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Peatland Impact Assessment: Effects of Management Actions on Achieving Environmental Aims

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Summary

Peatlands are important for supporting a range of ecosystem services, including carbon storage, flood prevention, filtration of water, food production as grazing land, and soil health. They are also crucial for supporting rare and specialised biodiversity. However, many peatlands in Northern Ireland are in poor condition, due to a history of impacts such as turf cutting, drainage, overgrazing and pollution. Understanding the impacts that different management actions and restoration interventions will have on these ecosystem services is therefore crucial to inform peatland-relevant policies and actions, such as the Peatland Strategy, the Environmental Farming Scheme and the Farming with Nature scheme (Northern Ireland's agri-environment schemes).

The aim of this report, therefore, is to review the literature on the impacts of peatland management actions on achieving a range of environmental aims. A quick scoping review of both scientific and grey literature was undertaken, the findings of which are summarised in Table 1.

Table 1. A summary of literature review findings, showing the effect of peatland restoration actions on a range of environmental aims.

Environmental aim	**Rewetting and work to raise water levels** (e.g. ditch blocking, gully blocking, bankside reprofiling)	**Control of non-peatland vegetation** (e.g. bracken/ scrub control, tree felling)	**Restoration of peatland vegetation** (e.g. grazing reduction, sphagnum plugs)
Restore, preserve and enhance **biodiversity**	Positive impact	Mixed/neutral impact	Revegetation = positive impact; grazing reduction = mixed/neutral impact
Improve **water management**	Positive impact	Not enough information to draw a conclusion	Positive impact
Improve **water quality**	Positive impact	Initial negative but long-term positive impact	Mixed and context dependent effects
Improve **soil management**	Positive impact	Positive impact	Positive impact
Reduce **greenhouse gas emissions**	Positive impact	Not enough information to draw a conclusion	Not enough information to draw a conclusion
Food/fibre provision (crops)	Negative impact	Not enough information to draw a conclusion	Not enough information to draw a conclusion

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1. Introduction

1.1. Background and rationale

Peatlands are "wetland ecosystems that are characterised by the accumulation of organic matter called peat, which derives from dead and slowly decaying plant material under wet conditions" (DAERA 2025). It is estimated that between 18% and 24.6% of Northern Ireland is covered in peat or peaty soils (DAERA 2025; JNCC 2011).

As well as their significant contributions to climate change (storing more carbon globally than forests do), peatlands are also important for supporting a range of other ecosystem services (IUCN UK Peatland Programme 2019). These include flood prevention, filtration of water (with 70% of UK drinking water coming from upland areas dominated by peatlands), preservation of archaeology, food production as grazing land, and socio-cultural ecosystem services such as outdoor recreation (DAERA 2025; IUCN UK Peatland Programme 2019).

Peatlands are also important in supporting rare and specialised biodiversity. They form the UK's largest area of semi-natural habitat and are home to many species that have been identified as conservation priorities due to their rarity or declining populations (IUCN UK Peatland Programme 2024).

However, many peatlands in Northern Ireland are in poor condition, due to a history of impacts such as turf cutting, drainage, overgrazing and pollution (DAERA 2025). Effective protection and restoration of peatland will therefore not only contribute to addressing the climate crisis, but also to supporting natural capital and tackling the nature crisis. Understanding the impacts that different management actions will have on ecosystem services is therefore crucial to inform policies and ensure actions deliver environmental aims.

1.2. Policy context

Northern Ireland's Peatland Strategy includes a goal that "by 2040 peatland habitats in Northern Ireland are conserved, restored or appropriately managed". This ties into the wider UK Peatland Strategy (IUCN 2024). The strategy also highlights the relevance of peatlands to a number of other policy areas including the Green Growth Delivery Framework (which aims to "find a workable balance between the three pillars of Climate, Environment and the Economy," with peatland of relevance to all three of these), the Environmental Improvement Plan (which includes aims relevant to peatland such as reducing greenhouse gas emissions and to restoring habitats and species), and Northern Ireland Ammonia Strategy (as ammonia pollution is especially toxic to peatland lichen mosses and heather).

Northern Ireland's agri-environment schemes (the Environmental Farming Scheme (EFS) and the Farming with Nature Scheme) present opportunities for delivery of peatland restoration. For example, the EFS offers participants a five-year agreement to deliver a range of environmental measures and assessing applicants on their ability to deliver the most environmental benefit against the objectives of restoring, preserving and enhancing biodiversity, improving water quality and mitigating against climate change. Whilst these measures can be delivered anywhere, given that such a high proportion of Northern Ireland (18% to 24.6% – see above) is peatland or has peaty soils, it is likely that a reasonable proportion of actions will be taking place in this environment. A deep understanding of the effects of management actions in this context is therefore key to effective design and implementation of such schemes, and to ensure successful delivery of environmental benefits.

1.3. Aims and scope

The key objective of this report (hereafter referred to as the 'impact assessment') is therefore to review the literature on the impacts of peatland management actions for achieving a range of environmental aims.

The impact assessment aims to enhance understanding of the likely effects of implementing management interventions in peatland environments. It does so by grounding the assessment in the following EFS priorities:

- restoring, preserving and enhancing biodiversity;
- improving water management and water quality;
- reducing soil erosion and improving soil management;
- fostering carbon conservation and sequestration; and
- reducing greenhouse gas emissions.

Additionally, to the EFS aims, provisioning services (food/fibre provision) are included.

Actions considered to have potential for application within peatland were grouped into the following categories:

- rewetting and work to raise water levels (e.g. ditch blocking, gully blocking, bankside reprofiling, creation of shallow bunds);
- control of non-peatland vegetation (e.g. bracken/scrub control, tree felling);
- restoration of peatland vegetation (e.g. grazing reduction, stock proof fencing, sphagnum plugs).

Actions related to burning were excluded, as it is an intervention known to have a complicated evidence base, which would require a more in-depth review protocol (e.g. systematic review) than the one applied here for robust conclusions to be drawn.

2. Methods

The impact assessment was undertaken as a ‘quick scoping review’ as per the guidance in Collins *et al*. (2015). It aimed to answer the question “What is the impact of peatland management actions on delivery of ecosystem services in Northern Irish peatlands?” based on the PICO elements outlined in Table 2.

Table 2. PICO elements of the study question.

Question	What is the impact peatland management actions on delivery of ecosystem services in Northern Irish peatlands?
Population	Ombrotrophic peatland (raised bog and blanket bog).
Intervention / Exposure	Presence of management actions aiming to restore peatland, including: • rewetting and work to raise water levels (e.g. ditch blocking, gully blocking, bankside reprofiling, creation of shallow bunds); • control of non-peatland vegetation (e.g. bracken/scrub control, tree felling); • restoration of peatland vegetation (e.g. grazing reduction, stock proof fencing, sphagnum plugs).
Comparator	Absence of peatland-relevant management actions, as listed above
Outcome	Changes in: • biodiversity; • water management (flooding and drought); • water quality; • soil erosion and soil management; • carbon conservation and sequestration / greenhouse gas emissions; • food/fibre provision.

To answer the question above, the search string *“("peatland" OR "peat" OR "bog" OR "mire" AND "management" OR "action" OR "restoration" OR "conservation" OR "rewetting" AND "ecosystem service" OR "natural capital" OR "biodiversity" OR "carbon" OR "flood" OR "water quality" AND "UK" OR "United Kingdom" OR "England" OR "Ireland" OR "Scotland" OR "Wales")”* was input into Scopus for the dates 1900 to 31 July 2024, returning 447 results. Abstracts were screened in batches and the articles of those considered relevant were reviewed in full (Figure 1). For the 67 papers reviewed in full, the details outlined in Table 3 were recorded in an Excel document.

For inclusion in the review, each paper had to meet all the following criteria:

- Reviewers were able to access the full paper, not just the abstract.
- The study was located within the British Isles, in an ombrotrophic peatland (raised bog and blanket bog), to ensure only those with greatest geographic relevance for a Northern Irish context were considered. Review studies that cover temperate/boreal regions including studies from the British Isles but not only the British Isles were included.
- A relevant management option was undertaken (see ‘Intervention’ section of Table 1).

- A relevant ecosystem service was assessed as an outcome (see 'Outcome' section of Table 1).
- A link was established between the management option and the ecosystem service.
- The paper was published in English.

Noting the limitations of Scopus for assessing grey literature, and Collins *et al*. (2015) recommendation to use more than one search approach, an additional 17 papers were reviewed based on articles provided by contacts and a snowballing approach. This included those provided by the DAERA steering group, Northern Ireland Environment Agency contacts working on EFS, JNCC staff with a background in peatland, and review of reports from organisations with known expertise in this area, such as the International Union for the Conservation of Nature, Statutory Nature Conservation Bodies, environmental NGOs (e.g. national trusts) and key regional partnerships (e.g. Moors for the Future). The same information (Table 3) was recorded for these papers.

Table 3. Information recorded from each paper that passed abstract screening.

Column header	Description
Source/citation	The citation details of the study (author, title, journal, etc)
Link	URL to the paper
Management Action	See the 'Intervention' section of Table 2
Ecosystem Service	See the 'Outcome' section of Table 2. If a study was looking into more than one action-ES combination, multiple rows for that study were included
Impact of action on ES	Positive, negative, neutral, mixed, or unclear, based on the evidence provided in the study
Notes/quote relating to impact of action on ES	The relevant sentence(s) from the study were copy and pasted to provide evidence for the selection made in the previous column, or notes were provided justifying the choice
Context dependencies	Any context dependencies raised within the study were recorded (e.g. different taxa responding differently, different effects seen if actions undertaken at different times of the year/in different weather/based on different starting conditions)
Practical considerations (if mentioned)	Any practical considerations that the study mentions were noted (e.g. time / costs / resources required)
Location of study (if available)	Description of the study location, if available
Brief description of methods	Papers were recorded as either observational, experimental, secondary information or modelled
Brief description of peatland condition ahead of the management actions (if available)	A description of the peatland condition before the action took place was copy and pasted, if available
Other notes	Free text field for anything else considered useful to note down about this paper
Reviewer	Reviewer's initials

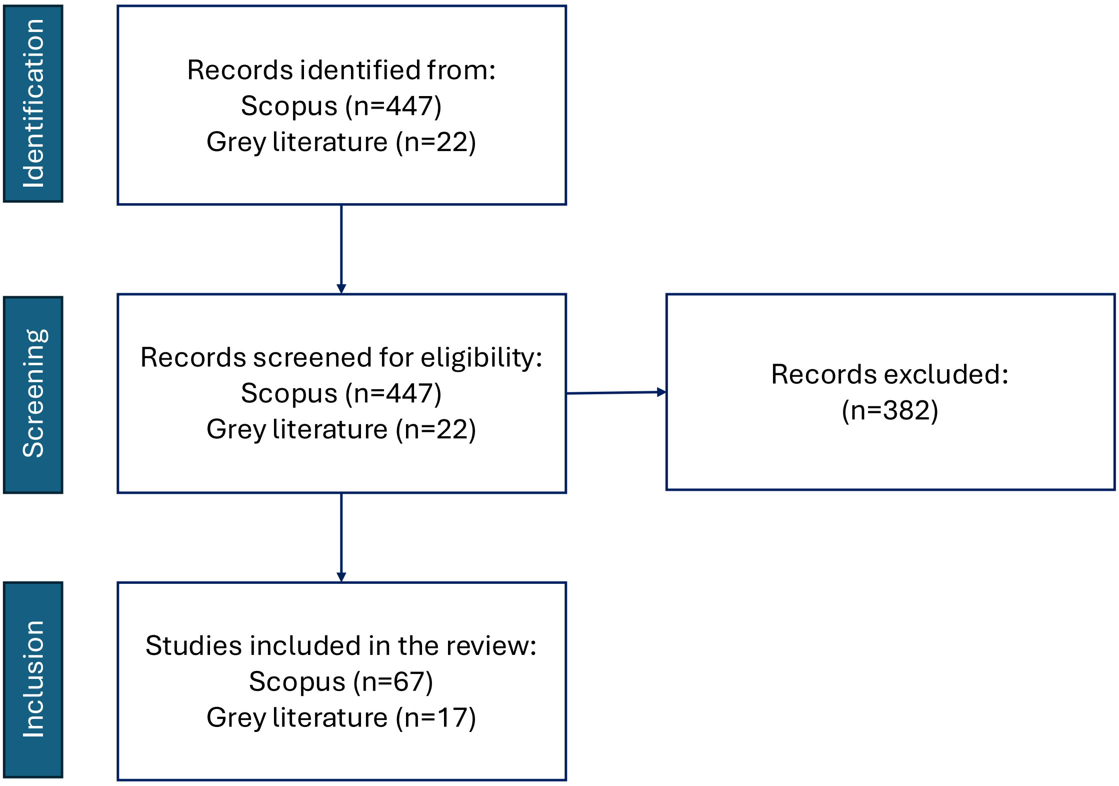

Figure 1. A PRISMA diagram outlining the records identified, screened and included/ excluded from the quick scoping review.

3. Restore, preserve and enhance biodiversity

Restoring, preserving and enhancing biodiversity is essential for supporting the healthy, stable ecosystems that are necessary for life, through provision of services such as food, clean air, and water. Biodiversity is also important culturally, economically, and ethically. Northern Irish peatlands host a range of rare and specialised biodiversity, including many species that have been identified as conservation priorities due to their rarity or declining populations (IUCN UK Peatland Programme 2024). Understanding the effects of management actions on peatland biodiversity is therefore important, and would also have policy relevance to Northern Ireland's Peatland Strategy, Environment Strategy, and Biodiversity Strategy.

3.1. Rewetting and work to raise water levels

A total of 26 of the papers reviewed assessed the effects of rewetting and work to raise water levels on biodiversity. Twenty of these showed evidence of a positive impact on biodiversity (Artz *et al.* 2018; Beadle *et al.* 2023; Bonnett *et al*. 2009; Brown *et al*. 2016; Carroll *et al.* 2011; Donahue *et al.* 2022; Evans *et al.* 2023; Grand-Clement *et al.* 2015; Heinemeyer *et al*. 2019; House *et al.* 2010; Howson *et al*. 2023; Mazzola *et al.* 2021; Morris & Edwards 2011; Natural England 2020; Northern Ireland Water 2019; Payne & Jessop 2018; Peacock *et al*. 2013; Renou-Wilson *et al.* 2019; Shepherd *et al.* 2013; Swindles *et al*. 2016).

Of those remaining, two (Anderson & Peace 2017; Hannigan *et al*. 2011) showed neutral effects (i.e. no change in biodiversity following rewetting), two (Lunt *et al.* 2010; Ramchunder, Brown & Holden 2009) showed mixed effects (i.e. positive at some sites, but negative at others), and two (Joy & Pullin 2001; Verberk *et al*. 2010) showed negative effects (one in the form of threatening the population of one particular butterfly species, *C. tullia,* and the other in the form of reduced species richness). The study with neutral effects was focused particularly on the context of whether rewetting in addition to tree felling brought additional benefits compared to tree felling alone, so may not be appropriate to draw conclusions related to cases where rewetting is not also accompanied by tree felling (Anderson & Peace 2017). The study showing reduced species richness considered that this may have been due to disturbance during the restoration process, suggesting that a longer timeframe may have been needed to show ultimate impact (Verberk *et al*. 2010). Verberk *et al*. also noted that the restoration caused homogenisation of environmental conditions, highlighting the importance of ensuring that rewetting occurs in a way that promotes a heterogeneous landscape reflective of a natural bog. One of the papers with mixed effects also noted timescales as a likely reason for this, with sites within or close to blocked drains showing evidence of revegetation, but sites within the wider landscape lagging behind (Ramchunder, Brown & Holden 2009).

Most papers showing a positive impact provided evidence of increases in population sizes for multiple named peatland species, of increases in species richness of peatland species, or of community structure moving towards that of intact peatland condition (i.e. of reference peatland sites that have never been drained). One study also showed that taxon richness, species composition and community structure in restored sites resembled those measured in intact peatland sites (Ramchunder *et al*. 2012). However, several studies had a more limited focus on a small number of individual species (Carroll *et al.* 2011) or on less ecologically specific observations such as the occurrence of revegetation (Artz *et al.* 2018; Howson *et al.* 2023; Morris & Edwards 2011).

Fifteen papers were focused on ditch blocking as the specific action taken to achieve rewetting, while others considered gully, drain and grip blocking, bankside reprofiling, stump flipping, creation of shallow bunds, and smoothing of the microtopographic features (to leave the site compacted, flattened and covered with small pools). The studies showing mixed or neutral effects were all within the set of papers focusing on ditch blocking. This may suggest that the specific action taken to achieve the rewetting is less important to effects on biodiversity than the success of the action in raising the water level (Lunt *et al.* 2010).

Most studies focused on a particular taxonomic group rather than assessing biodiversity in a more holistic sense. These included macroinvertebrates (Brown *et al*. 2016; Hannigan *et al.* 2011; Ramchunder *et al.* 2012), microcrustaceans (Hannigan *et al.* 2011), wetland birds (Northern Ireland Water 2019), craneflies (Carroll *et al.* 2011), microbes (Evans *et al.* 2023; Payne & Jessop 2018; Swindles *et al*. 2016) and plants (Anderson & Peace 2017; Grand-Clement *et al.* 2015; Howson *et al*. 2023; Mazzola *et al.* 2021; Northern Ireland Water 2019; Payne & Jessop 2018). Plant studies commonly focused on *Sphagnum spp*., *Eriophorum* spp. and *Calluna vulgaris* as key indicator species representing peatland condition, or rare species such as marsh saxifrage and bog orchid. In the case of macroinvertebrates, studies typically focused on either those found within streams (Ramchunder *et al.* 2012), or those found within pools (Brown *et al.* 2016; Hannigan *et al*. 2011). Some papers did have a broader focus covering multiple taxonomic groups (House *et al.* 2010; Peacock *et al*. 2013; Shepherd *et al.* 2013).

Studies also varied in their timescales, with some assessing biodiversity just a few months after rewetting, and others up to 15 years after rewetting. Many of the studies noted time since restoration as a key factor likely to influence biodiversity responses observed (i.e. biodiversity takes a significant amount of time after the restoration action has taken place to re-establish to its full potential (Beadle *et al*. 2023; Donahue *et al*. 2022; Evans *et al.* 2023; Natural England 2020; Ramchunder, Brown & Holden 2009; Renou-Wilson *et al.* 2019; Swindles *et al.* 2016)). For example, one study identified that ponds created earlier during the restoration process contained a higher diversity and stability of invertebrate communities compared to those created more recently (Beadle *et al.* 2023). Other context dependencies noted within the papers included that biodiversity response is likely to be dependent on the methods and scale of the restoration (Donahue *et al.* 2022), the size and depth of ponds created (Beadle *et al.* 2023), the weather conditions (Evans *et al.* 2023; Swindles *et al.* 2016), disturbance such as trampling and machine use during the restoration process (Swindles *et al.* 2016), nitrogen deposition rates (Evans *et al.* 2023) and existing hydrology (Swindles *et al.* 2016).

Most studies were observational in nature, suggesting correlation in their results, but not necessarily causation. However, nine were reviews or secondary information (Artz *et al.* 2018; Bonnett *et al*. 2009; Grand-Clement *et al.* 2015; Heinemeyer *et al*. 2019; House *et al.* 2010; Lunt *et al*. 2010; Natural England 2020; Ramchunder, Brown & Holden 2009; Shepherd *et al.* 2013), whilst four used a more rigorous experimental design involving controls (Anderson & Peace 2017; Evans *et al*. 2023; Joy & Pullin, 2001; Verberk *et al.* 2010). It is notable that three of the four experimental studies diverged from many studies in their findings, suggesting a neutral or negative impact of rewetting on biodiversity. This highlights a need for further experimental research on this topic to gain a more robust understanding.

Overall, there appears to be general agreement in the literature that rewetting, regardless of specific action to cause the rewetting, has a positive effect on biodiversity, if sufficient time is left following the intervention.

3.2. Control of non-peatland vegetation

A total of seven of the papers reviewed assessed the effects of control of non-peatland vegetation (trees and scrub) on biodiversity. Two of these papers showed evidence of a positive impact on biodiversity (Anderson & Peace 2017; Shepherd *et al*. 2013), three showed a neutral or unclear impact (Andersen *et al*. 2018; Konings *et al*. 2019; Pravia *et al.* 2019), and two showed mixed effects (Artz *et al.* 2018; O'Driscoll *et al.* 2013). Both papers showing a positive impact observed species composition slowly moving towards that of intact reference bogs (Anderson & Peace 2017; Shepherd *et al*. 2013). All papers included tree felling as the specific action taken to achieve vegetation control, with one study (Artz *et al.* 2018) also covering scrub control.

As in the previous section, most studies focused on a particular taxonomic group rather than assessing biodiversity in a more holistic sense. These included plants (Anderson & Peace 2017; Konings *et al.* 2019; Shepherd *et al*. 2013), carabids (Pravia *et al.* 2019), diatoms (O'Driscoll *et al.* 2013) and Atlantic salmon (Andersen *et al.* 2018). It is notable that the two studies showing a positive impact had a broader taxonomic coverage (plants and invertebrates) than most of the others. This may suggest that the mixed effects are related to the specific species and families selected in these studies, although the number of studies considered is too low to draw such a conclusion with any certainty.

The length of time after tree cutting or scrub control at which biodiversity was assessed varied from months (Andersen *et al*. 2018) to around 20 years (Konings *et al*. 2019; Pravia *et al.* 2019). Many of the studies noted time since restoration as a key factor likely to influence biodiversity responses observed (Andersen *et al*. 2018; Anderson & Peace 2017). For example, the study with the shortest timescale between restoration and data collection noted the short study period as a limitation and suggested research spanning a greater length of time (Andersen *et al*. 2018). Other studies collected data throughout an extended period of time and observed variation in effects on biodiversity throughout this time period. For example, one noted that species composition of vegetation became less like an intact reference bog within the first five years following restoration and only began shifting towards that of the reference bog in the subsequent five years of the study (Anderson & Peace 2017).

Most studies were observational in nature, suggesting correlation in their results, but not necessarily causation. However, one example was a review article that relied on secondary evidence (Shepherd *et al*. 2013), and two examples used a more rigorous experimental design involving controls (Anderson & Peace 2017; O'Driscoll *et al.* 2013). This suggests a need for further experimental research on this topic to gain a more robust understanding.

Overall, it appears likely that there is a mixed or neutral link between control of non-peatland vegetation and enhanced biodiversity, but it should be noted that this is based on a low number of studies with a lack of clear consensus.

3.3. Restoration of peatland vegetation

A total of 10 of the papers reviewed assessed the effects of restoration of peatland vegetation on biodiversity. Five of these papers showed evidence of a positive impact on biodiversity (Alderson *et al.* 2019; Holden *et al.* 2007; Pilkington *et al*. 2021; Shepherd *et al*. 2013; Yorkshire Integrated Catchment Solutions Programme 2019), while the other five showed mixed or neutral effects (Alday *et al.* 2022; Elliott *et al.* 2015; Heinemeyer *et al*. 2019; Pakeman *et al.* 2019; Robroek *et al.* 2009). One paper showing mixed effects found differing responses for different habitat types within the peatland category, for example with wet heath showing a rapid response towards reference conditions when grazing is removed, but *Molinia* mire showing little change (Pakeman *et al.* 2019).

Four of the five papers showing a positive impact were based on actions related to revegetation (e.g. Sphagnum plugs, seed mixes, nurse grasses), with only one (Holden *et al.* 2007) focusing on grazing reduction. In contrast, three of the five with mixed or neutral effects related to grazing reduction (e.g. stock proof fencing, changing the density of livestock on the land), whilst two (Elliott *et al.* 2015; Robroek *et al.* 2009) focused on revegetation.

All 10 papers focused on plants as the taxonomic group of interest, suggesting a possible evidence gap relating to the effects of restoration of peatland vegetation on other taxonomic groups.

Four of the studies (Alday *et al*. 2022; Pakeman *et al.* 2019; Pilkington *et al.* 2021; Robroek *et al.* 2009) were experimental in nature, whilst three were review articles relying on secondary evidence (Heinemeyer *et al*. 2019; Shepherd *et al*. 2013; Yorkshire Integrated Catchment Solutions Programme 2019), and three were observational (Alderson *et al.* 2019; Holden *et al.* 2007; Elliott *et al.* 2015).

Overall, it is likely that revegetation has a positive impact on biodiversity, whilst grazing reduction has a mixed or neutral impact. However, being based on few studies in each case, this conclusion should be treated with caution.

4. Improve water management and water quality

Effective water management, including through flood prevention, drought resilience and water quality, is important for protecting lives, preventing damage to homes and businesses, food security, provision of safe and accessible water sources, and economic success. Risks associated with floods and droughts are also predicted to increase with climate change. Understanding the effects that management actions in peatlands may have on these ecosystem services would therefore be useful.

4.1. Water management (flood and drought)

4.1.1. Rewetting and work to raise water levels

A total of 21 of the papers reviewed assessed the effects of rewetting and work to raise water levels on water management. All these related to flood prevention, with two (Grand-Clement *et al.* 2013; Wilson *et al.* 2011) also covering drought mitigation. No papers were found focusing solely on drought mitigation.

Both papers that included drought mitigation showed evidence of positive effects of rewetting on drought mitigation (Grand-Clement *et al.* 2013; Wilson *et al.* 2011).

Sixteen of the papers focusing on flood prevention showed evidence of improvements following rewetting work (Edokpa *et al.* 2022, 2017; EU Natural Water Retention Measures+ 2024; Grand-Clement *et al.* 2013, 2015; Heinemeyer *et al.* 2019; Holden *et al.* 2011; Holden *et al.* 2018; Howson *et al*. 2023; Lunt *et al*. 2010; Morris & Edwards 2011; Morris *et al.* 2019; Northern Ireland Water 2019; Payne & Jessop 2018; Shuttleworth *et al*. 2019; Wilson *et al.* 2011).

One review paper identified mixed results relating to rewetting's effectiveness on flood regulation, specifically on reducing the flashiness of flood hydrographs (Shepherd *et al.* 2013). Three papers showed neutral or unclear results (Anderson & Peace 2017; Regensburg *et al*. 2021; UKCEH 2023). Two of those with neutral or unclear results had a different primary focus of the study (e.g. water quality), with water management being mentioned or covered briefly but without sufficient evidence on water management provided to conclude a firm link (Anderson & Peace 2017). Another of those with neutral or unclear results demonstrated that permanent blocking of peat pipes had no direct impact on streamflow, although the study did note significant leakage and seeping as a limitation (Regensburg *et al.* 2021).

Some of the studies showing a positive impact identified effects such as increased water storage or increased hydraulic conductivity, which may lead to reduced flooding, but did not make the link explicitly (Howson *et al.* 2023; Morris *et al.* 2019). Other studies made a more direct link to flood prevention, such as through measurement of peak flow lag time, and pool overflow rates (Holden *et al.* 2018; Shuttleworth *et al.* 2019). One study made a direct link to flood prevention through measurement of downstream hydrology (Edokpa *et al.* 2017).

In many studies, details about the exact methods for rewetting or raising water levels were unclear. In those where specific actions were identified, thirteen studies referred to ditch or drain blocking (Anderson & Peace 2017; Edokpa *et al*. 2017; EU Natural Water Retention Measures+ 2024; Grand-Clement *et al.* 2013, 2015; Heinemeyer *et al*. 2019; Holden *et al.* 2011; Lunt *et al*. 2010; Morris & Edwards 2011; Morris *et al*. 2019; Northern Ireland Water 2019; Shepherd *et al.* 2013; Wilson *et al.* 2011), one study to the creation of scrapes (Holden *et al.* 2018), one study to the creation of stone and timber dams in gullies (Howson *et al.* 2023), and one to pipe blocking (Regensburg *et al.* 2021).

Nine of the studies were observational in nature, suggesting correlation but not necessarily causation (Edokpa *et al*. 2017; EU Natural Water Retention Measures+ 2024; Holden *et al.* 2011; Holden *et al*. 2018; Howson *et al.* 2023; Morris & Edwards 2011; Morris *et al.* 2019; Northern Ireland Water 2019; Wilson *et al.* 2011). Three of the studies had a more robust experimental design, such as BACI (Before, After, Control, Intervention – Anderson & Peace 2017; Edokpa *et al.* 2022; Regensburg *et al.* 2021). Again, it is interesting to note that two of the three experimental studies are those in the minority in terms of results, with a neutral or mixed association demonstrated (Anderson & Peace 2017; Regensburg *et al.* 2021). Other studies provided secondary evidence, for example through hypotheses made in a paper's discussion section, as review articles, and from expert workshop write-ups (Edokpa *et al.* 2022; Grand-Clement *et al.* 2013, 2015; Heinemeyer *et al.* 2019; Lunt *et al.* 2010; Payne & Jessop 2018; Shepherd *et al.* 2013; UKCEH 2023).

Overall, there appears to be general agreement in the literature that rewetting has a positive effect on flood prevention, although review of additional studies would be required to understand if the specific actions involved affect success. It has not been possible to conclude whether there is a notable link between rewetting and drought mitigation from only two studies.

4.1.2. Control of non-peatland vegetation

Two of the papers reviewed assessed the effects of control of non-peatland vegetation on water management.

One experimental study concluded that water levels increased quickly following tree felling, and when combined with damming continued to increase slowly across all ten years of the experiment to values close to reference bog levels (Anderson & Peace 2017).

Another study, which was observational, found areas restored through tree felling to have longer periods of peak flow following a storm event than either reference bogs that had never been drained or the control areas that had not been restored (Pickard *et al*. 2022). However, the authors noted that this may have been due to measurements being taken at different catchment elevations (the restored area was the only one where measurements were taken from the 'upper catchment') and to water leaving the area through unmeasured flow paths in the unrestored area (e.g. sub-surface and overland).

Overall, it has not been possible to conclude from the studies reviewed whether there is a notable link between control of non-peatland vegetation and enhanced water management.

4.1.3. Restoration of peatland vegetation

Four of the papers reviewed assessed the effects of restoration of peatland vegetation on flood management (Alderson *et al.* 2019; Lunt *et al.* 2010; Shuttleworth *et al.* 2019; Yorkshire Integrated Catchment Solutions Programme 2019). All this provided evidence of a positive impact, with revegetation reducing peak storm flow and increasing lag times. However, the inclusion of just four studies means that this conclusion should be treated with caution.

4.2. Water quality

4.2.1. Rewetting and work to raise water levels

A total of 25 of the papers reviewed assessed the effects of rewetting and work to raise water levels on water quality. Twelve of these papers showed evidence of improved water quality following rewetting work (Armstrong *et al.* 2010; EU Natural Water Retention

Measures+ 2024; Gaffney *et al*. 2021; House *et al.* 2010; Lunt *et al.* 2010; Morris *et al*. 2019; Natural Capital Solutions & RSPB, n.d.; Northern Ireland Water 2019; Payne & Jessop 2018; Ramchunder *et al.* 2012; Wallage, Holden & McDonald 2006; Williamson *et al.* 2023).

Two papers showed no evidence of a change in water quality following rewetting work (Bussell *et al.* 2010; Peacock *et al.* 2018). Four papers showed evidence of decreased water quality following rewetting work (Gaffney *et al.* 2024; Natural England 2020; Toberman *et al*. 2008; Worrall, Armstrong & Holden 2007). Seven papers showed mixed effects, four of which are review articles reporting on differences in findings across studies (Artz *et al*. 2018; Grand-Clement *et al.* 2015; Ramchunder, Brown & Holden 2009; Shepherd *et al.* 2013). Of the studies showing mixed effects across studies, one highlighted differences in findings across different quality variables being measured (Holden *et al.* 2007), and two give evidence of decreased water quality in the years immediately following restoration, but increased quality for most (but not all) variables measured in the longer term (Gaffney *et al.* 2018; Grand-Clement *et al.* 2013). This time series effect may also explain the decreased water quality in Gaffney *et al.* (2024) and the lack of change in Peacock *et al.* (2018), both of which were undertaken on a relatively short time frame. The authors of Gaffney *et al.* (2024) additionally recognised that the experimental design involved inundation of peat, needles and branches, which is likely to accelerate their decomposition compared to a typical restoration situation. Other factors noted as possible limitations or context dependencies include variations based on storm events, peat depth, underlying geology, and proximity to the coast (Gaffney *et al*. 2018, 2021).

Of those showing a positive impact, most evidence of changes in chemical compositions were only studied at a site level; only five studies (EU Natural Water Retention Measures+ 2024; Lunt *et al.* 2010; Northern Ireland Water 2019; Ramchunder, Brown & Holden 2009; Worrall, Armstrong & Holden 2007) were identified that tested whether such changes also occurred at a catchment level or at the point of abstraction for drinking water supply, where such findings would have the biggest implications from both an economic and health perspective.

In most of the studies assessed, details about the exact methods for rewetting or raising water levels were unclear. In those where specific actions were identified, all referred to ditch blocking.

Studies varied substantially in the aspects of water quality that were measured, including Dissolved Organic Carbon (DOC – Armstrong *et al.* 2010; Gaffney *et al.* 2024; Grand-Clement *et al.* 2013, 2015; Holden *et al.* 2007; Ramchunder, Brown & Holden 2009; Toberman *et al*. 2008; Wallage, Holden & McDonald, 2006; Williamson *et al.* 2023), Dissolved Organic Matter (DOM – Peacock *et al.* 2018; Williamson *et al.* 2023), phosphates (PO_4^{3-} – Gaffney *et al.* 2024), sulphate (SO_4 – Ramchunder *et al.* 2012) ammonium (NH_4^+ – Gaffney *et al.* 2024), potassium (K – Gaffney *et al.* 2024), phosphorus (P – Natural England 2020), arsenic (Natural England 2020), bromide (Artz *et al*. 2018; Natural England 2020), sedimentation or turbidity (House *et al.* 2010; Natural Capital Solutions & RSPB n.d.; Northern Ireland Water 2019; Ramchunder *et al.* 2012) and nitrogen/nitrates (N/NO_3 – Payne & Jessop 2018). Water discolouration was also measured in many of the studies. One study estimated a reduction of 20% in water treatment costs (EU Natural Water Retention Measures+ 2024) and another estimated savings of £4,158 to £17,325 per year in water treatment costs alone (i.e. without considering the value of other benefits) from a single (area not specified) catchment (Northern Ireland Water 2019).

Nine of the studies were observational in nature, suggesting correlation but not necessarily causation (Armstrong *et al.* 2010; EU Natural Water Retention Measures+ 2024; Gaffney *et al.* 2018; Morris *et al.* 2019; Natural Capital Solutions & RSPB n.d.; Northern Ireland Water 2019; Ramchunder *et al.* 2012; Wallage, Holden & McDonald 2006; Worrall, Armstrong &

Holden 2007). Three of the studies had a more robust experimental design, such as BACI (Gaffney *et al.* 2024; Peacock *et al.* 2018; Toberman *et al*. 2008). Other studies provided secondary evidence, for example as review articles or through hypotheses made in a paper's discussion section (Artz *et al.* 2018; Bussell *et al.* 2010; Gaffney *et al.* 2021; Grand-Clement *et al.* 2013, 2015; Holden *et al.* 2007; House *et al.* 2010; Lunt *et al.* 2010; Natural England 2020; Payne & Jessop 2018; Ramchunder, Brown & Holden 2009; Shepherd *et al.* 2013; Williamson *et al.* 2023).

Overall, there appears to be general agreement in the literature that rewetting has a positive effect on water quality, although review of additional studies would be required to understand if the specific actions involved affect success.

4.2.2. Control of non-peatland vegetation

Eight of the papers reviewed assessed the effects of control of non-peatland vegetation (specifically tree felling in seven cases and scrub control in one case) on water quality. Four of these studies showed evidence of decreased water quality following felling (Gaffney *et al*. 2024, 2021; Muller *et al*. 2015; Shah n.d.). However, all of these were short-term studies, lasting for days to months. Another study was a review article focusing on the effects of varying management options, including tree felling, on downstream DOM, which concluded that whilst considerable uncertainty remains on this topic, in many cases DOM concentrations increase in the short term and then fall in the longer term as bog vegetation re-establishes (Williamson *et al.* 2023). Other studies reviewed suggested a similar pattern in terms of timeframes, for example with short-lived increases in DOC, phosphate and iron concentrations (Artz *et al*. 2018), and with water chemistry variables generally showing a marked change initially followed by a longer-term recovery (17 years after restoration). However, this varied depending on which water chemistry variables were being measured (Cummins & Farrell, 2003) and some chemicals were still found in elevated levels even after 17 years (Gaffney *et al.* 2018).

Overall, it appears likely that control of non-peatland vegetation has an initial negative but long-term positive effect on water quality.

4.2.3. Restoration of peatland vegetation

Five of the papers reviewed assessed the effects of restoration of peatland vegetation on water quality (Artz *et al.* 2018; Natural Capital Solutions & RSPB n.d.; Stimson *et al.* 2017; Shuttleworth *et al.* 2015; Williamson *et al.* 2023).

One study identified short-term (~6 month) improvements in water colour and reduction in DOC concentration by 50%, but no long-term (~4 years) difference to levels prior to revegetation with lime and fertiliser (Stimson *et al.* 2017). The study also noted higher than recommended levels of phosphate downstream from the study area, suggesting that the fertiliser application was carried out at a higher than optimum level for the system.

Another was a review article focusing on the effects of varying management options, including revegetation of peatland species (*Agrostis* sp., *Deschampsia flexuosa* and *Festuca* sp., applied in combination with lime and fertiliser to ensure growth), on downstream DOM (Williamson *et al.* 2023). This identified mixed effects across a range of studies, peatland species and other contexts. For example, they noted that revegetation can help to stabilise peat and reduce overland flow, thereby reducing particulate loss, but that the re-establishment of vegetation can also increase the rate of new DOM being produced (e.g. through litter decomposition). They also noted that the addition of lime as part of the revegetation process is likely to increase the solubility of DOM through reducing acidity, and that it is easier to remove DOM from water where it has come from *Sphagnum* spp., rather than vascular plants. The study concludes that revegetation is unlikely to lead to significant changes in DOM at a catchment scale.

A further study noted a decrease in turbidity of 4% and a reduction in ‘mean raw water colour’ of 3% following a reduction in grazing (Natural Capital Solutions & RSPB n.d.). However, this intervention was undertaken alongside a range of others (ditch block, drain blocking, and dam construction) without adequate sample design to differentiate the effect of each action individually from the aggregate effects of these actions.

Shuttleworth *et al.* (2015) observed slightly lower lead export at a revegetated site; lower even than at an equivalent intact site, although it was believed this was due to a dilution effect with the revegetated gully walls having a larger pool of clean material.

The final study was a review article which provided secondary evidence on the stabilising effects of revegetation leading to decreases in DOC and lead fluxes (Artz *et al.* 2018).

Overall, it appears likely that restoration of peatland vegetation has mixed and context dependent effects on water quality.

5. Reduce soil erosion and improve soil management

Soil is critical for supporting plant life, thereby underpinning ecological functioning and food security. Understanding the implications of management actions on soil erosion and management in peatlands is therefore pertinent.

Wind and water driven soil erosion often occurs on degraded and bare peat (Li *et al.* 2018). Many of the effects of this are captured in other sections of this report, for example runoff of particulate matter under water quality and aquatic loss of carbon in the carbon emissions section. However, one review article did address the topic of soil erosion directly, highlighting reduction in grazing and burning, rewetting through reducing drains, constructing dams and reprofiling gully walls, and stabilisation through revegetation as factors contributing to a reduction in soil erosion in peatland environments (Li *et al.* 2018). Another review article identified reduced bulk density at a drain-blocked site compared to a drained site (Ramchunder, Borwn & Holden 2009).

Two of the studies reviewed identified additional soil related impacts in the form of recovery from land subsidence through restoration, with damming plough furrows found to increase ground surface height by 5–7 cm (Anderson & Peace 2017; Payne & Jessop 2018), but due to lack of studies directly assessing this relationship, it is inconclusive from the evidence gathered in the impact assessment’s timeframe.

6. Foster carbon conservation and sequestration, and reduce greenhouse gas emissions

Climate change from greenhouse gas (GHG) emissions is leading to more extreme weather events, rising sea levels, shifting ranges for crops we rely on, biodiversity loss, health and welfare risks, and economic disruption. Peatlands store more carbon globally than forests do, and release carbon when in poor condition. Understanding the impacts of peatland management actions on greenhouse gas emissions is therefore important. It also has relevance to Northern Ireland's Peatland Strategy and Green Growth Delivery Framework (which aims to "find a workable balance between the three pillars of Climate, Environment and the Economy,"), as well as international commitments such as the Paris Agreement (which aims to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels").

6.1. Rewetting and work to raise water levels

A total of 38 of the papers reviewed assessed the effects of rewetting and work to raise water levels on carbon emissions. Nineteen of these showed evidence of a positive impact, with reduced greenhouse gas emissions (Armstrong *et al.* 2010; Bonnett *et al.* 2009; Bullock, Collier & Convery 2012; Dean *et al.* 2024; Evans *et al.* 2021; Grand-Clement *et al.* 2013; Holden *et al.* 2007; House *et al.* 2010; Lunt *et al.* 2010; Natural Capital Solutions & RSPB n.d.; Northern Ireland Water 2019; Paul *et al*. 2018; Payne & Jessop 2018; Turner, Worrall & Burt 2013; Wallage, Holden & McDonald 2006; Wilson *et al.* 2022, 2016; Wilson, Müller & Renou-Wilson 2013; Worrall, Bell & Bhogal 2010).

Six papers showed evidence of a neutral or unclear effect, with no significant change in carbon or methane balances following restoration (Edokpa *et al.* 2017; Gatis *et al.* 2020; Green *et al.* 2018; Natural England 2012; Peacock *et al.* 2013; Pickard *et al*. 2022). One of these suggested high spatial variabilities within treatments, combined with a small sample size, as a possible reason for the lack of significant effect (Green *et al.* 2018). Eleven papers showed evidence of mixed or context dependent effects, including increasing emissions in nutrient rich areas but decreasing emissions in nutrient poor areas (Aitova *et al.* 2023), a trade-off between decreasing carbon emissions but increasing methane emissions, especially in the short term (Bonnett *et al.* 2009; Bussell *et al*. 2010; Mazzola *et al*. 2021; Natural England 2020; Shepherd *et al.* 2013), varying emissions depending on the microsite type, vegetation cover and water table depth (Rigney *et al.* 2018), identification of 'hotspots' that release GHGs at a different rate to their surrounding areas (Fenner *et al.* 2011), and varying emissions across different studies reviewed (Grand-Clement *et al.* 2015; Ramchunder, Brown & Holden 2009; UKCEH 2023). The final two studies concluded that pools in restored blanket peatland had higher DOC concentrations than those in areas that had not undergone restoration, but do not make clear what the implication of this is on overall emissions and fluxes (Chapman *et al.* 2022; Toberman 2008).

Many of the papers showing a positive impact made a clear and quantified link to a reduction in carbon emissions following rewetting, often converting from a net carbon source to a net carbon sink (Aitova *et al.* 2023; Evans *et al.* 2021; Rigney *et al.* 2018; Wilson *et al.* 2022). GHG emissions prior to rewetting or in control sites ranged from 1.21 t C per ha per year to 2.18 t C per ha per year (all acting as a carbon source). GHG emissions following rewetting ranged from -6 t C per ha per year to 5.8 t C per ha per year (normally acting as a sink, but certain cases acting as a source), with most studies falling between 0 and -3 t C per ha per year. It should be noted that one of the studies in which rewetted peat sometimes acted as a source did not have a baseline or control to compare against (Rigney *et al.* 2018), and another pointed towards the nutrient richness of the area as a possible explanation for it remaining a source (Aitova *et al.* 2023). One study estimated that halving the depth of the aerated peat layer in all drained agricultural peatlands globally could reduce total anthropogenic emissions by more than 1%, suggesting significant potential for this as an intervention in the climate crisis (Evans *et al.* 2021).

In many of the studies assessed, details about the exact methods for rewetting or raising water levels were unclear. In those where specific actions were identified, most referred to ditch blocking, with one additionally undertaking bankside reprofiling.

Most studies focused on the weight of C or C equivalent per unit area (e.g. tonnes per hectare), but 14 also considered methane emissions separately (Artz *et al*. 2018; Bonnett *et al*. 2009; Bussell *et al*. 2010; Evans *et al.* 2021; Fenner *et al.* 2011; Grand-Clement *et al.* 2013, 2015; Green *et al*. 2018; Mazzola *et al*. 2021; Natural England 2020, 2012; Payne & Jessop 2018; Shepherd *et al.* 2013; UKCEH 2023; Wilson *et al.* 2022), and eighteen considered aquatic carbon (i.e. DOC) rather than or in addition to gaseous emissions (Armstrong *et al.* 2010; Bussell *et al*. 2010; Chapman *et al.* 2022; Dean *et al*. 2024; Edokpa *et al.* 2022; Fenner *et al.* 2011; Grand-Clement *et al.* 2015; Holden *et al.* 2007; Payne & Jessop 2018; Peacock *et al.* 2013; Pickard *et al.* 2022; Shepherd *et al.* 2013; Ramchunder, Brown & Holden 2009; Toberman 2008; Turner, Worrall & Burt 2013; UKCEH 2023; Wallage, Holden & McDonald 2006; Worrall, Bell & Bhogal 2010).

Studies noted seasonality of wet and dry periods (Dean *et al.* 2024; Gatis *et al*. 2020; Wilson *et al.* 2022), nutrient richness (Aitova *et al*. 2023), depth of rewetting (Gatis *et al.* 2020; Rigney *et al.* 2018), plant community (Rigney *et al.* 2018), and time since intervention (Pickard *et al.* 2022) as factors that may have caused variability in results. The time period over which measurements were taken (Gatis *et al*. 2020; Renou-Wilson *et al.* 2019), access issues (Dean *et al*. 2024), a small number of study sites (Chapman *et al.* 2022; Renou-Wilson *et al.* 2019), and high spatial variability in measurements obtained (Green *et al.* 2018) were also noted as limitations to consider when interpreting results.

Eleven of the studies were observational in nature, suggesting correlation but not necessarily causation (Armstrong *et al.* 2010; Dean *et al.* 2024; Edokpa *et al.* 2017; Natural Capital Solutions & RSPB n.d.; Northern Ireland Water 2019; Peacock *et al.* 2013; Pickard *et al.* 2022; Renou-Wilson *et al.* 2019; Turner, Worrall & Burt 2013; Wallage, Holden & McDonald 2006; Wilson *et al.* 2016). Six of the studies had a more robust experimental design, such as BACI (Aitova *et al*. 2023; Fenner *et al.* 2011; Gatis *et al*. 2020; Green *et al.* 2018; Toberman 2008; Wilson *et al*. 2022). Two studies were based on modelling rather than primary field measurements (Evans *et al.* 2021; Paul *et al*. 2018). Other studies were secondary information in review articles or paper discussion sections.

Overall, there appears to be general agreement in the literature that rewetting, regardless of specific action to cause the rewetting, has a positive net effect on carbon and GHG emissions. Further research would be required to unravel the context dependencies of this relationship, such as nutrient levels, to plan interventions as effectively as possible.

6.2. Control of non-peatland vegetation

Seven of the papers reviewed assessed the effects of control of non-peatland vegetation on carbon emissions. Two of these showed evidence of a positive impact, with reduced greenhouse gas emissions (Artz *et al*. 2018; Howson *et al*. 2023), whilst four of the other studies showed mixed (Rigney *et al.* 2018; UKCEH 2023) or unclear/neutral (Pickard *et al.* 2022; Shepherd *et al.* 2013) effects. The final study showed evidence of a negative effect, identifying carbon disbenefits following deforestation on peat soils (Worrall, Bell & Bhogal 2010). One of the studies showing a positive impact undertook both scrub control and tree felling, and investigated carbon content of the peat, rather than GHG fluxes (Howson *et al.* 2023), whilst another focused only on scrub control (Artz *et al.* 2018). The effect sizes were small but statistically significant. All the neutral/mixed effects studies only considered tree felling, but in two cases this was undertaken alongside rewetting, and the relative contributions of these two types of intervention were not investigated. One covered DOC, whilst the others focused on gaseous carbon emissions.

Overall, it has not been possible to conclude from the studies reviewed whether there is a notable link between control of non-peatland vegetation and carbon emissions.

6.3. Restoration of peatland vegetation

Eight of the papers reviewed assessed the effects of restoration of peatland vegetation on carbon emissions.

Five of these showed evidence of a positive impact, with reduced greenhouse gas emissions. This included one review paper that reported on a reduction in carbon dioxide (CO_2) and methane (CH_4) fluxes following a reduction in grazing (Aitova *et al*. 2023); one observational study showing evidence of a reduction in GHG emissions (and projected shift from a net source to a net sink going forwards) following reductions in grazing, although this was done in parallel with rewetting activities and the relative effects of each were not identified (Natural Capital Solutions & RSPB n.d.); another observational study that focused specifically on particulate organic carbon (POC), noting a reduction in loss in revegetated areas (Shuttleworth *et al.* 2014); a review article that concluded revegetation improves carbon and greenhouse gas budgets (Worrall, Bell & Bhogal 2010); and another review article that summarised revegetation as likely to reduce carbon loss (House *et al.* 2010).

One of the papers reviewed did not find any significant trend in DOC concentrations (representing aquatic loss of carbon from the peatland) following revegetation (Alderson *et al.* 2019).

The final two papers were review articles identifying mixed effects. One concluded there were variable effects between studies, and few projects that carried out revegetation in the absence of other interventions (UKCEH 2023). The other concluded that there were variable effects between the different types of carbon being studied, with revegetation helping to reduce losses of POC, but not of DOC or CO_2 gas (Shepherd *et al.* 2013).

Overall, it has not been possible to conclude from the studies reviewed whether there is a notable link between restoration of non-peatland vegetation and carbon emissions.

7. Provisioning services (food/fibre provision through crop production)

Food and fibre provision is required for food security, health, and the economy. Understanding how this ecosystem service is affected by peatland management actions, and how these effects interact with those on the other ecosystem services within scope for this review, is therefore also key.

7.1. Rewetting and work to raise water levels

Four of the papers reviewed considered the effects of rewetting of peatland and work to raise water levels on provisioning services. In general, wet peatlands may be used as grazing land but are not typically used as cropland, because current agricultural practices rely almost exclusively on crops originating from dryland ecosystems (Evans *et al.* 2021). This means that to grow crops, drainage of peatlands is required before production begins, and rewetting of this land would discontinue crop production. As of 2016, analysis showed that there was almost no arable farming on peat in Northern Ireland (Rhymes *et al.* 2023).

However, paludiculture is an emerging field focusing on the development of wetland-adapted crops (Evans *et al.* 2021; Payne & Jessop 2018). Whilst not currently a viable alternative to current agricultural practices if implementing at a large scale (Evans *et al.* 2021), it shows promise for the future and may be a useful avenue for investment in research and innovation. Crops such as reed, cattail, alder and peatmoss can be used in the production of insulation and construction materials, fodder, and fuel (Payne & Jessop 2018).

Nonetheless, paludiculture may face challenges in a Northern Irish context. Many studies focus on flat and nutrient-rich lowland fen areas, whereas much of the peat in Northern Ireland is found in upland blanket bog environments that may be less well suited to large scale agriculture. Further research is needed on the potential of paludiculture in lowland raised bogs, as the other main type of peatland present in Northern Ireland (DAERA n.d.).

In contrast, the rewetting of peatlands used for sheep grazing has been shown to have a neutral or potentially positive impact on both welfare and productivity, through reduced tick abundance and reduced stock losses relating to entrapment (Morris & Edwards 2011). One review article also concluded that peatland restoration would have little effect on agricultural productivity in the areas in which it is being undertaken (Grand-Clement *et al.* 2013).

Overall, there appears to be general agreement in the literature that rewetting has a negative effect on provisioning services, currently often preventing further food and fibre production from taking place on the rewetted land. However, paludiculture presents an option that may help balance trade-offs between provisioning services, such as food and fibre provision, and regulating services, such as carbon storage and water regulation. The downstream effects of the other ecosystem services reviewed here (e.g. if floods are prevented downstream from restored peatland, and this prevents crop damage there) should also be considered.

7.2. Control of non-peatland vegetation

No studies assessing the effects of control of non-peatland vegetation on provisioning services were reviewed within this study.

7.3. Restoration of peatland vegetation

No studies assessing the effects of restoration of peatland vegetation on provisioning services were reviewed within this study.

8. Conclusions

In conclusion, there is evidence that most of the actions assessed have positive impacts across the range of ecosystem services within scope of this review, except for food/fibre provision (the effect of which may be mitigated with ongoing innovations related to paludiculture). Whilst the extent of this positive impact did not typically extend to matching that of reference intact peatland, it was notably improved from that of drained sites. This may suggest that protection of remaining intact peatland should be the priority. In most cases, restoration actions require extensive amounts of time (more than ten years) for effects to stabilise. This highlights the importance of long-term planning. For example, funders only specifying the action that needs to take place without long-term follow-up to ensure that it has not been reverted, may be ineffective. Overall, peatlands are an important ecosystem and the evidence in this report supports the use of a range of actions to restore them, thereby improving ecosystem service delivery and meeting EFS environmental aims.

References

Aitova, E., Morley, T., Wilson, D. & Renou-Wilson, F. (2023) A Review of Greenhouse Gas Emissions and Removals From Irish Peatlands. *Mires Peat,* **29**, 04. https://doi.org/10.19189/MaP.2022.SNPG.StA.2414

Alday, J.G., O'Reilly, J., Rose, R.J. & Marrs, R.H. (2022) Long-term effects of sheep-grazing and its removal on vegetation dynamics of British upland grasslands and moorlands; local management cannot overcome large-scale trends. *Ecol. Indic* **139**, 108878. https://doi.org/10.1016/j.ecolind.2022.108878

Alderson, D.M., Evans, M.G., Shuttleworth, E.L., Pilkington, M., Spencer, T., Walker, J. & Allott, T.E.H. (2019) Trajectories of ecosystem change in restored blanket peatlands. *Sci. Total Environ*. **665**, 785–796. https://doi.org/10.1016/j.scitotenv.2019.02.095

Andersen, R., Taylor, R., Cowie, N.R., Svobodova, D. & Youngson, A. (2018) Assessing the effects of forest-to-bog restoration in the hyporheic zone at known Atlantic salmon (*Salmo salar*) spawning sites. *Mires and Peat,* 1–11. https://doi.org/10.19189/MaP.2017.OMB.299

Anderson, R. & Peace, A. (2017) Ten-year results of a comparison of methods for restoring afforested blanket bog. *Mires and Peat,* 1–23. https://doi.org/10.19189/MaP.2015.OMB.214

Armstrong, A., Holden, J., Kay, P., Francis, B., Foulger, M., Gledhill, S., McDonald, A.T. & Walker, A. (2010) The impact of peatland drain-blocking on dissolved organic carbon loss and discolouration of water; results from a national survey. *Journal of Hydrology,* **381**(1-2), 112-120. https://doi.org/10.1016/j.jhydrol.2009.11.031

Artz, R.E., Faccioli, M., Roberts, M. & Anderson, R. (2018) Peatland restoration – a comparative analysis of the costs and merits of different restoration methods. Available from: https://www.climatexchange.org.uk/wp-content/uploads/2023/09/peatland-restoration-methods-a-comparative-analysis.pdf [Accessed 02 June 2025].

Beadle, J.M., Holden, J. & Brown, L.E. (2023) Landscape-scale peatland rewetting benefits aquatic invertebrate communities. *Biol. Conserv*. **283**, 110116. https://doi.org/10.1016/j.biocon.2023.110116

Bonnett, S.A.F., Ross, S., Linstead, C. & Maltby, E. (2009) A review of techniques for monitoring the success of peatland restoration (No. NECR086). University of Liverpool under contract to Natural England. Available from: https://publications.naturalengland.org.uk/publication/46013 [Accessed 02 June 2025.]

Brown, L.E., Ramchunder, S.J., Beadle, J.M. & Holden, J. (2016) Macroinvertebrate community assembly in pools created during peatland restoration. *Sci. Total Environ*. **569–570**, 361–372. https://doi.org/10.1016/j.scitotenv.2016.06.169

Bullock, C.H., Collier, M.J. & Convery, F. (2012) Peatlands, their economic value and priorities for their future management – The example of Ireland. *Land Use Policy,* **29**(4), 921-928. https://doi.org/10.1016/j.landusepol.2012.01.010

Bussell, J., Jones, D.L., Healey, J.R. & Pullin, A. (2010) How do draining and re-wetting affect carbon stores and greenhouse gas fluxes in peatland soils? CEE review 08-012 (SR49). Collaboration for Environmental Evidence. Available from: www.environmentalevidence.org/SR49.html [Accessed 15 September 2025].

Carroll, M.J., Dennis, P., Pearce-Higgins, J.W. & Thomas, C.D. (2011) Maintaining northern peatland ecosystems in a changing climate: effects of soil moisture, drainage and drain blocking on craneflies. *Glob. Change Biol.* **17**, 2991–3001. https://doi.org/10.1111/j.1365-2486.2011.02416.x

Chapman, P.J., Moody, C.S., Turner, T.E., McKenzie, R., Dinsmore, K.J., Baird, A.J., Billett, M.F., Andersen, R., Leith, F. & Holden, J. (2022) Carbon concentrations in natural and restoration pools in blanket peatlands. *Hydrol. Process*. **36**, e14520. https://doi.org/10.1002/hyp.14520

Collins, A.M., Coughlin, D., Miller, J., Kirk, S. (2015) The Production of Quick Scoping Reviews and Rapid Evidence Assessments: A How to Guide. Available from: https://www.gov.uk/government/publications/the-production-of-quick-scoping-reviews-and-rapid-evidence-assessments [Accessed 15 September 2025].

Cummins, T. & Farrell, E.P. (2003) Biogeochemical impacts of clearfelling and reforestation on blanket-peatland streams: II. major ions and dissolved organic carbon. *Forest Ecology and Management,* **180**(1-3), 557-570. https://doi.org/10.1016/S0378-1127(02)00649-7

DAERA. (2025) Northern Ireland Peatland Strategy to 2040. Available from: Northern Ireland Peatland Strategy to 2040 | Department of Agriculture, Environment and Rural Affairs [Accessed 16 April 2026].

DAERA. (n.d.) Peatlands. Available from: https://www.daera-ni.gov.uk/articles/peatlands [Accessed 08 May 2025].

Dean, J.F., Billett, M.F., Turner, T.E., Garnett, M.H., Andersen, R., McKenzie, R.M., Dinsmore, K.J., Baird, A.J., Chapman, P.J. & Holden, J. (2024) Peatland pools are tightly coupled to the contemporary carbon cycle. *Glob. Change Biol*. **30**, e16999. https://doi.org/10.1111/gcb.16999

Donahue, T., Renou-Wilson, F., Pschenyckyj, C. & Kelly-Quinn, M. (2022) A Review of the Impact on Aquatic Communities of Inputs from Peatlands Drained for Peat Extraction. *Biol. Environ. Proc. R. Ir. Acad*. **122b**, 145–160. https://doi.org/10.1353/bae.2022.0010

Edokpa, D., Milledge, D., Allott, T., Holden, J., Shuttleworth, E., Kay, M., Johnston, A., Millin-Chalabi, G., Scott-Campbell, M., Chandler, D., Freestone, J. & Evans, M. (2022) Rainfall intensity and catchment size control storm runoff in a gullied blanket peatland. *J. Hydrol*. **609**, 127688. https://doi.org/10.1016/j.jhydrol.2022.127688

Edokpa, D.A., Evans, M.G., Allott, T.E.H., Pilkington, M. & Rothwell, J.J. (2017) Peatland restoration and the dynamics of dissolved nitrogen in upland freshwaters. *Ecol. Eng*. **106**, 44–54. https://doi.org/10.1016/j.ecoleng.2017.05.013

Elliott, D.R., Caporn, S.J.M., Nwaishi, F., Nilsson, R.H. & Sen, R. (2015) Bacterial and fungal communities in a degraded ombrotrophic peatland undergoing natural and managed re-vegetation. *PLoS ONE*, **10**(5), e0124726. https://doi.org/10.1371/journal.pone.0124726

EU Natural Water Retention Measures +. (2024) Exmoor Mires peatland restoration, UK.

Evans, C.D., Peacock, M., Baird, A.J., Artz, R.R.E., Burden, A., Callaghan, N., Chapman, P.J., Cooper, H.M., Coyle, M., Craig, E., Cumming, A., Dixon, S., Gauci, V., Grayson, R.P., Helfter, C., Heppell, C.M., Holden, J., Jones, D.L., Kaduk, J., Levy, P., Matthews, R., McNamara, N.P., Misselbrook, T., Oakley, S., Page, S.E., Rayment, M., Ridley, L.M., Stanley, K.M., Williamson, J.L., Worrall F. & Morrison R. (2021) Overriding water table control on managed peatland greenhouse gas emissions. *Nature* **593**, 548–552. https://doi.org/10.1038/s41586-021-03523-1

Evans, C.R.F., Mullan, D.J., Roe, H.M. & Fox, P.M. (2023) Response of testate amoeba assemblages to peatland drain blocking. Available from: https://www.researchgate.net/publication/374116286_Response_of_testate_amoeba_assemblages_to_peatland_drain_blocking [Accessed 28 March 2025].

Fenner, N., Williams, R., Toberman, H., Hughes, S., Reynolds, B. & Freeman, C. (2011) Decomposition 'hotspots' in a rewetted peatland: implications for water quality and carbon cycling. *Hydrobiologia*, **674**(1), https://doi.org/10.1007/s10750-011-0733-1

Gaffney, P.P.J., Hancock, M.H., Taggart, M.A. & Andersen, R. (2021) Catchment water quality in the year preceding and immediately following restoration of a drained afforested blanket bog. *Biogeochemistry, Springer Nature Link* **153**, 243–262.

Gaffney, P.P.J., Hancock, M.H., Taggart, M.A. & Andersen, R. (2018) Measuring restoration progress using pore- and surface-water chemistry across a chronosequence of formerly afforested blanket bogs. *J. Environ. Manage*. **219**, 239–251. https://doi.org/10.1016/j.jenvman.2018.04.106

Gaffney, P.P.J., Tang, Q., Pap, S., McWilliam, A., Johnstone, J., Li, Y., Cakin, I., Klein, D. & Taggart, M.A. (2024) Water quality effects of peat rewetting and leftover conifer brash, following peatland restoration and tree harvesting. *J. Environ. Manage*. **360**, 121141. https://doi.org/10.1016/j.jenvman.2024.121141

Gatis, N., Luscombe, D.J., Benaud, P., Ashe, J., Grand-Clement, E., Anderson, K., Hartley, I.P. & Brazier, R.E. (2020) Drain blocking has limited short-term effects on greenhouse gas fluxes in a *Molinia caerulea* dominated shallow peatland. *Ecol. Eng.* **158**, 106079. https://doi.org/10.1016/j.ecoleng.2020.106079

Grand-Clement, E., Anderson, K., Smith, D., Luscombe, D.J., Gatis, N., Ross, M & Brazier, R.E. (2013) Evaluating ecosystem goods and services after restoration of marginal upland peatlands in South-West England. *Journal of Applied Ecology,* **50**(2), 324-334. https://doi.org/10.1111/1365-2664.12039

Grand-Clement, E., Anderson, K., Smith, D., Angus, M., Luscombe, D.J., Gatis, N., Bray, L.S. & Brazier, R.E. (2015) New approaches to the restoration of shallow marginal peatlands. *Journal of Environmental Management*, **161**, 417–430. https://doi.org/10.1016/j.jenvman.2015.06.023

Green, S.M., Baird, A.J., Evans, C.D., Peacock, M., Holden, J., Chapman, P.J. & Smart, R.P. (2018) Methane and carbon dioxide fluxes from open and blocked ditches in a blanket bog. *Plant Soil* **424**, 619–638. https://doi.org/10.1007/s11104-017-3543-z

Hannigan, E., Mangan, R. & Kelly-Quinn, M. (2011) Evaluation of the success of mountain blanket bog pool restoration in terms of aquatic macroinvertebrates. *Biol. Environ. Proc. R. Ir. Acad.* **111B**, 95–105. https://doi.org/10.2307/23033869

Heinemeyer, A., Vallack, H.W., Morton, P.A., Pateman, R., Dytham, C., Ineson, P., McClean, C., Bristow, C., Pearce-Higgins, J.W. & Lindsay, R. (2019) Restoration of heather-dominated blanket bog vegetation on grouse moors for biodiversity, carbon storage, greenhouse gas emissions and water regulation (Defra Project No. BD5104). Stockholm Environment Institute.

Holden, J., Shotbolt, L., Bonn, A., Burt, T.P., Chapman, P.J., Dougill, A.J., Fraser, E.D.G., Hubacek, K., Irvine, B., Kirkby, M.J., Reed, M.S., Prell, C., Stagl, S., Stringer, L.C., Turner, A. & Worrall, F. (2007) Environmental change in moorland landscapes. *Earth-Science Reviews*, **82**, 75–100. https://doi.org/10.1016/j.earscirev.2007.01.003

Holden, J., Wallage, Z.E., Lane, S.N. & McDonald, A.T. (2011) Water table dynamics in undisturbed, drained and restored blanket peat. *Journal of Hydrology,* **402**(1-2), 103-114. https://doi.org/10.1016/j.jhydrol.2011.03.010

Holden, J., Moody, C.S., Edward Turner, T., McKenzie, R., Baird, A.J., Billett, M.F., Chapman, P.J., Dinsmore, K.J., Grayson, R.P., Andersen, R., Gee, C. & Dooling, G. (2018) Water-level dynamics in natural and artificial pools in blanket peatlands. *Hydrol. Process*. **32**, 550–561. https://doi.org/10.1002/hyp.11438

House, J.I., Orr, H.G., Clark, J.M., Gallego-Sala, A.V., Freeman, C., Prentice I.C. & Smith, P. (2010) Climate change and the British Uplands: evidence for decision-making. *Climate research,* **45,** 3-12. https://doi.org/10.3354/CR00982

Howson, T., Evans, M., Allott, T., Shuttleworth, E., Johnston, A., Rees, J., Milledge, D., Edokpa, D., Lockyer, C., Kay, M., Spencer, T., Brown, D., Goudarzi, S. & Pilkington, M. (2023) Peatland gully restoration with stone and timber dams (Kinder Plateau, UK). *Ecol. Eng*. **195**, 107066. https://doi.org/10.1016/j.ecoleng.2023.107066

Howson, T.R., Chapman, P.J., Holden, J., Shah, N. & Anderson, R. (2023) A comparison of peat properties in intact, afforested and restored raised and blanket bogs. *Soil Use Manag.* **39**, 104–121. https://doi.org/10.1111/sum.12826

IUCN. (2024) UK Strategy | IUCN UK Peatland Programme. Available from: https://www.iucn-uk-peatlandprogramme.org/uk-strategy [Accessed 07 March 2025].

IUCN UK Peatland Programme. (2024) Biodiversity. Available from: https://www.iucn-uk-peatlandprogramme.org/about-peatlands/peatland-benefits/biodiversity [Accessed 20 May 2024].

IUCN UK Peatland Programme. (2019) What's so special about peatlands?

Joy, J., & Pullin, A.S. (1999) Field studies on flooding and survival of overwintering large heath butterfly *Coenonympha tullia* larvae on Fenn's and Whixall mosses in Shropshire and Wrexham, U.K. *Ecological Entomology*, **24**(1), 26–33. https://doi.org/10.1046/j.1365-2311.1999.00208.x

JNCC. (2011) Towards an assessment of the state of UK Peatlands.

Konings, W., Boyd, K.G. & Andersen, R. (2019) Comparison of plant traits of sedges, shrubs and Sphagnum mosses between sites undergoing forest-to-bog restoration and near-natural open blanket bog: a pilot study. *Mires and Peat*, 1–10. https://doi.org/10.19189/MaP.2017.OMB.307

Li, C., Grayson, R., Holden, J. & Li, P. (2018) Erosion in peatlands: Recent research progress and future directions. *Earth-Sci. Rev*. **185**, 870–886. https://doi.org/10.1016/j.earscirev.2018.08.005

Lunt, P., Allott, T., Anderson, P., Buckler, M., Coupar, A., Jones, P., Labadz, J. & Worrall, P. (2010) Peatland Restoration. IUCN UK Peatland Programme.

Mazzola, V., Perks, M.P., Smith, J., Yeluripati, J. & Xenakis, G. (2021) Seasonal patterns of greenhouse gas emissions from a forest-to-bog restored site in northern Scotland: Influence of microtopography and vegetation on carbon dioxide and methane dynamics. *Eur. J. Soil Sci*., **72**, 1332–1353. https://doi.org/10.1111/ejss.13050

Morris, M. & Edwards, T. (2011) Breathing LIFE into Blanket Bog - Lake Vyrnwy to Aberdeen. RSPB.

Morris, P.J., Baird, A.J., Eades, P.A. & Surridge, B.W.J. (2019) Controls on Near-Surface Hydraulic Conductivity in a Raised Bog. *Water Resour. Res*., *55*, 1531–1543. https://doi.org/10.1029/2018WR024566

Muller, F.L.L., Chang, K.-C., Lee C.-L. & Chapman, S.J. (2015) Effects of temperature, rainfall and conifer felling practices on the surface water chemistry of northern peatlands. *Biogeochemistry,* **126**, 343–362. https://doi.org/10.1007/s10533-015-0162-8

Natural Capital Solutions & RSPB. (n.d.) Valuing our peatlands.

Natural England. (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources (No. NERR043).

Natural England. (2020) Managing Ecosystem Services Evidence Review (Formerly Ecosystem Services Transfer Toolkit NECR159) (JP033).

Northern Ireland Water. (2019) Garron Plateau Bog Restoration Project. Available from: https://www.niwater.com/garron-plateau-bog-restoration-project/ [Accessed 06 May 2025].

O'Driscoll, C., de Eyto, E., Rodgers, M., O'Connor, M., Asam, Z.-u.-Z. & Xiao, L. (2013) Biotic response to forest harvesting in acidic blanket peat fed streams: A case study from Ireland. *Forest Ecology and Management*, **310**, 729–739. https://doi.org/10.1016/j.foreco.2013.09.018

Pakeman, R.J., Fielding, D.A., Everts, L. & Littlewood, N.A. (2019) Long-term impacts of changed grazing regimes on the vegetation of heterogeneous upland grasslands. *J. Appl. Ecol.* **56**, 1794–1805. https://doi.org/10.1111/1365-2664.13420

Paul, C., Fealy, R., Fenton, O., Lanigan, G., O’Sullivan, L. & Schulte, R.P.O. (2018) Assessing the role of artificially drained agricultural land for climate change mitigation in Ireland. *Environ. Sci. Policy*, **80**, 95–104. https://doi.org/10.1016/j.envsci.2017.11.004

Payne, R.J. & Jessop, W. (2018) Community-identified key research questions for the future of UK afforested peatlands. *Mires and Peat,* 1–13. https://doi.org/10.19189/MaP.2018.OMB.362

Peacock, M., Evans, C.D., Fenner, N., & Freeman, C. (2013) Natural revegetation of bog pools after peatland restoration involving ditch blocking—The influence of pool depth and implications for carbon cycling. *Ecological Engineering*, **57**, 297–301. https://doi.org/10.1016/j.ecoleng.2013.04.055

Peacock, M., Jones, T.G., Futter, M.N., Freeman, C., Gough, R., Baird, A.J., Green, S.M., Chapman, P.J., Holden, J. & Evans, C.D. (2018) Peatland ditch blocking has no effect on dissolved organic matter (DOM) quality. *Hydrol. Process.,* **32**, 3891–3906. https://doi.org/10.1002/hyp.13297

Pickard, A.E., Branagan, M., Billett, M.F., Andersen, R. & Dinsmore, K.J. (2022) Effects of peatland management on aquatic carbon concentrations and fluxes. *Biogeosciences,* **19**, 1321–1334. https://doi.org/10.5194/bg-19-1321-2022

Pilkington, M., Walker, J., Fry, C., Eades, P., Meade, R., Pollett, N., Rogers, T., Helliwell, T., Chandler, D., Fawcett, E. & Keatley, T. (2021) Diversification of Molinia-dominated blanket bogs using Sphagnum propagules. *Ecol. Solut. Evid.,* **2**, e12113. https://doi.org/10.1002/2688-8319.12113

Pravia, A., Andersen, R., Artz, R.E., Pakeman, R.J. & Littlewood, N.A. (2019) Restoration trajectory of carabid functional traits in a formerly afforested blanket bog. *Acta Zool. Acad. Sci. Hung*., **65**, 33–56. https://doi.org/10.17109/AZH.65.Suppl.33.2019

Ramchunder, S.J., Brown, L.E., & Holden, J. (2009) Environmental effects of drainage, drain-blocking and prescribed vegetation burning in UK upland peatlands. *Progress in Physical Geography*, **33**(1), 49–79. https://doi.org/10.1177/0309133309105245

Ramchunder, S.J., Brown, L.E. & Holden, J. (2012) Catchment-scale peatland restoration benefits stream ecosystem biodiversity. *J. Appl. Ecol.* **49**, 182–191. https://doi.org/10.1111/j.1365-2664.2011.02075.x

Regensburg, T.H., Chapman, P.J., Pilkington, M.G., Chandler, D.M., Evans, M.G. & Holden, J. (2021) Effects of pipe outlet blocking on hydrological functioning in a degraded blanket peatland. *Hydrol. Process*., **35**, e14102. https://doi.org/10.1002/hyp.14102

Renou-Wilson, F., Moser, G., Fallon, D., Farrell, C.A., Müller, C. & Wilson, D. (2019) Rewetting degraded peatlands for climate and biodiversity benefits: Results from two raised bogs. *Ecol. Eng.* **127**, 547–560. https://doi.org/10.1016/j.ecoleng.2018.02.014

Rhymes, J., Stockdale, E., Napier, B., Williamson, J., Morton, D., Dearlove, E., Staley, J., Young, H., Thomson, A. & Evans, C. (2023) The Future of UK Vegetable Production – Technical Report. UKCEH.

Rigney, C., Wilson, D., Renou-Wilson, F., Müller, C., Moser, G. & Byrne, K.A. (2018) Greenhouse gas emissions from two rewetted peatlands previously managed for forestry. *Mires and Peat,* 1–23. https://doi.org/10.19189/MaP.2017.OMB.314

Robroek, B.J.M., van Ruijven, J., Schouten, M.G.C., Breeuwer, A., Crushell, P.H., Berendse, F. & Limpens, J. (2009) *Sphagnum* re-introduction in degraded peatlands: The effects of aggregation, species identity and water table. *Basic and Applied Ecology,* **10**(8), 697-706. https://doi.org/10.1016/j.baae.2009.04.005

Shah, N. (n.d.) The effects of peatland restoration on water quality. Available from: https://www.forestresearch.gov.uk/research/the-effects-of-peatland-restoration-on-water-quality/ [Accessed 06 May 2025].

Shepherd, M.J., Labadz, J., Caporn, S.J., Crowle, A., Goodison, R., Rebane, M. & Waters, R. (2013) Natural England review of upland evidence - Restoration of Degraded Blanket Bog. Natural England Evidence Review, Number 003. Available from: https://publications.naturalengland.org.uk/publication/5724822 [Accessed 15 September 2025].

Shuttleworth, E.L., Evans, M.G., Hutchinson, S.M. & Rothwell, J.J. (2014) Peatland restoration: controls on sediment production and reductions in carbon and pollutant export. *Earth Surface Processes and Landforms,* **40**(4), 459-472. https://doi.org/10.1002/esp.3645

Shuttleworth, E.L., Evans, M.G., Pilkington, M., Spencer, T., Walker, J., Milledge, D. & Allott, T.E.H. (2019) Restoration of blanket peat moorland delays stormflow from hillslopes and reduces peak discharge. *J. Hydrol. X*, **2**, 100006. https://doi.org/10.1016/j.hydroa.2018.100006

Stimson, A.G., Allott, T.E.H., Boult, S., Evans, M.G., Pilkington, M. & Holland, N. (2017) Water quality impacts of bare peat revegetation with lime and fertiliser application. *Appl. Geochem*., **85**, 97–105. https://doi.org/10.1016/j.apgeochem.2017.09.003

Swindles, G.T., Green, S.M., Brown, L., Holden, J., Raby, C.L., Turner, T.E., Smart, R., Peacock, M. & Baird, A.J. (2016) Evaluating the use of dominant microbial consumers (testate amoebae) as indicators of blanket peatland restoration. *Ecol. Indic*., **69**, 318–330. https://doi.org/10.1016/j.ecolind.2016.04.038

Toberman, H., Freeman, C., Artz, R.R.E., Evans, C.D. & Fenner, N. (2008) Impeded drainage stimulates extracellular phenol oxidase activity in riparian peat cores. *Soil Use and Management,* **24**(4), 357-365. https://doi.org/10.1111/j.1475-2743.2008.00174.x

Turner E.K., Worrall, F. & Burt, T.P. (2013) The effect of drain blocking on the dissolved organic carbon (DOC) budget of an upland peat catchment in the UK. *Journal of Hydrology,* **479**, 169-179. https://doi.org/10.1016/j.jhydrol.2012.11.059

UKCEH. (2023) Qualitative impact assessment of land management interventions on Ecosystem Services (No. AQ0858).

Verberk, W.C.E.P., Leuven, R.S.E.W., van Duinen, G.A. & Esselink, H. (2010) Loss of environmental heterogeneity and aquatic macroinvertebrate diversity following large-scale restoration management. *Basic Appl. Ecol*., **11**, 440–449. https://doi.org/10.1016/j.baae.2010.04.001

Wallage, Z.E., Holden, J. & McDonald, A.T. (2006) Drain blocking: An effective treatment for reducing dissolved organic carbon loss and water discolouration in a drained peatland. *Science of the Total Environment,* **367**(2-3), 811-821. https://doi.org/10.1016/j.scitotenv.2006.02.010

Williamson, J., Evans, C., Spears, B., Pickard, A., Chapman, P.J., Feuchtmayr, H., Leith, F., Waldron, S. & Monteith, D. (2023) Reviews and syntheses: Understanding the impacts of peatland catchment management on dissolved organic matter concentration and treatability. *Biogeosciences,* **20**, 3751–3766. https://doi.org/10.5194/bg-20-3751-2023

Wilson, D., Farrell, C.A., Fallon, D., Moser, G., Müller, C. & Renou-Wilson, F. (2016) Multiyear greenhouse gas balances at a rewetted temperate peatland. *Glob. Change Biol*., **22**, 4080–4095. https://doi.org/10.1111/gcb.13325

Wilson, D., Mackin, F., Tuovinen, J.-P., Moser, G., Farrell, C. & Renou-Wilson, F. (2022) Carbon and climate implications of rewetting a raised bog in Ireland. *Glob. Change Biol.* **28**, 6349–6365. https://doi.org/10.1111/gcb.16359

Wilson D., Müller, C. & Renou-Wilson, F. (2013) Carbon emissions and removals from Irish peatlands: present trends and future mitigation measures. *Irish Geography,* **46**(1-2), 1-23. http://dx.doi.org/10.1080/00750778.2013.848542

Wilson, L., Wilson, J., Holden, J., Johnstone, I., Armstrong, A. & Morris, M. (2011) The impact of drain blocking on an upland blanket bog during storm and drought events, and the importance of sampling-scale. *Journal of Hydrology,* **404**(3-4), 198-208. https://doi.org/10.1016/j.jhydrol.2011.04.030

Worrall, F., Armstrong, A. & Holden, J. (2007) Short-term impact of peat drain-blocking on water colour, dissolved organic carbon concentration, and water table depth. *Journal of Hydrology,* **337**(3-4), 315-325. https://doi.org/10.1016/j.jhydrol.2007.01.046

Worrall, F., Bell, M.J. & Bhogal, A. (2010) Assessing the probability of carbon and greenhouse gas benefit from the management of peat soils. *Science of the Total Environment,* **408**(13), 2657-2666. https://doi.org/10.1016/j.scitotenv.2010.01.033

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Weblinks

Table 4. Full URLS for weblinks used in the text.

Weblink text	Full URL
Environmental Farming Scheme	https://www.daera-ni.gov.uk/topics/environmental-farming-scheme-efs
Green Growth Delivery Framework	https://www.daera-ni.gov.uk/articles/green-growth-strategy-northern-ireland-balancing-our-climate-environment-and-economy
Northern Ireland Ammonia Strategy	https://www.daera-ni.gov.uk/consultations/draft-ammonia-strategy-northern-ireland-consultation
Northern Ireland Biodiversity Strategy	https://www.daera-ni.gov.uk/publications/biodiversity-strategy-northern-ireland-2020
Northern Ireland Environment Strategy	https://www.daera-ni.gov.uk/consultations/environment-strategy-consultation
Peatland Strategy	https://www.daera-ni.gov.uk/publications/northern-ireland-peatland-strategy-2040
UK Peatland Code	https://www.iucn-uk-peatlandprogramme.org/peatland-code-0