A literature Review for the
Office for Environmental Protection

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Literature Review: Changes in upland biodiversity resulting from agriculture in NI

Contents

INTRODUCTION

Hills and uplands are an integral part of the farmed landscape in NI and deliver a wide range of ecosystem services. Ecosystem services can be broadly grouped as:

Provisioning services: the products obtained from ecosystems such as food, fibre, and fresh water;

Regulating: the benefits obtained from ecosystem processes such as pollination and control of the climate and water;

Cultural: the non-material benefits obtained from ecosystems; for example through, cultural heritage, recreation and tourism, sense of place and rural community;

Supporting: ecosystem functions that are necessary for the production of all other ecosystem services, including biodiversity, soil formation and the retention and cycling of nutrients and water.

It is estimated that upland peatlands cover 14% of the land area of NI but hold 53% of the soil carbon stocks (Tomlinson and Milne, 2006).

In this context and in this report, the **impacts** of the causal actions, pressures and drivers on **biodiversity** (plant communities and vegetation; soil flora and fauna: invertebrates; birds; mammals; landscape) will be considered. Where relevant and appropriate, impact on soil and peatland quality, water quality and hydrology and the cumulative impact of multiple pressures will also be considered.

SUMMARY

This review is only concerned with impacts of agriculture-related activities on upland biodiversity.

***Grazing*.** The majority of upland habitats in NI are peatland with *Sphagnum* mosses as the main building block, usually supporting a heathland vegetation layer, along with unenclosed grassland habitats with peaty substrate. Grazing is a vital natural process and management tool to maintain a vegetation structure which delivers a range of ecosystem services, including food production, carbon sequestration soil health and biodiversity. Overall, grazing has the most significant impacts on upland and peatland biodiversity. These impacts have been variable - most driven by wider scenarios and successive government policy. Positive impacts have been the application of appropriate grazing regimes to maximise the range and quality of ecosystems services delivery. Negative impacts have been mismanagement

resulting in over or under grazing affecting plant and animal communities. The balance of these has shifted over time. Earlier evidence of damage by significant overgrazing following entry to the EEC had resulted in habitat deterioration and loss. This had been redressed to some extent by successive agri-environment (AE) support measures and there is documented local evidence for the impact of both. There is also documented evidence on the condition of designated upland sites. These are generally reported as being in an unfavourable condition (as a result of past history and some ongoing practices). Grazing impacts on vegetation and wider biodiversity have been tested under rigorous scientific conditions on a few sites in NI, but by and large inferences have to be made on biodiversity responses from wider studies in similar environments across the British Isles. On a wide range of peatland and upland vegetation communities, moderate and variable (both spatially and temporally) levels of grazing are the most appropriate for the delivery of many ecosystem services (including those related to soil carbon and biodiversity), though not necessarily those related to animal production and reduction in fuel loading. While the history of management of these areas has fluctuated around successive government-driven schemes, local knowledge, experience, and intergenerational skills built up over a long history of sustainable care for the farmed landscape have not always been given the priority they merit or the inherent value it contributes to upland management.

From one replicated trial and wider observation, complete cessation of grazing on blanket bog led to vegetation with lower conservation value than where it had been sustainably grazed and there was some evidence of under grazing with associated climate, biodiversity and wildfire hazard risks and of overgrazing with evidence of habitat damage.

Upland birds which have documented declines are curlew, lapwing, snipe, redshank, red grouse and a range of raptors including Hen Harrier. Reasons for decline can rarely be specifically attributed to grazing, but general habitat loss, predation, illegal persecution, afforestation, land reclamation and pressures in other migratory locations have all played a part. With raptors in particular, habitat loss, afforestation and persecution have been identified as significant contributors to their decline.

Ground beetles are recognised as indicators of habitat change in upland habitats. Detailed studies in NI showed that vegetation structure was important for invertebrate diversity, though several species were opportunists, adapting quickly to changing conditions and bare ground creation. There were no negative interactions between grazing and Irish hare - which has undergone cyclic population densities and the position regarding smaller reptiles and mammals is relatively unknown

Fire/Burning. Wildfires have resulted in significant biodiversity loss. In the absence of appropriate vegetation management, risks associated with wildfires may increase mainly because elevated fuel loads enhance the likelihood of fire events occurring with increased degrees of severity and subsequent impact on upland ecosystems. There is mixed evidence that controlled burning or using burning as a one-off restorative measure on heathland to create so-called “cool burns” can help shift vegetation to favourable condition. Monitoring studies at Glenwherry, (CAFRE) have been positive in this respect but there needs to be more widespread evidence.

Drainage. Most of the published evidence for the impact of drainage alone focuses on water chemistry and quality rather than biodiversity and it is likely that river biota will be severely affected. Drainage associated with more extensive land reclamation has a negative impact on the *Sphagnum* base of peatland and on biodiversity. Evidence on impact of age of drains, condition and functionality on biodiversity (and other ecosystem services) is lacking.

Ammonia. Nitrogen deposition (largely from non - upland sources) is well documented and modelled from specific site monitoring and has a significant and widespread impact on upland plant communities and water quality. Less is known about impacts on other biota.

Tree removal & afforestation. Most large-scale upland afforestation is state planted and managed, but it does impact on adjoining farmland biodiversity. Loss of habitat, water quality impacts and cover for predators are the main negative effects though the Forest Service no longer ploughs or drains sites prior to planting. There is some good evidence of the disturbance effect on indicator invertebrates. Coniferous forests are also largely biodiversity-poor and harbour predators which negatively impacts on ground nesting birds in the uplands. Upland raptors have been particularly affected by habitat and landscape-level change associated with afforestation. Dispersed shelterbelts have a generally beneficial effect, and the biodiversity value of upland and wet native woodlands is recognised but insufficiently monitored for impact on loss.

Mechanical peat cutting. An expansion in mechanical peat extraction in the 1980s and 90s had a significant impact on biodiversity, and though the practice is reduced, it is still active in places. Detailed research had been carried out locally to measure the effect on vegetation, invertebrates and hydrology. The overall impact depended on the method used and frequency of extraction and ground beetles and spiders were good indicators of habitat quality. Habitat recovery has been very variable and site specific depending on the degree of intensity of the original, and subsequent, extraction episodes.

Climate change. Predicted increased temperatures and windspeed will have an effect on peat and the associated vegetation, but effects on biodiversity are largely unknown and difficult to predict. Effects on water quality (dissolved particulate carbon and other nutrients) and on the increased fire risk in upland peatlands will likely be substantial. Peat slips and erosion occur and cause loss of biodiversity, though this is not quantified. They are caused by a complex interaction of conditions, some of which are farming related.

Multiple impact studies. Evidence from only five replicated studies on multiple impacts of causal factors on upland biodiversity in NI are used and 15 significant multi-factor reviews/reports represent the best sources of information from which inferences can be made. Given the overriding likely impact of climate change more multiple impact studies will be required.

CAUSAL ACTIONS/PRESSURES/DRIVERS

1. *LIVESTOCK GRAZING*

i. Introduction

Cattle and sheep farms account for most (89.5%) of the land area designated as Severely Disadvantaged (SDA) in Northern Ireland (DAERA, 2019) and ruminant grazing is the predominant method of managing upland habitats (Fraser et al., 2014) to deliver as wide a range of ecosystem services as possible. Grazing is a non-uniform process where livestock alter the vegetation cover (both the *Sphagnum* moss foundation and the structural vegetation component) through selective defoliation, trampling and excreta deposition. In this section, evidence for impacts of grazing (including: stock type, management, density, seasonality, intensity, support measures) on upland biodiversity will be reviewed

ii. Historic position

Whilst grazing animals are widely recognised as an important management tool for habitats of conservation importance, grazing-related damage to European uplands was most notable in the UK and Ireland up until 1999 (European Environmental Advisory Councils, 1999). Overgrazing due to increased livestock production has historically been blamed for changes in biodiversity and habitat modification (e.g. Fuller and Gough, 1999). Thus, there is a requirement to identify optimal grazing strategies that will work for the benefit of both biodiversity and livestock production, and therefore ensure the sustainability of these environments (Fraser et al., 2014).

Following accession to the EEC in 1973, sheep numbers in NI had risen substantively from 1.3 million in 1981, peaking at 3 million in 1998 under headage payment regimes and LFA support (80% of sheep were in LFAs). Upland heath, heather moorland and blanket bog are the dominant habitats in the uplands. In these, heather is the dominant shrub and vegetation feature and biodiversity is highly dependent on it. Hence its condition is considered as a measure of upland habitat quality. In 1964 the then Ministry of Agriculture purchased a 1,040 ha hill sheep and cattle farm at Glenwherry in the south Antrim hills. The Glenwherry Hill Farm (now run by CAFRE) has been used for education, reseach and demonstration purposes and full stock and grazing records have been kept since 1966. The Glenwherry Hill Regeneration Partnership (GHRP) was formed in 2009 to demonstrate best management practices, underpinned by appropriate scientific monitoring for multiple outputs from the hill farm. Loss in heather habitats on the farm through overgrazing and winter grazing was found (McAdam, 1988; McAdam & Chance, 1988). From the vegetation and stock histories at Glenwherry over a 20 year period (1964-1985), across the range of grazing densities practiced, summer grazing by sheep and cattle was not detrimental to heather and indeed may have been slowing down the cycle of natural succession to unfavourable condition of the heather stand. More damage to the heather had likely occurred where stock (particularly cattle) had grazed in early winter. The situation for early spring/ late winter grazing was less clear and indicated that more suppression of tall heather growth before grass growth started could be beneficial at that time.

By 2011, sheep numbers in NI had declined to 1.9 million and have remained at approximately that level following the introduction of area-based payments, reduced stocking rates under agri-environment schemes and the decline in profitability of hill farming.

A review of Heather Moorland Management was carried out by AFBI for DAERA in 2013 (Flexen and McAdam, 2013). The review was confined to blanket bog and heathland and, based on scientific evidence from research and monitoring carried out in Northern Ireland and elsewhere in the UK, assessed the impact of management strategies on heather moorland habitats. It specifically considered grazing and burning management options for agri-environment schemes. At that time there was concern across the UK around the increasing evidence for undergrazing on upland heather habitats (Holland 2011). The picture emerging was not a simple one as Holland et al (2010) demonstrated in their review of the complexities of upland grazing and the grazing needs of the different habitats or site selection features on protected sites.

The National Ecosystem Assessment (Christie et al, 2010) stated that while uplands in NI had suffered previously from overgrazing, undergrazing was now a threat to some (though not all) semi-natural habitats. Previous eligibility rules for heather under the Basic Payment Scheme encouraged unsustainable practices such as uncontrolled burning and flailing. These no longer apply and there is now incentive to manage heather for a range of purposes which include a vegetation structure to accommodate biodiversiy and grazing livestock objectives.

iii. Habitat condition assessments of designated sites

NIEA's overall view is, that the uplands are recovering from a period of sustained overgrazing, and with the right AES measures in place, this restoration / maintenance of habitats for biodiversity can continue (subject to landscape pressures such as ammonia) being addressed. There will shortly be Conservation Management Plans (CMP) in place for the majority of large upland SACs. The picture outside of protected sites is unclear although evidence from NICS, MEF and from searches for ASSIs from Cruickshank and Tomlinson peatland layers shows a continued trend of poor condition in the uplands as indicated in Article 17 reports (see below). “Extrapolating the evidence from the protected sites network to the wider peatland resource suggests that a high proportion of the overall resource is likely to be in unfavourable condition, and this is supported by general trends identified in the NI Countryside Survey 1998-2007 (Cooper, et al., 2009). Although the latter is now somewhat out of date, NIEA consider it is likely that the broad trends identified are still valid.”

Evidence from Article 17 reporting. The condition of the SACs/ASSIs are reported regularly (usually on a 6 yearly cycle though in some cases this is substantially longer) and this forms the main body of evidence on the conservation status of habitats and species for the Habitats Directive to ensure that the protected sites network is healthy. This evidence is collated with condition of priority habitats in the wider countryside to establish conservation status of Habitats Directive Annex 1 habitats. These reports form the basis of the decision-making process for resource inputs and decision making for biodiversity within Northern Ireland through priority action frameworks (PAF) and the biodiversity strategy. They use the best available monitoring evidence to draw conclusions on the status of upland habitats using common standards monitoring within SAC/ASSIs described above and evidence from last available Northern Ireland Countryside Survey. NIEA carry out SAC site monitoring but the farmer/land owner is not involved in the monitoring or site evaluation process.

The most recent Article 17 report for upland habitats in Northern Ireland was in 2019 (Article 17 Habitats Directive Report, 2019) and although the majority of the habitat in the SAC network reported as *unfavourable*, following survey, a significant amount of the habitat was in “*unfavourable recovering*” status and, taking into consideration the substantial time that may have elapsed since the last assessment for some sites, this situation (*unfavourable recovering*) may well have improved considerably.

In their summary of the Article 17 reports overall NIEA have not found under-grazing as a risk. However, under-grazing or land abandonment as a fire risk are not evaluated as a habitat risk. The Article 17 reports use monitoring evidence to draw conclusions, and a summary of these is provided below (Article 17 Habitats Directive Report 2019 (Habitats) | JNCC - Adviser to Government on Nature Conservation).

Blanket Bogs (Areas in km^2 :Total ***1400***;Good condition; ***8.975;*** Not good condition ***119.34***; Condition Unknown ***1271.68*** Status; ***Stable***). A high proportion are in *unfavourable* condition, although a reasonable proportion of this is recorded as *recovering*. This change has mainly come about from relaxation of grazing since monitoring started in early 2000s. Overgrazing, drainage and peat cutting remain as significant impacts on the habitat, in addition to construction of windfarms. Despite some positive developments within the protected sites network as a result of conservation measures both already in place and planned for the future, the structure and function of the habitat is generally *unsatisfactory*. Future prospects are uncertain in the light of potential impacts climate change, but the added impact of atmospheric Nitrogen deposition make this attribute *Unfavourable Bad*.

Wet Heath (Areas in km^2 :Total ***583***;Good condition ***0***; Not good condition ***22.734***Condition Unknown ***560.266*** Status; ***Decreasing***). A high proportion of the overall resource is likely to be in *unfavourable* condition. Previously, heavy grazing was responsible for much of this poor condition. However, recent condition assessments suggest that grazing intensity has been reduced over a significant area of the resource. Structure and function, *Unfavourable Bad* assessment.

Dry Heath (Areas in km^2 :Total ***168***; Good condition; ***0;*** Not good condition ***56.093***; Condition Unknown ***111.907*** Status; ***Increasing*)**. A high proportion of the overall resource is likely to be in *unfavourable* condition although showing signs of *improvement*. Although the situation in the lowlands is less well-known, NI Countryside Survey data suggest that the habitat is generally *improving* in condition (i.e. dry heath increasing in extent at the expense of acid grassland (as grazing pressures have reduced and heath plants have gradually been able to recover). Structure and function, *Unfavourable Bad* assessment.

Alpine Heath (Areas in km^2 :Total ***0.8***; Good condition; ***0;*** Not good condition 0***.209***; Condition Unknown ***0.321*** Status; ***Stable***) A high proportion of Alpine heath is in *unfavourable* condition. Previously, heavy grazing was responsible for much of this poor condition. However, recent condition assessments suggest that grazing intensity has been reduced. Accidental burning by fires is another factor that may affect the habitat.

NIEA monitoring has indicated that nearly half of sites monitored in upland areas has the wrong EFS classification applied i.e. purple moor grass was selected, but the underlying habitat was blanket bog. The grazing prescriptions for purple moor grass in such sites will not permit restoration of the underlying blanket bog habitat types. Further monitoring of the habitats across Northern Ireland will be carried out for the EFS programme within and outside designated sites using the UK agreed CSM approach. This should add to understanding of the condition and conservation status of these habitats. NIEA carried out condition assessment analysis on the Tier 3 habitats surveyed for EFS Tranches 2, 3 & 4 and found that the main upland habitats – blanket bog and wet heath were in unfavourable condition using the same CSM methodology as is used for designated sites. The forthcoming Northern Ireland Countryside Survey (due to start in 2024) will also inform this discussion.

None of the upland SAC sites has been highlighted as being in unfavourable condition from under-grazing. Although this must be taken as a general position, however some pockets of these may suffer from under-grazing and constitute a fire risk and having reduced habitat quality through scrub and conifer incursion. The Conservation Management Plans aim to identify pressures and threats to sites.

Upland management going forward should also consider the needs of species, especially those listed in the Habitats and Birds Directives, and features of designated sites. Golden plover and some wader species benefit from shorter vegetation. However, extensive SPAs are designated for Hen Harrier which require a both forage areas e.g. blanket bog or upland heathland grazed and in favourable condition and areas for nesting consisting of large blocks of taller (under grazed) heather (ideally heather height of c50 cm height over >40 ha) in close proximity to each other.

Conversely more diverse vegetation structure and more grazing can benefit many species, but this has to be carefully balanced where blanket bog is present. There is however the likelihood that habitat condition will have noticeably changed over the past 6 years, in some cases through the introduction of prescriptive stocking requirements under EFS which could have led to habitat condition decline. Although note the assessment above that there is considerable mis-classification in EFS ssMRPs. In some key sites such as Cuilcagh, Article 17 assessments have not been carried out for 12 years and since then the impact of climate change, farming practices and priorities and agri-environment scheme prescriptions (where there are participants) may well lead to a different assessment of condition - one reflecting a deterioration in condition through changed stocking conditions (either increases and subsequent overgrazing or decreases or even abandonment).

In the case of 'mosaic habitats' within an overall management unit, there is no scientific evidence to support the concept that the most restrictive grazing periods and/or stocking densities that are required under current EFS will result in the most favourable overall habitat condition on a landscape scale. For example, such grazing periods will clearly result in under-grazing on the dominant Rush - Purple Moor Grass habitat and it has been shown that cattle grazing can be more preferential on this grassland habitat type than sheep as they graze taller, ranker vegetation. Farmers in these cases face the difficult decision to either completely change their style of management from cattle that may have been traditionally managing the ground very well over generations, over to sheep. This would severely reduce their livestock numbers and such farmers often elect not to join the EFS scheme at all.
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A detailed habitat survey (including condition assessment) of part of the Glenwherry Hill Farm was carried out at the commencement of the GHRP project (Flexen et al 2008) and resurveyed in 2016 (AFBI, 2017). There was a slight improvement in mean habitat condition between 2008 and 2016. Grazing impacts were generally lighter in 2016 than at baseline. Setting appropriate stocking rates over the whole grazing season had generally improved condition on most of the habitats.

iv. Current position on land management measures

The Environmental Farming Scheme (EFS) Higher Level covers hill and upland grazing. This is a 5 year, prescription-based, tiered scheme focused only on farmland located within designated sites and priority habitats. On entry to the scheme, farmers must have a habitat survey carried out by an authorised planner and a Site - Specific Remedial Management Plan produced (ssRMP). This allows some flexibility in the management options chosen for any one site, but the bespoke options within the programme are not always taken up. Management prescriptions are habitat-based and payments are made accordingly. Any deviations from the agreed prescriptions can be penalised by payment deductions. Capital items to facilitate vegetation and stock management are also funded. There is no specific monitoring procedure place and the scheme requires a proper analysis to help formulate the next generation of AE schemes. Future AE schemes are expected to be less prescriptive and more rewards-based. They may also be more site-specific and facilitate farmer input from the scheme planning stage.

v. Impacts of grazing on biodiversity

Impacts of grazing on vegetation.

The IUCN UK Committee Peatland Programme Briefing note No. 1 including "*Peatland Definitions";* "*Grazing and Trampling" (*Lindsay et al 2014*)* includes key definitions of peatlands and highlights the need for clear definitions of upland habitats when reviewing their response to and condition under grazing. The issue of local definitions of habitats reflecting the location - and hence climatic and edaphic conditions found in NI - needs to be addressed and merits wider discussion. For example, blanket bog habitat in the NE of Scotland will differ substantively from the west of NI yet at the minute the same management criteria tend to be applied across the UK. The Article 17 assessments and outcomes could feed into this discussion which should involve the skills and experience of those involved in managing these habitats.

In any upland vegetation enclosure, there is huge variation in vegetation species composition and proportions and nutritional value of different species varies seasonally. A fundamental principle of stock grazing management is to match the available food resource to the nutritional needs of the animal. These will vary throughout the year depending on the reproductive cycle, stage of lactation and growth targets. Livestock are selective grazers and will choose the most nutritious plants they have available. The availability of these vary substantially through the grazing season. Heather is wintergreen and young shoots are the most nutritious source of feed in early spring. However, once grass growth starts (usually about 3 weeks after the heather) animals will selectively graze grasses. This window of opportunity to graze the heather can be very short depending on the season, so rigidly fixing a prescriptive grazing date mitigates against flexible vegetation management to meet the nutritional demands of stock and the maintenance of vegetation structure.

Grazing density/ stocking rate.

Prior to the introduction of AE schemes, there was widespread recognition of overgrazing damaging heather and other vegetation communities in the hills and uplands across Ireland and Northern Ireland. There are some examples of underpinning scientific evidence for this damage to biodiversity e.g. from Connemara in Ireland (Bleasdale 1998) and in NI at Glenwherry (McAdam 1988).

The Glenwherry Hill Regeneration Partnership Project (GHRP) established in 2009, aims to develop, implement and promote sustainable habitat management practices on the

Greenmount Hill Farm to deliver a wide range of ecosystem services in tandem with sustainable livestock production.

A common feature across most of the AE schemes reviewed across the British Isles was that, over a period of years, they have attempted to address vegetation condition caused by successive major policy direction decisions, operating across a hugely diverse soil and vegetation mosaic and very diverse farming structure, through a one - size fits all prescriptive approach. This has resulted in a spectrum of vegetation condition, which shows, at one end, an accumulation of herbage for various reasons such as an attempt to shoe-horn management prescriptions into too few, broad vegetation classes and the resultant lower grazing pressures which have, in some cases resulted in scrub encroachment, over-mature heather and rush infestation. This is an undesirable trend given the proven link to reduced biodiversity value and increased fire risk. At the other end of the spectrum, vegetation condition has resulted from stock densities which have either not matched the growth patterns of the diverse vegetation structure that animals graze or the density of grazing has been excessive for some of the plant communities within the vegetation classification applied. In between these extremes of vegetation condition is a spectrum of diversity of condition which agri-environment prescriptions should seek to address in their complexity to bring those plant communities to a condition where they are delivering across a widespread range of ecosystem services. This is the principle behind Site-Specific Remedial Management Plans which facilitate, within scheme principles, a more bespoke and targeted approach to upland grazing management.

Although there is widespread consultation embedded in the assessment process, consultees do not include the actual farmers or land owners who manage the sites and have local site knowledge, often passed down over generations of experience. Also the length of time that can elapse between measurement periods can be very long, the process is relatively insensitive to detecting recent changes in habitat condition. This can result in a lag period before remedial grazing measures can impact – either positively or negatively. The outcome of the most recent Article 17 assessments have been presented.

Livestock type and breed.

Fraser et al (2009) compared diet selection by cattle and sheep in heathland to quantify differences in grazer impact on vegetation. There is much publicised research demonstrating the benefits of mixed grazing on the uplands and this is borne out where cattle are permitted to graze on peatlands and uplands. Cattle are particularly beneficial in controlling scrub encroachment and bracken incursion onto bogs, helping keep dense heather stands more open and liable to colonisation by a wider range of species of plants and birds and in controlling bracken on selected areas in blanket bogs and upland heath.

A recent study (Magennis, Meharg and Montgomery, 2020) demonstrated the conservation value of using Irish Moiled cattle (which have wider hooves than introduced breeds and therefore do less trampling damage), and showed that older cattle had greater potential for habitat management than younger animals. An English Nature review (Martin et al, 2013) found that differences between cattle breeds in terms of grazing effects were less significant than overall size differences, unless the quality of the vegetation avaiable was very low, in which case traditional, slower-growing breeds would fare better as they can utilise the lower quality forage available. The Beef Carbon Reduction Scheme in NI will be unlikely to appeal to Hill and Upland farmers. It relies on fast finishing of breeds not suited to Hill conditions and the high concentrate input necessary to achieve the target finishing dates would be counter -intuitive to the perceived outcomes of the scheme. A conservation grazing scheme encouraging native breeds at appropriate stocking densities would be much more appropriate for hills and uplands.

Developments in fence-free grazing control using GPS collars will increasingly allow control of cattle grazing on upland and hill mosaics. In one of the first studies using GPS tracking collars, Williams et al (2012) found that habitat selection by hill ewes in the west of Ireland was significant. Typically acid grassland was selected most followed by wet heath with blanket bog habitats selected least. There was also seasonal variation in habitat selection. The effects of sheep breed and breed changes on upland habitats in N Ireland have been investigated (McCloskey, 2010) by electronic tagging of animals and monitoring grazing patterns and habitat selection of crossbreds compared to traditional Scottish Blackface. Sheep grazed more grass-based habitats than dwarf-shrub based ones. Blackface and Swaledale X Blackface crosses had more flexibility and were better suited to extensively foraging and grazing all upland habitats than lowland type breeds such as Texel and Cheviot. Hence foraging behaviour could be a desirable management trait for managing undergrazing on uplands and thus meeting cross compliance regulations.

In a study of grazing behaviour at Glenwherry, McKinney (1992) found that sheep moved in diurnal patterns between areas of higher nutritional value grassy vegetation where they spent disproportionately more time than on heath or blanket bog (McKinney, et al, 1989) i.e. they were selective grazers. There were very low levels of grazing on heather dominant vegetation in mixed vegetation anyway and the work was further evidence that predetermined fixed stocking rates are not an appropriate tool to enforce management of hills with complex mosaics of vegetation. Habitats grazed in this manner are therefore likely to be under-grazed.

It is fully accepted that, given the sensitive nature of the Blanket bog habitats in, for example, EFS they could be vulnerable to trampling and poaching. However, as discussed previously, although ssRMPs do allow some level of flexibility, only a small number of farms have requested or been permitted to use cattle on upland mosaics including Blanket bogs. This may have impacted on biodiversity in upland areas where the evidence base is more supportive of a mixed cattle and sheep grazing regime. These criteria and findings are more intuitive than empirical and need to be more rigorously tested in NI.

Grazing on plants and plant communities.

Biodiversity levels in upland vegetation are largely dependent on a diverse vegetation structure creating opportunities throughout the canopy and ground surface for a wide range of species of insects, spiders and plants to live, and consequently birds, reptiles and mammals to feed (McAdam 1983). As such they will be greatly influenced by grazing strategies and management decisions.

The selective nature of grazing by hill sheep has been well documented in UK and Ireland (e.g. Fraser et al 2009). Significant increases in stocking (particularly by sheep) in the era up until the introduction of A-E measures in the early 1990s led to widespread habitat deterioration in the hills (e.g. Bleasdale 1998; Bleasdale and Sheehy-Skeffington 1992). These affected the structure and botanical composition of the vegetation and although most of the reported scientific evidence is from western Ireland, the same effects were happening across the island. Agri- environment schemes were the first significant attempt to address this situation and, in NI at least, the high level of uptake and generally positive biodiversity outcomes reflected this change (McAdam, McEvoy, Flexen, and Hoppe 2006). Although monitoring showed that habitat improvement was slowest in upland habitats, species diversity and vegetation composition of the habitats had been maintained under AE scheme (Environmentally Sensitive Area and Countryside Management Schemes) management. Condition assessment showed some improvement of habitats, particularly degraded heath (Flexen, O'Mahony and McAdam, 2010) but arresting the significant decline in habitat quality evident at the time was recognised as a positive outcome (McEvoy, Flexen and McAdam, 2006).

Following concern over increased sheep density on hill land in NI, McAdam (1992, 1995) measured the effect of sheep grazing density on four vegetation types (low-high heather content and Purple Moor Grass/Bog cotton-dominant) in a replicated trial at Glenwherry. It was shown that habitats had greater plant species diversity through the canopy when grazed with 6 wethers/ha for 4 months than at lower rates of 3 wethers/ha or no stock at all. There was greater selection for vegetation components other than heather, but live heather was reduced by increased grazing pressure. This, and other aspects of what was a major grazing trial, demonstrated clearly that complete cessation of grazing on blanket bog led to vegetation with lower conservation value than where it had been grazed.

Grazing and birds.

Diversity in cover and vegetation structure favours a wider range of bird species than tall, dense vegetation. Hence mosaics creating spatial and temporal heterogeneity of vegetation are best suited to maintaining and enhancing high levels of biodiversity. It is highly likely that on some sites where there has been gradual increase in vegetation canopy, accumulation of dead plant material and resultant decrease in structural variability are mitigating against biodiversity enhancement.

Ground-nesting birds, such as breeding waders, are of high conservation concern throughout Europe, experiencing population declines and low breeding success driven by predation, land-use and climate changes and agricultural intensification. In Northern Ireland, declines and range contractions have been documented since the 1980s (Colhoun et al., 2015; Henderson et al., 2002; Partridge & Smith, 1992), with the most recent survey on a subset of sites indicating that lapwing declined by 70%, curlew by 80%, redshank by 76% and snipe by 71% between 1987 and 2019 (Booth Jones et al., 2022). Hunt et al (2023) have shown positive responses of breeding wader numbers to targeted conservation advice and habitat management when these are used to enhance existing wader conservation initiatives in Northern Ireland. The authors cite the benefits of Agri-environment schemes in delivering such initiatives.

In relation to upland birds, the GHRP project aims to: contribute to the requirements of the Red Grouse Species Action Plan, through creation of a sustainable grouse moor in the Glenwherry area. It achieved well beyond its target of increasing the number of grouse on the project farms from 9 pairs in 2012 to 15 pairs by 2014. This was in line with the 50% target contained within the Northern Ireland Red Grouse Species Action Plan (increase from 200 to 300 pairs across Northern Ireland). The actual figure reached was over 200 birds recorded during the summer of 2014. It was found that the provision of predator control had a significant positive impact on breeding wader and Irish hare numbers in addition to red grouse. The project showed the impact that predators (mainly foxes and crows) have had on upland bird populations and factors which have led to their increase e.g. afforestation have led, indirectly to declines in upland birds. Farmers regularly report the impact of predators in the uplands e.g. corvids and foxes, not only on their own stock but on a wide range of birds, small mammals, amphibians and reptiles. Their disturbance of a balanced dynamic ecosystem structure has given cause for concern and merits more scientific monitoring and evaluation.

The project also aimed to secure the management of 550ha of foraging habitat for Hen Harriers and Merlins as part of the Antrim Hills SPA. This was achieved but there was no concomitant increase in Hen Harrier numbers or breeding success recorded. The project also secured management for 2 breeding pairs of breeding waders (primarily curlew and snipe) per square km by 2019. Although this was only partially achieved, partnership initiatives such GURP have shown that decline in upland birds can be corrected through habitat-focused integrated land management. The strength of the project has been the recognition that not every party can achieve all their objectives for upland management, but with dialogue and clear goals a compromise which is outcomes focused can be achieved. A further strength has been that all the projects activities have been underpinned by best-practice guidelines underpinned by science. There are a number of annual and long-term review reports produced.

The Hen Harrier, an iconic raptor species largely confined to the hills and uplands across Ireland and has extensive areas of SPA designated for its protection. It requires both forage areas e.g. blanket bog or upland heathland, grazed and in favourable condition and areas for nesting consisting of large blocks of taller (under- grazed) heather (ideally heather height of c50 cm height over >40 ha) in close proximity to each other. From recent population surveys in Ireland (Ruddock et al, 2024) breeding distribution in 2022 has contracted further since the previous 2015 survey, and the total national population has also declined. The extent of declines varies locally, regionally and between SPA populations. The hen harrier population in Ireland was estimated at 84 confirmed and 21 possible breeding pairs (85-106) in 2022. This is a decline of one third (33%) in the total population since the previous national survey in 2015 and a 27% contraction in their breeding range for the same period. Illegal killing is listed as the main cause of death in young Hen Harriers (1 and 2 year old) and a major cause of deaths in birds under 1 year, according to satellite-tracking research led by the RSPB in UK (Ewing et al 2024 and reported in Birdcrime 2022).

Hen Harriers are one of the UK's rarest breeding birds of prey. Despite being fully protected by law, and a UK Red Listed species, they are being heavily illegally persecuted. This is due largely to the ongoing conflict raptors face when on land managed for gamebird shooting, particularly driven grouse moors in the uplands. These data refer largely to Great Britain and do not cover NI, where there is little history of keepering and grouse moor management, but nonetheless the picture is roughly the same across Ireland. Increased afforestation on moorland is a major cause of decline in the Irish populations. The most frequently occurring pressures and threats highlighted by raptor surveyors in2022 as negative for hen harriers close to breeding / nesting sites (*i.e.* in the 500 m zone) included; forest management and use; the mechanical removal of peat; increased access (via paths, tracks, cycling tracks (includes non-paved forest roads); non-intensive grazing; wind energy production and agricultural intensification. These activities, at distances proximate or close to nesting sites (*i.e.* within 500 m) of breeding pairs, are considered to heighten risk of negative outcomes (*e.g.* reduced productivity, nest failures via abandonment or predation or nest destruction) although it is recognised that some of these factors can also have positive effects.

Grazing and invertebrates.

Agri-environment policy under EC Directive 2078/92 had resulted in the designation of 5 ESAs in Northern Ireland covering 21% of the Land area. This scheme aimed to improve habitat quality, amongst other things, and effective monitoring and evaluation was a key component of the scheme. Because of their central role in the food chain and their responsiveness to environmental change, the use of Carabidae (Ground beetles) in monitoring has been of major importance.

Ground beetles were used as indicator species in a series of impact studies on key issues in land management between 1985 and 1998 (McAdam and Montgomery, 2000). The environmental issues covered in these studies in Northern Ireland broadly reflect the history of land use in Northern Ireland, and the change of priorities in land use imposed by factors such as environmental awareness and EC policy. Arnott et al (2022) demonstrated that AES management of upland grassland in NI was associated with higher terrestrial invertebrate abundance and family-level richness compared to conventional management by maintaining more diverse swards with a higher coverage of native plant species. Despite not having before-and-after data, they concluded that AESs in upland grassland systems maintain, and thus offset declines in, terrestrial invertebrates seen in conventionally managed grasslands across the wider countryside.

In the uplands, significant loss of habitat through land use change has occurred, including the effects of conifer afforestation and mechanical peat cutting. The advent of inexpensive cutting machines resulted in a significant increase in the amount of fuel peat extracted from peatlands (over that cut traditionally by hand). The impact of mechanical peat extraction upon ground beetles has been examined by Todd (1995). Heathland habitat modification through overgrazing and burning has also been widespread and persistent during this period and has been studied by Meharg (1988) and McFerran (1991). McFerran et al (1994) found that low intensity grazing on heathland was less favourable to ground beetles than the higher density. The more open canopy created by grazing favouring larger numbers of individuals of common species.

Climate induced, periodic infestations of Heather Beetle (*Lochmea suturalis*) can have significant impact on heather vegetation canopy structure and food availability (leaves) (Gillingham et al ,2016). The impact on biodiversity can be inferred as negative but there are no studies on the interaction with agricultural practice.

Upland afforestation and invertebrates.

Government policy aimed at the production of a timber crop from land of low agricultural value has meant that large tracts of blanket bog have been afforested with alien species, mainly conifers and especially Sitka spruce and Lodgepole pine. Large scale afforestation commenced in the 1920s and accelerated in the 1960s and 1970s to create over 55,000ha (50,000 state, 5,000 private) of coniferous forest, mostly on peatland (NI Woodland Register 2022). Afforestation involves deep ploughing and drainage of the peat as well as the addition of fertilizers. The environmental impact was direct on the afforested land and indirect upon considerable areas of adjacent moorland. The effects of afforestation upon ground flora are well known, but there has been little research on areas within forests that remain unplanted.

Cameron (1994) investigated the effects of afforestation on beetle populations in unplanted areas, and on areas of blanket bog adjacent to coniferous forests. The extent of these effects was investigated by surveying at various distances from the forest edge. The effects of plantations of various ages on adjacent populations were also investigated. He found that age of adjacent tree stands up to 32 years old had little effect on the variation in physical characteristics of vegetation and beetle communities of adjacent blanket bog. However, there were geographical differences in vegetation and beetle communities. Beetle communities on unplanted areas differed from those in the forest and on open areas of blanket bog, with only a 38% similarity in species compliment. Unplanted areas within forests supported species found in the forest, but not found on open blanket bog, which in turn supported species that were absent from enclosed areas. For example, very wet areas of blanket bog without forests, supported *Carabus clatratus*, a relict peatland species and one of the largest ground beetles found in Northern Ireland. The distribution of this species is limited to very wet habitats. Enclosed areas of blanket bog, therefore, do not have ground beetle faunas representative of larger tracts of unplanted blanket peat. Beetle species are sensitive to a range of physical factors, especially variation in microclimate (due to afforestation), and these may be responsible for differences in beetle communities in areas adjacent to plantations. The drying effects of afforestation on peat may also be responsible for loss of habitat for species specific to wetland. One result of this study was a recommendation that large areas of blanket bog remain free from afforestation to retain very wet areas and the species dependent upon them. While the study was limited by the lack of availability of unplanted areas of blanket bog adjacent to areas planted more than 35 years ago, it would seem likely that as the forest ages, effects on areas left unplanted will intensify.

Grazing and ground beetles.

Meharg (1988) studied the effect of cessation of grazing on ground beetle communities in five vegetation types at Greenmount College Hill Farm, Glenwherry, Antrim. The two most abundant species, *Carabus granulatus* and *Nebria salina* comprised over 50% of the catch, while the ten most abundant species totalled 92%. Rare species had relatively little effect on the overall composition of ground beetle communities, and are of limited interest in the elucidation of the effects of grazing in exclosure experiments. The experimental cessation of grazing had relatively little impact on species richness, at least within the short time span of the experiment (3 years). Ground beetle diversity and individual abundance varied with respect to both heathland community and grazing intensity. This study demonstrated the importance of vegetation structure (and hence grazing) on beetle assemblages.

McFerran (1991) took this work further during a time when stocking level increases (mainly between 1964 and 1984) were having a considerable impact on habitats and reflected the effects of stock increases throughout the British Isles (McAdam, 1988). Heather cover was shown to be reduced by increased grazing (McFerran, Montgomery & McAdam, 1994) and despite the relatively short duration of this preliminary investigation, it was apparent that grazing effects upon the vegetation canopy were already having an influence upon the associated ground beetle assemblages. This effect was particularly evident for non-forest or open ground species (McFerran, Montgomery & McAdam, 1994). Whether this was a preference for the grassland environment or for more open conditions could not be ascertained, but the latter interpretation appears likeliest.

Kelly (unpublished MSc thesis, QUB) further analysed McFerran's (1994) data and found no significant differences between carabid species numbers on sites on grazed heathland and heathland which had been substantially modified (heather burning, ploughing draining and reseeding with grasses). However she found that abundance of several indicator species was affected by habitat disturbance

Burning and its impact on invertebrates.

Burning is a well-documented and practised management tool for heathland in upland Britain. It has not been widely used in NI for many years, but accidental or unplanned fires do occur. The effect of such fires on ground beetles and the use of these species as indicators of recolonised, burnt areas was studied in north Antrim by McFerran (1991) and McFerran *et al*. (1995), and in south Antrim by McFerran (1991).

In the north Antrim study, the impact of burning and grazing on plants and ground beetles was investigated experimentally in stands of varying ages (burnt in 1982 and 1988 and unburnt plots) in an area of heather moorland. Burning initiated complex succession pathways which appear to have characteristic plant and invertebrate species associations. The study concluded that the various stages in heathland succession greatly increased the diversity of micro-environments available to different plant and invertebrate species, and suggests that the maintenance of a mosaic of stands of varying age of heather is as essential for the conservation of invertebrate groups as it is for the management of plant species and vertebrates, such as Red Grouse The presence of invertebrates in these open areas may represent a more important food source to vertebrates than those of mature heather stands. McFerran, et al (1994, 1995) also measured the impact of grazing and burning on communities of ground-dwelling spiders in upland vegetation types on the Antrim plateau. Although newly burnt heather heath may appear to be a poor environment for invertebrates, results from this study suggested that considerable numbers of beetles and spiders are active on burnt areas though some species abundances may be changed. This is one of the few studies investigating multiple factor impact. Likewise, Kelly, Montgomery and Reid (2023) found that the nationally rare beetle *Carabus nitens* was more common in the aftermath of wildfire than before.

Grazing on small mammals and other fauna.

There has been little published information on the impact of hill farming on populations of small mammals, the common lizard and the frog, though it should be expected that habitat loss and deterioration in water quality will have had an impact. There is anecdotal evidence (borne out by detailed record keeping by the Glenwherry Upland Regeneration Project) that fox numbers have steadily increased in the upland catchment due to agricultural and other activity and that fox control can lead to substantial increases in ground nesting birds, particularly breeding waders.

Irish hare

The Irish Hare (*Lepus timidus hibernicus*) is an endemic sub-species of the Mountain Hare (*L. timidus*) and the only lagomorph native to Ireland. There is an invasive population of non-native European Brown Hare (*Lepus europaeus*) in Northern Ireland. The Mountain Hare is listed under the EC Habitats & Species Directive (92/43/EEC) and Article 17 requires that member states regularly undertake national conservation assessments of its status. Up until 2002, there was evidence that that Irish hare numbers had declined due to intensification of pastoral agriculture (Dingerkus and Montgomery, 2002). However the current status of the Irish Hare within the criteria of i) Range, ii) Population, iii) Habitat for the species and iv) Future prospects was assessed as Favourable with the overall national conservation assessment stable in common with the two most recent Article 17 reports (dated 2013 and 2019) (McGowan, et al 2019).

2. ***BURNING/FIRE***

The increase in global wildfires has been partially linked to climate change and to mitigate future fires, vegetation load will have to be decreased. This can be achieved by periodic use of controlled fires or appropriate grazing strategies. Peatlands are more susceptible to wildfire due to poor condition of bogs resulting from drainage or inappropriate grazing in terms of timing and stock density. Wildfires cause significant environmental damage that can take many years to recover. An uncontrolled, unexpected fire on peatland can quickly get out of control creating a high temperature burn that destroys much of the fragile and all-important plant cover. In many cases, the very specialist bog species that are lost are replaced by more generalist species that do not have the same impact on bog growth and diversity. In some cases, successive AE schemes with relatively low levels and restricted timing of permitted grazing have resulted in an accumulation of ungrazed herbage which is a significant fire hazard. This can be best remedied by gradually increasing stocking density limits and allowing more flexibility in timing of grazing and using appropriate stock type to help meet a target of reduction in wildfire risk.

Kelly, Montgomery and Reid (2023) found that wildfires were associated with a loss of blanket bog and heath indicator species. Broad vegetation groups showed initial recovery characterized by a decrease in bare ground and increasing cover of shrub species and bryophytes. However, at a species level, *Sphagnum* spp and bryophyte communities, which are central to peatland ecosystem functioning, showed no sign of recovery to pre-fire composition. Similarly, composition of arthropod communities (ground beetles and spiders) differed between burnt and unburnt areas and showed no evidence of a return to species composition in unburnt areas. Whilst, long-term recovery was not investigated, these short-term changes suggest enduring detrimental impacts on the distinctive communities associated with peatlands, primarily through the loss of *Sphagnum* spp., affecting ecosystem services such as carbon sequestration and water and soil retention. Reid Kelly and Montgomery (2023) also found wildfires on moorland reduced bird species richness and abundance, along with the seedbank and abundance of ground beetles and spiders. The effects were detectable three years after the fires took place.

In the absence of appropriate vegetation management, risks associated with wildfires may increase mainly because elevated fuel loads enhance the likelihood of fire events occurring and their degree of severity and impact on upland ecosystems. A key feature of many upland farms is the presence of heather and many farmers believed that the presence of tall, rank heather may have limited their ability to claim Basic Payment for land accessible to grazing livestock. This no longer applies but controlled and uncontrolled prescribed burns, and accidental, careless or malicious wildfires do frequently occur in NI. In some cases these can cause significant extensive damage e.g. in the Mourne Mountains.

The potential impacts of wildfire and fire management on biodiversity, will depend upon the species and community affected and, on the extent, and severity of the fire (Hobbs & Gimingham, 1987). No evaluation or data is available in relation to this in NI or ROI. Research is needed to quantify the effects of wildfires on biodiversity in NI. Low severity fire is often used across regions worldwide to constrain the encroachment of invasive and woody species, to encourage new vegetation, and to increase the area which can be effectively grazed (Stavi, 2019). There are guidelines to protect ground nesting birds and specific management of designated sites such as Natura 2000 (DAERA, 2017). Fire is an integral part of the functioning of many ecosystems and both heather and gorse for example, have been traditionally managed by prescribed, controlled burning.

Managed burning has been used for at least 200 years in UK uplands to create a mosaic landscape suitable for red grouse (Davies et al., 2016) and to sustain suitable conditions for grazing. Indeed, lack of upland vegetation management promotes the establishment of invasive and/or woody species which preclude cattle and sheep grazing, can increase evapotranspiration and significantly increase the risk of wildfire due to a proliferation of dry fuel. Wildfires burn longer and hotter than prescribed ”cool” fires and thus, cause greater damage to soil structure and water quality, and pose a risk to human and livestock safety. Currently management of fuel structure is not quantified in NI and ROI but there have been recent examples of wildfire management strategies for specific regions e.g. for the Breffni/Cuilcagh upland region in the CANN project.

Managed low severity fire (so called “cool burn”) is also used to encourage habitat heterogeneity and for conservation purposes. For example, it has been used to create and maintain structural diversity in dry heaths (Defra, 2007). Burning is also used to create new growth for livestock, and to encourage favourable conditions for game management e.g. red grouse. Management for grouse through burning may also benefit certain bird species. A study in the central and eastern Highlands of Scotland in 1995, and in the North Pennines, Northumberland and North York Moors in England in 1996 demonstrated that on grouse moors, golden plover, curlew and lapwing occurred at higher densities while meadow pipit, skylark, whinchat and crows occurred at lower densities compared to other moors (Tharme et al., 2001). In the Glenwherry (GURP) project, controlled burning was trialled and monitored on small areas to bring the over - mature heather, which was prevalent on some parts of the farm, into a condition which would be more favourable for sheep grazing, carbon sequestration, water quality and biodiversity - and remain within the overall objectives of the SPA. Results for vegetation response were variable but overall there was very little damage to the *Sphagnum,* supporting the findings of Shaw et al (1996) who found no evidence to support the claim that burning is necessarily always detrimental to *Sphagnum* - based vegetation. Impacts on other vegetation types were very variable and site-dependent. Heather regeneration on burnt sites was generally good, but only where grazing was removed or controlled. The GURP project highlighted the need for further long – term studies the interaction between burning, flailing and grazing and their subsequent effects on vegetation, wider biodiversity, water quality, soil carbon and DOC.

The benefits of managed burning within uplands may also extend to terrestrial and aquatic macroinvertebrates. However, it is also important to consider that the upland/moorland contain many priority habitats under the EU Habitats Directive (Council Directive 92/43/EEC 1992) and there is evidence that regular burning can have considerable negative implications for biodiversity in certain situations. Stevenson and Rhodes (2000) examined the relationship between heather and catchment fire history through pollen and microscopic charcoal analysis for seven moorland lake catchment in the UK and Ireland and found that burning may have been a significant factor contributing toward the decline in heather cover on at two of the seven study sites. This may be attributed to burn temperatures. For example, grassland fires may be hot enough to remove ground litter but not enough to cause damage to the regeneration abilities of any heather or other shrubs that are present. Lichen diversity can also be effected especially immediately after a fire event when diversity can be reduced significantly. Davies & Legg (2008) suggest that lichen diversity recovers 10-15 years post-burn but that changes in lichen diversity can be attributed to the development of heather stand structure following burning. It was observed for older unburnt stands of heather greater than 25 years that lichen diversity was less than in the 15 year-old burned patches. This highlights the need to consider synergetic relationships within uplands and the need to consider the role of such relationships in managing diversity.

Burning can also have adverse effects on bird species such as the meadow pipit (Tharme et al., 2001; Smith et al., 2001). Tucker (2003) raises concern more generally about negative impacts of burning on vegetation, invertebrates, soil structure and hydrology, water quality and carbon storage. Regular burning can also change succession patterns which many be critical to biodiversity within the uplands. This is because regular burning contributes to the dominance of a select number of species who have a competitive advantage. Typically observed is the replacement of dwarf shrubs by grasses (Stewart, Coles & Pullin, 2004, 2005). Further studies are required on the effects of regular and rotational burning on diversity within the uplands. In addition, timing of burning is an important question with serious ecological consequence which also requires further research and especially the impacts it may have on arthropod populations. Burning later in spring, for example, is likely to directly kill invertebrates but it is unclear the impact this many have on populations at landscape scale across the uplands.

There are numerous scientific studies which demonstrate that wet peatlands are less prone to wildfire and that rewetting is a better strategy than burning to achieve peatlands that are resilient to wildfire (Baird et al., 2019). The most effective long-term sustainable solution for addressing wildfire risk on peatlands is to return the sites to fully functioning bog habitat by removing those factors that can cause degradation, such as drainage, unsustainable livestock management and accumulated dry vegetation. Re-wetting and restoring will naturally remove the higher fuel load from degraded peatland vegetation, so re-wetting peatlands is therefore viewed as crucial in mitigating wildfire risk.

Management by flailing (or cutting) to regenerate heather has been an option under AE schemes, but little interest has been shown in the practice. Heather can regenerate from buds at the base of the stem and, from studies elsewhere, in younger or building heather, regeneration has been more successful under flailing than burning. The opposite was found in more mature heather stands. There have been some scale trials in NI comparing flailing and burning (Flexen and McAdam, 2013) but the results have been site specific and inconclusive and highlight the need for future research, such as GURP propose (see above).

3. *DRAINAGE*

Typically, peatland is wet and farmers have reduced the water table by drainage to *a.* encourage drying out of the heathland and replacement of moss and heath communities with grass *b.* enable the land to carry stock over a longer part of the year, *c.* as a prerequisite to other heath/bogland agricultural activity. Foresters have drained peatland prior to tree planting to reduce the water table and hence increase the rooting depth of the trees. Changes in land use in hill and upland areas from natural peatland to improved grassland or forestry often cause peatlands to be drained (Landry and Rochefort 2012).

Multiple studies over the last decade show that peatland degradation is typically associated with variations of the water table depth, which can lead to peat layers becoming drier for longer periods and thus exposed to very different biogeochemical conditions, which favour soil C losses (Fenner & Freeman 2011). The ability of a peatland soil to sequester C is strongly influenced by the presence of an actively growing Sphagnum moss community, local hydrology. Although there are no documented studies investigating the impacts of artificial drainage on peatland stream ecology for the UK, Ramchunder at al (2009) given the hydrological and physiochemical evidence they present, it is likely that river biota will be severely affected. Conversely, habitat restoration method for peatlands typically involves blocking drains to promote re-wetting, thereby increasing the water table and ultimately re-establishing their potential to act as a C sink (Wilson et al. 2016). Yet, re-wetting can also cause increased emissions of GHGs, particularly CH_4 to the atmosphere with a wide range of CO_2, CH_4 and N_2O emissions reported from re-wetted peatlands depending on previous land management, vegetation composition and cover (Wilson et al. 2016; Premrov et al. 2021). When peatlands are in good conditions (e.g. associated with high water table) then soil conditions are mainly anaerobic and phenol oxidases are inhibited thus determining the accumulation of phenolic compounds and peat layers. In degraded peatlands where the water table has retreated in deeper peat layers than surface peat soils are in aerobic conditions which favour the activity of phenol and hydrolase enzymes which lead to increases in decay processes and thus to the loss of carbon (Fenner & Freeman 2011).

There has been extensive drainage in the hills and uplands of NI over many decades. Ramchunder, Brown and Holden (2009) reviewed the hydrological, physicochemical and ecological effects of artificial drainage, drain blocking and rotational burning across the UK. They report evidence for a wide range of stream chemistry following drainage, though after time most of these decline substantially. They summarised that drainage and burning of peat often lead to altered runoff regimes, oxidation of organic matter, changes to C, N and P cycling and increased metal and suspended sediment concentrations in streams relative to intact peatlands. However their assumption is that actual peat is burnt following a fire (which would assume it is too hot) and does not reflect on the interactive active following a so-called “cool burn”. They incorporate long-existing drains into their model and the effect of drain -blocking management as a rewetting mechanism. The review is valuable in that it attempts to model the cumulative effect and interactions between these three peat management procedures. It also emphasises the need to take a whole landscape/catchment approach to considering the impacts of burning, drainage and restoration on upland ecosystems as advocated by Holden et al (2007). It should be recorded the Forest Service no longer drains sites prior to planting.

4. *AMMONIA*

The impact of Nitrogen deposition (mainly from ammonia) on sensitive upland habitats is well documented and is an area of current and future concern. Critical loads of nitrogen are estimated to be exceeded in 98% of Northern Ireland's priority habitats), which include 394 Areas of Special Scientific Interest (ASSIs) and 58 Special Areas of Conservation (SACs). Most (95%) of Northern Ireland's Special Areas of Conservation, have been reported to the European Commission as part of the EU reporting requirements (Article 17) as being under threat of damage from N deposition. 93% of ASSIs are also being impacted with sensitive plants and habitats exceed damage thresholds for nitrogen deposition. Almost one third (32%) of emissions come from the beef sector and while upland farms, as a sector, do not make a significant or widespread contribution to the overall problem of ammonia emissions, there are localised pockets of emissions from intensive beef units within the sector. However, most nitrogen deposition, mainly from ammonia originates from intensive lowland livestock, pig and poultry units and most effort will need to be targeted at reduction of point source emissions in those sectors.

NIEA (in association with UK Centre for Ecology & Hydrology, Ulster Wildlife, Monaghan County Council and the National Trust) has evaluated impacts of elevated ammonia concentrations and nitrogen deposition on sensitive ecosystems in NI. The work has focused on eight designated sites, two of which are upland -Slieve Beagh and Cuilcagh Mountain. Unlike the findings from the 6 lowland raised bog sites, the mean annual concentration of ammonia at these 2 sites has been measured at just below the 1µg m^{-3} annual critical level for ammonia. However levels of nitrogen in plants (including lichens and mosses) sampled from Cuilcagh Mountain SAC were elevated despite ammonia concentrations in the air being just below the 1µg m^{-3} annual critical level. This requires further investigation but may have been climatic and time related (van Dijk et al, 2021).

The adverse effect of ammonia on sensitive habitats is through direct exposure of vegetation to the gas and also when it is deposited on land and water. In many semi-natural and natural habitats, nitrogen is scarce and local species of plants, such as mosses, liverworts, lichens and fungi are very sensitive to added nitrogen. The presence of additional nitrogen from airborne ammonia has a direct toxic effect on these nitrogen-sensitive plants leading to increased vulnerability to drought, frost damage and pests. In addition, excess nitrogen in these environments encourages the growth of nitrogen-loving species such as grasses and nettles, which are fast growing and which out compete sensitive, slow-growing species such as lichens and mosses. This results in a significant impact on upland biodiversity (Guthrie et al 2018) though there is little direct information on the effects on biodiversity (other than plants) in NI.

5. *TREES/ SCRUB/ AFFORESTATION*

In the past the use of land for food production has always superseded growing trees for timber. Hence traditionally only poorer quality land was used for afforestation (with exotic conifers such as Lodgepole pine and Sitka Spruce). These species grow well on upland peatland but create a habitat which is often very low in biodiversity. Such afforestation is state planted and on upland heath or bog. In some cases tree planting or afforestation and scrub removal may be carried out by the landowner (rather than the state). Afforestation, mainly in the form of conifer plantations, and scrub invasion can degrade peatland ecosystems. Protected bird species such as Hen Harrier are negatively impacted by conifer plantations. Habitat and biodiversity loss and increased evapotranspiration and carbon loss are directly associated with trees on blanket bog. Afforestation is often associated with changes in drainage resulting in degraded upland habitats due to biodiversity losses, soil compaction, increased run-off and peat degradation/decomposition potentially causing the release of GHGs (Hambley et al. 2019). However, Sloan et al. (2018) acknowledge that there is a paucity of information available on the complex interactions between changes in soil/peat biogeochemistry and hydrology caused by afforestation, C sequestered by planted trees (biomass C and soil C accumulation) and GHG emissions in the UK although there is some evidence of afforestation increasing soil respiration and decrease in CH4 emissions (Byrne and Farrell 2005). Scrub removal (particularly of invasive scrub species) is a funded measure under EFS and, where carried out will have resulted in habitat improvement. As mentioned previously, the Forest Service no longer ploughs or drains sites prior to planting.

Hill and upland farmers have been encouraged to plant shelterbelts because of the obvious advantages to stock in a cold windy environment. There can be positive benefits to biodiversity from shelterbelt planting - habitat diversity, soil structure and biological enhancement - and negative impacts – they provide a refugia for foxes and crows. Shelterbelts are generally not planted on blanket bog or deep peat for stability reasons, and on shallower mineral/high organic soils the resultant reduction in evapotranspiration can enhance the ecosystem services derived from them. Another point with respect to upland farming and biodiversity. The removal of entitlements from areas of small native woodland planted on hill farms has been seen by farmers as a deterrent to encouraging good environmental practice and encouraging biodiversity.

6. *PEAT CUTTING/EXTRACTION*

Many anthropogenic activities have been responsible for the loss of blanket bog in Northern Ireland and by the late 1980s it was estimated that less than 15% of the original blanket bog remained intact (Cruickshank & Tomlinson, 1990). One such activity has been peat cutting and extraction. Traditionally such turbary was done by hand with little impact on biodiversity. However low cost, low power machines employed for extracting peat were first introduced to NI in 1981 and their numbers increased rapidly over the following decade. The main areas of blanket peat in NI were surveyed for extent of peat cutting/extraction by Cooper, Murray and McCann (1991). They found that the effect of a single cut was to damage surface vegetation, cause compactness, destroy micro-topographic variation, impede drainage and reduce biodiversity in the short term. Multiple cutting created much bare peat. Bayfield et al (1991) reported to DoENI that extruder cutting and milling are particularly damaging, whereas hand cutting and facing were less so. They also found that extrusion compresses the acrotelm (upper layer of blanket peat), raising the water table while reducing the capacity of the surface to hold water so that surface flow and ponding became more frequent.

The effect of extraction on bog hydrology at Glenwherry Hill Farm was reported by Lees (1993). Meharg (1988) studied the effects of cutting once and twice on blanket bog with Heather and Wavy hair grass co-dominant. After cutting once, 42% of cover was dead vegetation, after twice cutting, branched mosses and Bog cotton were co-dominant with dead vegetation. Some abandoned, hand cut areas had higher biodiversity value than intact bog, but the original integrity of the area had been altered.

In an early study on unreplicated plots at Douglas Top, mid Antrim, Meharg (1988) found that species diversity was changed (but not reduced) by successive peat cutting episodes. This important work highlighted the need for a more detailed study on which to base recommendations for future management. As a consequence of the concern over the impact of mechanised peat extraction on habitat quality and grazing potential, and the need to provide a proper scientific basis on which to base recommendations, the Environment and Heritage Service (of DoENI) funded a PhD project to provide quantitative information from replicated trials set up to compare intact and cutover blanket bog flora and fauna. From this project, Todd (1995), found in controlled, replicated trials on 4 sites that: 1 where the dominant vegetation was Purple Moor-grass, after 2 seasons extrusion cutting, the resultant vegetation was still Purple Moor-grass-dominant but the proportion of Deergrass and Fine-leaved Bog cotton had increased; 2 Where the vegetation was Heather with Deergrass, after cutting, Fine -leaved bog-cotton had increased while the proportion of Broad Bog cotton increased 3. On one site which was predominately heather, all vegetation was destroyed by cutting and 4. on another heather-dominant site Deer grass and Fine-leaved bog cotton had replaced the heather. She also measured the effects of extraction on vegetation canopy structure and on spiders and beetles and the interaction of peat extraction and sheep grazing, all in fully replicated trials. Spiders showed a greater decline in species richness and numbers following extraction than beetles. This was largely due to the detrimental effect on canopy structure though some species were recorded on greater abundance on some cutover areas than uncut areas. Sheep grazing was found to have little effect on invertebrate communities; grazing generally exacerbated the effects of grazing on vegetation on cutover areas.

Whilst peat cutting may be detrimental in some respects to particular invertebrate species, some preferred the new habitat or microhabitat created. Todd's (1995) study supports the general findings of Meharg (1988) who noted that the effect of peat cutting was more marked and consistent among spiders than ground beetles. The effect of peat cutting on invertebrates, however, is highly related to the vegetation type of the area subjected to peat cutting. Cooper, McCann and Hamill (2001) investigated vegetation regeneration on blanket mire after mechanized peat-cutting and , as in the other studies, found ericaceous species and Sphagnum particularly sensitive to cutting, typically being replaced by fine-leaved Bog cotton and heath star moss. Vegetation recovery was dependent on frequency of cutting and other environmental pressures.

This work highlighted the need to control incidences of peat extraction, and illustrated that in some scenarios (dependent on ground wetness and vegetation cover) limited (but not repeated) peat cutting may have only very minimal environmental impact. The scientific verification of such conclusions are extremely important in drawing up conservation guidelines which are not totally prohibition-oriented, and recognise the need for properly controlled rural land use activity.

The extent of mechanical peat cutting has not been quantified since Cruickshank et al (1991). The current draft NI Peatland Map being delivered by the James Hutton Institute has not yet been released but should help quantify the current extent of mechanical peat extraction on farmland.

NIEA produced a Position Statement on peat cutting at designated sites (NIEA 2011) which clearly laid out the issues and the reasons for banning extraction from designated sites but the situation is not clear cut due to the existence of Turbary rights and the role of the Planning process in licensing.

7. *CLIMATE CHANGE*

Climate change predictions for the uplands do not carry the same threat as those for drier, shallower lowland soils. Although the likelihood is that predicted temperature increase and drying out will lead to greater levels of vegetation growth in the hills and uplands these do not negate the likely risk to biodiversity of warmer temperatures and heavier rainfall episodes. Hence AE schemes should build in climate resilience by encouraging optimal vegetation condition which is based on best available guidelines targeted in a much more bespoke basis recognising the diversity of vegetation mosaics which each site represents.

Drying out of the peatland surface through direct loss from exposed peat or through increased evapotranspiration from plant cover, results in soil temperature increase, oxidation of the peat, carbon loss through increased root activity and overall increased CO_2 emissions (Oleszczuk et al 2008). Maintaining a damp peat surface and high water table either through rewetting in extreme cases or through retaining a tight mat of vegetation cover as possible will help keep the soil surface cool, control erosion and sequester carbon. Scrub and trees on peatland increase evapotranspiration and dry out the peat and should be removed wherever possible.

8. *OTHER STUDIES*

Flood risk mitigation and water quality enhancement.

In contrast to many lowland wetlands, blanket bogs act as sources of water, with finite storage capacity, and frequently form the headwaters of rivers. Peatland condition influences the capacity to generate flood waters, and although activities such as drainage lower the water table and increase potential storage capacity, drains increase runoff delivery rates. Longer term effects of peatland drainage result in subsidence and changes to plant cover; this enhances rates of water loss. Consequently, artificial drainage on bogs generates flash flow downstream and thus elevate the risk of runoff resulting in flooding, with consequent loss of biodiversity.

Significant numbers of upland areas containing blanket peat are being used as drinking water catchments. There is a linkage between water quality and land use in these areas. Drainage has increased ranges of groundwater fluctuation in peat; this has been linked to higher colour/ dissolved organic carbon (DOC) levels in groundwater and stream runoff. These changes in raw water quality incur additional treatment costs. The combined capacity of blanket bog to regulate flow and water quality feeds into the wider picture of providing society with increased water security. The more intact bogs are, the better they are at maintaining base flow during prolonged dry periods. This arises largely through the high storage capacity of peat-accumulating plant communities (active blanket bog), which facilitates slower drainage to streams. Consequently, improved coverage of active blanket bog contributed to improved water security and reduces the need for upscaling infrastructure to adapt to drinking water demand during more prolonged dry periods. In summary, maintaining as dense a vegetation cover as possible through appropriate grazing (particularly avoiding overgrazing) and encouraging revegetation of bare areas through positive rewetting will all help deliver water quality and retention objectives from peatlands.

Climate forecasts also predict drier summers. This is likely to have many indirect effects including temperature increases which can impact on the rate of biophysical processes, influencing production and release of nutrients (Bardgett et al., 2008). Local factors, such as riparian shading, may significantly reduce water temperature locally, particularly in upland catchments where groundwater temperature has a smaller impact than in larger lowland catchments, thus buffering the impacts of high temperature on water quality (Malcolm et al., 2004). Moreover, increasing temperatures, which together with decreased summer rainfall is likely to disproportionately affect upland areas through greater risk of drought and wildfires. Gillingham et al. (2012) proposed that even a 4°C rise in temperature, would leave upland habitat unsuitable for the ground beetle, *Carabus glabratus* (a key upland indicator species in NI). Birds may also be susceptible to climate change instances where breeding seasons and food abundance fall out of sync (Moss et al.,2005; Both et al., 2006). Such seasonal related changes may have direct effect of plant diversity having possible effects on the length and timing of the growing season as well as survival, growth and reproductive success. It may also lead to changes in observed vegetation cover as warmer wetter climates may encourage growth of graminoids and bryophytes. Therefore, range expansion may be expected where species previously limited by prevailing environmental conditions are able to thrive. This may lead to a more homogenous landscape and have direct effect on grazing management. Conversely, contractions of species ranges may also be observed as species populations are unable to survive. Such changes in species may led to both local abundance and composition changes and impact the relation of biodiversity to ecosystem function.

Another important consideration under scenarios of climate change is that land and farm management practices may change. For example, if winters become milder and wetter, diseases and parasites associated with livestock production may persist for longer leading to the need for more biocide use. This would therefore further exacerbate the impacts outlined above.

Bog bursts/peat slides

Although bog bursts and peat slides are relatively infrequent in Northern Ireland,(Tallis, 2001; Dykes & Kirk, 2001; Dykes, Gunn and Convery, 2008; Dykes 2018) there have been extreme flooding events in more recent years (e.g. Slieveanorra in 1980-7 peat slides; Cuilcagh in 2000,; Glenelly in 2017 -13 slides) which have resulted in locally significant soil cover and vegetation - and hence biodiversity - loss (though this has not been quantified in NI).

Given the predicted direction of climate change with more frequent extreme flooding events highly likely, there is every likelihood this will be an increasing source of biodiversity loss in the uplands. The conditions which cause peat slides/landslips are complex and usually involve a combination of factors - slope, peat depth, land use, extraction history, excavation, accumulation of weather events.

Research findings from previous landslide events in Ireland (Dykes, 2008) showed that 50% of Irish peat landslides have anthropogenic causal factors such as: peat cutting/extraction, drainage ditches, forestry activity, road construction. Short and longer term effects have been: significant impact on, and risk to associated farming activity; complete loss of habitat (and biodiversity); significant impact on water quality and dependent activities downstream of the events, landscape degradation. Over-grazing has not been cited as a primary cause in any of the reports.

9. *MULTIPLE IMPACT STUDIES*

Few replicated studies on multiple impacts of causal factors on upland biodiversity in NI have been carried out in the field. Those that have been reported are mentioned in this report. Significant multi-factor review reports probably represent the best sources of information on from which inferences can be made. These are listed below.

Multi-Impact Research projects

Author	*Impacts*	*Date*	*Region*
McAdam	Factors affecting the botanical composition of hill land -field survey	1983	NI
McFerran et al	impact of burning and grazing on heathland	1995	NI
Meharg	Changing Management and the Ecology of Uplands	1988	NI
Ramchunder, SJ	Environmental effects of drainage, drain blocking and prescribed vegetation burning -Modelling	2009	UK
Todd PA	Ecological effects of mechanised peat extraction (and interaction with grazing) on blanket bogs	1995	NI

Multi-Impact Reviews

Author	*Impacts*	*Date*	*Region*
Artz et al	Managing and restoring blanket bog	2014	Eng
Bleasdale and Sheehy-Skeffington	Agricultural practices generally on upland biodiversity	1992	Irl
Dykes AP,	Natural and anthropogenic causes of peat instability and landslides	2008	UK & Irl
Flexen &McAdam	Review of heather moorland management	2013	Irl
Fraser et al	Comparative diet selection by cattle and sheep grazing	2009	Eng
Guthrie et al	The impact of ammonia emissions from agriculture on biodiversity	2018	UK
Holden	Environmental change in moorland landscapes.	2007	UK
AFBI	Livestock farming impacts on the agri-environment	2021	NI
AFBI	Env impacts of beef and sheep farming in the uplands	2021	NI
Glaves et al	The effects of managed burning on upland peatland biodiversity, carbon and water	2013	Eng
Montgomery & McAdam	impact of land use changes and management on ground beetles	2000	NI

Martin	Review of Upland Evidence Impact of Moorland Grazing and Stocking Rates	2013	Eng
Tucker	impacts of heather and grassland burning in the uplands on soils, hydrology and biodiversity	2003	Eng
Montgomery, McAdam, Smith	Land use and land use change in N I Uplands. Conference reporting range of local studies	1988	NI
Hobbs and Gimingham	Vegetation, fire, and herbivore interactions in heathland	1987	EU

GLOSSARY

AE Schemes/Measures. Agri-Environment schemes and measures.

AFBI. Agri-Food and Biosciences Institute

ASSI. Area of Special Scientific Interest. Areas of Special Scientific Interest (ASSIs) are protected areas that represent the best wildlife and geological sites in Northern Ireland. They are declared under the Environment (Northern Ireland) Order 2002.

Biodiversity. The diversity of all living things at genetic, species and ecosystem levels.

Bog. A particular type of wetland, which is waterlogged by direct rainfall only. Bogs are nutrient-poor and acidic habitats, support a less diverse range of species than other wetlands and contain many unique species that are specialised to bog peatlands.

CAFRE. College of Agriculture Food and Rural Enterprise

CANN Project. Collaborative Action for the Natura Network. This is a cross-border environmental conservation project with a focus on improving the condition of protected habitats and supporting priority species.

Carabidae. Ground beetles

Carbon Sequestration – A natural or artificial process by which carbon dioxide is removed from the atmosphere and stored.

CMPs. Conservation Management Plans

CMS. The Countryside Management Scheme. An AE scheme in NI 1999- 2005. This scheme and any remnants of land under ESA scheme were absorbed into the NI Countryside Management Scheme (NICMS) 2005-2015

CSM. Common Standards Monitoring.

DAERA. Department of Agriculture, Environment and Rural Affairs

EFS. DAERA's Environmental Farming Scheme (2016-). The EFS offers participants a 5-year agreement to deliver a range of environmental measures and has three levels: a **Higher** Level, primarily for environmentally designated sites and other priority habitats**,** a **Wider** Level to deliver benefits across the countryside, outside of environmentally designated areas and **a Group** Level to support co-operative action by farmers in specific areas

ESA. The Environmentally Sensitive Areas scheme. An AE scheme in NI 1985 -1999

Glenwherry. The CAFRE Hill and Upland research and development farm at Glenwherry, Co Antrim.

GHGs. Green House Gases -Carbon Dioxide, Nitrous oxide, Methane

GHRP. Glenwherry Hill Regeneration Partnership Project

GPS. Global Positioning Systems. When fitted to livestock can be used to remotely track animals' movements.

Keepering. Upland heath and moorland management for game species (e.g. Red Grouse). Includes vegetation management, game protection and predator control.

LFA. Land designated by the European Union under the Less - Favoured Area directive (1975) on support for farming in hill and mountain areas. Later divided into SDA (Severely Disadvantaged Areas) and DA (Disadvantaged Areas)

LU. A Livestock Unit. 1 dairy cow approximates to 1 LU. a beef cow , 0.8, a ewe 0.2.

NICS. Northern Ireland Countryside Survey

NIEA. Northern Ireland Environment Agency

Raptors. Birds of prey or predatory birds, which are carnivorous and actively hunt and feed on other vertebrates (mainly mammals, reptiles and other smaller birds)

SAC. Special Area of Conservation. An EU land designation

Sequester. Take up Carbon from the atmosphere into soil or plants.
SPA. Special Protection Area. An EU Landscape directive

SSRMP. Site-Specific Remedial Management Plans. A component of entry into the Higher Level EFS.

Sustainable Management. Management of natural resources in a way and at a rate that maintains and enhances the resilience of ecosystems and the benefits they provide.

Turbary. The term used to describe the right to cut turf on a particular area of bog,

UW(T). Ulster Wildlife (Trust)

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***Evidence based case studies considered*;**

"Source to Tap"; Derg catchment; F-W Pearl Mussel Project; Glenwherry Hill Regeneration Project; EIPs in Ireland-Hen Harrier; Burren Life , Wicklow Hills