improve landscape character [WS]. A recent qualitative study in Germany found that local people valued a diversity of living elements in peatland landscapes (Heindorf et al., 2024).	➜ **Avoid expansive monocultures** [WS].

Reduced prevalence of unattractive land use options. It has been suggested that paludiculture sites are generally more attractive than degraded peatlands (Wichtmann & Joosten, 2007) and conventional agricultural crops (Mulholland et al., 2020). Attractiveness may be highly dependent on the vegetation type, farming system (e.g. intensive cultivation vs extensive harvesting from semi-natural habitats), extent and location.

Impacts on scenic quality associated with conventional agriculture. Conventional agriculture, on drained peat, maintains the "open landscape with extensive vistas to level horizons" characteristic of areas such as The Fens (Natural England, 2015a; Reed et al., 2020). Low-stature paludiculture crops such as *Sphagnum*, berries and vegetables would preserve this open character. Tall crops, like common reed, willow and alder, could alter it [WS]. Novel species could also alter landscape character by introducing different textures and colours [WS].

- **Situate crops where they will have minimal negative impact on landscape character**. For example, place tall crops away from footpaths and viewpoints.

Visual impacts of different stages of the crop cycle. Certain points of the crop cycle may be visually attractive. For example, large-scale cranberry harvests are appreciated for their beauty, with extensive crops of floating deep red berries (Gorokhova, 2023). Similarly, flowering willows could add visual interest to the landscape. In contrast, post-harvest cut vegetation or bare wet peat may be perceived as "untidy" or "ugly" [WS]. Conventional farming has similar impacts, but typically for shorter periods compared to paludiculture (e.g. because crops are on shorter rotation). The visual impact of harvesting from semi-natural sites may be particularly striking and unpalatable (Anttila, 2016; Ludwig, 2019).

- **Encourage visitors during attractive periods**. For example, allow visitors on site, and perhaps create an associated festival/celebration.
- **Leave some vegetation in place after harvesting to speed up recovery**. For example, removing <70% of *Sphagnum* cover (Whinam & Buxton, 1997) or only 10–15 cm depth (Diaz & Silva, 2012; Silvan et al., 2012) leaves some living material from which shoots can regrow and colonise bare patches.
- **Harvest patches in rotation**, rather than simultaneously [WS].

Reduced scenic quality due to paludiculture site infrastructure. Paludiculture may require permanent infrastructure not used for conventional agriculture, such as trickle or drip irrigation systems rather than temporary spray irrigation (Eversham & Stanier, 2022). It will likely require construction of farm reservoirs, which are a potentially intrusive addition to the landscape (Suffolk Coast and Heaths AONB, 2022).

- **Situate infrastructure where it will have minimal impact on landscape character**. For example, place it away from footpaths and viewpoints, conceal it (e.g. by burying or behind vegetation), avoid breaking the skyline (Suffolk Coast and Heaths AONB, 2022).

Diminished landscape character due to paludiculture processing infrastructure. For example, there are economic and environmental incentives to build facilities for biomass processing (e.g. storage, drying, combustion) in rural areas, near to where biomass is produced. This saves transporting large amounts of wet or low-density material over long distances (Nordt et al., 2022; Ozola et al., 2023; Wichtmann & Wichmann, 2011). Similarly, displaced food production may be moved to vertical farms (Caudwell, 2023). Economic and social factors may mean these are also situated in rural areas: on cheaper land, on land already owned by a farmer, or near biomass sources for heating (Lapwing Energy, 2022). This infrastructure could have visual impacts (e.g. buildings, smoke) and auditory impacts (e.g. from operating machinery).

- **Convert/renovate existing buildings**, such as those associated with existing agriculture, rather than constructing new ones.
- **Situate infrastructure where it will have minimal impact on landscape character**. In particular, place it away from settlements, footpaths and viewpoints.

Reduced scenic quality and wildness due to installation of photovoltaic (PV) panels. Although PV panels are not paludiculture in themselves, some paludiculture sites will use them to generate power to pump water (Lancashire Wildlife Trust, 2023). Other paludiculture sites will present opportunities for PV installation alongside a crop, also known as "paludi-PV" (Nordt et al., 2022; Seidel et al., 2024). PV panels could conceivably have little impact on, or even improve, yields of crops such as cranberries (Ozola et al., 2023) and *Sphagnum* moss (Aitkenhead et al., 2021). PV panels in rural areas may reduce scenic quality and relative wildness, by dramatically altering views of the countryside (CPRE, 2021) and contributing to its "industrialisation" (Maddison et al., 2023). The cumulative effect of PV panels across the landscape may be substantial, even if individual installations are relatively inconspicuous (CPRE, 2021).

- **Situate panels where they will have minimal impact on landscape character**. For example, conceal them behind vegetation and avoid breaking the skyline.
- **Landscape planning to avoid coalescence of PV panel developments** (CPRE, 2021).

Impacts on natural heritage and tranquillity due to impacts on biodiversity. People appreciate the biodiversity of England's lowland peat landscapes: both the presence of individual species and the general richness and diversity (Flint & Jennings, 2022; Rawlins & Morris 2010; Reed et al., 2020). Positive effects of paludiculture could include an increase in overall biodiversity, and an increase in the number or abundance of wetland-characteristic, threatened or charismatic species – at least under certain land uses and management regimes (see BIODIVERSITY). Negative impacts could include the loss of charismatic species associated with conventional farmland, like skylark *Alauda arvensis* and woodpigeon *Columba palumbus* (Finch et al., 2023), or species that rely on connected waterways without pumps or barriers, like eels *Anguilla anguilla* (Horton, 2023).

- **Choose paludiculture type and management techniques to benefit biodiversity** (see BIODIVERSITY / Box 5.1). There may be a particular focus on species most valued by local people.

Impacts on soundscapes. Recent qualitative studies in England and Germany have found that soundscapes are valued and engaging aspects of lowland peat landscapes (Flint & Jennings, 2022; Heindorf et al., 2024). This includes sounds such as animal calls, but also the "absence of sound" or "silence". Paludiculture may enhance tranquillity by introducing gentle natural sounds such as movement of tall vegetation in the wind [WS], or insect, amphibian and bird calls (see BIODIVERSITY). Local soundscape quality may be diminished by the loss of farmland-specialist species like skylark *Alauda arvensis* and woodpigeon *Columba palumbus* (Finch et al., 2023), noise from water management infrastructure such as pumping stations [WS], and excessive noise from vegetation movement [WS].

- **Situate noisy infrastructure away from people** (e.g. footpaths or residential buildings).
- **Screen noisy infrastructure with fences or vegetation**, acknowledging potential impact of those features on scenic quality.

Impacts on scenic quality of surface waters. Paludiculture could have varied and context-specific effects on the appearance of water bodies. For example, eutrophication and associated algal blooms are generally considered unattractive (Pretty et al., 2003). Paludiculture could lower the risk of eutrophication where it reduces nutrient loading (e.g. due to export of nutrients in harvested vegetation) or raise the risk of eutrophication where it increases nutrient loading (e.g. following rewetting or application of fertilisers) (see WATER QUALITY). Similarly, a high dissolved organic carbon (DOC) content makes water browner and less clear, which is generally perceived as

- **Implement measures to maintain or improve water quality** (see WATER QUALITY).

less attractive, especially when this is not its natural or normal state (Albrecht et al., 2023; Kritzberg et al., 2020). Paludiculture could potentially increase or reduce DOC concentrations in water bodies, depending on the site history and time since rewetting (see WATER QUALITY).

Impacts of animal paludiculture on landscape character. Inclusion of grazing animals in the landscape could increase its scenic quality and give perception of a wilder landscape (Serrano-Montes et al., 2019) [WS]. Indeed, Konik horses and Highland cattle are proving to be a visitor attraction at Wicken Fen (Tegala, 2024). However, introducing animals where they have not previously been present could negatively impact landscape and scenic quality [WS], due to the presence of the animals and/or their impacts on habitats (e.g. changing vegetation structure or poaching soils; see BIODIVERSITY and SOILS).

Modify density and type of livestock, and timing of grazing. For example, low livestock densities may be more visually acceptable and have less obvious impacts on biodiversity and soil.

Visual impact of fencing. Fences may be erected to contain livestock, such as water buffalo, that could cross the ditches traditionally used to contain animals in lowland peat landscapes. Fences may also be used to exclude problematic species from paludiculture sites (see BIODIVERSITY). Fences could be very visible on open peat landscapes, altering their scenic quality.

Use "virtual fences" based on GPS technology and livestock collars (Issimdar, 2025; VIPNL, 2024).

Figure 6.1 Typical flat and open lowland peat landscape in the Somerset Levels. Credit: Jack Pease (Flickr, CC BY 2.0).

b) Cultural heritage

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
Maintenance of working agricultural landscapes. Agriculture is recognised as part of the landscape character of England's lowland peat, from the Somerset Levels to the Fens (Natural England, 2013, 2015a). Referring to the Fens, the naturalist David Bellamy stated, "Farming has played a central role in the history of this unforgettable landscape. It must perform a central role in its future." (NFU, 2008). Traditional agriculture on drained lowland peat is not sustainable due to peat degradation and loss (Caudwell, 2023; Morris et al., 2010). Paludiculture provides a way to maintain working agricultural lowland peat landscapes.	

Maintenance or restoration of traditional uses of lowland peat landscapes. There is a tradition of willow farming and crafts on the Somerset Levels (Campbell, 2008), reed cutting in the Fens (Wildlife Trust BCN, 2024b), and low-intensity livestock grazing on semi-natural peatlands of the Humberhead Levels (Historic England, 2020). Remnants of semi-natural peatlands, such as Wicken Fen, support traditional crafts like sedge and willow weaving that are of interest to locals and visitors alike (Waylen et al., 2016). Paludiculture could ensure continuation of, or return to, these and similar practices (IUCN, 2023). Payments for non-productive benefits of paludiculture (e.g. BIODIVERSITY, carbon storage) could contribute to economic viability.

Incorporate paludiculture into cultural events to share traditional practices and products with local people. This offers space for learning and reflection, and may help to build community support (Heindorf et al., 2024).

Loss of cultural heritage associated with *conventional* agriculture and *food production*. Conventional agriculture (on drained soils) may be perceived as the 'normal' land use in lowland peat landscapes that have been used in this way for centuries (Natural England, 2013, 2015a; Page et al., 2020). It is certainly a familiar land use for current residents and visitors. Further, many land managers in England's lowland peat landscapes are intensely proud of their role in feeding the country and see this as a major part of their identity (Reed et al., 2020). Farmer Jimmy Doherty stated, "The Fens is a crucial chapter in the British food story. Its work must be allowed to carry on, not just for now, but for the future." (NFU, 2019). Rewetting for paludiculture, and growing mostly non-food crops, could threaten this heritage.

Emphasise synergies between paludiculture and traditional agriculture, e.g. ability to grow willows and continue pastoral agriculture (albeit with different species or breeds) in the Somerset Levels.

Contribution of paludiculture products to cultural heritage and associated landscape quality [WS]. A domestic supply of reeds, for example, may provide impetus to maintain or restore thatched properties, coinciding with rising demand for sustainable materials (Delaney, 2024; Natural England, 2015a). Thatched properties are a traditional part of lowland peat landscapes like the Fens (Historic England, 2024) and are recognised for their aesthetic value (Delaney, 2024). The number of thatched houses in England declined by 96% between 1800 and 1960 (English Heritage, 2000).

Incorporate paludiculture into cultural events to share traditional practices and products with local people (as above).

Impacts on cultural heritage related to impacts on biodiversity (see also BIODIVERSITY). In some cases, paludiculture could harm culturally significant species. For example, eels *Anguilla anguilla* are culturally entwined in England's lowland peat landscapes. They have been used historically as food and currency (Horton, 2023). They are the focus of an annual festival in the Fens, and community conferences and education programmes in Somerset (Farmer, 2024; SERP, 2024). Barriers associated with water management for paludiculture could threaten local populations. In other cases, paludiculture could maintain or restore cultural heritage. Wetland habitats provided by paludiculture could support rare and specialised species, maintaining the scientific heritage of lowland peatlands. The Fens have been the laboratory of Cambridge zoologists and botanists for centuries (National Trust, 2024; Waylen et al., 2016) and into the present day (CLR, 2025).

Manage paludiculture sites to benefit biodiversity – particularly culturally valuable, rare or specialised species and habitats (see BIODIVERSITY / Box 5.1).

Figure 6.2 Cultural heritage in lowland peatlands. **Left** – An archaeological dig at Must Farm, Cambridgeshire. Credit: Colleen Morgan (Wikimedia Commons, CC BY 2.0). **Right** – Wind pumps, like this one at Wicken Fen, Cambridgeshire, are an important part of the cultural heritage of lowland peat landscapes and contribute to landscape and scenic quality. Credit: Alex Brown (Flickr, CC BY 2.0).

✅ **Mitigation of drainage-induced damage to buried cultural heritage**. When peat is drained, air can enter the pore spaces. This can damage artefacts and the palaeoecological record via oxidation, microbial degradation and acidification (Davies et al., 2015; Gearey et al., 2010; High, 2018). Drained peat may be more susceptible to fire, which can cause heat damage to artefacts, or expose them to weathering (Gearey et al., 2010).

➔ **Retain intact (undrained) peatlands wherever possible** to minimise impacts associated with drainage.

✅ **Maintenance or renewal of the archival value of peatland sites through peat formation**. Paludiculture sites may form new peat (see SOILS). This will preserve new information about the environment, and human uses of it, as it accumulates – for example in the form of pollen or isotopes (Gaudig et al., 2014).

➔ **Choose paludiculture type and management techniques that favour peat formation** (see SOILS).

❓ **Impacts of rewetting on buried cultural heritage**. If a site has been drained, rewetting may halt further damage to artefacts and the palaeoecological record. However, will not be able to restore some lost information (e.g. tool marks on desiccated wood; Gearey & Everett, 2021). Further, the shock of rewetting can actually increase degradation of some materials [WS].

➔ **Carefully assess site conditions before rewetting**, to inform decisions about whether and how to rewet.

➔ **Remove artefacts** before rewetting, but note that this may diminish their archaeological significance (High, 2018).

➔ **Utilise existing peatland vegetation** for low-intensity harvesting or grazing, reducing the need to alter hydrology. ⚠ *GHG emissions if peat remains dry*.

❌ **Damage to buried cultural heritage from machinery** [WS]. Machinery that disturbs the soil, for example excavators used during initial site preparations or ploughs used for seasonal preparations, could damage buried artefacts and disturb the palaeoecological record. There is also a risk that pressure from vehicles driving over peat damages buried artefacts. Finally, vehicle damage to the peat structure (see SOILS) can expose it to erosion, which involves loss of the peat archive and in turn may expose buried artefacts (Gearey et al., 2010).

➔ **Minimise soil disturbance**: use existing vegetation for low-intensity harvesting or grazing; use no-till farming methods; grow perennial rather than annual crops (Abel et al., 2016; Närmann et al., 2021).

➔ **Minimise pressure on peat**, for example by using adapted vehicles, or avoiding use of ground-based vehicles entirely (see SOILS) [WS].

6.2 Research questions / knowledge gaps

Sources: Own work, Workshop.

- What are the contemporary perceptions of landscape character and heritage in English lowland peat landscapes? How might these be affected by different forms and configurations of paludiculture?
- How do stakeholders that live in and/or visit lowland peat landscapes envisage the future of these landscapes? What is the role of paludiculture in these visions, or (how) can they incorporate paludiculture?
- What is the likely impact of increased domestic production of paludiculture products on the use of these products (e.g. reed for thatching) in the landscape?
- What are the likely impacts of rewetting land for paludiculture on public access, and therefore their ability to appreciate aspects of landscape character and heritage?
- How does animal paludiculture affect perceptions of landscape character in English lowlands? How do these perceptions vary among livestock types and densities?

7. Cross-cutting points

Given the relationships between the five dimensions of the natural environment considered above, many points appear under >1 dimension. This section mops up some general points that cut across multiple dimensions.

7.1 Paludiculture impacts and management options

Impacts are not guaranteed: many are context dependent. Management options are some ideas to consider: they are not necessarily effective or feasible in all contexts, so should not be read as recommendations.

a) General impacts

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✔ **Paludiculture as a stepping stone to restoration of near-natural peatlands**. Paludiculture systems will involve infra-structure to raise the water level, could preserve the peat body, and could remediate sites (e.g. by removing excess nutrients). After a period of productive use, paludiculture sites may therefore be suitable for restoration to semi-natural peatland – whether this is a deliberate choice or due to displacement by imports once markets for paludiculture crops are established (Stuart et al., 2023). As an example, cranberry production on a former peat extraction site in Nigula, Estonia created suitable conditions for the eventual recovery of bog vegetation (Küttim et al., 2018). More active intervention may be needed in systems that modify the substrate to suit production, as in intensive cranberry farms that add layers of sand to the peat surface (Casperd, 2024).	➔ Where there is a choice, **situate paludiculture sites where they will complement existing near-natural peatlands**. For example, paludiculture sites adjacent to or linking existing peatland nature reserves may have disproportionate biodiversity benefits if later restored to a near-natural state.
✔ **Reduced fire risk across the landscape**. Through keeping or making peatlands wet, paludiculture could reduce the risk of fires breaking out (Sirin et al., 2020; Wichtmann & Joosten 2007). Harvesting vegetation also prevents accumulation of fuel loads. Bunds, embankments and ditches could act as fire breaks. Peat fires can affect all aspects of the natural environment considered above (Brown et al., 2015; Middleton et al., 2006; Page et al., 2020; Sherwood et al., 2013; Worrall et al., 2010). Fires are a particular problem in drained tropical peatlands, but are also a risk in English lowlands, particularly as summers become drier and warmer (Glaves et al., 2020).	➔ Where there is a choice, **situate paludiculture sites or infrastructure strategically to act as fire breaks**.
✘ **Concentration of pollutants in recipient sites for paludiculture biomass**. Paludiculture plants can accumulate nutrients and heavy metals in their tissues, especially when used for remediation of contaminated soil or water (see SOILS and HYDROLOGY). These will be concentrated wherever the paludi-culture products are used and/or residues are disposed. For example, burning biomass can contribute to air pollution as contaminants are released in smoke (Pogrzeba et al., 2011) and soil or water pollution if large quantities of ash are deposited in	➔ **Use 'contaminated' material where the pollutants will be contained**, e.g. as construction board or for thatching.

one place (Bonanno et al., 2013; Vervaeke et al., 2006). Biodiversity and landscape quality may be affected as a result.

b) Telecoupled impacts

Telecoupling refers to environmental and socioeconomic interactions between distant coupled human and natural systems (Hull & Liu, 2018).

Observed or potential impacts of paludiculture	Options to minimise negative / maximise positive impacts
✗ **Damage to donor sites if material for paludiculture is collected from the wild**. For example, wild-harvested vegetation has been used to establish *Sphagnum* paludicultures in Germany (GMC, 2021; Wichmann, 2012). Harvesting from donor sites can harm various aspects of the natural environment. Removal of vegetation can diminish biodiversity and landscape character. Vehicles can damage soils and, consequently, hydrology. Wild donor sites may be particularly attractive for paludiculture trials and pioneering farms. However, the risk should be low over the long term, given the likely availability of donor material from established paludiculture operations and propagation services (e.g. www.beadamoss.com for *Sphagnum*), along with legal protection afforded to wild wetland sites.	➜ **Source material from *ex situ* propagation services**. ➜ **Source material from existing paludiculture sites**. ➜ If sourcing material from wild sites, **collect infrequently, from a limited area, and leave some material in place to facilitate regeneration** (Silvan, 2019; Silvan et al., 2012; Whinam & Buxton, 1997).
✓ **Telecoupled benefits for nature from domestically sourced materials**. Harvesting material from domestic paludiculture that would otherwise be imported could reduce impacts on the natural environment in source countries. Many of these have higher biodiversity than England, but less stringent environmental protection regulations (OECD, 2016). For example, in the medium term (to 2035), the UK Government intends to develop biomass use for power, heat and transport. This will be sourced both domestically and through imports (HM Government, 2023a). In 2023, the UK imported 46% of its required plant biomass (HM Government, 2023b), mostly from Brazil, Canada and the United States (HM Government, 2023b; Immerzeel et al., 2014). Increasing domestic production of biomass (e.g. from cattail, sedges or willow; Table 1.1) could reduce imports from, and environmental impacts in, these source countries [WS].	
✗ **Telecoupled harm to nature from displaced food production**. Lowland peat is a major contributor to UK food production. In 2021, there were 53,337 ha of vegetables and 86,643 ha of cereals (excluding maize) grown on lowland peat in the UK (Rhymes et al., 2023). The Fens alone comprise less than 4% of England's farmed area but produce one third of its fresh vegetables, one fifth of its potatoes, and one fifth of its sugar beet (NFU, 2019). But many paludiculture systems would generate non-food products (Table 1.1). Assuming stable demand for food products, they will need to be grown elsewhere in the UK, or offshore. Production leakage will	➜ **Focus paludiculture in marginal land** (e.g. depressions) where farmers are already struggling to produce a conventional dryland crop. ➜ **Shift food production to vertical farms**. These could be powered using energy from paludicultures (e.g. short-rotation coppice willow; Lapwing Energy, 2022). ➜ **Recognise and report forgone production and potential for leakage from paludicultures** (Balmford et al., 2025).

likely lead to conversion of other valuable habitats for biodiversity – either directly (if former peatland crops replace a near-natural habitat) or indirectly (if former peatland crops replace other crops, which themselves are displaced) (Balmford et al., 2025; Morris et al., 2010). Given the high productivity of lowland peats, a larger area may be needed elsewhere to produce the same volume of food. Negative environmental impacts of commercial food production (e.g. pesticide pollution, soil degradation, changes to landscape character) may also be displaced.

- **Increase food crop yields elsewhere** to compensate for lost production. This could be on land adjacent to a new paludiculture, or in distant places that supply the same markets (Balmford et al., 2025). ! *GHG emissions*
- **Focus on conversion of drained grass pasture, rather than arable farmland, to paludiculture**. Rewetted pastures could be used for wetland grazing or converted to arable paludiculture. Reduced supply of animal products could be accommodated by sustainable supply chains and dietary choices (e.g. increasingly plant-based diets) (Rhymes et al., 2023; The Wildlife Trusts, 2025).

7.2 Research questions / knowledge gaps

Sources: Own work, Workshop, Freeman et al. (2022), Fritz et al. (2014), Nordt et al. (2022), Stuart et al. (2023), Tanneberger et al. (2022).

- What is the added value of services provided by paludiculture (including flood risk management, water quality, biodiversity, landscape character) compared to alternative land uses? How can these be quantified robustly so that they can be exposed to markets?
- How do the short-term and long-term impacts of paludiculture on the natural environment weigh up? Could short-term negative impacts be outweighed by longer-term positive ones, or vice versa?
- Are there fundamental differences between peatlands rewetted for paludiculture and those rewetted purely for nature conservation? How well can paludiculture sites provide the benefits of rewetted peatlands (e.g. in peat formation and for biodiversity)?
- How does paludiculture, and different configurations of paludiculture among other land uses, affect landscape fire risk? How is this risk affected by climate change?
- What are the telecoupled impacts of taking land out of food production for paludiculture? Where will this food be produced, and what are the implications of this shifting production for the natural environment?
- How can we best ensure coordination amongst the multiple stakeholders in lowland peat landscapes?

- Monitoring of paludiculture impacts over longer timescales and throughout the peat profile.
- A more nuanced understanding of context-dependencies in effects on natural environment, e.g. influence of site history, scale of paludiculture systems, vegetation type, land use in wider landscape.
- More studies comparing rewetted paludiculture to near-natural sites; most studies currently compare near-natural managed sites to near-natural unmanaged sites.
- More studies of combined effect of rewetting *and* management. This is the land use transition most commonly associated with paludiculture, but most existing studies look at impacts of either rewetting *or* management.
- More studies on paludiculture management and impacts in raised bogs, rather than fens.
- More empirical data on the environmental benefits of paludiculture to create robust payment schemes.
- More participatory research. Especially co-creation of paludiculture management practices that benefit the natural environment whilst being practical, feasible, cost-effective and congruent with productive land use.

8. SWOT analysis: impacts of paludiculture on the natural environment

In this section, we analyse key strengths, weaknesses, opportunities and threats that might mediate the impact of paludiculture on the natural environment.

- **Strengths** are *internal or intrinsic* characteristics of paludiculture that could contribute to positive impacts or minimise negative impacts.
- **Weaknesses** are *internal or intrinsic* characteristics of paludiculture that could contribute to negative impacts or dampen positive impacts.
- **Opportunities** are elements in the wider natural or human environment that paludiculture could exploit to maximise its positive impact and minimise negative impacts. These are sometimes called "positive risks".
- **Threats** are elements in the wider natural or human environment that could affect paludiculture such that it generates negative impacts or has smaller positive impacts. These are sometimes called "negative risks".

	↑ positive impacts / ↓ negative impacts	**↓ positive impacts / ↑ negative impacts**
Internal	**Strengths**	**Weaknesses**
External	**Opportunities**	**Threats**

Figure 8.1 Summary of difference between Strengths, Weaknesses, Opportunities and Threats in a SWOT analysis.

We focus here on impacts *given that paludiculture is occurring*, rather than opportunities and threats to the uptake of paludiculture at all. This section combines some points from previous sections with some new ideas. We do not provide detailed suggestions about how to exploit opportunities and mitigate threats; the *Lowland Agricultural Peat Task Force Chair's Report* (Caudwell, 2023) and *Roadmap to Making Wide-Scale Adoption of Paludiculture a Commercial Reality in England* (Stuart et al., 2023) provide many relevant recommendations and actions.

Closely related Strengths / Weaknesses and Opportunities / Threats are connected with this link icon.

8.1 Strengths / Weaknesses

Strengths	**Weaknesses**
[S1] Inherent **harvesting/biomass removal** means paludiculture sites will maintain early successional communities, benefitting some species (see BIODIVERSITY). It can also contribute to local reductions in nutrient levels (see SOILS and WATER QUALITY).	[W1] Inherent **harvesting/biomass removal** means paludiculture sites won't support late-successional communities (unless, for example, these are incorporated in a mosaic harvested at different times) or species that rely on mature vegetation. Optimal disturbance regimes for yields could exclude some species (see BIODIVERSITY).

[S2] **Sustainable extraction of resources** from semi-natural or near-natural peatlands could enhance arguments for their conservation (Joosten et al., 2016).

[W2] The primary **focus of paludiculture is likely to be yield and profitability**, which may lead to decisions with negative impacts on the natural environment (e.g. overfertilisation) [WS]. Management techniques can be vastly different in land that prioritises production compared to land that prioritises the local environment (Ward, 2024). Farmers are likely to prioritise food production and livelihoods over the natural environment, where there is a conflict between these aims (Blue Marble Research, 2024; Rawlins & Morris, 2010).

[S3] A **carefully managed water table** could facilitate site-level resilience to climate change (wetland conditions maintained except under extreme water shortages), preserve peat, and protect buried artefacts.

[W3] Holding the **water table relatively stable** within site (compared to natural fluctuations) will mean there is little temporal habitat variation (e.g. seasonal or interannual flooding at the right time for certain species).

[S4] A **water table close to the surface** is ideal for peat preservation and formation (see SOILS).

[W4] A **water table close to the surface** makes the peat susceptible to vehicle damage (see SOILS).

[S5] A **raised water table across the landscape** could create opportunities for wetland creation or restoration, for example in low pockets of land that become permanently flooded.

[W5] A **raised water table across the landscape** could damage existing wetland or dryland habitats. Impacts on these, and the species within, may require mitigation.

[S6] **Banks or bunds**, built to allow vehicle access or manage water levels, will increase topographic variation across site. They can provide habitat for species that would otherwise be drowned by paludiculture (C. Hainsworth pers. comm.). Sloped banks could provide sunny or shady microhabitats, helping species cope with climate change (Wildlife Trust BCN, 2024c).

[W6] **Where fields are precisely levelled**, to ensure consistency of conditions for crop growth across the site, there will be little spatial variation in habitats (e.g. small, shallow pools or slightly damper patches).

[S7] Some paludiculture plants, such as *Sphagnum*, are inherently **slow-growing** and will remain undisturbed by machinery for at least 2–3 years (Eversham & Stanier, 2022; Temmink et al., 2024). They can therefore provide refuges for wildlife (Eversham & Stanier, 2022; Wichmann, 2012), provide ongoing protection from erosion (Li et al., 2018), and reduce soil disturbance compared to conventional agriculture. However, regular mowing may be needed to control weeds such as *Juncus effusus* (Temmink et al., 2024).

[W7] Many **positive impacts of paludiculture may develop over relatively long timescales**, especially (a) peat formation within farms and (b) regeneration of near-natural wetland habitats in the surrounding landscape. Climate change adds further uncertainty in long-term outcomes (Anon, 2023). Delayed payment to offset initial investment and any yield loss could discourage practices that benefit the natural environment. For instance, farmers perceive rewetting as risky due to its high capital costs and uncertain returns (Blue Marble Research, 2024).

[S8] Many paludiculture products are **useful, and often in novel or innovative ways**. For example, cattail seed fluff is being used as an insulating filler in clothing, silicon extracted from reeds can potentially be used in batteries, and rare earth elements can be extracted from plants such as reed canarygrass – although not yet commercially (Nordt et al., 2022). Paludiculture products therefore have the potential to establish new connections between people and the peat landscape (Heindorf et al., 2024).

[W8] Paludicultures tend to produce products that are **not mainstream foods**. Food production, and its impacts on the natural environment, will likely be displaced elsewhere – perhaps to countries with higher biodiversity and less stringent environmental protection regulations.

[S9] Paludiculture **encapsulates traditional land uses** in many lowland peat landscapes (e.g. willow growing on the Somerset Levels, reed harvesting in the Fens; see LANDSCAPE CHARACTER & HERITAGE). It could therefore restore or maintain cultural heritage, even if this is not its primary aim.

[W9] Much **cultural heritage in peatlands can be hidden beneath the peat** (e.g. historical artefacts), so is not accessible to the general public without interpretation.

[S10a] By (partially) restoring physical, chemical and biological properties, paludicultures could act as **stepping stones to restoration** of near-natural lowland peatlands (see CROSS-CUTTING POINTS).

[S10b] Potential for paludiculture to **provide raw material for restoration**. *Sphagnum* paludicultures can provide donor material for peatland restoration (Grobe, 2023). Reed paludicultures could provide material for reedbed creation (Ross, 2025).

[W10] Potential for paludiculture to **deflect attention and funding away from conservation and restoration of near-natural lowland peatlands** (IUCN, 2023; The Wildlife Trusts, 2025). Conservation and restoration are separate goals, alongside sustainable management, of the UK Peatland Strategy (IUCN, 2018). Paludiculture is not an exact substitute for near-natural habitats (see BIODIVERSITY).

[S11] Potential for new paludiculture developments to **relieve production pressure on some semi-natural peatlands**, so the focus there can shift purely to nature conservation. Management to maximise yield and product quality (e.g. annual reed harvest) is not always aligned with optimal management for nature (see BIODIVERSITY).

[W11] Potential for paludiculture to **divert productive use away from semi-natural peatlands**. Abandonment of these sites could have negative impacts for species that rely on early-successional or managed habitats (see BIODIVERSITY).

[S12] **Shallow gradient and slow water flow** across paludiculture sites can contribute to nutrient management in flat, lowland landscapes. These features present practical challenges to the operation of other types of constructed water treatment wetlands (Comber et al., 2023).

[S13] Since many paludiculture plants **can tolerate periods of inundation** (Abel & Kallweit, 2022), paludiculture sites could be used to manage landscape flooding (see HYDROLOGY). This also opens opportunities for weed control by water management rather than chemical application (see WATER QUALITY).

[S14] Some paludiculture plants like *Sphagnum* have **low nutrient requirements**, minimising the need for fertiliser inputs (see WATER QUALITY).

[S15] Some paludiculture plants like cattail can **tolerate high nutrient levels** and assimilate them into their tissues. These plants can be used to reduce nutrient levels at a site or landscape, whether a legacy of past management or induced by rewetting.

[S16] Several livestock breeds suitable for paludiculture (e.g. water buffalo) are inherently **robust**, meaning they need less veterinary medication (e.g. deworming treatments) than conventional livestock. This can benefit the wider ecosystem: their dung, for example, provides a habitat for coprophilic insects, in turn supporting populations of their predators (Duncan et al., 2021; Joosten et al., 2016).

[W12] **Options for crop rotation may be limited in paludiculture** compared to conventional agriculture: there is a limited pool of crops and rotation periods can be long (decades) (de Jong et al., 2021; Ward, 2024). This limits temporal habitat variation. It could also lead to high pest and disease burdens, requiring agrochemical inputs (Ward, 2024).

[W13] Modern paludiculture is a relatively new form of land management in England, with **limited evidence and experience to guide decision making**. It won't always be possible to choose, upfront and with a high degree of confidence, management practices that have the desired impacts on the natural environment. Continual learning and adaptive management will be necessary. A lack of data also hinders the incorporation of paludiculture into payment schemes like the Peatland Code (IUCN, 2024a).

8.2 Opportunities / Threats

Opportunities

[O1] Situate paludiculture strategically with respect to **existing wetland habitats** to maximise biodiversity benefits. For example, paludiculture sites can be used to expand or connect patches of existing wetland habitat (see BIODIVERSITY).

[O2] Frame paludiculture as a **nature-based solution to wider environmental challenges**, e.g. planting crops like cattail and common reed in areas with high nutrient loads (Tan et al., 2021). This could link with legislation such as The Water Framework Directive Regulations 2017 (HM Government, 2017) and nutrient neutrality (Natural England, 2022).

[O3] Access **payments for the benefits paludiculture offers to the natural environment**. These benefits include water purification and biodiversity gain as considered in this report, plus others like carbon storage [WS]. Income streams related to co-benefits should encourage site management to realise them (as well as contributing to the overall economic viability of paludiculture). The UK Peatland Strategy explicitly recognises the need for public funding in return for the benefits that healthy peatlands provide to society, and financial support for land managers who manage peatlands sustainably (IUCN, 2018). Private funding could also contribute.

Payment schemes could operate at various scales. Locally, the West Country Rivers Trust Anglers' Passport uses revenue from anglers to maintain fish habitats, including by paying farmers for nature-friendly practices (WRT, 2025). Nationally, Countryside Stewardship actions SW17 and SW18 pay for raised water levels in cropped, arable, or permanent grassland on peat soils (HM Government, 2024a). Paludicultures can be part of Landscape Recovery schemes, as at Greater Sedgemoor in Somerset (Bridge, 2025; The Wildlife Trusts, 2025). The UK Peatland Code could facilitate payments for greenhouse gas emission reductions associated with paludiculture (IUCN, 2024a). Payments should make a meaningful contribution to costs (Reed et al., 2020).

[O4] Access **Biodiversity Net Gain (BNG) payments** to support habitat creation opportunities in a wetter landscape (HM Government, 2024c). Habitats of "very high" distinctiveness under BNG include fens, lowland raised bogs, and wet depressions on peat substrates. Habitats of "high" distinctiveness include lakes, ponds and reedbeds (HM Government, 2025c).

Threats

[T1] **Situating paludiculture near to existing wetland habitats could harm biodiversity**, for example if paludiculture sites act as ecological traps: used by wild species but becoming unsuitable because they are harvested at the wrong time of year, or don't contain suitable food/prey (see BIODIVERSITY).

[T2] **Misappropriation of paludiculture to peatland-degrading practices**, such as partial drainage or permanently flooded systems (Tan et al., 2021). This can diminish positive impacts or generate negative ones, e.g. partial drainage will reduce the rate of peat formation.

[T3a] **Potential for environmental payments to stimulate negative outcomes for the natural environment** via unsustainable forms of paludiculture (IUCN, 2023). For example, if the value of carbon credits exceeds the value of biodiversity credits, and they are mutually exclusive and not perfectly positively correlated, farmers may manage for carbon to the detriment of biodiversity (Nunez et al., 2020). This issue could arise whether payments are public subsidies or private investments.

[T3b] **Some environmental land management payments do not (clearly) apply to paludicultures**. For example, Countryside Stewardship action WT6 (reedbed management) only applies to priority habitat in good condition or degraded habitat with potential for restoration, and only on parcels >2 ha (HM Government, 2024d). If paludiculture farmers cannot access such payments, they may not be incentivised to incorporate nature-friendly practices (A. van Weeren pers. comm.).

[T3c] **Inability to bundle or stack credits for different nature benefits associated with paludiculture, or credits for nature and carbon** (Stuart et al., 2023). We currently lack robust mechanisms to combine paludiculture benefits into a single credit ("bundling") or sell separate credits for different benefits ("stacking") (McCarthy & Sarsfield, 2024).

[T4] **Potential for Biodiversity Net Gain (BNG) payments to stimulate negative outcomes for the natural environment**. BNG scores do not necessarily correlate with true biodiversity variables; additional species-focused conservation management will be necessary (Marshall et al., 2024).

[O5] Tap into **consumer willingness to pay a premium for nature-friendly products** (Ward, 2024). A recent global consumer survey identified willingness to pay a 9.7% premium for sustainable products (Durand-Hayes et al., 2024). A premium could be levied for paludiculture products generally (assuming benefits materialise and can be demon-strated), or for those produced using particularly nature-friendly practices. A recognisable certification, like the LEAF Marque (www.leaf.eco), could verify benefits and provide assurance to consumers.

[T5a] **Inadequate or inaccurate quantification of ecosystem services and co-benefits** associated with paludiculture will mean it is not fully exposed to market forces (Fritz et al., 2014; Turner et al., 2000).

[T5b] Paludiculture is **not a widely recognised concept or term**, so marketing any benefits it provides to the natural environment may be challenging (Ross, 2025).

[O6a] **Diverse markets for paludiculture overall**. This means production (e.g. crop types) within a site can be diversified, so paludiculture of some form can continue, along with the benefits it provides, even if a particular market shrinks.

[O6b] **Diverse markets for any given product**, so paludicultures can continue even if a specific market shrinks. For example, a reed paludiculture could maintain routes to market as construction material, packaging, or bioenergy (Goriup et al., 2019).

[T6] **Market volatility** leading to abandonment of paludiculture sites, and loss of the benefits they provide. This is a particular risk where paludicultures are exploring novel products and emerging markets. Domestic production could also be threatened by increased overseas production.

[O7] Exploit **influence of policy and markets on cropping decisions**. Policies or markets that encourage crop diversity within farms or across land-scapes (Upcott, 2021) would generally have positive impacts on biodiversity and landscape character.

[T7] **Influence of policy and markets on cropping decisions**. Policy or markets that favour certain crops (e.g. for bioenergy) would likely reduce crop diversity across landscapes (Upcott, 2021; Wichtmann & Wichmann, 2011), with generally negative impacts on biodiversity and landscape character.

[O8] Capitalise on **government commitments to secure a plentiful water supply**. Under its Plan for Water, the UK Government aims to increase the amount of water stored by the agriculture and horticulture sectors by 66% by 2050, and is providing £10 million of grants to help farmers with the costs of building on-farm water reservoirs and irrigation equipment (HM Government, 2023d). Such commitments could help paludicultures store sufficient water to supply the needs of their crops and avoid overexploitation of existing water sources.

[T8] **Insufficient water supply to manage water levels with maximum benefit for the natural environment** [WS]. It is unlikely that the current water infrastructure in English lowland peat land-scapes, particularly reservoir capacity, will support widespread paludiculture (Wootton & Jacobs, 2024). External factors may further increase competition for water between paludiculture and nature, meaning the full benefits of paludiculture cannot be realised (Labadz et al., 2010). Under **climate change** there will be less water available, especially in summers which will generally become drier (Met Office, 2022). **Human population growth** will also increase demand for water (Jenkins et al., 2024; Somerset Council, 2024).

[O9] Cooperate with **Internal Drainage Boards** (IDBs) to manage rewetting for paludiculture. IDBs are experienced at managing water levels; their expertise could be applied to paludiculture projects to avoid negative impacts on the natural environment.

[T9] **Internal Drainage Boards (IDBs) are currently set up to lower water levels** and reduce flood risk within their districts. Adapting this remit will require legislative change (including a review of the Land Drainage Acts to legally alter the role of IDBs), re-organisation of the existing structures for distributing drainage rates and license fees, and funding for infra-structure and equipment to support altered water management goals (Blue Marble Research, 2024; Caudwell, 2023; Wootton & Jacobs, 2024).

[O10] Comply with **institutions to prohibit use of pesticides deemed to have unacceptable negative impacts on the natural environment**. Pesticides must be approved for use in the UK based on efficacy and environmental assessments (Stockdale et al., 2024). They must be used according to terms specified on the label. Regulations to prevent pesticide contamination of water bodies will apply to paludiculture sites surrounded by ditches (Stockdale et al., 2024).

[T10] Restrictions on pesticide application to waterlogged soils **would not apply to paludiculture sites where the surface is not saturated** (Stockdale et al., 2024).

[O11] Capitalise on **government vision for commercial drones**: "By 2030 [they] will be commonplace in the UK in a way that safely benefits the economy and wider society" (HM Government, 2022). This aligns with the potential for the use of drones in paludiculture to carry out agronomic tasks, whilst minimising many immediate impacts on the natural environment (see SOILS).

[O12] Utilise **digital technologies for paludiculture management** (e.g. to monitor and manage agrochemical application and water levels, or to detect faults in water systems; Rowan et al., 2022) and respond appropriately.

[O13] Utilise **genetic technologies**, such as environmental DNA (Kestel et al., 2022) and metagenomics (Duque Zapata et al., 2023), to monitor and respond to the impacts of paludiculture. This is especially relevant to soil health, water quality and biodiversity.

[O14] Engage **citizen or community scientists in paludiculture monitoring**, largely as an environmental education opportunity, but also to provide data on impacts. There are particular opportunities in water quality and biodiversity monitoring, inspired by existing successful programmes, e.g. The Big Windermere Survey, The Riverfly Partnership, Catchment Systems Thinking Cooperative (CaSTCo).

[O15] **Cultural events** (perhaps centred around products or traditional practices) as an opportunity to promote the values of paludiculture in harmony with conservation and regeneration, and to provide space for learning and reflection (Heindorf et al., 2024). This can help to build support from local lowland peatland communities for nature-friendly paludiculture (as well as paludiculture overall).

[O16] Many **farmers are already familiar with, and using, nature-friendly farming practices**, such as limiting soil disturbance to preserve peat (Blue Marble Research, 2024). Many peatland farmers are members of the Nature Friendly Farming Network (www.nffn.org.uk). Thus, there is existing sentiment and skills to support nature-friendly paludiculture.

[T11] Development of paludiculture markets or incentives could **encourage harvesting of undisturbed peatlands or conversion of these peatlands to paludiculture** (Ward, 2024). It is unlikely that all negative impacts on the natural environment could be mitigated (e.g. see WATER QUALITY and BIODIVERSITY). If productive use of near-natural peatlands is unavoidable, paludiculture should always be preferred over drainage-based production (Joosten et al., 2012).

[T12] Potential **competition for land between ecosystem restoration and paludiculture**. Given current attention on ecosystem restoration (e.g. www.decadeonrestoration.org), peatlands could be designated for restoration where paludiculture would be more appropriate and beneficial for the natural environment (e.g. maintaining cultural heritage, or maintaining disturbance regimes that benefit biodiversity) and for local people. Equally, paludiculture might be prioritised where restoration could be more appropriate (e.g. particularly valuable sites for biodiversity, or difficult sites to farm).

[T13] **Land use may be restricted if legally protected species colonise** (Gaudig et al., 2014; Stuart et al., 2023). This might discourage farmers from implementing paludiculture or specific practices to benefit biodiversity. Ironically, restrictions could change the conditions that benefit the species.

[T14] **Limits on how far the water table can be raised** (e.g. to the height of surrounding bunds or agricultural land; Temmink et al., 2024). This would, for example, limit the continued accumulation of peat in paludiculture systems.

[T15] **Water use regulations could limit access to water**, meaning water management to benefit the natural environment might be impossible (or be subordinate to crop needs). Licenses are needed for water impoundment, abstraction or transfer (Environment Agency, 2023b). Consumptive licenses may be limited where there is little water available for use, as is the case for groundwater across much of the Broads National Park (Knowles, 2024).

[O17] Use **existing evidence, guidance, tools and advice to inform practice**. Sources of free relevant information include Farming and Wildlife Advisory Groups, Catchment Sensitive Farming advisors, FarmScoper www.adas.co.uk/services/farmscoper, FarmWildlife www.farmwildlife.info, the Cool Farm Tool www.coolfarm.org, and Conservation Evidence www.conservationevidence.com.

[T16] **Policy to minimise greenhouse gas emissions could limit scope for flooding paludiculture sites to benefit biodiversity**. Current evidence suggests that total greenhouse gas emissions will increase when the water table is raised higher than ca. 10 cm below the peat surface (Evans et al., 2021), but many wetland species would benefit from higher water levels (see BIODIVERSITY).

[T17] **Sea level rise** will likely impact coastal wetlands, for example via saltwater flooding and saline intrusion (Mulholland et al., 2020). This can affect water chemistry and peatland hydrological properties, cause a loss of peat strength and sub-sidence, and damage freshwater communities and species in paludiculture sites (Sirianni et al., 2023).

[T18] **Inconsistent policy across departments** could discourage management of paludiculture sites in ways that benefit the natural environment (as well as posing a challenge to the uptake of paludiculture at all; Johnson et al., 2017). For example, policy support for nature-friendly paludiculture should be coordinated across the Department for Environment, Food and Rural Affairs, the Department for Energy Security and Net Zero, and the Department for Business and Trade.

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