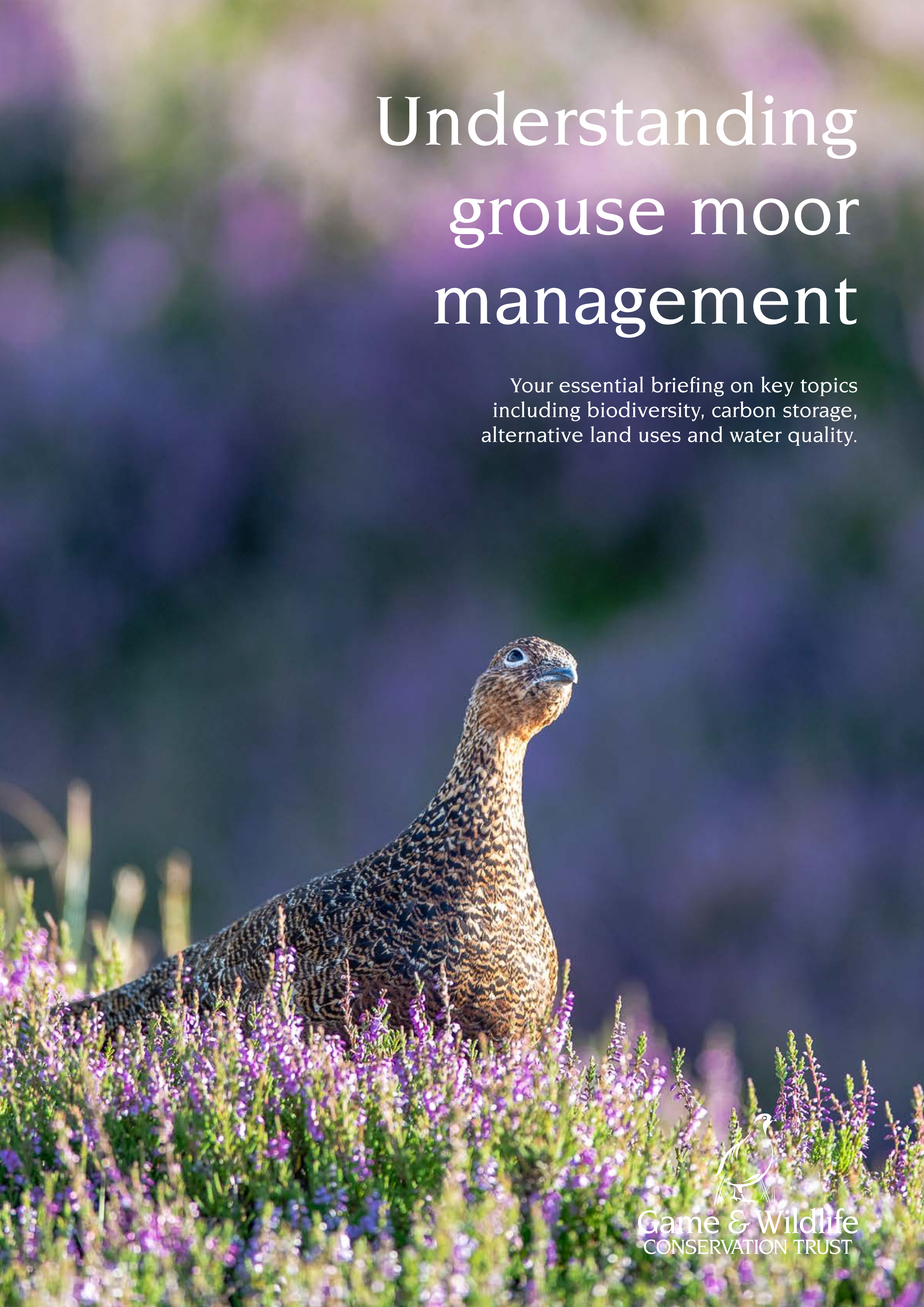
Understanding grouse moor management

Your essential briefing on key topics including biodiversity, carbon storage, alternative land uses and water quality.



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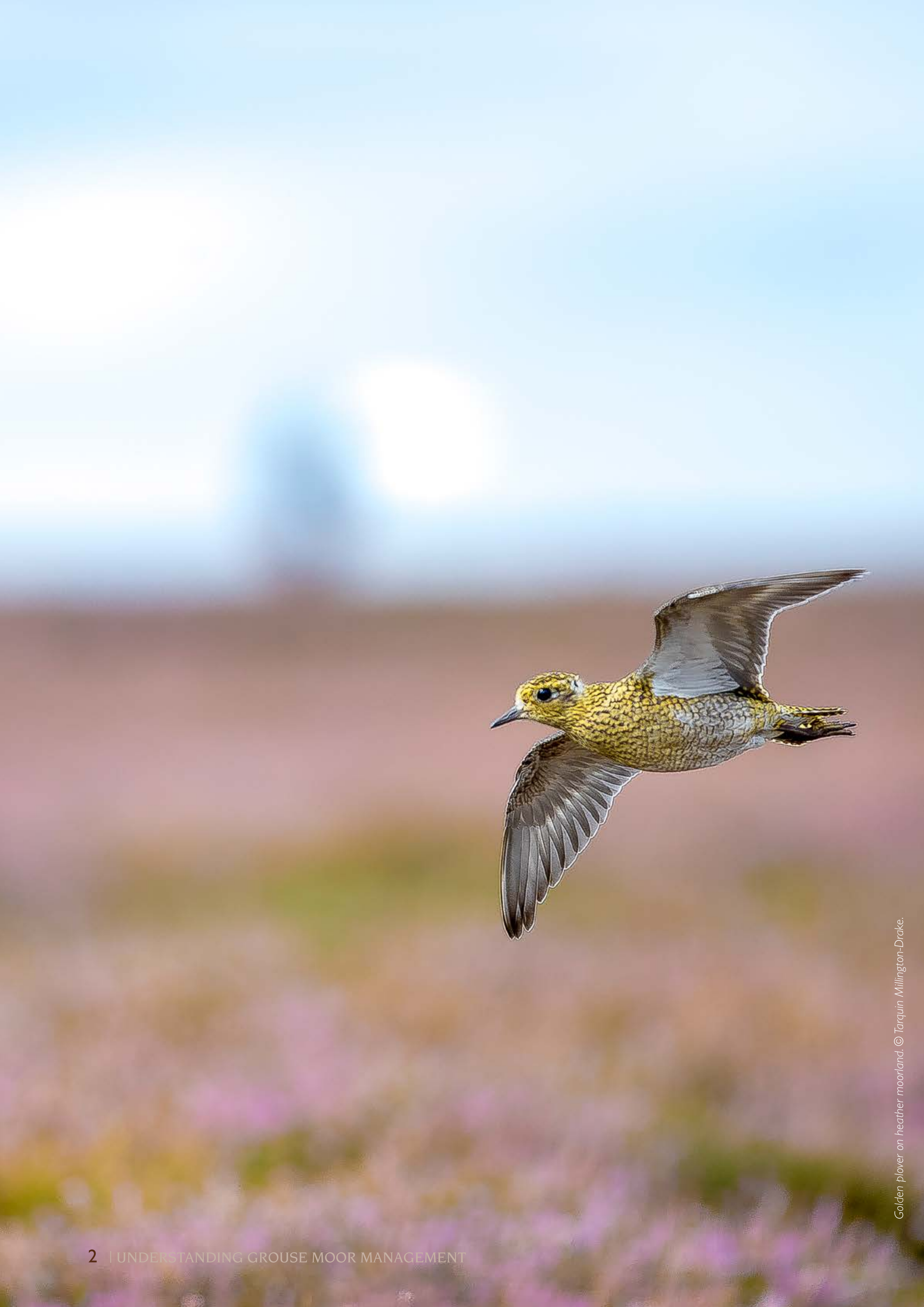


Golden plover on heather moorland. © Tarquin Millington-Drake.

Contents

These briefing sheets draw on information from the GWCT's 2020 Peatland Report and the Moorland Balance, which are fully referenced and available at www.gwct.org.uk/read or by clicking on the following links.

2020 Peatland Report

The Moorland Balance

Biodiversity and conservation on grouse moors

KEY POINTS

- Grouse moors help preserve the heather-dominated moorland landscapes that many value in the uplands, slowing heather loss compared to areas not managed for grouse.
- Grouse moors provide important refuges for many moorland ground-nesting birds such as curlew and golden plover, because of habitat management and predator control.
- Lapwing, golden plover and curlew were found to fledge more than three times as many young when predator control was carried out, compared to without it.

Grouse moors are found in the UK uplands on heather-dominated moorland, an environment which is valued for both its unusual plant communities and breeding birds. Although sometimes imagined as an open, uniform expanse of moorland, the UK's uplands actually consist of a variety of environments and habitats, supporting different activities across the landscape.

Farming, forestry, grouse moors, deer management, wind farms and nature reserves are all found in the uplands. These different areas support different communities of plant and animal species, but fragmentation of open moorland environments by these other land uses can be detrimental to some species. Although grouse moor management can be controversial, its importance to certain habitats and species means that its role within the mix of land uses is of recognised conservation value.

The two main aspects of grouse moor management that affect biodiversity are heather management and predator control. Heather is managed by cutting, light grazing and prescribed heather burning, to encourage the growth of new shoots. This will also suppress tree and scrub spread and preserve heather moorland by preventing conversion to woodland. Managed heather burning is not just used on grouse moors, it is also carried out to improve livestock grazing on moorland and other types of heathland However, its use on grouse moors is most often the focus of debates on the environmental impact, including biodiversity and conservation. Predator control is carried out on grouse moors to protect nesting grouse and their chicks from generalist predators such as foxes and crows. It is well established that this reduced predation pressure has benefits for many other ground-nesting birds including threatened waders such as curlew and golden plover.

IMPORTANCE

Heather-dominated moorland supports groups or 'communities' of plants growing together that are either only found in the UK or are found more abundantly here than elsewhere in the world. These communities are different to those found under other land uses such as commercial forestry, so grouse moor management can help increase overall biodiversity in the uplands. They include species of berry, grass, sedge and mosses such as sphagnum, which together define habitats that are listed under the EU's Conservation of Natural Habitats and of Wild Flora and Fauna Directive. The 1992 Rio Convention on Biodiversity recognised the global importance of UK heather moorland.

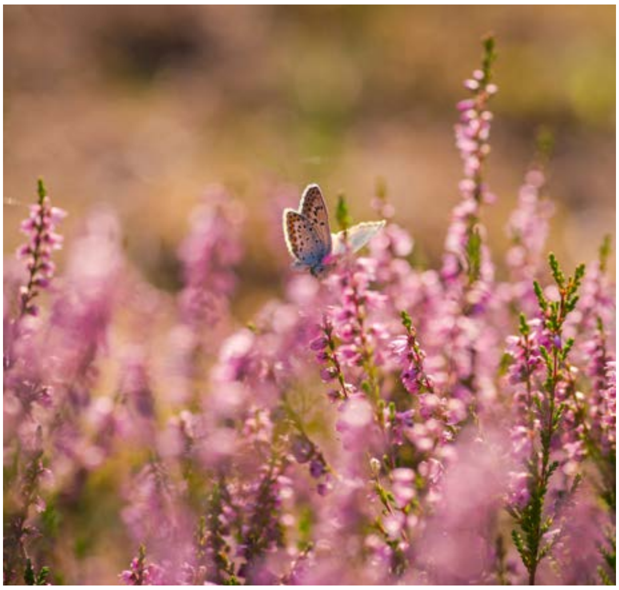
GROUSE MOOR MANAGEMENT AND HEATHER CONSERVATION

Grouse moor management can help conserve heather moorland. In the early 2000s, heather cover was falling sharply in the UK, generally as a result of overgrazing and commercial forestry plantations. However, a GWCT study showed that management for driven grouse shooting slows the loss of heather from our landscape. Between the 1940s and 1980s, moors that stopped grouse shooting lost 41% of their heather cover, while moors retaining shooting lost only 24%. Historically, a landowner's commitment to grouse management may have dissuaded them from converting moors to other land uses such as forestry or agriculture.

Many designations in the uplands were originally made because of the habitats and species on moorland, which can be supported by grouse management. Some of the best examples of heather moorland in the UK are designated as Sites of Special Scientific Interest (SSSIs) and 'Natura' sites – Special Protection Areas (SPA) and Special Areas of Conservation (SAC) – in recognition of their importance. In England, 74% of upland SPAs are managed as grouse moors. However, on some grouse moors inappropriate burning or the lack of agreed heather management plans have led to the classification of the site as being in unfavourable condition.

INVERTEBRATES

Although invertebrate diversity tends to be relatively low when compared with other habitats, rare species are associated with moorland, including moths, bees, butterflies, various money spider species, craneflies, and



Invertebrates such as butterflies can benefit from good upland management.

ground beetles. For example, the bilberry or mountain bumblebee is only found in bilberry-rich moorlands with heather, which provides nectar late in the summer and protection from the weather. Butterflies and moths tend to be more diverse and abundant on moorland areas when heather is older, compared to recently burnt areas. Overall, the number of species of plants or animals found on heather moorland can be fairly low, but those species that thrive are often uncommon, specialist species not found elsewhere, meaning that maintaining heather moorland is important for their conservation.

BIRDS

The moorland environment also supports a variety of bird species, many of European or international importance. Some birds occur at higher densities and breed more successfully on moors managed for red grouse than on other moorland. These include threatened species such as curlew and merlin but also red grouse and golden plover, with lapwing and black grouse on the fringes of grouse moors.

There is strong evidence from several studies that grouse moor management is beneficial for a group of wader species, including curlew, golden plover and lapwing.

- The GWCT's Upland Predation Experiment found that lapwing, golden plover, curlew, red grouse and meadow pipit bred on average three times more successfully when predator control was performed, compared to the same moorland when predators were not controlled. As a result, breeding numbers increased in subsequent years, but in the absence of predator control, they declined.

- Results from the Langholm Moor Demonstration Project showed that restoring grouse management was beneficial for three wader species. Overall, curlew numbers rose by 10% per year on average, golden plover by 16% and snipe by 21%.

- A recent GWCT analysis of upland bird species trends in southwest Scotland found declines in several upland bird species, including red and black grouse, golden plover, lapwing and curlew, and these are generally attributed to large-scale changes in land use, including afforestation, more intensive farming and reductions in grouse moor management.

- An analysis of the status of grouse management in the north of England, the Scottish mainland, Wales and southwest of England showed that range contraction for curlew, golden plover, lapwing and dunlin was smallest where grouse shooting was retained and greatest where it had disappeared completely.

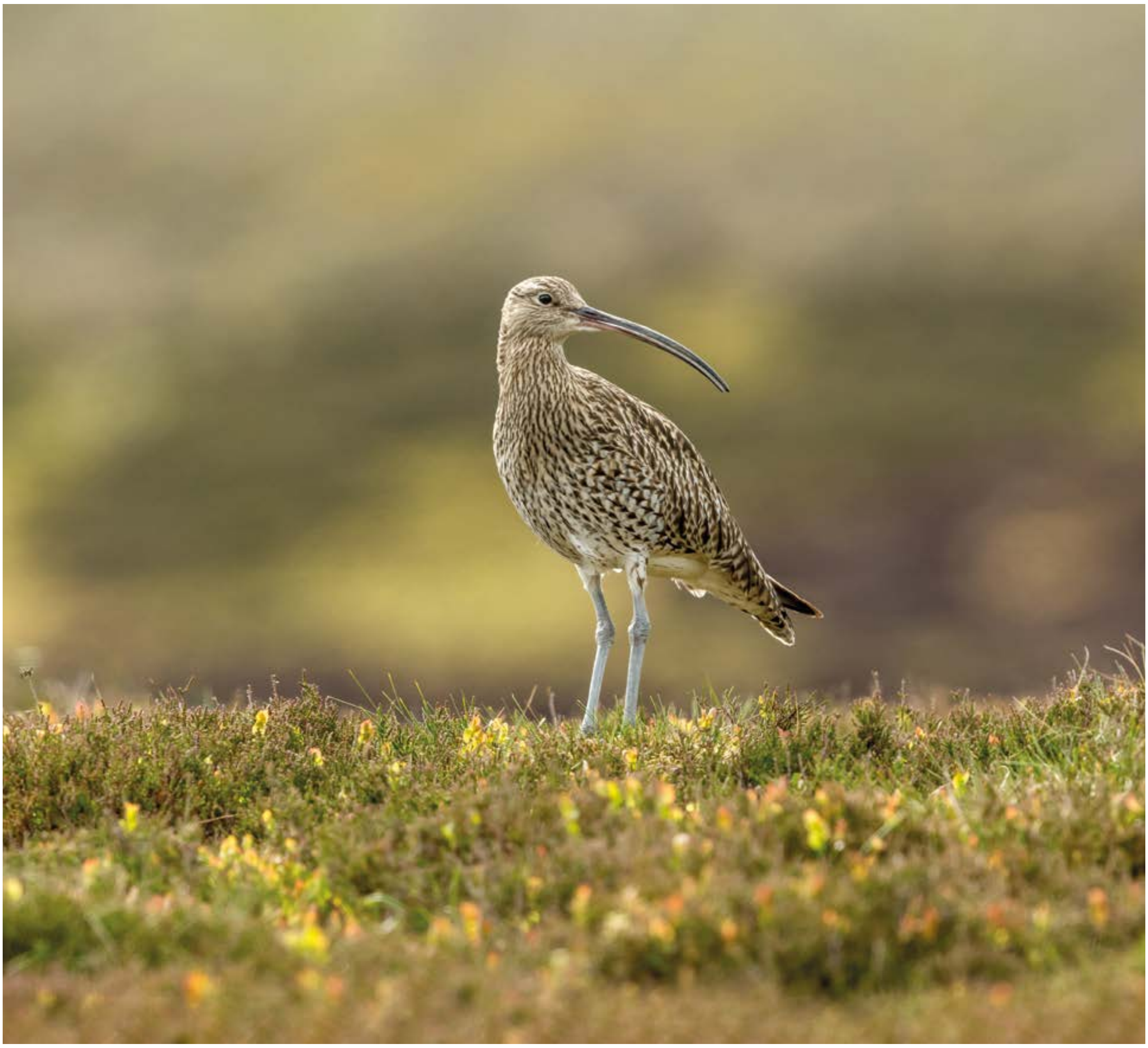
- Another study looking at the change in bird numbers when moorland management stopped also found that some species of moorland bird declined when grouse moor management ended.

Grouse moors also provide important refuges for the black grouse. The last estimate of black grouse numbers in the whole of Britain was 5,078 males in 2005 with the population centred on a few key upland areas of Scotland, northern England and North Wales. In England, black grouse are confined to the North Pennines, where 90% of the remaining population lives on the edges of moors keepered for red grouse. Research in the UK indicates black grouse are vulnerable to predation by foxes, stoats and raptors, whilst high densities of livestock can reduce essential cover and render them more at risk from those predators. For this reason, land management measures associated with upland farms on the fringes of grouse moors, including predator control and grazing restrictions, can benefit black grouse breeding success and overall survival.

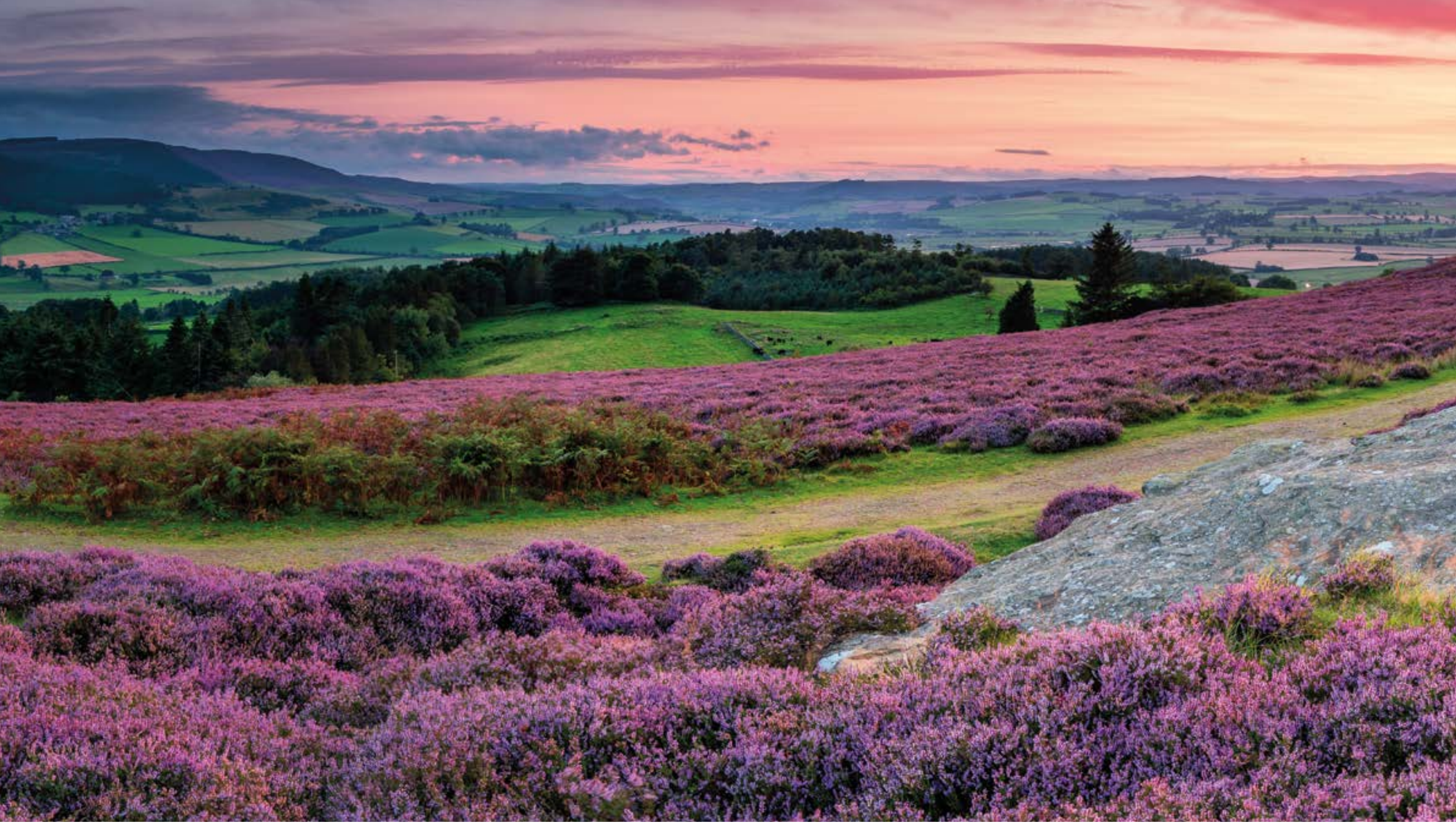
In Wales a GWCT study found that black grouse numbers declined in parallel with the loss of driven grouse shooting, with now an estimated 85% of the Welsh black grouse population associated with the only remaining driven moor.

On the other hand, there is evidence for the ongoing illegal killing of birds of prey like golden eagle, hen harrier and peregrine on grouse moors. This is has impacts at the national population level and must stop. However, in the absence of illegal killing, grouse moors have the potential to benefit raptors by supporting large amounts of prey, whilst predation control benefits ground-nesting species.

One study showed that hen harrier breeding success was twice as high when a moor was keepered, likely as a result of reduced predation on hen harrier eggs and chicks, particularly by foxes, which was found to be the main cause of breeding failure. Hen harriers and merlins may also benefit from the vegetation management carried out on grouse moors, as heather is their preferred upland nesting habitat and grouse moors are managed to retain heather; however, some passerine species including meadow pipit and skylark occur at lower densities on grouse moors because they prefer a grassier environment. Merlins are predominantly ground-nesting birds of prey, so are also likely to benefit from the predator management carried out on grouse moors.



The Langholm Moor Demonstration Project showed that restoring grouse management was beneficial for three wader species. Overall, curlew numbers rose by 10% per year on average.



Carbon storage on grouse moors

CARBON STORAGE AND RELEASE IN PEATLANDS: SINK OR SOURCE?

In this second briefing sheet, we focus on the critical issue of carbon storage, and its release to the atmosphere. This is highly relevant as peatlands are the UK's largest carbon store, covering 11% of England's land area and estimated to store around 584 million tonnes of carbon. Peatlands are found across a wide variety of environments, including upland moors, bogs, grasslands and fens. Lowland peat habitats are often used for farming.

Carbon flow

Carbon cycles in and out of these natural carbon stores in various ways. For example, carbon dioxide gas (CO2) is taken up by growing plants, and dissolved carbon dioxide may be brought in within rainfall. Both CO2 and methane gases are released from the peat if dead or damaged plants decompose, as well as carbon itself and other carbon compounds escaping peatlands either dissolved in water or as particles. Carbon loss can be accelerated by certain events, such as dry periods or fire leading to drying of peat, and carbon capture can be encouraged by restoration, when peat starts forming again.

KEY POINTS

- Peatlands are the UK's largest carbon store, and include many agricultural areas, near-natural peatlands and upland moorland.
- In general, pristine peatlands are around carbon neutral, whereas those modified by humans tend to release carbon and account for 4% of the UK's greenhouse gas emissions.
- Over 90% of these emissions come from lowland peatland.
- Grouse moors store around 11-35% of England's total peatland carbon but emit only around 1-5% of total peatland carbon emissions.
- Managed heather burning releases a small amount of carbon, but carbon is then taken up with regrowth, and the reduction in fuel available means that it may reduce the risk of more damaging wildfires.
- The science on carbon flow in the uplands is complex and ongoing, for example with the role of biochar recently being investigated for the first time.

Human impact

Greenhouse gas emissions from our peatlands as a whole make up 4% or the UK's total. Of these, those that are pristine, or near-natural, are thought of as fairly carbon-neutral – they hold on to their store of carbon and do not release it. However, those that are modified by or managed by humans usually release carbon, but the amount of carbon being released into the atmosphere from different kinds of peatlands varies widely.

In general, those that are modified by drainage, cutting, burning or erosion are relatively low carbon sources, emitting between around two and five tonnes of CO2 equivalent (CO2e) per hectare per year. Peatlands managed for cropland, grassland, forestry (for example afforestation of moorland) or fuel harvesting emit many time more at around eight to 39 tonnes CO2e per hectare per year.

GROUSE MOORS AND CARBON

Carbon in the uplands

It is estimated that England's total upland peat area emits around 603,000 tonnes of CO2e per year, which is 5.6% of the total peatland greenhouse gas emissions in England. The remaining 94% of England's peatland emissions come from lowland peat.

Carbon on grouse moors

Peatland under grouse moor management represents only a portion of this upland peat. Using data from the Moorland Association, recent GWCT estimates put the amount of carbon stored in peat on grouse moors at between 66 and 205 million tonnes, which is 11-35% of the total carbon stored all English peatlands. We went on to estimate carbon emissions from grouse moors and found that English grouse moors emit around 1-5% of the net carbon emissions from England's peatlands per year. English grouse moor carbon emissions are therefore proportionally well below the proportion of carbon that they store, compared to other peatland uses.

These figures are helpful in contextualising various peatland emissions, but the important point is that the UK's peatlands are a large and precious store of carbon. There is enormous potential for carbon savings by prioritising the areas with most potential and we need to understand how best to manage them.

HEATHER BURNING

What is it?

On grouse moors and some other peatland environments, vegetation can be managed by prescribed burning, in accordance with the heather burning code. This is a rapid, cool burn of small strips of heather that removes the old, woody vegetation but does not penetrate down into the peat itself. Managed heather burning is often misrepresented in the media as "peat burning", but the aim of moorland managers is to remove only the old vegetation and allow the plants to regenerate, often not even affecting the litter layer beneath the heather, and certainly avoiding peat ignition.

Heather burning and carbon

When heather is burnt as part of a managed burning programme, some carbon is released during the burn. However, carbon is then captured by the regrowing vegetation afterwards. How you assess carbon capture/release on areas that are managed by burning depends on when you measure it in relation to time of burning. Studies looking at long-term carbon cycles on upland peatlands are very limited, and the science that is available has tended to focus on a few sites that have been intensively studied. This is a well-known limitation of the scientific evidence in this area.

When comparing peatland managed with burning to unburned areas, many studies find that there are short-term losses of above ground carbon from the burnt vegetation, but that this is stored again in vigorous regrowth in subsequent years. The science does not yet confirm whether the losses in smoke are cancelled out by vegetation re-growth. Many studies that have been conducted are short-term, carried out in the year of the burn or the few years thereafter, whereas for a full understanding of the carbon balance studies are needed that span much longer periods – for example perhaps 15 years of a burning cycle.

How much do we know?

Science in this area is progressing all the time. For example, one recent York University study began to investigate for the first time the role of pyrogenic charcoal – also known as char, black carbon or biochar – this is produced when vegetation is burnt, and can store large amounts of carbon for a very long time. The study found a positive relationship between managed burning frequency and the amount of carbon stored, meaning that where heather was managed with cool burns, more carbon was stored. Previous studies have not included charcoal in their calculations, but it may play an important and previously unknown role.

Every carbon stock study so far has found positive carbon and peat accumulation within flat and wet areas of blanket bog, whether managed by burning or not. In general, areas managed with a ten year burning cycle seem to accumulate less carbon than those that were not burnt recently, but a recent study found similar carbon storage rates between areas burnt on a 20 year rotation compared to plots unburnt since 1954 or 1923. Two further studies have found that recently burnt areas emitted less carbon than older burn or no burn plots. Clearly more work is needed to understand this complex subject, and it is an area of active research. Although carbon is released with heather burning, the authors of a recent study concluded that careful burning management at that site did not have a major detrimental effect on the overall carbon budget for the moor. The simple narrative that is sometimes heard that managed heather burning causes huge carbon losses is not supported by the science.

Wildfire

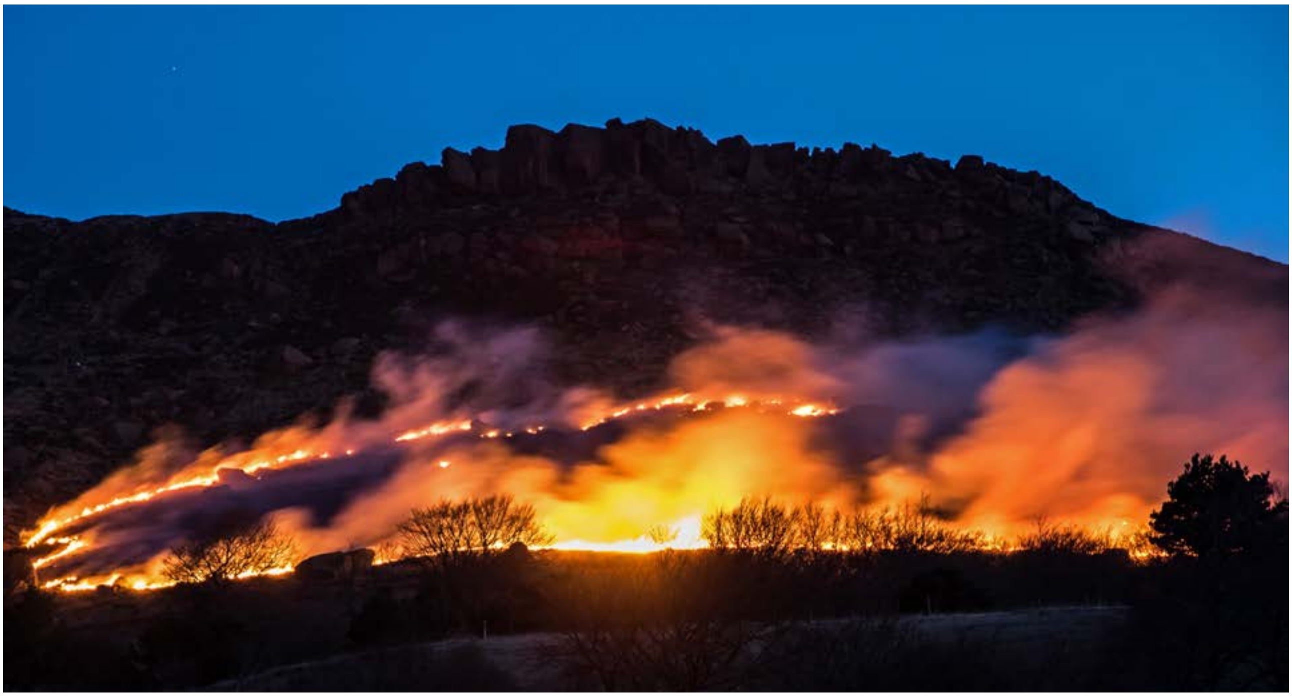
Although there are known limited losses of carbon associated with prescribed burning, the subsequent reduced fuel load may lower the risk of wildfire, which carries a much greater chance of huge carbon releases. In many places worldwide, managed burning is used as a tool to remove the build-up of fuel so that wildfire is less likely to occur or take hold. Although there is very little evidence on this from the UK, lessons can be learnt from wildfire management in areas such as Australia and the USA, especially in the light of climate change potentially leading to increased temperatures, drier peat and higher wildfire risk.

Managed heather burning is carried out in winter, when the ground is wet. Most of the damaging wildfires that have been seen on moorland in recent years have occurred in summer, when managed heather burning is not taking place, and in some cases (for example Saddleworth Moor) on areas that are run with a no-burn policy towards heather management, resulting in greater fuel load. These wildfires can lead to devastating losses of carbon, with many centimetres of peat burning and releasing their stored carbon that will take many years or even centuries to reform.

Restoration

The concept of blanket bog restoration burning has been created recently, where burning is used to reduce heather dominance and create conditions more favourable for good peat-forming plants. The recognition that well-managed heather burning can play this role is helpful. Burning should be for wider ecological purposes, rather than carried out solely on a strict time frame as is sometimes dictated in agency management instructions. The concept of restoration burning has allowed a common middle ground where practitioners assess and manage the land to benefit blanket bog condition and associated vegetation. Some commentators promote the idea that all burning is the same and make no distinction between managed/prescribed/cool burns and wildfires. This is a common mistake, but one which is easily avoided for the well-informed.

It is critical that we better understand the role of burning for heather management and how it relates to carbon storage, peatland condition and wildfire prevention/mitigation before making changes that may have damaging and long-lasting effects.



Wildfires, like this one on Saddleworth Moor, can release centuries of stored carbon. © Craig Hannah.

Alternative uses for upland moors

Moorland is less agriculturally productive than other land and most grouse moors are classed as 'Less Favoured Area' (LFA) because of their lower production and distance to market. Income generation from land in these areas is mostly from:

- Game management
- Livestock grazing
- Commercial forestry
- Renewable energy generation

Game management is the only one of these that is viable without substantial public or private subsidy, and the only one that invests in maintaining high quality heather moorland. In England, the loss of heather moorland has mostly been due to agricultural improvement and overgrazing; whereas in Scotland, heather moorland has been lost because of both agriculture, grazing and forestry.

FARMING

Light, seasonal grazing by sheep can be good for heather moorland and consequently for grouse. However, subsidies for livestock farming resulted in a 30% increase in sheep on UK moorlands between the 1970s and 1990s, often leading to overgrazing. In recent years, the average density of sheep across moorland has dropped, which has improved heather cover and condition in some areas and led to undergrazing in others.

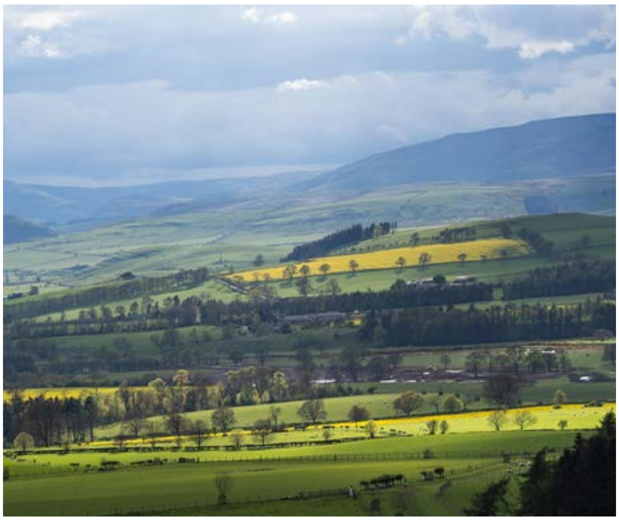
A well-established effect of overgrazing is that it reduces the condition and extent of heather cover, which is typically replaced with grass-dominated vegetation. Species that require a diverse moorland habitat and those that have a strong link to heather for food and cover, such as red grouse, hen harrier, merlin and mountain hare, tend to decline in abundance and productivity with these changes.

However, other species such as skylark and meadow pipit may benefit from a change to grassland provided it is not too heavily grazed.

Overgrazing by livestock can lead to soil erosion and may increase flood risk. A review from 2007 suggested that grazing can impact water flow across moorland to the extent that stopping grazing may reduce flood risk. This could be down to a variety of causes; for example, impacts on vegetation, and soil compaction from livestock trampling. Its effect on carbon capture and storage is variable and there is little impact on water quality.

A low-density, lighter grazing regime has some benefits in terms of the environment and biodiversity. The management techniques that are used to improve grazing, such as drainage and liming, can be damaging to the heather moorland and its ecosystem. However, sheep farming, especially a low-density grazing regime, is not economically viable. It needs supportive funding, either by private investment in the form of grouse management or public subsidy, perhaps in the future through agri-environment grants.

Grouse moors need sheep grazing to manage habitat and, in some places, to help control tick numbers. Sheep graziers need moorlands to summer graze their flock, thus saving their improved grass for winter, and they can benefit from nearby gamekeeping, which reduces the impacts of foxes and crows. Sheep treated with tick medication are sometimes used on moorland to attract ticks, aiming to help control overall tick numbers on the moor and reduce impact on grouse. Management arrangements between grouse moors and sheep graziers provide an incentive to manage heather moorland sustainably, maximising positive outcomes such as high nature value and rural employment, while minimising habitat damage.



There has been a great deal of tree planting in the Cheviots. © John Dal.

FORESTRY

Forestry has been one of the main causes of moorland habitat loss, with around 20% of former UK moorland now afforested with coniferous plantations. Afforestation causes an ecological transformation, in which open ground habitats and their wildlife largely disappear and are replaced by a woodland ecosystem.

Afforestation of the Southern Cheviots in southern Scotland is a good example of the impact of forestry on moorland birds. 15 years after planting, the forest canopy closed, and many species disappeared. The losses for that area alone were estimated to be 1,750 pairs of curlew, 1,200 pairs of golden plover, 200 pairs of dunlin, 25 pairs of merlin, and all the red grouse, snipe, redshank, wheatears, ring ouzels and hen harriers. Given that commercial forestry is growing, especially across Scotland, this situation is likely to be seen more often, particularly if grouse moor management becomes more challenging for landowners.

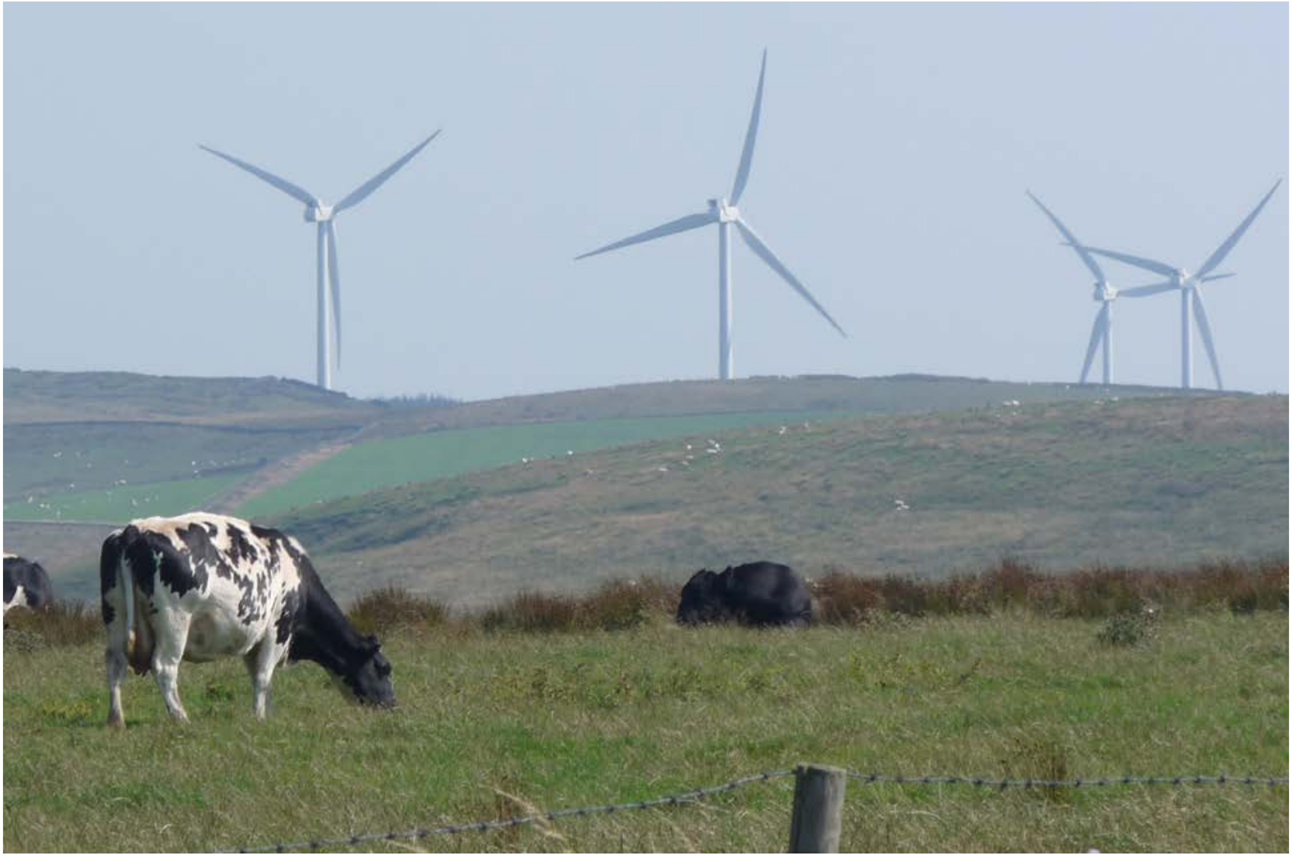
GWCT research into impacts of land use change in southwest Scotland also indicate that large-scale changes in land use, including afforestation, more intensive farming and reductions in grouse moor management, are responsible for declines in several bird species, including oystercatcher, golden plover, lapwing and curlew. One study in Scotland suggested that afforestation accounted for 58-78% of the decline in black grouse numbers in the region.

The mix of bird species in woodland is largely dependent on which trees are dominant and bird densities are lower in uniform woodland such as forestry plantations. Bird communities in the surrounding moorland can be affected up to a kilometre from the forest edge because of increased predation pressure, with reductions in golden plover and dunlin numbers, and reduced curlew breeding success. The introduction of forestry blocks into previously open moorland landscapes also fragments the remaining habitat, which can impact wildlife.

Beyond impacts on biodiversity, the most important effect of forestry is on soils and water. Before trees are planted, drains are often dug and fertiliser applied, which affects the nutrient composition of the soil and increases carbon release. As peatland soils store a large amount of carbon, the drainage, aeration and disturbance when areas are afforested leads to a period of carbon loss, which may not be compensated for by the growth of young trees.

A recent paper found that at sites forested both 12 and 39 years ago, loss of carbon from soil cancelled out the carbon taken up into the trees from the air and the amount of carbon stored at these sites overall did not increase. At one of the four forested sites there was an overall carbon loss. Peatland drainage for forestry lowers the water table, causing peat to shrink as it dries out and changing the habitat, which reduces its value for birds and other wildlife.

This drying process accelerates once the tree canopy closes and can lead to large-scale cracking of the peat, sometimes occurring some distance away from the forestry block itself. Streams that drain afforested areas tend to be more acidic and have higher levels of nitrogen. Water flow is also affected, with total peak flow increasing initially where land has been drained then reducing once the trees mature, after perhaps 20 years.



Wind turbines, like these in Northumberland, can negatively impact moorland bird species.

RENEWABLE ENERGY

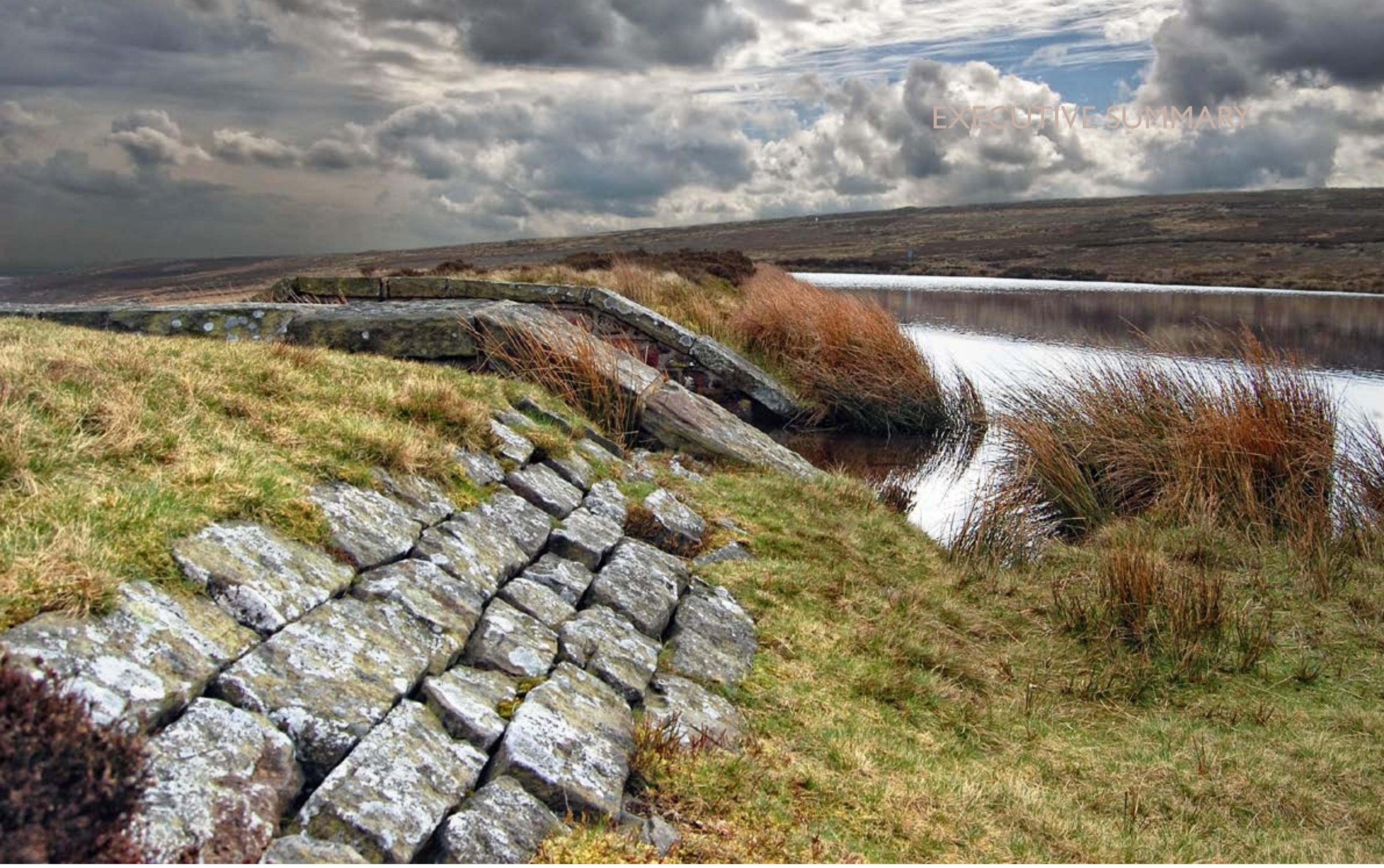
The UK's commitment to increasing renewable energy production is critical for reaching net zero carbon emissions. However, building wind farms on moorland affects its habitats, soil, and the wider landscape. The main impacts on moorland habitats are from the loss of land for tracks, crane hard standings, turbine bases, control buildings, borrow pits and changes in drainage. One study found the density of some moorland bird species near wind farms was reduced by between 15% and 48%. Another found that the impact of wind farms on moorland birds may be highest during the construction phase, with lower numbers of red grouse and curlew during construction.

Where forested areas are felled to return an area to moorland (albeit with turbines) for renewable energy generation, over time this could be beneficial in enhancing overall biodiversity. One study suggests some species such as skylark and stonechat may benefit from the habitat change. Where income from the windfarm is reinvested in surrounding moorland the increased management and small-scale scrub planting could benefit some species. Providing renewable energy is a main priority for the country with clear benefits that must be weighed up against ecological damage.

TOURISM

Tourism is an area of increasing interest as an income source for some upland landowners and is extremely important to rural economies more widely. The potential for generating revenue on a large scale to replace the main land uses is not yet known, nor are the possible ecological impacts. In general, more tourism requires more infrastructure in terms of access and services, bringing with it increased disruption, with likely consequences for breeding wildlife. Other concerns for the upland environment include higher risk of wildfires, which are already considerably more likely both in summer and at weekends and bank holidays due to increased visitor numbers.

However, whilst it seems unlikely that tourism can replace the principal economic land uses for landowners, it may provide a valuable additional income stream in some areas. Increasing the accessibility of moorlands to visitors in a sensitive way also brings advantages in terms of public appreciation and understanding of these beautiful environments



A reservoir on Ilkley Moor. © Tom Blackwell

Drainage, water quality and flood risk

Grouse moors are often located on blanket bog peatland, which sits across upland hills like a sponge, soaking up rainwater. This water is absorbed, trickles through the peat soils and is slowly released into streams and rivers flowing towards lowland areas. This means that how these blanket bogs are managed is important for water quality and flow.

In general, a healthy bog is a wet, low-oxygen environment, where plant matter cannot break down and the carbon within it is captured and stored as peat before it decomposes. However, when a bog dries out, oxygen from the air can come into contact with dead plant matter – leading to decomposition and carbon release.

The main impacts of moorland management for water come from drainage, with the potential effects of managed heather burning still being investigated. Drainage was carried out after the war in response to government incentives hoping to increase the productivity of these upland areas for livestock – not, as is often suggested, for grouse. It has since become clear that draining peatlands is very damaging, and many grouse moor and other upland land managers have been blocking the drains that remain in order to rewet their moorland. The possible impacts of managed heather burning on water quality and flood risk management are not clear and research is ongoing. It is important to be clear about the difference between managed heather burning and wildfire, the damaging effects of which are well established.

WATER QUALITY

The impact that managed heather burning may have on water quality is still being studied, with different pieces of evidence suggesting different effects. Some commonly cited evidence suggests that burning may be associated with increased water colour, with some papers equating this to an increase in dissolved organic carbon (DOC). However, one study showed that DOC did not rise in response to burning, and the colour of water is not always a good indicator of DOC. Several more recent studies examining water colour have found that managed burning has no effect.

The impact on water quality is not fully understood because results differ depending on both the length of time since burning, and the scale at which the studies are performed. Effects may be different at smaller, local scales, compared to the larger, catchment or landscape scales, as well as variations at different times since burning.

To further complicate the picture, there may also be short term changes in water coloration in response to heavy rainfall, where streams becomes more intensely coloured after rain events regardless of management. The possible effect of burning on water quality and amount of run-off is also complicated by interactions with other upland management, such as woodland expansion and grazing. These interactions have not yet been well studied.

FLOOD RISK

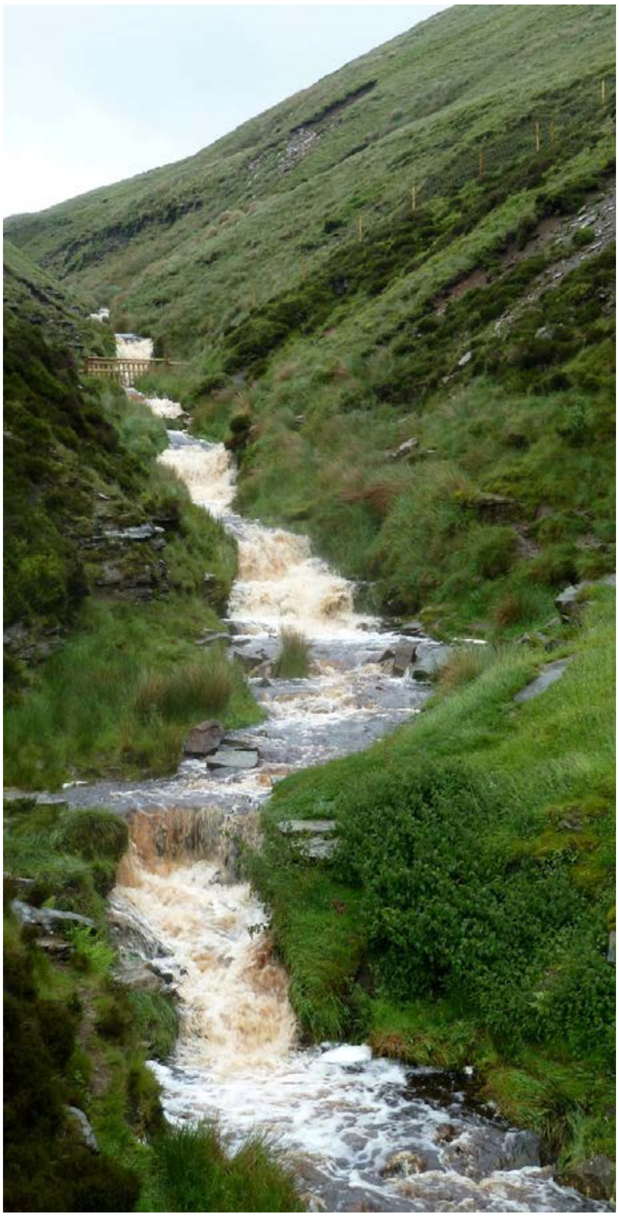
The evidence base regarding a possible impact of prescribed burning on flood risk is limited and still inconclusive. Although there are relatively few studies available, the authors of a 2013 Natural England report could not find any evidence that burning increases flood risk, and state that: "No evidence was identified specifically relating to the effect of burning on watercourse flow or the risk of downstream flood events. If there are any effects, these are likely to be highly site specific".

The EMBER study, also published in 2013, examined the effect of rotational burning on deep blanket peat sites and drew several conclusions. These include that the lag time to peak runoff is increased on burnt sites for most rain conditions – meaning that the movement of water is slowed down across areas managed with burning – but that for the heaviest of storms, although the lag time is the same, the peak flow is higher from burnt compared to unburnt catchments.

The explanation suggested for these seemingly contradictory finding is that in this study, water tables were found to be lower on sites managed with burning so more water could be absorbed into the peat during rain events and this slowed down water flow. However, when rain was very heavy and the peat became 'full' of water, any excess then ran across the surface, which was less rough on burned areas so the surface flow moved more quickly, leading to higher peaks. Although this study is often cited, there are flaws in the experimental design and the findings have been questioned by other academics.

Many studies have been done in this field recently, with some pieces of evidence seeming contradictory, so Natural England and the Moorland Association commissioned an update looking at evidence from 2013-2020, which was published earlier this year. For water quality and flow, this review finds that managed burning has no impact on water colour, but that the evidence is conflicting for pH (acidity). Managed burning may increase the likelihood of water flow across the surface, but the evidence is not robust, nor is it consistent for any possible effect on water table depth or stream flow.

A research project carried out for Defra and published earlier this year compared managed burning with cutting for heather management over a four-year time period,



There is conflicting evidence on the impact of heather burning on water quality. © Andrew Hill

and found that in areas managed with cutting, more rainwater was absorbed, the water table was closer to the surface and less water drained off the peatland into nearby streams and rivers, compared to areas managed with burning. This may have implications for river flow and flooding downstream. To better understand these complex questions, the studies designed to address them have to be long-term, extending at least for the duration of a complete management cycle. This year's study for Defra reported phase 1: preliminary findings from the first five years of a study, which continues in phase 2 for at least another five years.

Research is ongoing to better understand this complex topic, sometimes raising as many questions as it answers.

IMPACT OF DRAINAGE

Moorlands have been drained for centuries, often to enable peat cutting for fuel, but the extent and intensity of drainage increased from the 1950s to the 1980s. During this time, government subsidies were paid to landowners for digging drainage ditches (known in some places as 'grips'). Drainage was intended to lower the water table on moorland primarily for agricultural purposes, to improve grazing for livestock, as part of the post-war drive for "more food from our own resources". In the same era, large areas of British moorland were drained for commercial forestry. Woodland planting on the hill and hill edge continues to affect upland landscapes, habitat, and water.

It is often incorrectly stated that moor owners drained the moors for grouse shooting and that this practice continues. In fact, many grouse moor owners have contributed to blocking up these drains in recent years, thereby rewetting the landscape. This can be beneficial for grouse, as their chicks feed on insects emerging from these wet areas. The Moorland Association has reported an estimate by Natural England that around 18,000 hectares of moorland habitat on grouse moors has been restored in this way across northern England. Similar schemes and activity are underway in Scotland.

Upland drainage has been associated with several negative impacts on water. These include affecting the flow of water over and through the soil, increases in the rate at which water runs off the moor into rivers during rainstorms, greater sediment flow into river systems and increased colouration of water from the peat. Levels of DOC in water running off the moor have shown to be significantly higher on drained slopes.

There is good evidence that drain blocking is an effective way to reduce the amount of sediment reaching the stream and river network. Drains dammed at intervals along their length have been shown to have low sediment levels. Blocking has also been shown to reduce colouration by 60-70% compared with a drained site. Drain blocking generally reduces peak flows of water from peatlands, but this depends on many things; for example, drain orientation as well as other local factors, and computer modelling predicts that it may even increase peak flow in some situations.

We know that rewetting can enhance peatland as higher water tables and a wetter environment are the environmental conditions needed for healthy, peat-forming bog vegetation, in particular sphagnum mosses. Computer models predict that large-scale increases or reintroductions of sphagnum moss could reduce peatland catchment flood peaks, particularly in the areas around draining streams or rivers. Rewetting has also been shown to be highly successful in reducing DOC loss. Peat erosion can be reduced by blocking drains and focusing efforts on sloping drains is more efficient, as drains on flat ground are much less vulnerable to erosion. These effects are likely to improve peat health, and therefore benefit carbon storage. However, the responses to rewetting can be variable and we need more long-term studies.

Despite all the evidence that rewetting can be beneficial in many ways, there is still much to be learned about how and when it should be done. For example, some research suggests that rewetting blanket bog may increase emissions of methane, which is a powerful greenhouse gas. Because this effect is driven by increased levels of microbial activity in rewetted peat, it may be accelerated by the warming temperatures associated with climate change. Although methane itself is a potent greenhouse gas, it breaks down in the atmosphere in around ten years – much faster than carbon dioxide. The relative contributions of different forms of carbon release and how to account for these in climate change models is still under study. Research into these complex areas continues, and it is important not to draw absolute conclusions from incomplete evidence.

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