ASSESSING THE ROLE OF 'GREEN HAY' IN THE CREATION OF HAY MEADOWS AT THE NATIONAL BOTANIC GARDEN OF WALES AND THE IMPLICATIONS FOR THE MANAGEMENT OF AMENITY LAND FOR BIODIVERSITY

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Author's Declaration

I declare that the work in this dissertation was carried out in accordance with the regulations of the University of Wales, Trinity Saint David. The work is original except where indicated by special references in the text and no part of the dissertation has been submitted for any other degree.

Any views expressed in the dissertation are those of the author and in no way represent those of the University of Wales, Trinity Saint David.

The dissertation has not been presented to any other University for examination either in the United Kingdom or overseas.

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Signed: Laura Davies

Date: 20th August 2023

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Abstract

Flower-rich hay meadows contain some of the highest levels of biodiversity of any habitat in the world. However, as a result of agricultural intensification they have all but disappeared in the UK. It is assessed that there are only 1605 hectares of lowland hay meadows left in Wales. This is regarded as a priority conservation habitat in Wales and efforts have been made within the Waun Las National Nature Reserve at the National Botanic Garden of Wales to restore this important habitat.

Meadow species can also be found growing along roadside verges and within parks and public spaces. The improved management for biodiversity of this land by local authorities and other agencies offers opportunities to expand the area of land available for meadow communities, reduce fragmentation, improve connectivity and create a genetic reservoir for recolonisation.

This research aimed to establish long term monitoring plots within each meadow to assess the success of the use of 'green hay' as a restoration method when applied to species-poor neutral pasture, for this research project and for the long-term. The study surveyed the effects of green hay on the plant communities within two meadows Cae Derwen and Cae Gwair treated in 2016 and 2019, respectively, and compared the plant community to that found in the donor meadow, Cae Tegerianau. The results suggested that the green hay treatment increased species richness within both meadows and also showed some evidence for the development of the desired MG5 community in Cae Derwen although this was not yet established in the more recent Cae Gwair.

The questionnaire of biodiversity officers at Welsh local authorities showed that a broad range of restoration techniques are being used to support biodiversity in grasslands under local authority management; that these areas are likely to expand in the future and that there is the opportunity to create considerably more species rich grassland within the public realm if the barriers surrounding public attitudes, capacity and skills, political will and investment are overcome with direction and support from the Welsh Government.

Table of Abbreviations

CD	Cae Derwen
CG	Cae Gwair
CT	Cae Tegerianau
ha	hectare
LA	Local Authority
LNP	Local Nature Partnership
NBGW	National Botanic Garden of Wales
NVC	National Vegetation Classification
SNG	Semi-Natural Grassland
SOM	Soil Organic Matter
WLNNR	Waun Las National Nature Reserve

1.0 Introduction

1.1 History & Cultural Importance of Hay Meadows

Hay meadows are a manmade creation. In parts of Eastern Europe, there are grasslands that have been in existence since Neolithic times, established when forest clearings were first made to create opportunities for the grazing of domesticated livestock (Poschlod, Baumann and Karlik, 2009). Although it is believed that haymaking begun in the Iron Age, it is from Romans time that direct evidence, in the form of long scythes, has been found of that demonstrates that techniques for mowing and haymaking had been developed and as a result the managed meadow had become established (Hodgson *et al.*, 1999). There are deposits containing cut stems of grasses along with pollen or seed evidence of Oxeye Daisy, Yellow-rattle, clover and vetches at Claydon Pike, Gloucestershire, that show that haymaking was underway within the United Kingdom by 2nd Century AD (Robinson, 2007).

Stored hay enabled increasing numbers of farm animals, particularly cattle, to be kept through the winter and as a result meadows were often the most valued type of land on a property (Peterken, 2019). Making sufficient volume of hay was vital to the survival of the farm and increasingly as hay meadows became larger, the process became much more of a community effort with large gangs of men and women needed to cut, 'ted' and built hay into haycocks and finally move the dried hay into haylofts.

"*The technologies which have had the most profound effects on human life are usually simple. A good example of a simple technology with profound historical consequences is hay. ... It was hay that allowed populations to grow and civilizations to flourish among the forests of Northern Europe. Hay moved the greatness of Rome to Paris and London, and later to Berlin and Moscow and New York*." (Dyson, 1988)

This process has not just had a huge impact on the economic development of civilizations but on our collective memory, culture and the arts from Shakespeare's A Midsummer Night's Dream ("Good hay, sweet hay, hath no fellow") to Constable's The Hay Wain. Sunny meadows teeming with flowers and insects, and later the collective endeavour of the hay-making evoke a nostalgia for the quintessential unspoilt British countryside.

1.2 Biological Importance and Conservation of Hay Meadows

These flower-rich hay meadows teeming with wildlife are not just of immense cultural importance but are some of the most biodiverse environments in the world (Dahlström, Iuga and Lennartsson, 2013), providing a wide range of ecosystem services such as flood reduction, habitat, food resources and carbon sequestration (Tälle *et al.*, 2016). Tragically, these semi-natural grasslands have all but disappeared as agricultural intensification has led to the relatively unproductive hay meadow being abandoned or ploughed under for either arable crops or heavily fertilised silage fields for fodder (Strijker, 2005). Figure 1 below shows that in Wales there is 13 times as much improved grassland i.e., silage fields, improved pasture, etc., as there is of the priority habitat of semi-natural grassland (SNG), a mere 78,300 ha out of the total area of Wales of 1.8 million ha (under 5%).

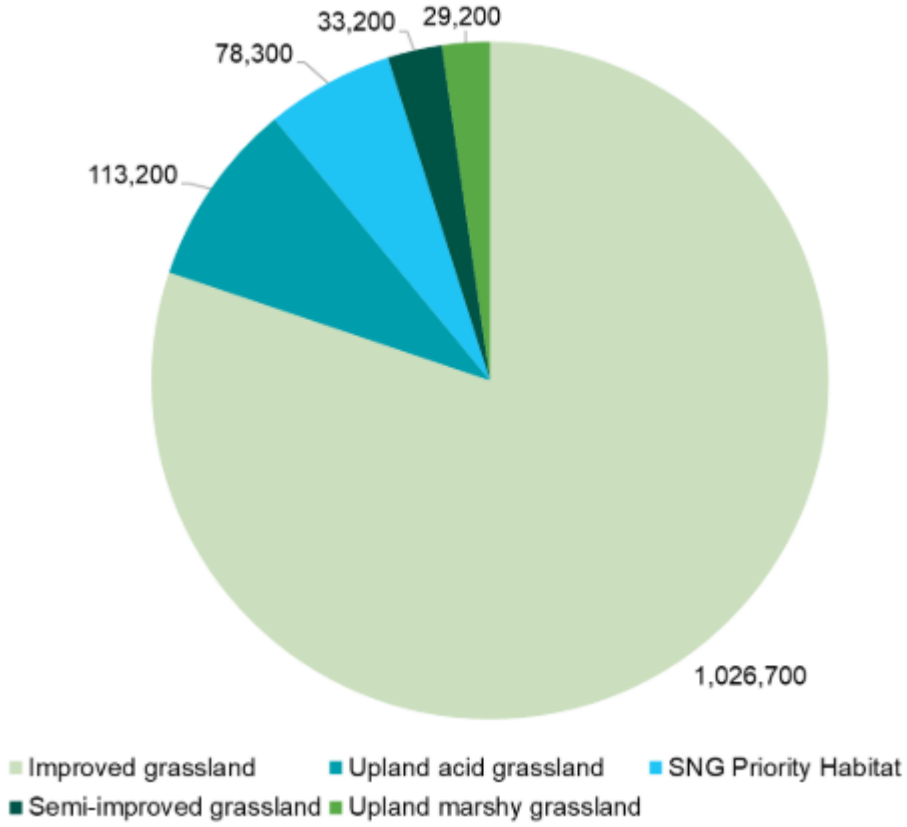

Figure 1 Grassland Areas in Wales in hectares (Blackstock et al., 2010) in (SoNaRR, 2020)

There is a concerted effort to protect and restore these important ecosystems, as demonstrated by conservation and education projects such as Save Our Magnificent Meadows (Plantlife, 2022) and the recent recognition of moist or wet mesotrophic to eutrophic hay meadow as endangered and low and medium altitude hay meadow and mountain hay meadow classified as vulnerable in the European Red List of Habitats (Janssen *et al.*, 2016). There are a range of different methods that have been pursued in the process of recreating/restoring species rich hay meadows, including management through timed cuttings, translocation of turf, addition of commercial dried seed mixes, addition of plugs, locally harvested seed by threshing or brush collector and the spreading of 'green hay' (Good *et al.*, 1999; Schaumberger *et al.*, 2021).

'Green hay' is plant material that is harvested from a donor site whilst the grass is still green and before the wildflowers and grasses have dropped the majority of their seeds. This fresh material is then spread within the same day, preferably within the hour over a receptor site, where the hay will then dry and release the seed of the desired species community. This method is increasingly being promoted as a cost-effective method of reinstating species rich grassland (Plantlife, 2018).

1.3 Research Aims and Rationale

This research will look at the use of green hay or hay transfer as a way of establishing a species-rich grassland on previously species-poor semi-improved grassland by studying the impact of the application of green hay to two fields on the Waun Las National Nature

Reserve (WLNNR) at the National Botanic Garden of Wales (NBGW) in Carmarthenshire. The use of green hay as a restoration method is increasing across Europe (Wagner, S. Hulmes, *et al.*, 2021). The Botanic Garden itself has been supplying both green hay and brush-harvested and dried meadow seed for conservation projects as a source of income for a number of years (Langridge 2021, pers. comm.) yet there has been no research carried out at NBGW to consider how effectively the species present in their donor meadows are represented in the species of newly created meadows created with their 'green hay' and what proportion of species are successfully transferred. Despite this, anecdotally at least, the technique is regarded as successful and is promoted by conservation organisations and to private individuals (Langridge, 2021a). There is also a relative lack of published research of the effectiveness of 'green hay' despite it now being the most common method used on restoration projects in the last 10 years (Kiehl *et al.*, 2010). A literature search revealed none completed in Wales on lowland grasslands in recent years, despite Figure 2 from the most recent State of Natural Resources Report showing that of the 78300 hectares of semi-natural grassland priority habitat mentioned above, there are only 1605 hectares are of lowland hay meadow left in Wales.

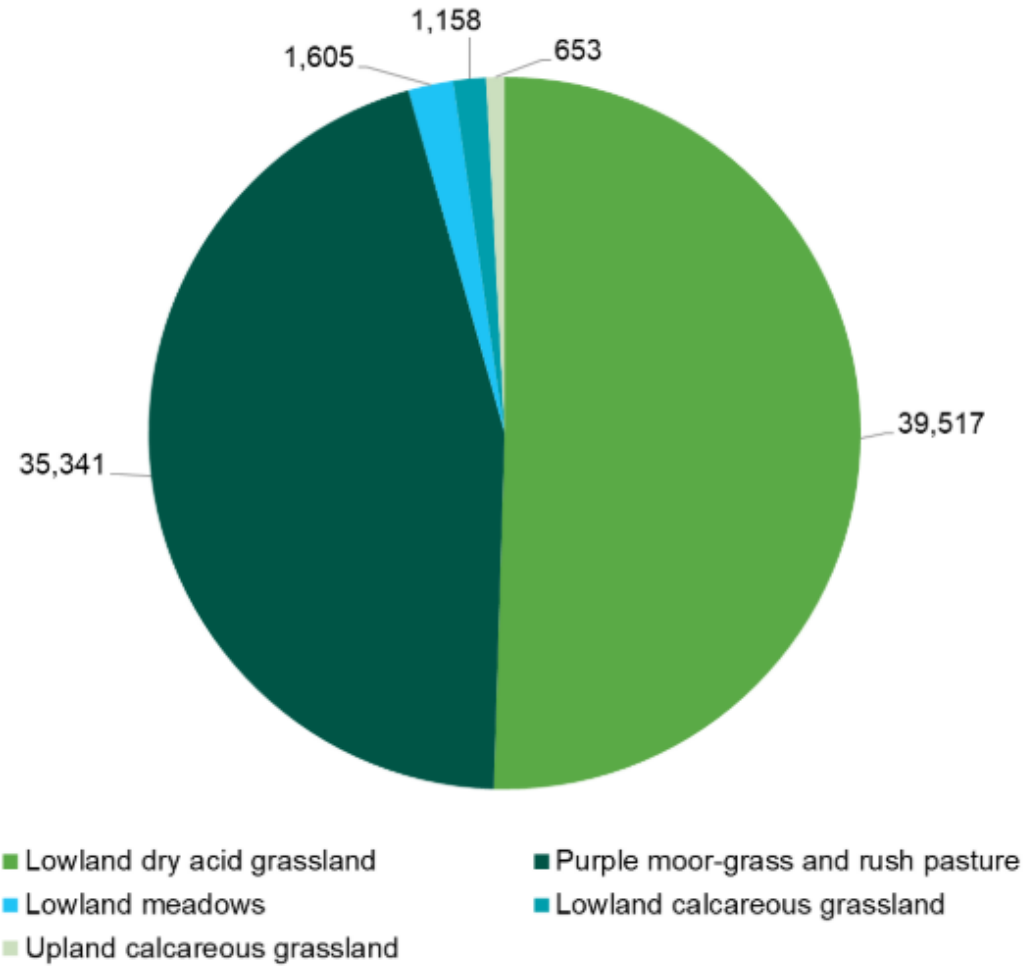

Figure 2 Semi-natural grassland Priority areas in Wales in hectares (SoNaRR, 2020)

One of the challenges of researching the impact of conservation methods such as this, is the length of time before impact can be measured. It is typical for longitudinal studies to be carried out over a significant number of years to measure the impact of conservation actions on species establishment for example, 5 years (Cornish and Hooley, 2012) and 11 years (Sullivan, Hall and Ashton, 2020) and many species take years to appear or reach flowering stage (Bischoff *et al.*, 2018). The fact that the two fields at WLNNR had received the application of green hay a differing number of years apart and the existence of some baseline data taken prior to the application of green hay, mitigates some of the limitations of researching the impacts of conservation activities in a single growing season and enables the quasi-longitudinal study to be attempted.

In common with the situation at WLNNR, many species-rich grasslands exist in isolation, in this case surrounded by woodland, formal gardens and semi-improved and improved pasture. Fragmentation is cited as a particular threat to the survival of meadow species (Blackstock *et al.*, 1999). If insufficient land is available to be reverted to meadow habitat, or suitable agricultural land allocated to create new species-rich hay meadows then other types of land such as road verges and other areas of grasslands need to be considered as appropriate alternatives. Road verges, in particular, in addition to increasing the extent of meadows would also enhance connectivity due to their linear and continuous situation.

In addition to assessing the method used for improving the biodiversity of agricultural land at WLNNR, this study will also survey the methods being used within Local Authorities within Wales for improving the biodiversity of grassland under their control and the challenges and barriers facing Local Authorities managing grassland for biodiversity and using green hay as a restoration method, in particular.

1.4 Research Objectives

Objective 1: Does species richness increase over time following application of green hay?

Objective 2: Are the plant communities within the receiver field developing towards the plant community in the donor field and/or a desirable NVC community?

Objective 3: Establish fixed survey plots within each field for the long-term monitoring of the meadow plant community.

Objective 4: What methods are being used to manage road verges and amenity grassland within local authorities across Wales?

Objective 5: What are the barriers to using green hay to increase biodiversity of local authority grasslands?

Objective 6: What would help overcome barriers to expanding the areas of grass being managed for biodiversity within local authorities?

2. Literature Review

This chapter will provide an overview of existing research concerning the key themes highlighted in the Introduction. The chapter will firstly look at the features, management and importance of hay meadows with a focus on why the many ecosystem services they deliver mean that their restoration or recreation is such a conservation priority.

There will be a review of the different methods currently being used to increase the floristic species diversity of semi-improved grassland and the challenges and opportunities associated with the various techniques with a particular focus on the use of 'green hay' to assess the rationale for this research. Examples of where the use of 'green hay' has been trialled or studied in other locations will be assessed.

The final part of the literature review will look at the value and benefits of non-agricultural land as spaces for creating flower-rich flower meadow. Local authorities and other public bodies are the custodians of large areas of public land, particularly road verges, parks and other amenity land. They are increasingly being directed by government policy and legislation to manage their land holdings sustainably to help tackle the climate and biodiversity crisis and provide their residents with increasing access to good quality green space. In Wales, the Wellbeing of Future Generations Act (Welsh Government, 2015), the Senedd declaring a Nature Emergency (Senedd, 2021) and policy documents such as the Greenspace Toolkit (Natural Resources Wales, 2023a) highlight the responsibilities of local authorities and demonstrate the direction of travel. However, they face a range of challenges and barriers, when turning regularly mown grass into meadows, not least the attitude of residents (Weston, 2023).

2.1 Meadows

Meadows are semi-natural grasslands (SNG) that are mainly constituted of wild species but developed by human activity (Dahlström, Iuga and Lennartsson, 2013). Peterken, (2019) describes 'meadows' as semi-natural grasslands that are left ungrazed between spring and late summer before they are cut for hay. This distinguishes them from pastures which can be grazed year around, although as both are managed, the timing and extent of grazing can be altered seasonally or annually. A pasture left ungrazed will resemble a meadow in high summer and a meadow can become pasture and likewise a pasture can become meadow.

Meadows are therefore defined as semi-natural grasslands because they are dependent on and modified by human intervention (Tälle *et al.*, 2016). They are managed systems, albeit with an absence of intensive cultivation such as regular ploughing and reseeding, or the cyclical application of fertilizers or pesticides or the typical treatment of a silage field (described as improved grassland) which may be harvested three or four times per year preventing flowering and the setting of seed. These semi-natural grasslands were formed from the modification of natural grasslands or the deforestation of woodlands, and as a result they are colonised by a mixture of species that have their origin in the ground flora of

open woodland, floodplain woods, steppe meadows, heaths and the edges of woodland glades (Ellenberg, 1988).

Unimproved neutral grassland, such as hay meadows, are classified as MG5 *Cynosurus cristatus – Centaurea nigra* (Crested Dog's-tail – Common Knapweed) grassland community under the National Vegetation Classification system with further sub-communities according to species present (J. S. Rodwell, 1992).

As well as in agricultural settings, types of semi-natural meadow habitat can be found on roadsides verges, in the 'rough' of golf courses, more neglected areas of old churchyards, beneath orchards, within public open spaces, anywhere in fact where grass and other herbaceous plants are allowed to grow uninterrupted and subject to a late summer mowing (Peterken, 2019).

2.2 Importance of Meadows and other semi-improved grasslands

2.2.1 Biodiversity Hotspot

Research assessing the species-richest areas of the world, found that the most biodiverse habitats, at spatial sizes smaller than 50m², were those managed as semi-natural grasslands with virgin tropical forests, the most species-rich at the remaining three largest spatial sizes out of the 18 assessed. The ancient, traditionally managed hay meadows of the Carpathian mountains in the Czech Republic were the record breakers for species richness for plot sizes of 0.004, 0.25, 16, 25 and 49 m² (Wilson *et al.*, 2012). Given the high numbers of species present (Myers *et al.*, 2000) highlighted the importance of these species-rich areas as conservation priorities.

Many meadow species are restricted to semi-natural grasslands, giving these habitats an elevated conservation value (Tälle *et al.*, 2016) due to high levels of endemism. Europe has over six thousand endemic higher plants and of these 18% are supported by grasslands, the second largest group of plants with a restricted habitat (Squires *et al.*, 2018). The decline in European semi-natural grasslands whether through neglect or agricultural intensification has produced a steep decline in the range of plants and animals supported (Poschlod and WallisDeVries, 2002).

2.2.2 Habitat

A diverse range of plants and animals are sustained by flower-rich meadows, including insects (Schwarz *et al.*, 2011) and insect-feeding birds (Seibold *et al.*, 2019), but also lower plants such as fungi, particularly waxcap fungi (Sanderson, 1998).

In Wales, semi-natural grasslands are vital for the range of higher plants, invertebrates and fungi that they support (SoNaRR, 2020). The undisturbed nature of the soils beneath hay

meadows supports even greater soil biodiversity, particularly of larger invertebrates such as earthworms and mites (Tsiafouli *et al.*, 2015).

A key indicator of the condition of this habitat and its basis for providing further ecosystem services is the diversity and health of higher plants. The 'shutting up' of hay meadows between spring and summer enables the vegetation to grow, flower and set seed unimpeded, providing a broad range of benefits such as nesting material and opportunities, a varied supply of nectar for pollinators (Byrne and delBarco-Trillo, 2019), seedeaters and both invertebrates and invertebrates that feed on plant tissue (Lavorel, 2013). A meta-analysis of habitat restoration projects and their impact on wild bee populations found strong evidence for their beneficial impacts (Tonietto and Larkin, 2018) and reductions in wild and honey bee populations have been directly linked to the loss of species-rich habitat (Biesmeijer *et al.*, 2006).

Calcareous and neutral grasslands have been shown to be the habitats with some of the highest recorded nectar levels (Baude *et al.*, 2016). Restored species-rich meadows are therefore vital for conserving insect populations and as well as benefitting bees, they provide forage for parasitoid wasps (Jervis *et al.*, 1993) and the four most species-rich butterfly habitats have been found to be different types of grassland (Wallis de Vries and van Swaay, 2009).

2.2.3 Carbon Sink

Across the globe, the soils beneath grasslands contain substantial stores of carbon in the form of soil organic matter (SOM) which is made up from decomposing plants, animals and microbial organisms (Lützow *et al.*, 2006).

Soil holds more carbon than the atmosphere and vegetation combined(Batjes, 1996), the storage of carbon in up to the first 3 metres of soil is estimated at approximately 4000 PgC (4 billion metric tonnes), although it continues to transfer between these carbon sinks with all three acting as both a potential source and reservoir as carbon cycles between them (Lal, Negassa and Lorenz, 2015). Read et al. (2009) estimated that temperate grasslands within their soils and vegetation (the majority with the soils) sequester approximately 12.3% of the world's carbon, the third largest after peat wetlands and boreal forests. In a survey of 180 permanent grasslands across England it was shown that carbon stocks within grassland soils were vulnerable to changes in management and negatively impacted by intensification through increased grazing and fertilizer even to a depth of over 1 metre. Interestingly, the highest levels of soil carbon were found in grasslands that were classified as 'intermediate' including fields with an average of 15 species per m^2 that were cut once for haylage or silage with the regrowth grazed in late summer and autumn with the addition of some fertilizer. Extensively managed grassland cut once for hay and with further reduced fertilizer application and an average of 21 plant species per m^2 contained the next highest soil carbon content (Ward *et al.*, 2016). However, other studies on the impact on plant diversity on soil

carbon levels suggest that the higher the diversity the higher the carbon levels (Weisser et al., 2017; Chen et al., 2020).

Enhancing SOM levels helps counteract increasing greenhouse gas (GHG) concentrations in the atmosphere (Paustian *et al*., 1998) whilst also providing mitigation of other effects of global warming, such as flooding, by increasing water holding capacity.

2.2.4 Flood and drought reduction and erosion regulation

Soil becomes more vulnerable to compaction and erosion with a resulting decline in soil biodiversity following a reduction in soil organic matter (SOM) in both mineral and peat soil, caused by removing the cover of permanent meadow or pasture (ADAS, 2019).

The roots of perennial meadow plants help solidify the banks of water channels, alleviates the impact of water flowing through floodplains and enables the penetration of water into the soil (Reed *et al.*, 2021). Figure 3 shows that the roots of some meadow perennials such as Common Knapweed (*Centaurea nigra*) and Great Burnet (*Sanguisorba officinalis*) can penetrate up to 2 metres deep into the soil. In a comparison of old and young grasslands, it was found that older grasslands were less affected by heavy rainfall because of a better soil structure which improved microporosity and were also better able to resist drought conditions (Iepema *et al.*, 2022). The increased biomass of the root systems of long-established meadows increases both the water-holding capacity and the water infiltration rates of grasslands (Lal, 2018) but they can become compacted over time due to the passage of livestock and particularly agricultural machinery in frequently moved silage fields (Batey, 2009). One of the challenges in Wales is that despite semi-natural grassland being able to play a significant role in flood prevention during heavy rains, it is unfortunate that currently intensively managed, often compacted, improved grasslands are often the dominant vegetation of floodplains.

2.3 The Loss of Meadows

By reviewing survey data from between 1930 and 1984 (Fuller, 1987) estimated 97% of lowland semi-natural grassland (under which flower-rich meadows are classified) had been lost with approximately 200,000 hectares remaining. He was concerned that this may have been an overestimate because grassland recorded as semi-natural or ‘unimproved’ with regard to agricultural standards, may still have been of low species and floristic diversity and dominated by courser grasses such as *Lolium perenne* (Perennial Rye-grass). The development of the National Vegetation Classification (NVC) from 1991, codified the classification of grassland communities based on their species composition (John S. Rodwell, 1992) and this coincided with co-ordinated grassland surveys at national and county level. In Wales, for example, comprehensive ‘Phase 1’ habitat surveys coordinated by Countryside Commission for Wales (CCW), had covered 80% of grasslands by 1997 and any areas of half

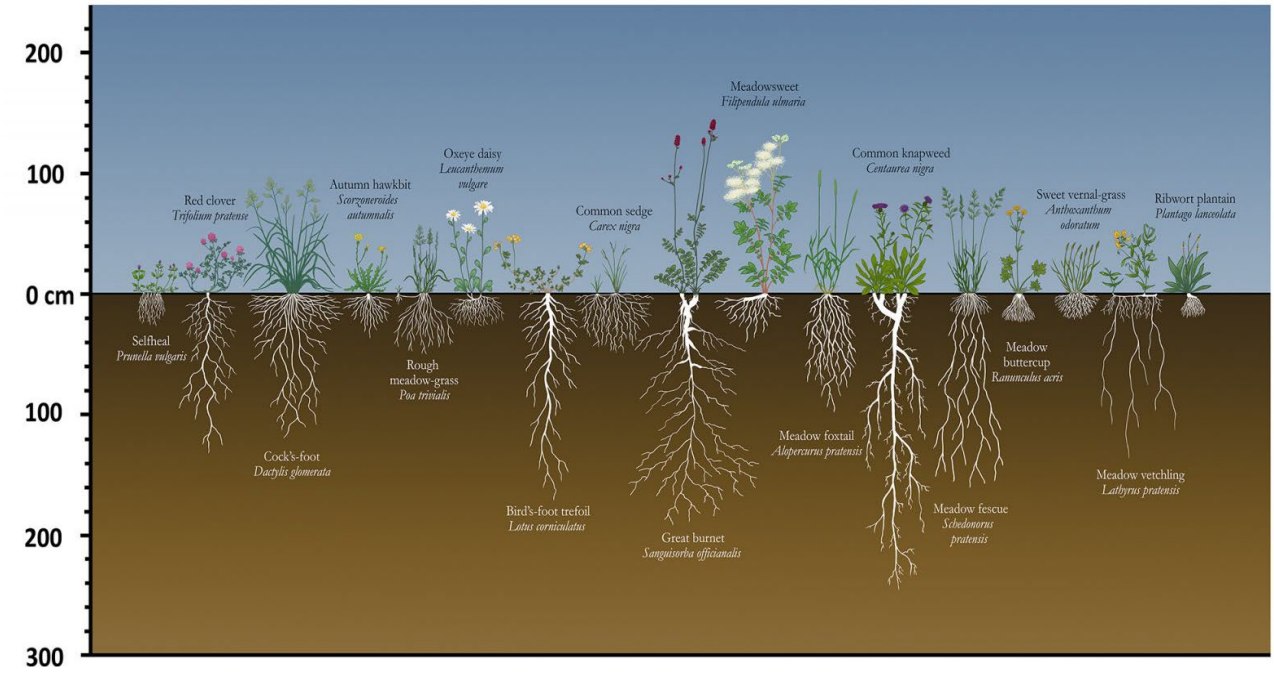

Figure 3 The above and below ground structure of meadow plants (Bowskill V. and Tatarenko I., 2021)

a hectare or more rare types of plant communities or 5 hectares or more of common semi-natural grassland vegetation were further surveyed at 'Phase 2' level to identify the grassland community and species composition using quadrat sampling. Using data from these NVC-based surveys (Blackstock *et al.*, 1999) were able to more accurately assess the most floristically diverse remaining areas of semi-natural grassland which had conservation value. Britain has five types of lowland grassland types (neutral or mesotrophic, calcareous, acidic, fens and rush pasture, and calaminarian) that are classed as semi-natural. It is neutral or mesotrophic grasslands which are typically used for hay production, the other grassland types tend to be used as grazing pasture (Crofts and Jeffereson, 1999).

The work of (Blackstock *et al.*, 1999) estimated that the true figure of flower rich meadows remaining was between 50,000 and 100,000 hectares, supporting Fuller's view that his original figure was an exaggeration and of these they estimated that a remnant of 7,500 to 15,000 hectares of neutral grassland hay meadows remained. Later studies have demonstrated that these losses have continued in Scotland (Dadds, N.J. and Averis, 2014) and across Europe (Diekmann *et al.*, 2019) and (Stevens *et al.*, 2010) found a quarter of non-designated sites across Wales showed a substantial decline. Reductions in the area of meadow habitat has led to significant reductions and even losses in Welsh populations of Green-winged Orchid *Anacamptis morio*, Frog Orchid *Coeloglossum viride* and Lesser Butterfly orchid *Platanthera bifolia* (Stroh *et al.*, 2019).

2.4 The Restoration of Meadows

In 2021, the United Nations declared the following 10 years as the Decade on Ecosystem Restoration, which provides an opportunity to further drive forward the restoration of semi-natural grasslands (Valkó, Rádai and Deák, 2022a). The importance of the conservation and restoration of meadow habitats has for decades been recognised by governments by their inclusion in agri-environment schemes; in Wales such as Glastir and Tir Gofal; Higher Level Stewardship in England and also EU funded schemes such as LIFE plus (Török *et al.*, 2011). Conservation charities are also funding and promoting the restoration of species-rich meadows (Plantlife, 2018; Hosie *et al.*, 2019). Increasingly, grassland restoration or recreation is a requirement of major construction and development projects like roadbuilding, as mitigation or compensation schemes (Sengl *et al.*, 2017). The need for continuing research to monitor outcomes is essential to improve and highlight success rates in order to maintain funding and support for such programmes (Török *et al.*, 2011), however the reality is that these schemes are proceeding anyway, funded by agri-environment schemes and being delivered by farmers and landowners with monitoring limited to the conditions of the grant being met. These semi-natural grasslands are also increasingly a source of income as their seed is collected and used for conservation schemes (Bullock *et al.*, 2011).

There are challenges in assessing and comparing the success of different schemes because of the variations in site conditions and restoration methods used but also the criteria and standards used to describe what success looks like (Kiehl *et al.*, 2010; Török *et al.*, 2011). Restoration schemes on ex-arable land require the addition of externally sourced seed mixes, those on previously intensively managed pastures rely on the seed bank of the site or surrounding landscape, accessed through grazing or mowing regimes, to restore biodiversity (Waldén *et al.*, 2017). The majority of restoration schemes are done through agri-environment schemes or conservation bodies and are not necessarily monitored as part of a research project and are usually completed without a control element for comparison because the restoration is applied to the whole field. Within the horticulture sector of botanic and public gardens, techniques and experiences of managing grass areas for biodiversity by reducing moving have been discussed at conferences for over 15 years with the sharing of practical experience and anecdotal evidence by horticulturists (PlantNetwork, 2022).

Where there have been studies on the effectiveness of grassland restoration schemes, they have often focused on the restoration of meadows habitat on formerly arable land. Examples such as, a study of the natural recolonisation of abandoned arable fields in Hungary and the impact of soil nutrients, particularly phosphorus (Boecker *et al.*, 2015), or a project in South of France comparing survival rates of the seedlings of perennial target species, which struggle to re-establish populations through the introduction of seed via hay transfer or the soil seed bank, in melon and cereal fields abandoned decades before. In this case, the impact of grazing, surface rocks (often removed from cultivated land) and neighbouring plants on the establishment of target species were assessed (Buisson et al., 2015). In a more recent study, the impact of hay transfer was studied on an intensively managed ex-sunflower field, again in Hungary, and how the similarity between the restored

field and the donor fields diversity changed over time for meadow specialists, generalists and weed species (Valkó, Rádai and Deák, 2022b), over six years in this case.

In the UK, research has concentrated more on restoring meadows or increasing the biodiversity of existing semi-improved and improved grassland, such as a 11-year study comparing the community composition of the donor and restoration sites and the impact of geographical isolation during the restoration of upland hay meadows in the Yorkshire Dales (Sullivan, Hall and Ashton, 2020). A review of restoration schemes on agriculturally improved lowland grassland in England and Wales assessed the impact of extensive management of the sward and nutrient levels as key factors governing success (Walker *et al.*, 2004).

On two sites in Southern England, Pywell et al. (2007) experimented on the impact of 5 main treatments (de-turfing, harrowing, slot-seeding, addition of nitrogen and potassium to reduce phosphorus) and intensive grazing) in combination with secondary treatments - the addition of Yellow Rattle (*Rhinanthus* spp.), molluscicide and soil inoculation with fungi, with all plots being managed as hay meadow with an annual cut. This is reflective of the majority conservation projects which seldom use one method but use a combination of methods depending on budget, resources and accessibility, etc.

The main aim of meadow restoration schemes is to reduce the dominance of grasses by reducing soil fertility to create opportunities for other flowering plants. Restoration schemes will often use more than one approach and there are a variety of methods that have been used to achieve either or both aims. A review of over 80 different conservation projects in 2012 showed that the key methods studied were restoration using commercial or local-provenance seed mixes (including the hemi-parasite *Rhinanthus* spp. (Yellow Rattle)), using green hay or natural regeneration through sward and nutrient management (Stevens and Wilson, 2012).

2.4.1 Sward management

One of the challenges of using annual hay cuts alone to establish a species-rich meadow from semi-improved pasture is the time it takes. At NBGW, the first field within the parkland estate that was targeted to improve its biodiversity because it contained remnant patches of indicators species of MG5 *Cynosurus cristatus–Centaurea nigra* grassland (J. S. Rodwell, 1992) was Cae Trawscoed (Bosanquet, 2011). Since the late 1990s, annually the field has been hay-cut in late summer and the arisings removed. This has been the only intervention and no wildflower seed has been added. For the first decade it was dominated by Ribwort Plantain (*Plantago lanceolata*) as populations of Yellow Rattle (*Rhinanthus* spp.) established and fertility reduced yet today, this field contains over 80 different species of grasses and flowers (Langridge, 2021 per comms), including large numbers of the four orchid species that are found growing wild at NBGW (Southern Marsh Orchid (*Dactylorhiza praetermissa*), Common Spotted Orchid (*D. fuchsia*), Heath Spotted Orchid (*D. maculata*) and Greater Butterfly Orchid (*Planthera chlorantha*) as shown in Figure 4. The experience from Cae Trawscoed demonstrates that in a nature emergency and the 2 to 3-year timescale of many funded projects, sward-management alone is not a viable option to deliver results. This anecdotal evidence is supported by a review of lowland grassland restoration projects

carried out on previously intensive agricultural land where it was found that aftermath grazing following a hay cut was better at increasing numbers of target species than grazing or cutting alone and that depending on the fertility of the land may take over 20 years to revert to species-rich meadow using sward management alone(Walker et al., 2004).

Figure 4 Species-rich meadow habitat in Cae Trawscoed (author)

Grazing, whether by cattle or sheep, can be key to introducing disturbance to the soil and creating gaps in the sward for the germination of seed from hay crops, sown seed or natural dispersal (Smith *et al.*, 2000). Aftermath grazing prior to and after the sowing of target seeds or spreading of hay creates gaps in the sward to enable germination (Walker *et al.*, 2004).

The timing of both grazing and cutting is also influential on the establishment of different species. Allowing grazing too late into the spring growing season, leading to defoliation, can have a detrimental effect on earlier flowering species such as Pignut (*Conopodium majus*) (Critchley, Fowbert and Wright, 2007). Traditional practice often involved a hay cut in mid-July when the grass is at its peak condition. This obviously benefits those species that flower earlier and it could be expected that they would then be more prevalent within the meadow. The establishment of later flowering perennials such as Greater Burnet (*Sanguisoba officinalis*), Common Knapweed (*Centaurea nigra*) and also later-flowering orchids requires a later cut which enables the species to successfully set seed. This supports the results of a study of floodplain meadows species which found that there needed to be both an early and late collection of seed to transfer the full community because a late only

collection will not capture those seeds which have already ripened and dropped to the ground (Bischoff et al., 2018). (Critchley, Fowbert and Wright (2007) concluded that an extended period of spring grazing was the most detrimental and this corresponds with evidence showing that in warmer seasons the meadow should be shut up earlier and periodic late cutting extending the hay cut into September better reflects the management of the past where although the cut may have started in mid-July in the absence of modern machinery it continued over a longer period allowing a wider range of flowers to set and drop their seed (PINCHES *et al.*, 2013).

2.4.2 Use of the hemi-parasite Yellow Rattle (*Rhinanthus* spp.)

Hemi-parasites (Figure 5) are used to aid the restoration of diverse grassland communities by reducing the vigour of the potentially most dominant grassland species such as the grasses *Agrostis* spp. (Bent grasses), *Lolium perenne* (Perennial Ryegrass), *Holcus lanatus* (Yorkshire Fog) and *Dactylis glomerata* (Cock's-Foot) and *Trifolium repens* (White Clover) and also the overall biomass and sward height of vegetation where it is present (Bullock and Pywell, 2005). The benefits of using Yellow Rattle in meadow restoration include its relative low cost and ready availability but also the other ecosystem services it provides such as being a nectar source, particularly for bee species (Meek *et al.*, 2002). *Euphrasia* spp. (Eyebright) is another hemi-parasite but has reduced impact compared to *Rhinanthus* spp. due to being a much smaller plant (Bullock and Pywell, 2005). Some researchers recommend using hemi-parasites as one element of a phased approach, using it initially to reduce competition before introducing target species in subsequent years (Pywell *et al.*, 2007).

Figure 5 Yellow Rattle (left) and Eyebright (above) in Cae Derwen at NBGW (author)

2.4.3 Introduction of wildflower plant material

There are a number of ways of adding species diversity to grassland – direct sowing using commercial or local provenance seed, brush-harvested seed mixes, the strewing of green

hay from donor sites, the planting of planting plugs or potted specimens or even the translocation of meadow turf. There are pros and cons to each method, Sengl et al. (2017) found the translocation of turf to be the most effective of the 5 techniques they tested but this could be outweighed by cost and damage to the donor site and is usually only used if the donor site is under threat. They found green hay transfer (Figure 6) moderately successful and cost effective but is dependent on finding a suitable donor site within the locality so that the collection from the donor site, transportation and then spreading on the recipient site takes no more than an hour. This prevents the green hay having time to heat up and impact seed viability (Sullivan, Hall and Ashton, 2020). Techniques such as green hay and brush-harvesting require access to specialised equipment and also sites that are accessible to machinery (Kiehl *et al.*, 2010). Advantages of brush-harvesting over 'green hay' include the ability to clean, dry, store and test the composition and viability of the seed mix (Schaumberger *et al.*, 2021). It can also be carried out several times over the same site during the same season, collecting species with a range of phenologies because it only takes off the seed heads rather than cuts the whole plant off at the base although this can cause shorter species to be missing from the collected seed (Albert *et al.*, 2019). The collection of seed by hand can be used in sites difficult to access and also enables the selection of seed from desired species rather than the collection of seed from the whole plant community but will only produce enough seed to restore smaller areas (Scotton and Ševčíková, 2017). However, hand collection enables the propagation of target species that only exist in small numbers both in the plant community, the seed bank and in resulting seed mixes such as from green hay. Plants that are slow to develop and poor competitors or where seed is scarce can benefit from being grown on into established plug or plants and planted into a semi-established meadow as part of a phased approach (Walker *et al.*, 2004; Sullivan, Hall and Ashton, 2020).

Figure 6 Green hay collection on Cae Teerianau at NBGW in August 2021 (Author)

2.4.4 Turf transplantation, soil removal & amelioration

Turf transplantation is a major and costly operation and tends only to be used when an already valuable habitat is facing destruction because of development, for example the translocation of MG5c and M24c communities from the site of a potential open cast mine (Good *et al.*, 1999). Another method is the use smaller turfs distributed across a site to act as a propagule for revegetation with the benefit of the inclusion of soil fauna and microbes and seed from the target community (Schaumberger *et al.*, 2021). Some conservation charities are using seeded wildflower turf as a way of instantly introducing biodiversity/food for pollinators, especially in urban areas (Keep Wales Tidy, 2023).

One of the challenges of restoring hay meadows to ex-agricultural land is the high nutrient levels and ruderal weed seed within the soil which can be overcome by removing between 25-50cm of topsoil (Török *et al.*, 2011). This method combined with soil transfer and hay transfer was the most successful at replicating the target Mediterranean steep community in SE France (Jaunatre, Buisson and Dutoit, 2014).

Soil disturbance, such as harrowing and tilling has been shown to have a positive effect on the re-establishment of meadow species by reducing the competition from the existing sward and creating areas of bare soil to aid germination, similar to the impact of aftermath grazing (Schmiede, Otte and Donath, 2012; Bischoff *et al.*, 2018).Pywell et al. (2007) found that in terms of creating the most species rich communities, turf removal was the most effective, followed by harrowing then slot-seeding and finally intensive grazing.

2.5 Non-Agricultural Land as Meadows

It is not just ex-arable fields or improved grassland that should be considered as potential new habitat for meadow species. Whilst dairy and beef cattle continue to be fed by grass silage through the winter, there remains competing demands for agricultural grassland and therefore there is a need to find additional types of land for meadow restoration.

Alternative land types, besides arable and improved farmland, in addition to providing opportunistic additional space for meadow restoration can also act as a source of genetic material for increasing biodiversity through natural dispersal. Typical meadow species can be found growing in road verges, gardens, abandoned ground, in mid-field islands and along field edges, all of which can contribute to the pool of available species for recolonisation of restoration schemes via anemochory and provide habitat corridors to further dispersal by zoochory (Plue and Cousins, 2013). In Norfolk, for example, the loss of native meadow habitat has been so great that this habitat is now only found in fragments on road verges, leading to their designation as Roadside Nature Reserves, such as Wood Lane Road-verge Meadow which supports a population of nationally scarce sulphur clover *Trifolium ochroleucon* (Coronation Meadows, 2023). These roadside nature reserves are now being used as a source of seed for restoring hay meadows elsewhere in the county.

Phillips et al. (2021) evaluated the extend of road verge across Great Britain and estimated that there are 2579 km² of road verges which is approximately 1.2% of land cover. Of this figure it was estimated that frequently cut and more natural grassland made up 1769km² which compares with the remaining areas of neutral grassland (Cottrell and Medcalf, 2019), this increases in urban areas to 4.2% of land, making it a significant element of urban green space which could contribute to green infrastructure benefits such as carbon sequestration, flood management, urban cooling as well as creating additional meadow habitat and opportunities for habitat connectivity. They suggested that the estimated 707km² of mainly urban road verge that is frequently mown could be enhanced by simply reducing mowing frequency to create opportunities for pollinating insects and by allowing flowers to set seed could create habitat favourable to other animals. Their other conclusion was that road verges of 3 metres or more (usually found outside of built-up areas) were the best candidates for enhancing nature as wildlife was at less risk of collisions with vehicles, these verges were less exposed to pollution, less likely to be regularly cut for enhancing visibility and lend themselves to conservation action done at scale. Of these wider road verges, the greatest proportion (18.4%) is found in the Strategic Road Network (major roads managed centrally) and they provide the opportunity for significant habitat restoration. An example of this is the Weymouth Relief Road scheme where the creation of a 3.6 hectare species-rich chalk grassland on the verges and slopes surrounding the A354 road which cuts through previously improved agricultural grassland was a key aim(Hetherington, Sterling and Coulthard, 2021).

The United Kingdom has about 1500 native plants and about 45% of them have been recorded growing in roadside verges (Styles, 2020). Natural Resources Wales's statutory report for the Welsh Government recognised that roadside verges across Wales could be an important reserve of semi-natural grassland with an estimated area of 10,000 hectares, with currently up to 500 hectares being species-rich, based on survey data from other areas in the United Kingdom (Bromley, Mccarthy and Shellswell, 2020; SoNaRR, 2020). Careful management could easily expand the areas of road-side verges of high biodiversity and SoNaRR (2020) also highlighted the opportunities within amenity sites and alongside watercourses.

The long-term survival of existing meadows and endemic meadow plants is dependent on not just increasing the number of these species-rich grassland but also reducing their fragmentation by joining them up (Deák *et al.*, 2018). (Arenas *et al.*, 2017) study of the road verges and areas of natural vegetation in Central Spain found that nearly all perennial plant species growing in the natural vegetation were also shown to have made their way to road verges communities. This demonstrates that not only can road verges provide a refuge for meadow species they can also act as a genetic reservoir enabling species to recolonise natural habitats.

Public parks and spaces also contain areas of frequently mown grass, such as lawns and areas of amenity grass which are the most frequently seen type of urban greenspace (Kaźmierczak, Armitage and James, 2010) and often require mowing at least 15 times per year (Land Use Consultants, 2011). This has resource implications in both time and cost

which can be financially unsustainable in the context of reduced council budgets in addition to the environmental impacts of the fuel used during mowing. This and an increased focus on the multiple benefits green infrastructure has led to the consideration of other types of vegetation to replace lawns sometimes known as urban grasslands and prairie plantings where the meadows are created from seeds or plants of non-natives such as North American prairie plants (Hitchmough and Fleur, 2006; Klaus, 2013). Although these meadows are not the restoration of native hay meadows, they provide many similar ecosystem services such as habitat and food sources for insects and may be more adaptable to climate change(Hoyle, Hitchmough and Jorgensen, 2017), and being full of highly ornamental non-natives, grown in a naturalistic style, are a sort of halfway house between mown lawns and native hay meadows which in an urban setting may be more visually palatable for residents used to manicured grass.

One of the challenges of converting mown grass into more informal areas is the perception that rather than being carried out for conservation purposes, these areas are simply being neglected to save money and that there can be a reluctance from local authorities to engage in these conservation activities because of the fear of complaints and negative press (Weston, 2023; Rogers, 2021 pers. comm.). There is also concern that the public simply prefers mown grass and that it why it is the ubiquitous feature of urban landscapes (Smith and Fellowes, no date) However, a recent survey of attitudes towards 'biodiversity-friendly greenspace' found that lawns are not always the preference within parks and that there is strong support for converting 50% lawns to meadow within an overall kept and tidy appearance when the ecological benefits were highlighted (Fischer *et al.*, 2020).

There have been a number of campaigns in Wales highlighting the benefits of changing the management of grasslands aimed at the public for example "Nature Isn't Neat" and "It's for Them" (Welsh Government, 2022c), but also local authority managers and importantly grounds maintenance staff (Bromley, Mccarthy and Shellswell, 2020). In these campaigns the focus is on engaging with local communities, explaining the changes to mowing practice that will happen and that some of the improvements will take time (Monmouthshire County Council, 2022; Pontypool Community Council, 2022).

The methodology chapter following will lay out the research approach chosen for both assessing the use of green hay as a conservation method at NBGW and also for reviewing the conservation activity taking place on road verges and amenity grassland within local authorities across Wales in with reference to some of the challenges and potential barriers above.

3. Methodology

This research is made up of two components; a series of vegetative surveys of the meadows at NBGW, including the siting of permanent survey plots within each meadow for ongoing monitoring and a questionnaire that reviews the management of local authority amenity grass and road verges across Wales for biodiversity from the perspective of biodiversity officers within local authorities. This chapter will describe the site, the vegetative data sampling strategy, vegetative survey method and the approach and delivery of the local authority questionnaire.

3.1 Survey site - Waun Las National Nature Reserve, The National Botanic Garden of Wales

The creation of the National Botanic Gardens of Wales was started in the late 1990s, on the site of the 18th Century Middleton Hall estate, near Llanarthne in Carmarthenshire, Wales. The site occupies rolling countryside on the watershed between the Afon Gwynon, which drains northwards into the Tywi valley, and various minor streams that drain southwards into the Afon Gwendraeth Fach.

The 230 hectare (ha) site is made up of ornamental gardens with the remainder (approx. 150 ha) managed for nature conservation by organic farming methods under the Welsh Government's Tir Gofal and more recently Glastir agri-environmental scheme. The farmland was designated as Waun Las National Nature Reserve(WLNNR) in 2008 and in between 2015 and 2021 the necklace of man-made Regency lakes and landscape which formed a boundary between the garden and the wider estate were restored.

Initial construction was funded primarily by the Millennium Commission. The National Botanic Garden of Wales opened to the public in 2000 "dedicated to the research and conservation of biodiversity, to sustainability, lifelong learning and the enjoyment of the visitor" (National Botanic Garden of Wales, 2023).

This study will be carried out in three fields within the Waun Las National Nature Reserve; Cae Tegerianau (the donor field) and Cae Derwen and Cae Gwair (the receiver fields) as shown in Figure 7, all of which are accessible to visitors to the WLNNR. No wildflower seed from external sources has ever been introduced to the WLNNR since the establishment of NBGW (Langridge 2021, pers. comm.), therefore all species present are from the site's own seed bank or brought in via other natural methods i.e., wind and animals.

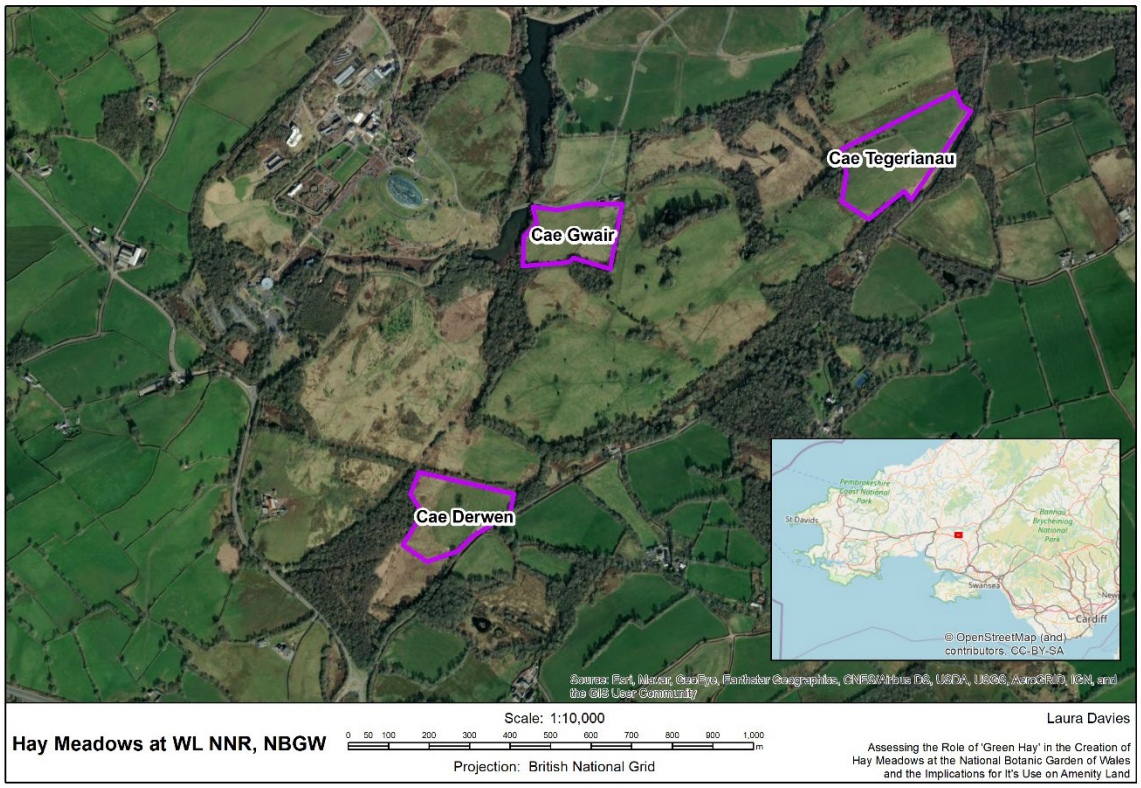

Figure 7 Survey Meadows within the Waun Las National Nature Reserve at NBGW

3.1.1 The Donor Field - Cae Tegerianau

Cae Tegerianau is one of two fields that have been managed as hay meadows since the National Botanic Garden of Wales took over the site in the late 1990s. The Bosanquet (2011) report of 2011 highlighted this meadow of one of the few areas of the wider estate which contained the MG5 *Cynosurus cristatus – Centaurea nigra* plant grassland (Bosanquet, 2011). It also contains areas of species rich MG6b and a species inventory conducted in June 2015 (Appendix A) captured 40 grassland species, including the rare and scarce flowers sometimes found in MG5 grasslands, Whorled Caraway (*Carum verticillatum*) and the Greater Butterfly Orchid (*Platanthera chlorantha*) (Natural England, 2013). An ecology survey carried out in 2016, ecologists noted the presence of the waxcap fungi, *Hygrocybe calyptriformis* and *H. punicea*, throughout Cae Tegerianau, highly indicative of land that hasn't been ploughed or received fertilizer in decades (Colley *et al.*, 2016).

The field is North to Northwest facing and moderately sloping as shown in Figure 8.

Figure 8 Meadow community in Cae Tegerianau showing meadow buttercup, orchids, cat's ear, eyebright, sweet vernal grass and yellow rattle seed heads (author)

3.1.2 Receiver field - Cae Derwen

Cae Derwen (Figure 9) is unsurprisingly named after the mature oak team found in the centre of the field. In 2011 it was described as dominated by "species-poor overwhelmingly grassy MG6" (MG6 – *Lolium perenne-Cynosurus cristatus* grassland) but also "low quality coarse M23a (*Juncus effusus/acutiflorus–Galium palustre* rush-pasture) with abundant nettle and thistle" and also a small remaining area of Molinia and associated habitat described as M25 (Molinia caerulea–Potentilla erecta mire) (Bosanquet, 2011).

In 2016, a decision was taken to increase the number of field managed as wild flower meadow with the WLNNR so in 2016 (Langridge, 2021b). The field was hay-cut, then half was scarified (due to time constraints) before newly-cut 'green hay' was applied with a much-spreader from the donor field, Cae Tegerianau. For the following years, the field was managed with a single cut in late summer with the grass removed. There was no grazing or further addition of wildflower seed or 'green hay'. An annual NPMS survey of one plot in Cae Gwair had been undertaken just prior to the first hay cut prior to the addition of green hay in 2016 and every year except 2020 since (Appendix B). These surveys only collected data at Indicator level (as few as three species) so are not statistically comparable with the more recent inventory list. The plot's proximity to the central oak tree seems to have had an impact on biodiversity compared to the rest of the field whether because the green hay did

not reach this area, hay machinery cannot access the area or the oak's roots and crown are having an impact on the grassland plant community. Comments on the survey form reveal that in June 1019, 3 years following green hay treatment, 100s of flowering orchids, including Greater Butterfly Orchid (*Platanthera chlorantha*), Southern Marsh Orchid (*Dactylorhiza praetermissa)* and Common Spotted Orchid *(D. fuchsia)* were visible for the first time*,* having never been seen in 20 years of previous monitoring.

Figure 9 Survey plot within Cae Derwen (Author).

3.1.3 Receiver field - Cae Gwair

This flat pasture field (Figure 10) has been grazed by sheep and cattle year-round for the last 20 years (Langridge, 2021, pers. comm.). Except for some M27 *Filipendula ulmaria–Angelica sylvestris* mire on the western edge Bosanquet, (2011), described this field, like Cae Derwen above, as species-poor, overwhelmingly grassy MG6 *Lolium perenne–Cynosurus cristatus* grassland.

The 2016 survey by Colley et al. (2016) also recorded Cae Gwair as MG6 with abundant Pignut (*Conopodium majus)*.

In August 2019 the grass on the whole field was cut and the arisings removed then in the afternoon, freshly cut 'green hay' from Cae Tegerianau (donor field) was chopped up and spread over the field using a muck-spreader. Following treatment, the grass has been cut and removed annually in late summer with no other inputs or actions.

3.2 Data Sampling Strategy

3.2.1 Meadow survey method

Research into the success of meadow restoration projects can use comparisons and degree of match with a reference site or community, increase in species richness, numbers and coverage of target species established to measure the degree of change on the restoration site (Rothero, Tatarenko and Gowing, 2020; Sullivan, Hall and Ashton, 2020).

Figure 10 Meadow community within Cae Gwair (author)

The National Botanic Garden of Wales had already begun to use the National Plant Monitoring Scheme (Pescott *et al.*, 2019) as a basis for initial monitoring of the effect of the application of green hay to Cae Derwen, using its survey form (Appendix C), habitat indicator species lists and establishing a single monitoring plot (Langridge, 2021, pers. comm). However, the data collected annually from 2016-2019 on recorded Indicator species rather than the complete plant community.

As this method is now well understood at the site (Langridge, 2021 pers. comm.) and one of the aims of this research is to enable consistent ongoing surveying of the meadows, the sampling of plant diversity and abundance would be conducted using the same method, including the already established monitoring plot.

The National Plant Monitoring Scheme was set up in 2015 by Botanical Society of Britain & Ireland (BSBI), Centre for Ecology and Hydrology (CEH), Plantlife and the Joint Nature Conservation (JNCC) as a standardised scheme for assessing the condition of semi-natural habitats and vascular plants across the United Kingdom (Walker *et al.*, 2015).

The key aims of the scheme are:-

- To measure any change in plant populations within semi-natural habitats over the long-term using positive and negative indicator species of different habitats
- To create a large national dataset
- To be easy to complete for people of all levels of expertise
- To be repeatable over a number of years
  (Pescott *et al.*, 2019).

This is a citizen science scheme, comparable to national volunteer-based schemes such as the Big Butterfly Count and the Royal Society for the Protection of Birds' (RSPB) Big Garden Birdwatch, with different levels of recording, dependent on plant knowledge and since its inception volunteers have been able to select a 1km x 1km square (monads) from a random selection of monads across the UK biased towards semi-natural habitats. Within these monads volunteer recorders will select a number of quadrats of 5m x 5m which are representative of the habitat type or types present. The location of these quadrats is documented for the purpose of revisiting the same quadrats over a number of years to establish any population changes or trends. There are significant resources available to participants via the scheme's website (https://www.npms.org.uk/) such as a standard survey form (Appendix C), species lists, identification guides and general guidance.

The scheme has been designed for long term monitoring by participants with a range of botanical skills which reflects the wide range of ability of volunteers available at NBGW. The scheme is designed to monitor change therefore instead of surveying whether a species is present or not, this scheme asks participants to record the presence and abundance of the species found using the Domin scale (Figure 11). Feedback from volunteers using the Domin scale for this scheme showed that they were more confident using assigning bands than precise coverage figures and as a result the surveys were quicker and easier to conduct (Pescott *et al.*, 2019).

For your plot, allocate an abundance score for each species using the Domin scale below (also see inside the back cover of the guidance notes). Please also include scores for the extra items listed at the end of the table below if possible.

Domin	1	2	3	4	5	6	7	8	9	10
% cover	<1% (1-2 indivs)	< 1% (several indivs)	1-4%	5-10%	11-25%	26-33%	34-50%	51-75%	76-90%	91-100%

Figure 11 Domin scale from NPMS survey form (National Plant Monitoring Scheme, 2023)

The Domin scale was also used by (Good et al. (1999) to assess trial plots prior to an actual translocation of a meadow SSSI habitat which was in the way of the development of an open cast coal mine. The scale was used mainly because it enables a quick assessment of

any change taking place at a species level. However, because the boundaries of values along the scale are unequal and the values can't be summed or averaged to create a total cover of 100%, the results were not subject to statistical analysis.

This is also consistent with the National Vegetation Classification (NVC) survey method that also uses larger quadrats (2m x 2m) over uniform/typical rather than random stands of vegetation and the Domin scale for recording percentage cover, and then uses the results of these surveys to match the survey site to one of the NVC plant communities, using tables or a software programme (Rodwell, 2006). There are previous surveys which have assessed areas of WLNNR against NVC plant communities (Bosanquet, 2011; Colley *et al.*, 2016), a continuation of this approach will be used and the data from each plot will be assessed against NVC grassland communities. It is recommended that 3 to 5 quadrats are undertaken within each distinct area(Save Our Magnificent Meadows, 2020).

In a recent survey of upland hay meadow restoration across 89 sites in the North Pennines, England, the survey data was used to create variables such as species richness (no. of species), Shannon Diversity Index, Positive Indicator Species Score, Best Fit to MG3b NVC meadow community (Starr-Keddle 2022). In addition to comparisons against NVC grassland communities, the meadow data at WLNNR will be compared for species richness which along with frequency of particular indicator species is the most frequently used measurement of restoration success (Natural England, 2012). In their recent paper examining the impact of green hay compared to seed mixes on the restoration of a MG5 meadow community at an improved grassland site in Buckinghamshire, Wagner, L. Hulmes, et al., (2021) progress was assessed using cover and density of positive indicator species; goodness-of-fit to MG5 grassland, species density and similarity to donor site. The use of 'Goodness-of-Fit' to a NVC grassland classification to compare sites have also been used in a number of other studies, the same plots over time (Kirkham *et al.*, 2013)and comparing donor and receiver sites restored via seeding or green hay annually for 4 years (Wagner, L. Hulmes, *et al.*, 2021).

As a visitor attraction, NBGW are also keen to create meadows that are visually stunning so they regard large populations of orchids and important local plants such as Whorled Caraway (*Carum verticillatum*) which also happens to be the county flower of Carmarthenshire as an equal if not more of a priority than restoring an exact assemblage of an NVC MG5 hay meadow (Langridge, 2021 pers.comm.). The 4 orchid species (*Dactylorhiza praetermissa, D. fuchsia, D. maculata* and *Planthera chlorantha)* and Whorled Caraway (*Carum verticillatum*) are regarded as NBGW priority species in this research.

3.2.1.1 Siting of Survey Plots

The intention of the NPMS is that survey plots can be easily located year after year without permanent markers (which would be impossible in an annually mown hay meadow). The plots in each field at WLNNR were selected in relation to a permanent feature such as a mature tree, permanent tree-guard or gate post. The 5m x 5m quadrats were temporarily marked out with a tape measure as shown in Figure 8. This location was then recorded in a

hand-drawn map on the survey sheet (Appendix D) and transferred into a GIS map (Figures 12,13 &14).

Locating the quadrats towards the boundaries of the hay-treated areas was avoided so that 'edge effects' could be reduced (Sullivan, Hall and Ashton, 2020)., except for 2 plots in Cae Gwair where they were used to sample untreated areas of the field. Plot locations were spread across the survey fields to capture the complete vegetation picture, for example, the western side of Cae Derwen was next to an area of marshland and noticeably damper underfoot.

The vegetative survey was completed between 26th May and 2nd July 2021 on dry days. A total of 16 plots (Table 1) had their location mapped, were surveyed and every plant species contained within was recorded and given a Domin scale coverage value. Two addition plots (Plots 2 & 7) were created within Cae Gwair on areas of the field not treated with green hay on the advice of NBGW staff as representatives of the previous vegetation community and for monitoring of the expansion of the meadow in future (Langridge, 2021, pers.comm.)

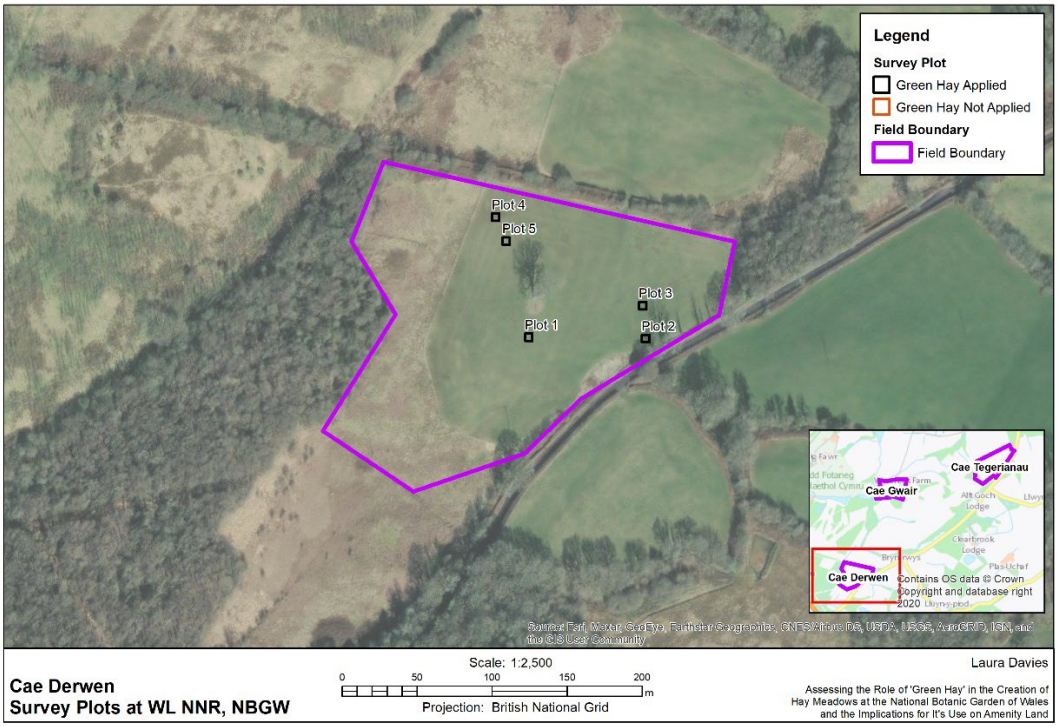

Figure 12 Survey plot locations in Cae Derwen

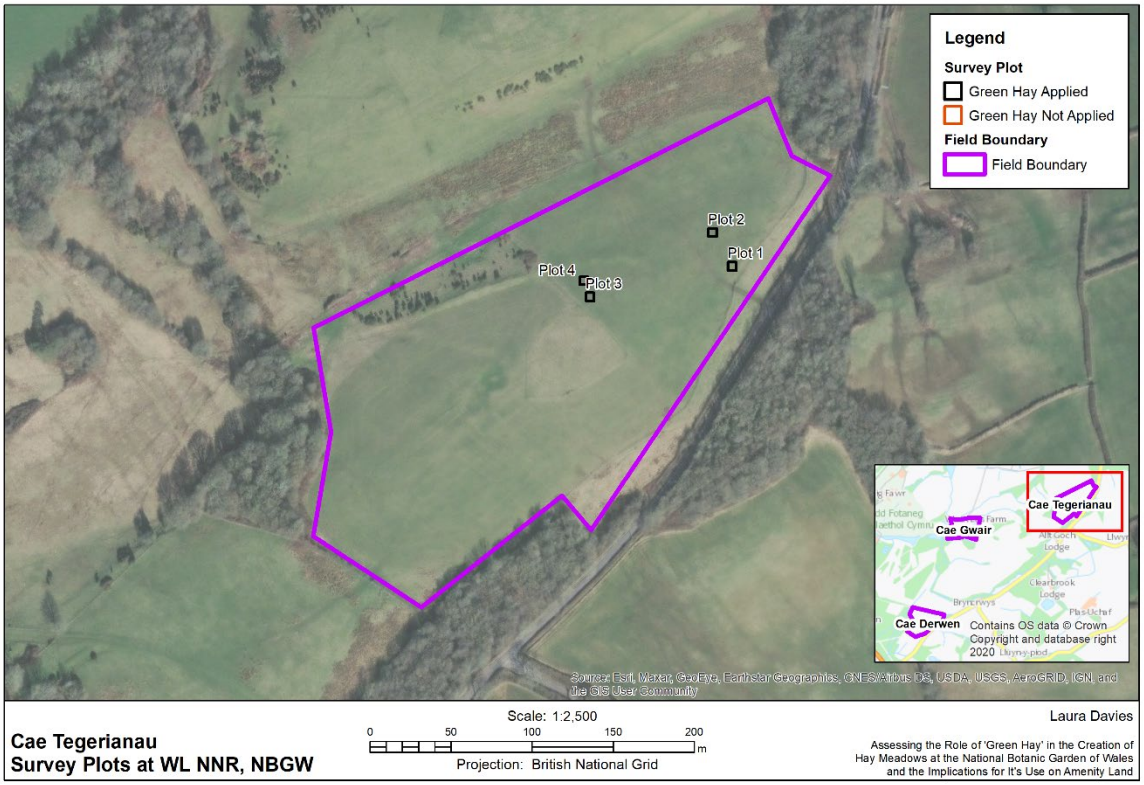

Figure 13 Survey plot locations Cae Tegerianau

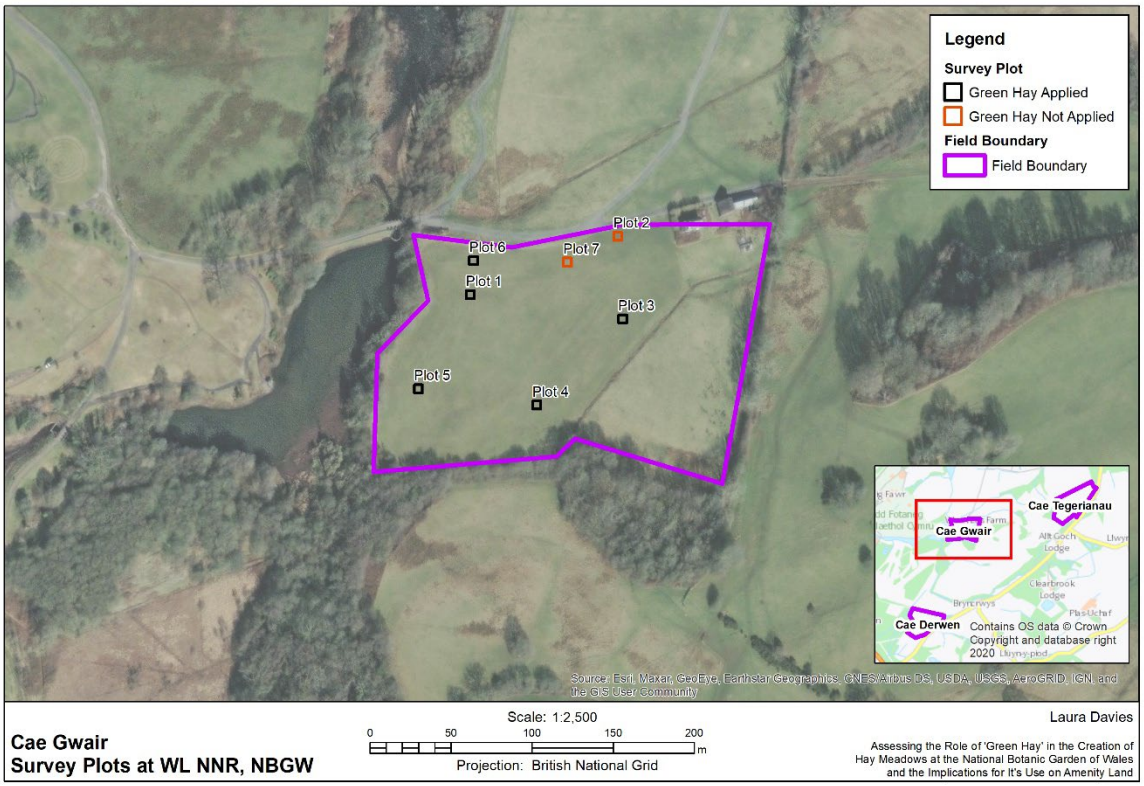

Figure 14 Survey plot locations in Cae Gwair.

3.2.1.2 Data Analysis

The characteristics of the meadow data that was assessed as part of this research was the calculation of (1) species richness (per 5m x 5m quadrat) and diversity (total no. of species recorded), (2) % cover of Indicator and Priority Species (using the NPMS neutral pastures and meadows indicator list in Appendix E) and (3) goodness-of-fit to NVC grassland communities using TABLEFIT, version 2.0 (Hill, 2015).

Cae Tegerianau (donor meadow)	Date Surveyed	Restoration treatment
Plot 1	02/07/2021	
Plot 2	02/07/2021	
Plot 3	02/07/2021	
Plot 4	02/07/2021	
Cae Gwair		
Plot 1	26/05/2021	green hay applied 2019
Plot 2	26/05/2021	no treatment
Plot 3	18/06/2021	green hay applied 2019
Plot 4	18/06/2021	green hay applied 2019
Plot 5	18/06/2021	green hay applied 2019
Plot 6	18/06/2021	green hay applied 2019
Plot 7	23/06/2021	no treatment
Cae Derwen		
Plot 1	26/05/2021	green hay applied 2016
Plot 2	23/06/2021	green hay applied 2016
Plot 3	23/06/2021	green hay applied 2016
Plot 4	23/06/2021	green hay applied 2016
Plot 5	23/06/2021	green hay applied 2016

Table 1 Details of the vegetative survey

3.2.2 Local Authority Questionnaire

There are 21 local authorities in Wales. Each local authority has a representative, usually the council's biodiversity officer or ecologist, on the Local Nature Partnership (LNP) Cymru (www.lnp.cymru), a network funded by Welsh Government to deliver nature recovery projects locally across Wales. An exploratory survey was developed to gain an understanding of the current extent of grassland biodiversity improvement taking place across Wales. This questionnaire was targeted at those LNP representatives. This pool of respondents is smaller than a sample size of 30 that is typically suggested as a minimum (Munn and Drever, 2004) for statistical accuracy, therefore because there is a relationship between target population and sample size, with a very small population the sample size is such that it is appropriate to include the whole population(Martínez-Mesa *et al.*, 2014) which actually makes the survey more akin to a census. However, the output of a small narrowly targeted group of knowledgeable respondents can also be likened to an expert panel which can be useful for exploring the substance of a research (Malhotra and Birks, 2017).

The familiarity of this respondent pool (working within the field of conservation) with the subject matter and vocabulary also means that there is sufficient knowledge base to

understand any technical jargon and provide more accurate responses that allows the researcher to have more confidence in the results(Choi and Pak, 2005) which can be an issue with randomised surveys of a general population. Questionnaire design is not an exact science (Malhotra and Birks, 2017) but the content of the questionnaire was reviewed twice, including by a member of the LNP to remove any biases causes by ambiguous questions, leading questions, change of scales, forced choice, etc. It was not tested prior to distribution due to the small size of the final distribution list, particularly as opinions as to the number of responses needed to reveal problems in a questionnaire range from 12-50 (Presser *et al.*, 2004).

The majority of questions were closed, either multiple choice (Figure 15 or Likert scale responses (to reduce the burden on respondents and encourage completion) with a catch-all 'other' for any additional answers, although too many different responses in the answers would suggest that the compiler had not researched the subject adequately (Munn and Drever, 2004). Most of Likert-scale questions were to establish the frequency of use of the five main methods of restoration discussed in the literature review on both amenity grassland and road verges and whether areas managed for biodiversity had increased or were likely to increase in the future with further questions probing the barriers to using green hay as a technique, barriers to expanding areas under management for biodiversity and how these barriers can be surmounted. Although Likert-scale surveys (example in Figure 15) were developed for measuring the attitudes of respondents to an opinion from 'strongly agree' to 'strongly disagree', they have also been used to measure frequencies of actions from 'often' to 'never' such as in self-reporting recycling rates (Xu, Ling and Wu, 2018), frequencies of environmental impacts caused on construction sites (Zolfagharian *et al.*, 2012) and frequencies of pro-environmental behaviours (Thomas, Poortinga and Sautkina, 2016) . However, Google forms only enables the compiler of the questionnaire to label the extremities of the scale (Figure 14), therefore the other values will be subject to a degree of individual interpretation.

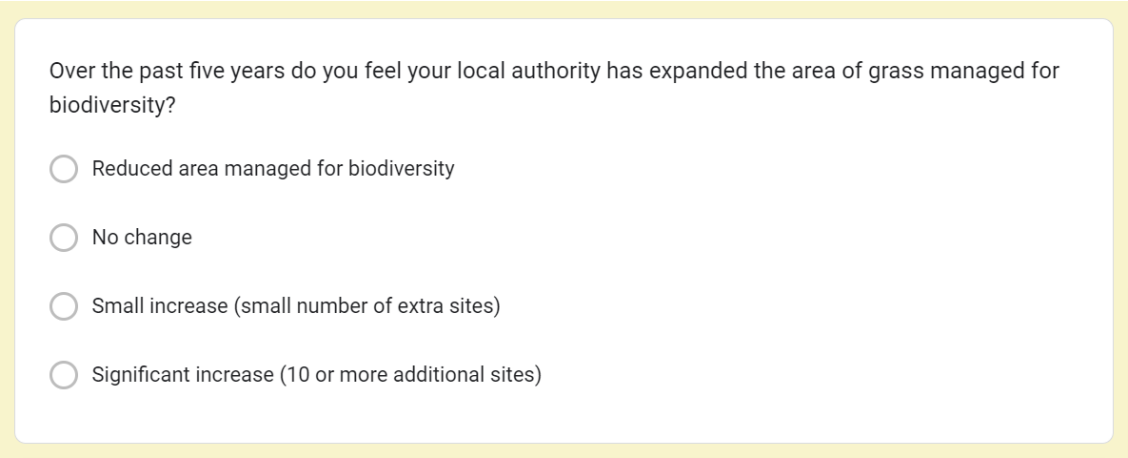

Figure 15 Example of multiple-choice question

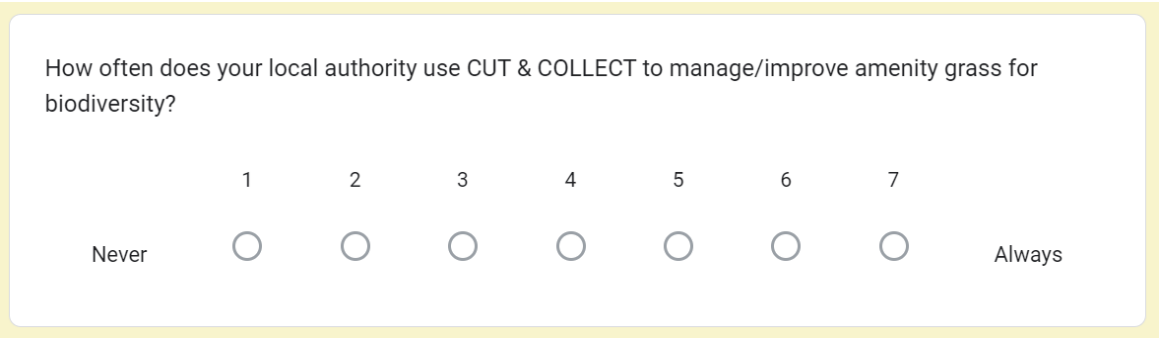

Figure 16 Example of Likert-type frequency question from survey

The questionnaire created and data collected using Google Forms (Appendix 5). The link to the online questionnaire was distributed by email by the LNP Cymru project officer on the 24th of February 2022 to all 21 local authority biodiversity officers/Local Nature Partnership Wales representatives, with a reminder sent a month later on 22nd March 2022.

4. Results and Discussion

4.1 Meadow Surveys

The complete species data from the 3 meadows can be found in Appendix G.

4.1.1 Species Richness

Overall, the total number of species recorded in the Cae Tegerianau (CT) survey plots was 26. Of the 26, 23 were found within Cae Derwen (CD) 88% and 18 were found within the Cae Gwair (CG) quadrats (69%). However, across all quadrats CD showed the greatest diversity with 37 different species recorded against 26 (CT) and 24 (CG). This figure is comparable with the 40 grassland species picked up in the 2015 inventory (Appendix 1).

The mean number of species per quadrat with their standard deviations are shown in Figure 17, demonstrating a general increase in richness between CG, the most recently treated field, to CD and GT the donor field. Although, there is little difference between the average species richness per quadrat of CT (20.75) and CD (20.8), the most species rich quadrat was in CT with 24 species.

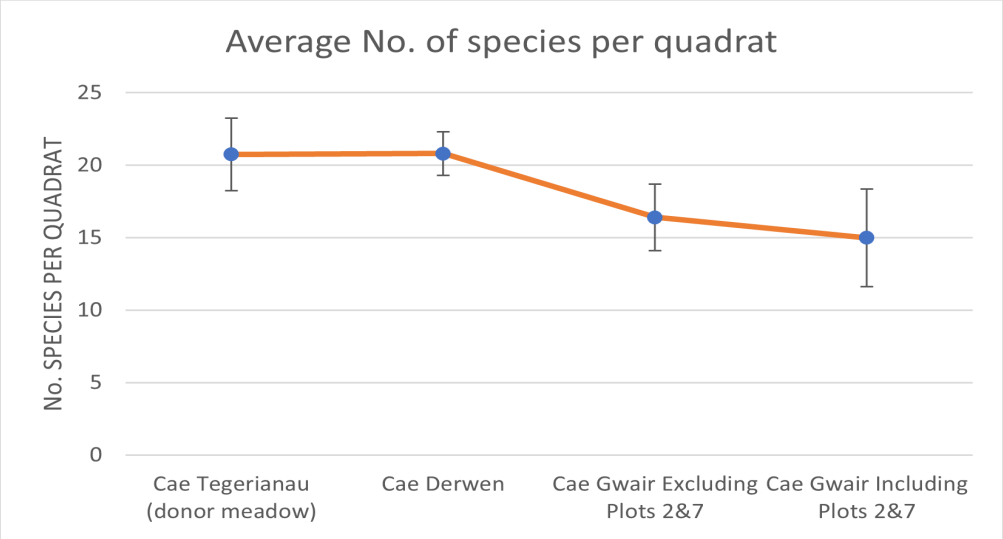

Figure 17 Mean Species Richness (No. species per 25m² survey plot) across the 3 meadows with standard deviation

Eyebright (*Euphrasia* spp), Cat's Ear (*Hypochaeris radicata*) and Yellow Rattle (*Rhinanthus minor*) are three meadow species virtually absent in the untreated CG plots that have notably increased in number in the treated survey plots in CG and increased in abundance in CT and CD. Notably absent in CG were the orchid species with only one quadrat picking up one individual of the Greater Butterfly orchid (*Platanthera chlorantha*), however all species were represented in the CD sample plots and in greater numbers still in CT.

Figure 18 compares the % cover (using the Domin scale) of all recorded species but excludes data from the untreated plots 2 & 7 and also the data relating to tree seedlings (*Quercus* spp.) was removed as these are obviously not meadow species and will not survive the annual hay cut to become part of the plant community. This graph shows the species with the highest coverage are Sweet Vernal Grass (*Anthoxanthum odoratum*) between approx. 51-80%, Yellow Rattle (Rhinanthus minor) approx. 26-75%, Eyebright (Euphrasia spp.) approx. 11-30%. Other notable characteristic meadow herb species appearing in all three fields included Cat's Ear (*Hypochaeris radicata*), Ribwort Plantain (*Plantago lanceolata*), Meadow Buttercup (*Ranunculus acris*), Sorrel (*Rumex acetosa*), Red Clover (*Trifolium pratense*), Dandelion (*Taraxacum officinale*), Lesser Trefoil (*Trifolium dubium*) and grasses Yorkshire Fog (*Holcus lanata*) and Common Bent (*Agrostis capillaris*).

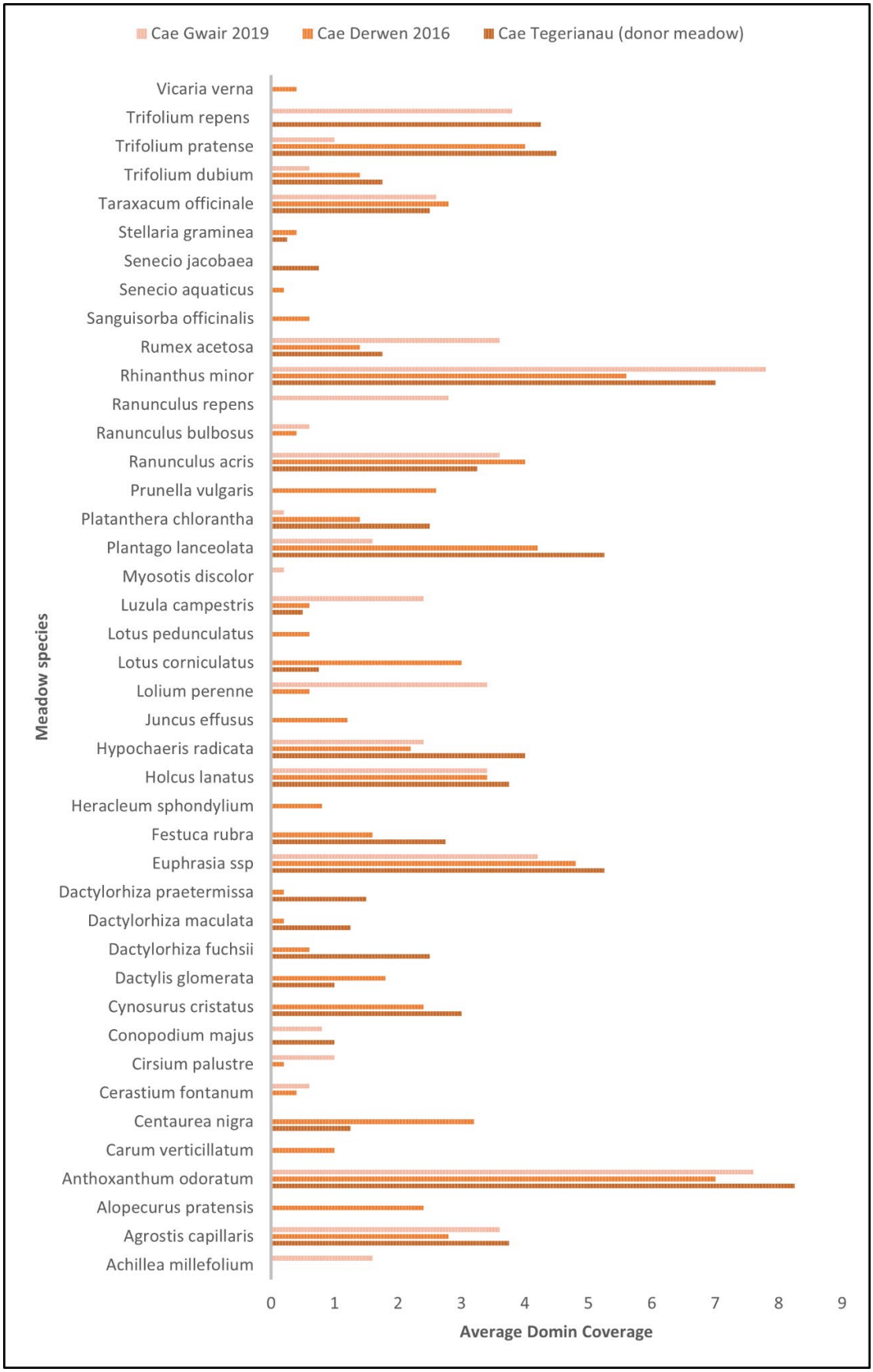

Figure 18 Graph showing average % cover (DOMIN scale) for recorded species

4.1.2 Goodness-of-fit

The survey data both species name and Domin scale value was subjected to a TABLEFIT analysis for each of the 16 plots which assigned the submitted assemblage to a NVC type communities. The full TABLEFIT output can be found in Appendix 7. The output provides the 5 most highly rated goodness-of-fit for the plant assemblage submitted. Any goodness-of-fit of <50 means that the plant assemblage is a poor match for any community and should not be assigned without further data (Hill, 2015).

Table 2 shows the highest goodness-of-fit NVC community for each of the survey plots and their rating. Out of the 16 plots, 14 are assigned to grassland of 'high botanical nature conservation value' – MG5, MG3 and U4 (Crofts and Jeffereson, 1999) although many of these results are by no means conclusive. 8 of the 16 survey plots show a goodness-of-fit match of Fair or above to a species rich grassland type. Figure 19 shows the rating of the highest placed MG5 community type and the standard deviation within the samples of each field. MG5 being the code for species rich lowland neutral grassland would be the expected grassland type for the whole site. 5 survey plots show a fair or above match to MG5 (including 3 survey plots in CT, the most established meadow. Both CT and CD have MG5 as one of the top 5 matches in all plots whereas CG only shows a match in 3 sample plots and with poorer ratings. According to Clewell and Aronson, (2013) it may be impossible for restoration projects to exactly reproduce a particular NVC community which may have evolved over 100s of years but that they should be used as a general guide and that the most positive outcome could just be a general if unpredictable increase in species diversity which is reflected in the meadows at WLNNR.

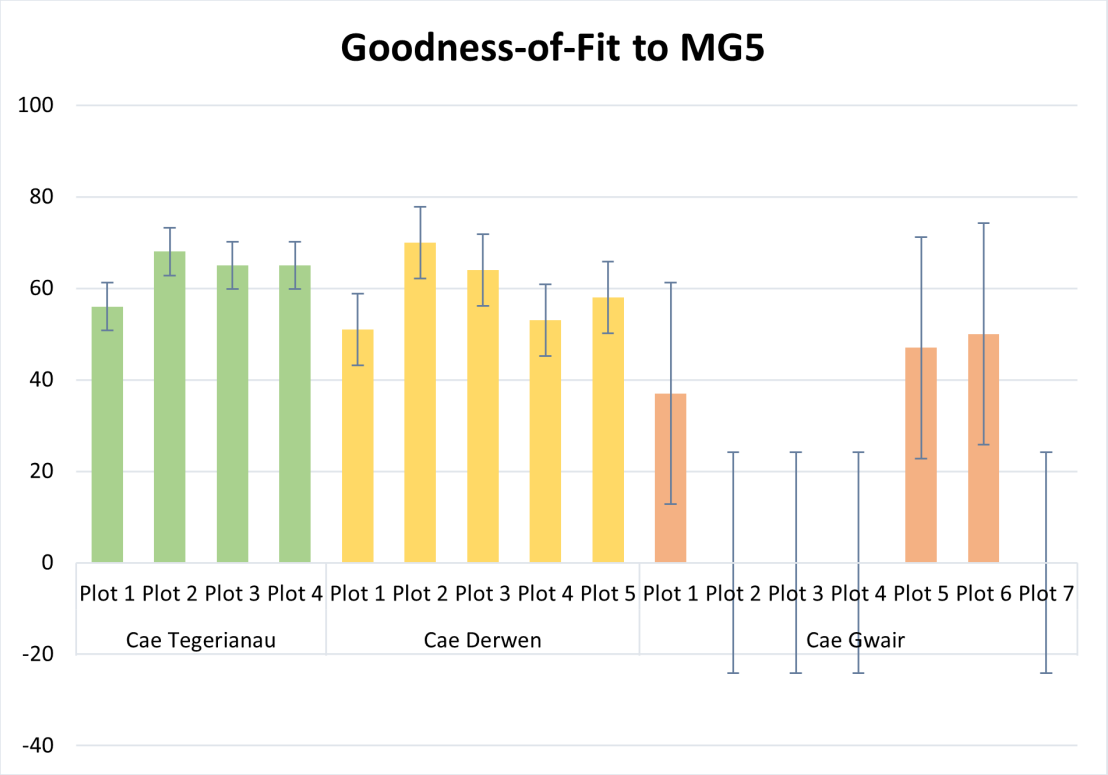

Figure 19 TABLEFIT Goodness-of-Fit to MG5 grassland.

Table 2 Highest rated Goodness-of-Fit NVC community for each surveyed quadrat

Meadow	Survey Sample	NVC	Goodness of Fit	NVC type	NVC Description
Cae Tegerian	Plot 1	MG 5	56	Cynosurus cristatus–Centaurea nigra grassland	Lowland hay meadow and pasture
Cae Tegerian	Plot 2	MG 5	68	Cynosurus cristatus–Centaurea nigra grassland	Lowland hay meadow and pasture
Cae Tegerian	Plot 3	MG 3b	72	Anthoxanthum odoratum–Geranium sylvaticum grassland Briza media	Northern hay meadow
Cae Tegerian	Plot 4	MG 3b	74	Anthoxanthum odoratum–Geranium sylvaticum grassland Briza media	Northern hay meadow
Cae Gwair	Plot 1	MG 3b	49	Anthoxanthum odoratum–Geranium sylvaticum grassland Briza media	Northern hay meadow
Cae Gwair	Plot 2	U 4b	68	Festuca ovina–Agrostis capillaris–Galium saxatile grassland	Upland (sub-montane) areas of north and western Britain associated with a range of acidic soils on lime-poor substrates. Examples do occur in lowland situations (<300m).
Cae Gwair	Plot 3	MG 6b	57	Lolium perenne–Cynosurus cristatus grassland	Improved permanent grassland.
Cae Gwair	Plot 4	U 4b	65	Festuca ovina–Agrostis capillaris–Galium saxatile grassland	Upland (sub-montane) areas of north and western Britain associated with a range of acidic soils on lime-poor substrates. Examples do occur in lowland situations (<300m).
Cae Gwair	Plot 5	U 4b	62	Festuca ovina–Agrostis capillaris–Galium saxatile grassland	Upland (sub-montane) areas of north and western Britain associated with a range of acidic soils on lime-poor substrates. Examples do occur in lowland situations (<300m).
Cae Gwair	Plot 6	U 4b	56	Festuca ovina–Agrostis capillaris–Galium saxatile grassland	Upland (sub-montane) areas of north and western Britain associated with a range of acidic soils on lime-poor substrates. Examples do occur in lowland situations (<300m).
Cae Gwair	Plot 7	MG 7d	47	Lolium perenne leys and related grasslands	Reseeded grassland. The major and ubiquitous sown grassland type in Britain.
Cae Derwen	Plot 1	MG 3b	58	Anthoxanthum odoratum–Geranium sylvaticum grassland Briza media	Northern hay meadow
Cae Derwen	Plot 2	MG 5	70	Cynosurus cristatus–Centaurea nigra grassland	Lowland hay meadow and pasture
Cae Derwen	Plot 3	MG 5	64	Cynosurus cristatus–Centaurea nigra grassland	Lowland hay meadow and pasture
Cae Derwen	Plot 4	MG 5	53	Cynosurus cristatus–Centaurea nigra grassland	Lowland hay meadow and pasture
Cae Derwen	Plot 5	MG 5	58	Cynosurus cristatus–Centaurea nigra grassland	Lowland hay meadow and pasture

KEY	
Goodness-of-Fit	Rating
80-100	Very Good
70-79	Good
60-69	Fair
50-59	Poor
0-49	Very Poor

4.1.3 Average cover of Indicator and Priority Species

The average % cover of the twelve Indicator (from Appendix 4) and NBGW Priority species (4 orchid species and whorled caraway) is represented in Figure 22. Nine of these species were recorded in CT, ten in CD and seven in CG. Where these species were found in both CD and CT, percentage cover for each species increased in CT. The only Indicator species found in CG alone was Creeping Buttercup (*Ranunculus repens*) this seems to have been replaces It's close relative (regarded as a characteristic herb of MG5 meadows (Natural England, 2013) but not included in the NPMS Indicator list) Meadow Buttercup (*Ranunculus acris*) in CT and CD and was found in every survey plot. This highlights that the NPMS has primarily been developed to monitor habitat change and the limited number of plant species included in their indicator lists have been selected with this in mind rather than for use as identifying improvement in discreet habitat types.

The data does show an increase in establishment of the four orchid species with the largest numbers and diversity in Cae Tegerianau (donor meadow), followed by Cae Derwen (treated 2016) and Cae Gwair (treated 2019). The data supports on-site observations that the Greater Butterfly Orchid (*Platanthera chlorantha*) is the first orchid species to establish and flower or be observed as a seedling (shown in Figure 20). There is a degree of debate over whether these orchids can have established in 3 years or whether they have been lying dormant in the soil waiting for favourable conditions despite not having been seen even though regularly looked for in over 20 years(Langridge, 2019). From on-site observations the Whorled Caraway (*Carum verticilatum*), shown in Figure 21, also showed a staged increase in numbers between CG and CT with 2 individuals found in the CG meadow (not captured with plots), several small patches within CD (captured within on plot) and greater numbers still in CT (although not captured within plots). This highlights the issue of using a method designed for capturing change in a series of locations over time and using it to compare differences between locations.

Figure 20 Greater Butterfly orchid seedling

Figure 21 Specimen of Whorled Caraway in Cae Gwair

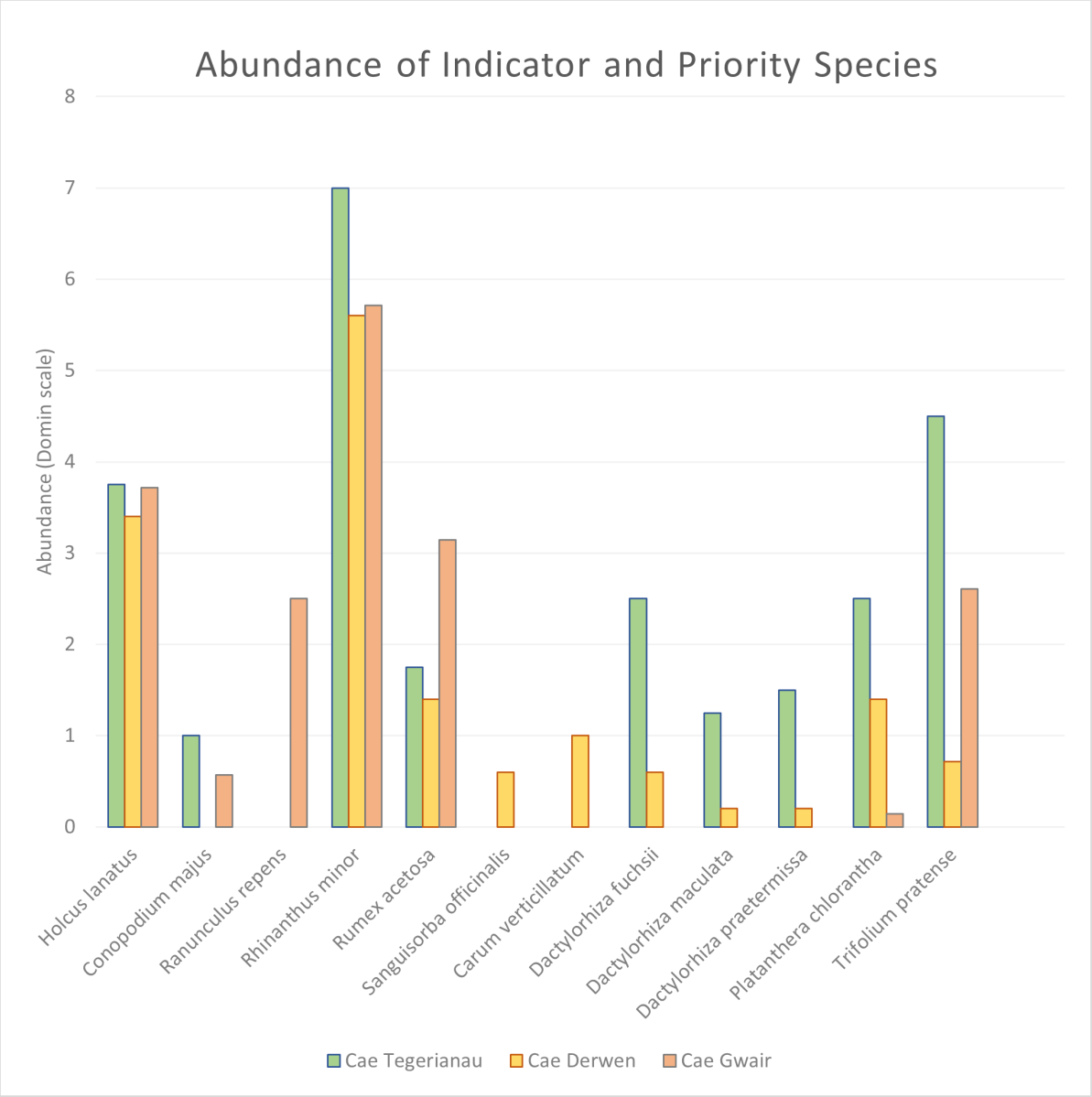

Figure 22 Average cover for Positive Indicator and NBGW Priority Species

4.1.4 Establishment of permanent survey plots

16 monitoring plots have been established with detailed aerial plans (example in Figure 23) created to enable future annual monitoring. These surveys were again conducted in 2022 by a student volunteer with support from NBGW staff. Only time will tell if this remains an ongoing project but even if monitoring is carried out only every other year, these meadows will provide a useful set of data for future assessment of the impact of green hay in the long term.

Figure 23 Location map of Cae Gwair plots 3 and 4.

4.2 Local Authority Questionnaire

There were 11 responses out of the 21 LNP officers contacted (Appendix I) which despite being a significant percentage (52% of questionnaires returned), is insufficient to make any assumptions with any degree of statistical accuracy. Although the officers targeted are key personnel with regard to enhancing biodiversity, they are not the only staff involved and from personal communication it was clear that several had to ask other colleagues, particularly maintenance teams, etc. for feedback (Rogers, 2021 pers. comm.). As a result, their responses can only be used as an insight into what is happening within local authorities across Wales who employ upwards of 140,000 staff (WLGA, 2023) from a particular perspective. In hindsight, a higher response rate might have been achieved if the participants had been emailed or contacted individually rather than through a single email to multiple addresses. The questionnaire could also have been conducted in person, or via telephone or videoconferencing.

The questionnaire contained sections on the methods used for the conservation/restoration of biodiversity (1) on road verges and (2) on amenity grassland, (3) challenges to the use of green hay within local authorities, (4) the direction of travel with regard to local authority grassland biodiversity and (5) the barriers and bridges to expanding the management of grassland for biodiversity.

4.2.1 Conservation measures

Table 3 shows that all local authorities that responded are using sward management ('timing of cuts') to a greater or lesser degree in their management of road verges, typically carrying out a cut in late summer which is left to decompose *in situ*. There is less variance in

the frequency of use of cut and collect and overall, this is less likely to be used, assuming respondents interpreted 4 on the scale to be 50% of the time, this method is used 50% of the time or less and never by one council. Wildflower seed and turf are used by approximately 73% and 55% respectively, of local authorities but with increasingly reduced frequency. Green hay has only been used by 4 out of the 11 Las but of the LAs that are using green hay, three are using it 50% of the time or more.

	Likert-type Scale						
Conservation Measure on Road Verges	1	2	3	4	5	6	7
	NEVER	⇨	⇨	⇨	⇨	⇨	ALWAYS
Timing of Cuts		1	3	1	2	3	1
Cut and Collect	1	2	4	4			
Wildflower seed	3	3	4	1			
Wildflower turf	5	4	1	1			
Green hay	7	1		2		1	

Table 3 Frequency of the use of different conservation measures on road verges.

The main difference between the management of road verges and amenity grassland is in the increased use and frequency of cut and collect and wildflower seed. There are a number of reasons why this might be the case, one of the challenges of cut and collect is the need for specialised mowers or collector and the removal and disposal of arisings. The easiest method for cheaply and quickly managing grass is to run a flail or topper over the grass in one pass and leave the arisings. Changing the timings of cuts, uses existing LA machinery and has been widely adopted by LAs because in many cases it has reduced the number of times grass has been cut in the year, reducing pressure on budgets whilst improving opportunities for biodiversity. The main issue with not removing arisings is that nutrient levels do not reduce and the grass cuttings left on the surface reduce opportunities for wildflowers and favour rank grasses and ruderal weeds such as nettles and docks. Therefore, on road verges it is likely to be most common regime until there is reduced pressure on LA budgets. The increased use of cut and collect within amenity spaces is linked to both enhancing biodiversity but hand in hand also improving the visual impact of public spaces, not collecting arisings can have a negative effect of species diversity and appearance. In free text responses and emails several LAs inferred that they were looking to invest in cut and collect equipment. The increase in use of wildflower seed as a method could be down to a number of reasons. Local nature partnership officers have a remit to support community/volunteer projects which are more likely to be within amenity spaces than road verges. These projects are increasingly using wildflower instead of cultivated plants for enhancing biodiversity and creating attractive public spaces. This trend is likely to continue as the demand for green infrastructure increases to mitigate the effects of climate change, flooding and pollution.

	Likert-type Scale						
Conservation Measure on Amenity Grassland	1	2	3	4	5	6	7
	NEVER	⇨	⇨	⇨	➡	➡	ALWAYS
Timing of Cuts	1	2	2	2	3	1	
Cut and Collect	1	2	2	1	2	2	1
Wildflower seed		6	1	2	1	1	
Wildflower turf	6	3		2			
Green hay	7	3				1	

Table 4 Frequency of the use of different conservation measures on amenity grassland.

Additional methods used by individual LAs but not listed (and submitted as free text in response to 'Other') included cattle grazing, local provenance seed, scarification, the use of community groups for monitoring and planting wildflowers grown from local provenance seed, trailing turf-stripping and seeding and importing impoverished soil and seed. This suggests that within Wales as a whole across LAs staff have knowledge of the full gamut of methods for enhancing biodiversity within grasslands. What is not clear from the survey is how widespread this knowledge is between and within individual LAs. "Lots of our grassland management has been focused on public realm sites" suggesting that some LAs are concentrating their main efforts in the sites which are most accessible and therefore have the most positive impact on the public. Some of these methods are only suitable for use on amenity parkland rather than verges, such as cattle grazing and large scale wild-flower planting for reasons of space and safety.

4.2.2 Use of Green Hay

A single LA is making use of green hay as a conservation measure at a significant level which suggests that there must be significant barriers to its use, considering that it is relatively cheap and only takes a limited amount of time to carry out. Figure 24 highlights the answers to the question concerning these barriers and the respondents seem fairly united in their understanding of the challenges - lack of donor sites, lack of appropriate equipment and lack of experienced staff. The urban LAs are unlikely to have as much access to their own species-rich grasslands to use as donor sites as rural LAs unless they happen to be responsible for the management of country parks which may have been subject to appropriate management regimes. The solution to this and indeed the other primary barriers is for the creation of partnerships with conservation charities, like the Wildlife Trusts, private landowners via county meadow groups both to create access to donor sites but also access to knowledge and potentially machinery. The process of cutting, transporting and spreading green hay is over within a day. Much of this work can be carried out by contract as is the case at NBGW where agricultural contractors cut and transported green hay from Cae Tegerianau in August 2021 to species-poor grassland at nearby Paxton's Tower, managed by the National Trust (own observation).

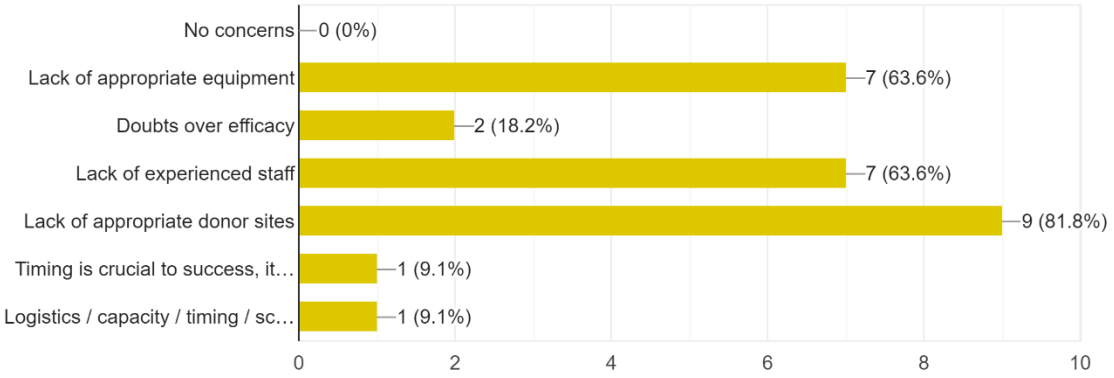

Figure 24 Responses to the question " What are the THREE main challenges to using green hay to improve biodiversity?"

In hindsight, an obvious question to have asked and used to segregate the data would have to define the LA as rural or urban. One LA specifically mentioned '*running out of areas*' as a free text response to the later question in Figure 27 about barriers to doing more.

Being rural or urban could possibly influence the ability of LAs to use different methods of conservation/management techniques and also the amount of grassland with which to work with on improving species richness similar to results from Welsh recycling rates where overall rural councils outperform urban councils due to increased levels of green waste composting, etc. (Welsh Government, 2022b). Alternatively, it may equally highlight that being urban and rural has no impact on the commitment to and delivery of the conservation and creation of further species-rich grasslands and that the reason some LAs do more than others is down to priorities within individual LAs.

4.2.3 Level of conservation activity

The questions assessing the level of conservation activity happening on grasslands provide an optimistic direction of travel, with all participants believing that their councils had increased the areas managed for biodiversity with just under half assessing this increase as 10 sites or more (Figure 25).

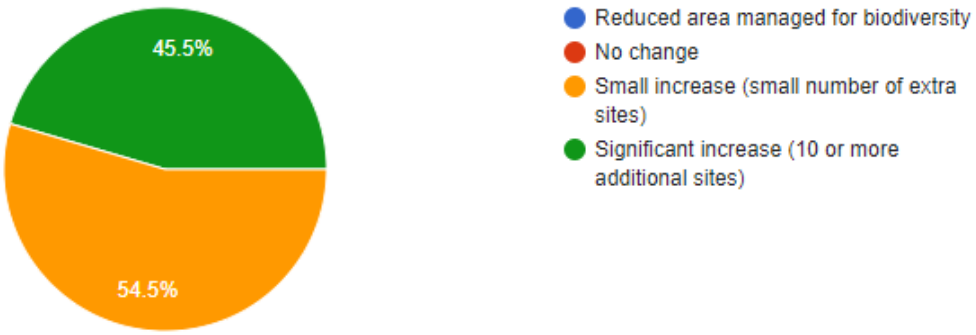

Figure 25 LA grassland managed for biodiversity over last 5 years.

This positive stance was maintained in the forward look (Figure 26), with half of the respondents expecting further significant increases in areas of grassland managed for biodiversity, 4 expecting their councils to make a small increase in area and only one expecting no change from the status quo.

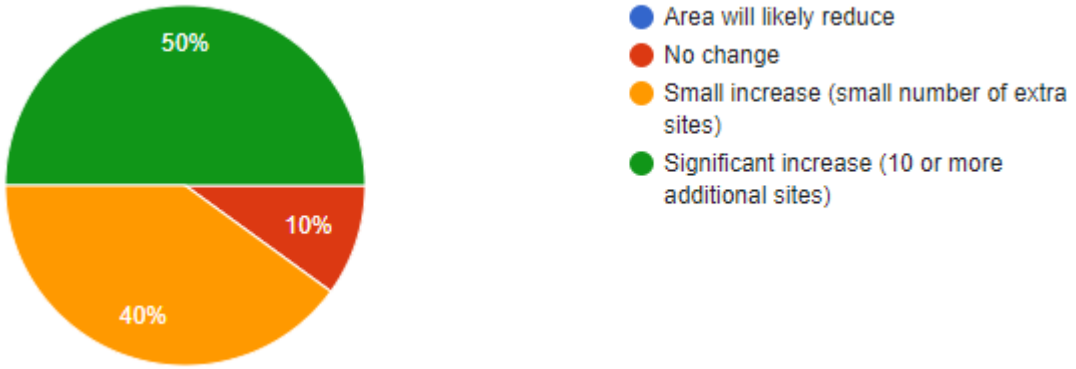

Figure 26 LA grassland managed for biodiversity over next 5 years

4.2.4 Barriers to enhancing grassland management

The final section of the questionnaire asked for the three most significant barriers to further increasing the biodiversity of LA grasslands (Figure 27) and what three things would most help in overcoming these barriers (Figure 29). The most selected barrier with 8 out of 11 LAs, was 'Concerns of increased costs and time', followed by 'Concerns regarding complaints' with 6 out 11 votes and then 'Lack of skills and knowledge within workforce' with 5 out of 11. Councils facing challenging a financial situation are naturally averse to the potential risk of increased cost from changing existing management regimes. These concerns are not unfounded with one Scottish council suggesting taking part in No Mow May could cost them £350,000 in staff costs and machinery charges (BBC News, 2023). However, the Burnley Council website highlights the benefits of its reduction in the frequency of mowing as 'Saving money', 'Reducing $C0_2$ emissions' and 'Increasing biodiversity' (Burnley Council, 2023). The manager responsible for Dorset council's road verges described a reduction in £500,000 in mowing costs from changing their road verge mowing regimes to produce low fertility species-rich grasslands as shown in Figure 28 (Sterling, 2021).

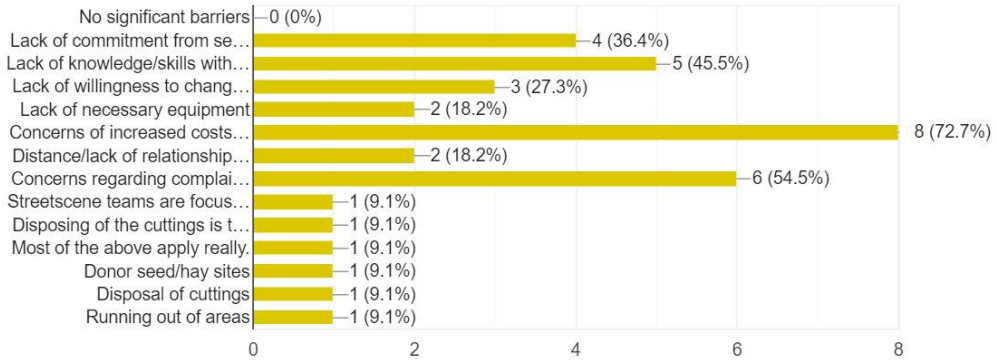

Figure 27 Barriers to expanding grassland managed for biodiversity.

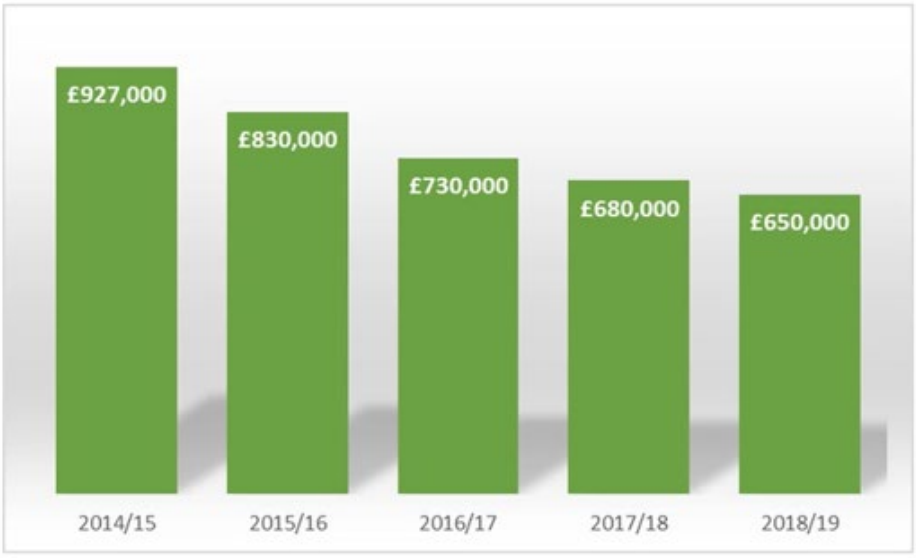

Figure 28 Highway verge maintenance budget in Dorset since 2014 (from (Sterling, 2021)*)*

The literature review above covered research suggesting that concerns about potential complaints from the public about areas where grass is left to grow long can be unfounded or at least overcome with sufficient engagement and education, for example, Fischer et al., (2020). However, a simple internet search of 'complaints long grass' reveals numerous examples of council residents concerned about untidiness, weeds, poor visibility, etc, and politicians happy to take up these complaints on residents' behalf (Davies, 2023).

'Lack of knowledge/skills of staff' is a problem that can be addressed and was a priority for the 'Nature Isn't Neat' project, where all council staff involved in the maintenance of public spaces and road verges were engaged on the benefits and challenges of changing grassland management regimes through a series of workshops(Carroll, 2023). Although 'willingness to change' was only cited as a reason by 3 LAs, it could be argued that apart from 'lack of donor sites', all the other barriers have their basis in a whether or not the council has the motivation to look at doing things differently and make positive steps to overcoming perceived barriers whether by investing in equipment or engaging with staff and residents.

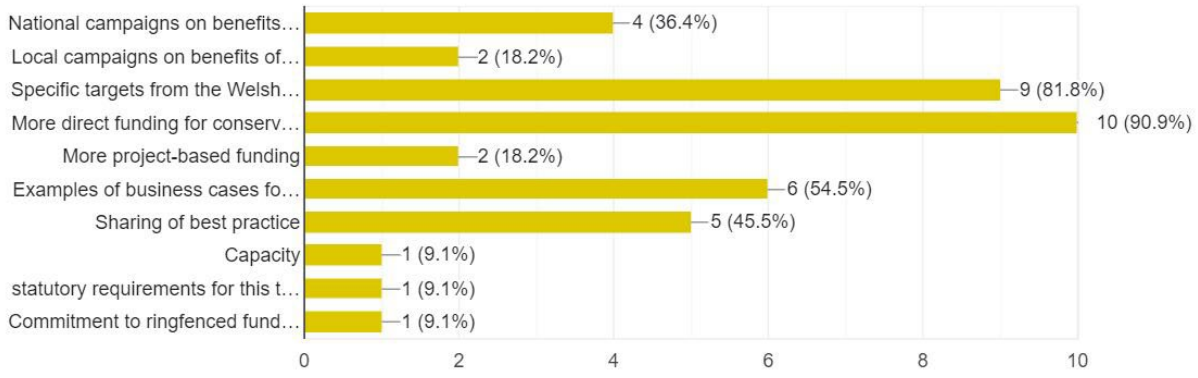

Figure 29 Overcoming barriers to grassland managed for biodiversity.

Unsurprisingly, all bar one local nature partnership officers cited ‘more direct funding for conservation’ as the best way of overcoming barriers to change within their LAs. Not only does this bypass reduced maintainance budgets but also any lack of commitment from more senior managers. Likewise ‘specific targets from Welsh government’ is a mechanism for forcing reluctant councils to act and more than anything highlights the relatively junior positions of these LNP officers within the LAs and the tiny part of the overall budgets that biodiversity takes up and resulting lack of influence (Rogers, 2021 pers.comm.). Sterling (2021) demonstrates with his work in Dorset that when staff focused on outcomes for wildlife are in senior positions with control of significant budgets that change can be delivered on a countywide scale. Both ‘examples of business cases’ and ‘sharing of best practice’ are inextricably linked and there are now forums in Wales where the transfer of knowledge can take place, such as the Local Nature Partnership Cymru’s own monthly meetings & newsletters and the Wales Green Infracture Forum coordinated by Natural Resources Wales(Natural Resources Wales, 2023b). The challenge for biodiversity officers is using examples of best practice and business cases to institute change within their own organisations.

In terms of action from the Welsh government, in 2023 they have delivered a national campaign ‘It’s for Them’ with an extensive toolkit of signs and graphics to support councils and other stakeholder, for example Figure 30, and recommendations from the 2022 Biodiversity Deep Dive included a commitment to further supporting Local Nature Partnerships, addressing financial and funding barriers, capacity building and developing skills, supporting behaviour change through public and private sector engagement (Welsh Government, 2022a).

Figure 30 Sign template from 'It's for Them' (Welsh Government, 2023)

5. Conclusion

These meadow survey results suggest that the addition of green hay has enhanced species richness within the two treated meadows. However, at this stage, particularly in the development of the plant community of Cae Gwair the most recently treated field, despite an uptick in the number of species has not shown a similarity to any desirable NVC grassland community as yet, unsurprising considering it has only been 2 years since treatment with green hay. Cae Derwen restored in 2016 is showing an increasing resemblance to desired NVC communities and data shows a steady increase in species diversity. The donor meadow Cae Tegerianau although showing a resemblance to desired NVC communities shows a degree of variability across the field but then this field is also only the product of its management over the last 20 years since NBGW took over the site. It was not an existing hay meadow when NBGW took over the site and its diversity is limited by its isolation from other hay meadows.

The survey of Local Nature Partnership Cymru officers suggests that across Wales areas of grassland in both public spaces and road verges are increasingly being managed for the benefit of wildlife and that there is evidence of all the methods mentioned in the literature being are being used within local authorities. The use of green hay is not widespread reflecting the challenge of needing specialised machinery not normally used within grounds maintenance teams and access to existing high-quality meadows for use as donor sites.

Clearly there are ways of overcoming all the barriers highlighted by respondents but above all this requires commitment and investment to lead to a renaissance in hay meadows and their dependent biodiversity.

5.1 Limitations of the research

The fundamental limitations of this project are the fact the restoration was already underway and no consistent and comprehensive baseline data had been recorded and that research projects measuring the impact of restoration actions usually take place over multiple years. The use of fields of different ages following treatment with green hay was a way of attempting to mitigate this but it would be advisable for NBGW to set up survey plots prior to treatment if they intend converting further pasture to hay meadow.

This research project used the NMPS method for surveying the vegetation to form the basis of long-term monitoring at the site. The most obvious limitation is the bias implicit in the selection of plots by the survey. Cae Derwen Plot 1 highlights one of the issues. Here, the need to choose a plot in relation to a permanent fixed structure for future monitoring, in this case the mature oak in the centre of the field caused the plot to be selected too close to the tree which although not apparent in the first year, it was clear that this proximity impacted the plant community in this plot. Issues such as this with single plots are alleviated by surveying a number of plots in each habitat but had this plot continued to be the only plot monitored in this habitat, the increasing diversity would have been significantly underestimated. The lack of randomness of the survey plots could have been overcome by the use of transects but these are usually carried out using considerably smaller quadrats

and equally transects or randomised plots could miss small and localised populations of key species.

The data produced by the NMPS was suitable for the TABLEFIT analysis of 'Goodness-to-Fit' to NVC grassland classifications which produced results showing movement towards species-rich grassland classifications between the most recently treated field and the one treated 3 years earlier. However, the use of the Domin scale for assessing cover meant that the data wasn't suitable for statistically comparing percentage cover, etc because there was a range with unequal boundaries rather than a single % value which could be summed/averaged, etc.

A key variable not picked up by the research is that from the point that the green hay was added to the fields, the ongoing management was also permanently changed and the fields were hay cut once per year. It is impossible to pick out from the data the degree to which it is the green hay or the cutting regime that has influenced the increase in biodiversity although onsite experience of the number of years that it has taken to create meadow at Cae Trawscoed through hay-cutting alone and the sudden increase in species such as Yellow Rattle in Cae Gwair suggests that the initial increase in species at least in the early years is due to the green hay. There are unlikely to be any restoration projects where fields are treated with green hay or meadow seed and then not subjected to hay cuts so the true influence of either variable, particularly over the long term is difficult to assess.

Other variables that could have been measured alongside the botanical survey could have been the impact on numbers of wildlife such as pollinating insects or soil invertebrates and nutrient levels in each of the plots could have been established for further comparison. However, because of the institutional ownership of the whole site, there was certainty regarding the previous lack of addition of fertilizer within the last 20 years which is not the case for many restoration projects elsewhere which are taking place on previously arable land.

The prime limitation with the survey of local authorities was the small number of responses from a small potential pool of potential respondents, this could have been address by expanding the survey to included other members of staff within local authorities. The time involved in locating suitable respondents across Wales was not practical for this type of project but with more time, visits to individual local authorities to interview a number of staff might be a suitable solution.

If conducted again, it would be valuable to link more of the questions and responses, for instance to assess the degree to which a LA being rural or urban affected responses and whether there were statistical relationships between a respondent giving a certain answer to different questions.

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Verbal Sources

Langridge, B: Head of Interpretation, National Botanic garden of Wales.

Rogers, A: Biodiversity Officer, Pembrokeshire County Council.

Appendices

Appendix 1 Cae Tegerianau 2015 Species Inventory

WILDLIFE TRUST SOUTH & WEST WALES
EAST CARMARTHENSHIRE GROUP

HAY MEADOW WALK, WAUN LAS NATURE RESERVE

19 people met at Allt Goch Lodge on Saturday 6 June 2015 at 2.00 pm.
The walk in the Hay Meadow was led by Richard and Kath Pryce.

Alder Buckthorn, hedge - Frangula ulnus
Guelder Rose, hedge - Viburnum opulus
Angelica - Angelica silvestris
Bedstraw Heath - Galium saxatile
Bird's-foot -trefoil, Common - Lotus coniculatus
Bird's-foot -trefoil, Greater - Lotus pedunculatus
Bittercress, Wavy - Cardamine flexuosa
Bugle - Ajuga reptans
Burnet, Greater - Sanguisorba officinalis
Buttercup, Bulbous - Ranunculus bulbosus
Buttercup, Creeping - Ranunculus repens
Buttercup, Meadow - Ranunculus acris
Caraway, Whorled - Carum verticillatum
Catsear - Hypochaeris radicata
Clover, Red - Trifolium pratense
Coltsfoot - Tussilago farfara
Cuckoo Flower - Cardamine pratensis
Eyebright - Euphrasia sp
Forget-me-not, Changing - Myosotis discolor
Gorse - Ulex europaeus
Hemp-nettle, Common - Galeopsis tetrahit
Hogweed - Heacleum sphondylium
Horsetail, Wood - Equisetum sylvaticum
Knapweed, Common - Centaurea nigra
Lousewort - Pedicularis sylvatica
Meadowsweet - Filipendula ulmaria
Mouse-ear, Common - Cerastium fontanum
Nettle Common - Urtica dioica, 2 ssp Nettle Small - Urtica urens
Orchid, Common-Spotted - Dactylorhiza fuchsii
Orchid, Heath Spotted - Dactylorhiza maculata
Orchid, Common Spotted x Heath Spotted
Orchid, Greater Butterfly - Platanthera chlorantha
Orchid, Southern Marsh - Dactylorhiza praetermissa
Pignut - Conopodium majus
Ragged Robin - Silene flos-cuculi
Silverweed - Potentilla anserina
Sorrel Common - Rumex acetosa
Speedwell, Germander - Veronica chamaedrys
Thistle, Marsh - Cirsium palustre
Tormentil - Potentilla erecta
Vetchling, Yellow - Lathyrus aphaca, L. Very Rare
Yellow Rattle - Rhinanthus minor 6 ssp

Crested Dog's-tail - Cynosurus cristatus grass
Sweet Vernal-grass - Anthoxanthum odoratum
Purple Moor-grass - Molinia caerulea
Tufted Hair Grass - Deschampsia cespitosa 3ssp
Yorkshire-fog - Holcus lanatus
Red Fescue - Festuca rubra agg
Common Bent-grass - Agrostis capillaris
Common Wood-rush, Probably Field - Luzula campestris
Not sure which rushes were in the meadow:-
Rush, Soft - Juncus effusus
Rush, Hard - Juncus inflexus
Rush, Sharp-flowered - Juncus acutiflorus
Rush, Conglomerate - Juncus conglomeratus
Hairy Sedge - carex hirta

Howard Mead contributed Latin names

Appendix 2 NPMS Survey form

National Plant Monitoring Scheme

Name(s):

1km square grid ref ☐☐-☐☐☐☐

Date of 1st survey: ☐☐ - ☐☐ - ☐☐

Date of 2nd survey: ☐☐ - ☐☐ - ☐☐

At which level are you surveying?

Wildflower ☐

Indicator ☐

Inventory ☐

Plot number: ☐

SQUARE plot - OS Grid ref for SW corner

☐☐ - ☐☐☐☐☐ - ☐☐☐☐☐

LINEAR/VERTICAL plot - OS Grid refs for plot ends

1. ☐☐ - ☐☐☐☐☐ - ☐☐☐☐☐

2. ☐☐ - ☐☐☐☐☐ - ☐☐☐☐☐

Please estimate the 6 figure grid ref. If you have GPS then enter the 10 figure ref.

Habitat type and description (see guidance notes, pp.27-39, for categories to use):

Broad habitat: Fine habitat:

Please also fill in the following information where possible (see the guidance notes pages 20-23).

If your plot is on a slope, in which direction does it face (optional)? Please circle one or more:

N NE E SE S SW W NW

How steep is the plot (optional)? Flat (0-5°) ☐ Moderate (6-30°) ☐ Steep (>30°) ☐

Management type/description (optional):

Grazing pressure (optional): Low ☐ Moderate ☐ High ☐ (See page 23 of the guidance notes)

Which animals graze the plot, if known?

How wooded is your plot?

Dense tree and/or shrub cover ☐ Scattered trees and/or shrubs ☐ Hedgerow ☐ No trees or shrubs ☐

Vegetation height, please enter in the box how much of the vegetation falls into each category (excluding the canopy layer if in woodland) using the following scores: 0 = 0%; 1 = 1-33%; 2 = 34-66%; 3 = 67-100%

<10cm ☐ 11-30cm ☐ 31-100cm ☐ 101-300cm ☐ >300cm ☐

Please use this space for any additional comments: e.g. weather conditions; are plants/trees looking healthy?

Please make a sketch that would aid someone else in relocating your plot, or take a maximum of two photos to upload to the website.

For your plot, allocate an abundance score for each species using the Domin scale below (also see inside the back cover of the guidance notes). Please also include scores for the extra items listed at the end of the table below if possible.

Domin	1	2	3	4	5	6	7	8	9	10
% cover	<1% (1-2 indivs)	< 1% (several indivs)	1-4%	5-10%	11-25%	26-33%	34-50%	51-75%	76-90%	91-100%

Species name	Domin visit 1	Domin visit 2	Species name	Domin visit 1	Domin visit 2
			Bare soil		
			Bare rock/gravel		
			Litter		
			Mosses & lichens		

Appendix 3 Filled in NMPS Survey Form showing map

Cae Gwair Plot 1

National Plant Monitoring Scheme

Name(s):

1km square grid ref

Date of 1st survey: 26.05.23

Date of 2nd survey:

At which level are you surveying?

Wildflower ☐

Indicator ☐

Inventory ☑

Plot number: ☐

SQUARE plot - OS Grid ref for SW corner

SW 52566 18058

LINEAR/VERTICAL plot - OS Grid refs for plot ends

1.

2.

Please estimate the 6 figure grid ref. If you have GPS then enter the 10 figure ref.

Habitat type and description (see guidance notes, pp.27-39, for categories to use):

Broad habitat: Inland grassland Fine habitat: neutral grassland

Please also fill in the following information where possible (see the guidance notes pages 20-23).

If your plot is on a slope, in which direction does it face (optional)? Please circle one or more:

(N) NE E SE S SW W NW

How steep is the plot (optional)? Flat (0-5°) ☑ Moderate (6-30°) ☐ Steep (>30°) ☐

Management type/description (optional): hay cut 2019. first green hay applied Aug 2019 hay meadow sheep + cattle grazed pasture year around

Grazing pressure (optional): Low ☐ Moderate ☐ High ☐ (See page 23 of the guidance notes)

Which animals graze the plot, if known? None

How wooded is your plot?

Dense tree and/or shrub cover ☐ Scattered trees and/or shrubs ☐ Hedgerow ☐ No trees or shrubs ☑

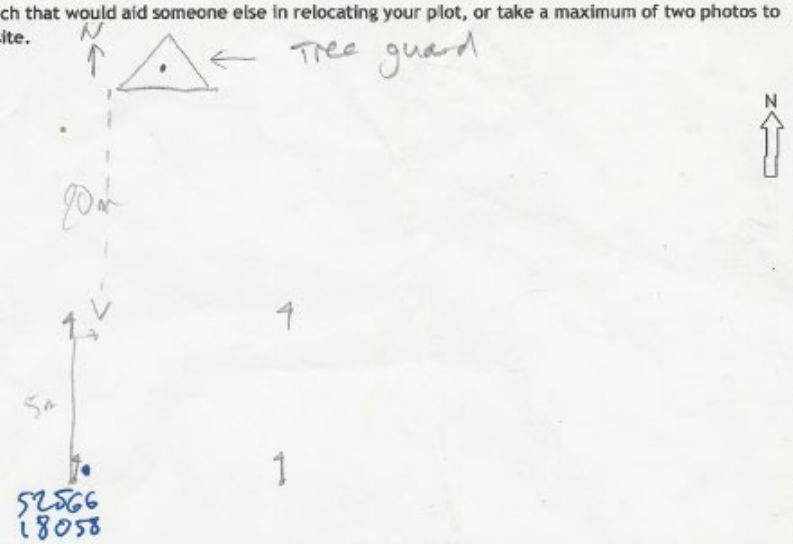
Vegetation height, please enter in the box how much of the vegetation falls into each category (excluding the canopy layer if in woodland) using the following scores: 0 = 0%; 1 = 1-33%; 2 = 34-66%; 3 = 67-100%

<10cm 1 11-30cm 3 31-100cm 1 101-300cm ☐ >300cm ☐

Please use this space for any additional comments: e.g. weather conditions; are plants/trees looking healthy?

Waun Las / Cae Gwair Plot 1

Please make a sketch that would aid someone else in relocating your plot, or take a maximum of two photos to upload to the website.



For your plot, allocate an abundance score for each species using the Domin scale below (also see inside the back cover of the guidance notes). Please also include scores for the extra items listed at the end of the table below if possible.

Domin	1	2	3	4	5	6	7	8	9	10
% cover	<1% (1-2 indivs)	< 1% (several indivs)	1-4%	5-10%	11-25%	26-33%	34-50%	51-75%	76-90%	91-100%

Species name	Domin visit 1	Domin visit 2	Species name	Domin visit 1	Domin visit 2
Rhinanthus minor	7				
Euphrasia officinalis	3		eyebright		
Ranunculus bulbosus	3				
" acris	3				
Trifolium repens	3				
" pratense	1				
Cirsium palustris	1				
Hypochaeris radicata	2		cats ear		
Taraxacum	2		dandelion		
Achillea millefolium	3				
Myosotis sp	1				
Rumex acetosa	2				
Cerastium ~~fontanum~~	2				
Anthoxanthum	3				
Holcus lanatus	3				
Luzula campestris	4				
Ranunculus repens	1				
Plantago lanceolata	1				
Conopodium majus	2				
			Bare soil		
			Bare rock/gravel		
			Litter		
			Mosses & lichens		

Botanical Society of Britain & Ireland · Centre for Ecology & Hydrology · JNCC · Plantlife

Appendix 4 NPMS Neutral Pastures and Meadows Indicator species

Neutral pastures and meadows

Name	Common name	WF	Indicator	Page No.
Carduus nutans	Musk Thistle / Nodding Thistle		+	86
Cerastium fontanum	Common Mouse-ear		+	8
Cirsium arvense	Creeping Thistle		-	87
Colchicum autumnale	Autumn Crocus		+	68
Conopodium majus	Pignut		+	11
Crataegus monogyna	Hawthorn		-	150
Cruciata laevipes	Crosswort		+	35
Daucus carota	Wild Carrot		+	11
Galium album (Galium mollugo)	Hedge Bedstraw		+	14
Geranium sylvaticum	Wood Crane's-bill		+	92
Holcus lanatus	Yorkshire-fog		+	135
Juncus inflexus / effusus / conglomeratus	Hard Rush / Soft Rush / Compact Rush		-	138/139
Knautia arvensis	Field Scabious		+	93
Leucanthemum vulgare	Oxeye Daisy		+	18
Ophioglossum vulgatum	Adder's-tongue		+	128
Pastinaca sativa	Wild Parsnip		+	48
Pimpinella major	Greater Burnet-saxifrage		+	23
Ranunculus repens	Creeping Buttercup		+	51
Rhinanthus minor	Yellow-rattle		+	53
Rumex acetosa	Common Sorrel		+	64
Rumex crispus / obtusifolius	Curled Dock / Broad-leaved Dock		-	113/114
Sanguisorba officinalis	Greater Burnet		+	65
Saxifraga granulata	Meadow Saxifrage		+	27
Silaum silaus	Pepper-saxifrage		+	56
Stellaria holostea	Greater Stitchwort		+	30
Succisa pratensis	Devil's-bit Scabious		+	101
Symphytum officinale	Common Comfrey		+	101
Trifolium pratense	Red Clover		+	80
Urtica dioica	Common Nettle		-	117
Valeriana officinalis	Common Valerian		+	82

The management of grassland for biodiversity in Welsh Local Authorities by Laura Davies

This research contributes to my dissertation as final part of the Masters Degree in Environmental Conservation and Management at the University of Wales Trinity St David which looks at 'green hay' as a tool for boosting biodiversity and its application to local authority settings. My research is in two parts, I am studying the impact of the using green hay on the plant biodiversity of grassland, by comparing the species composition of 2 fields treated with 'green hay' to the original donor field and measuring the changes over time within the National Botanic Garden of Wales Waun Las NNR.
This survey contributes to the second part of my research that reviews the management of local authority amenity grass and road verges across Wales for biodiversity, the different methods used, the barriers to managing more grassland for biodiversity and examples of good practice.
This survey is being sent to the Local Nature Partnership Coordinator in each of the 22 local authorities in Wales. I would be really grateful if you could respond as soon as possible.

Participant Information
By agreeing to participate in this research, you are doing so voluntarily and can withdraw at any time. Each of the questions are voluntary. The information you provide is confidential, except that with your permission anonymised quotes may be used. If you request confidentiality, beyond anonymised quotes, information you provide will be treated only as a source of background information, alongside literature-based research. Personal identifying information will not appear in any publications resulting from this study; neither will there be anything to identify your place of work. Examples of best practice will not be linked to the survey data in any way.

Management of Roadside Verges

The following questions apply to roadside verges only.

1. How often does your local authority use the TIMING OF CUTS to manage verges for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

2. How often does your local authority use CUT & COLLECT to manage verges for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

3. How often does your local authority use WILDFLOWER SEED (including yellow rattle) to manage/improve verges for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Frequently

4. Has your local authority used WILDFLOWER TURF to manage/improve verges for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Frequently

5. Has your local authority used 'GREEN HAY' to manage/improve verges for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Frequently

6. Has your local authority used any method not listed for the management/improvement of verges for biodiversity?

Management of Amenity Grassland

The following questions apply to amenity grassland only

7. How often does your local authority use the TIMING OF CUTS to manage/improve amenity grass for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

8. How often does your local authority use CUT & COLLECT to manage/improve amenity grass for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Always

9. How often does your local authority use WILDFLOWER SEED (including yellow rattle) to manage/improve amenity grass for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Frequently

10. How often does your local authority use WILDFLOWER TURF to manage/improve amenity grass for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Frequently

11. Has your local authority used 'GREEN HAY' to manage/improve amenity grass for biodiversity?

Mark only one oval.

	1	2	3	4	5	6	7	
Never	◯	◯	◯	◯	◯	◯	◯	Frequently

12. Has your local authority used any method not listed for the management/improvement of amenity grass for biodiversity?

_____

Use of Green Hay

13. What do you regard as the THREE main challenges to using green hay to improve biodiversity?

Tick all that apply.

- [ ] No concerns
- [ ] Lack of appropriate equipment
- [ ] Doubts over efficacy
- [ ] Lack of experienced staff
- [ ] Lack of appropriate donor sites
- [ ] Other: _____

Barriers to Change

14. Over the past five years do you feel your local authority has expanded the area of grass managed for biodiversity?

Mark only one oval.

- ◯ Reduced area managed for biodiversity
- ◯ No change
- ◯ Small increase (small number of extra sites)
- ◯ Significant increase (10 or more additional sites)

15. Over the next five years do you feel your local authority will expand the area of grass currently managed for biodiversity?

Mark only one oval.

- ◯ Area will likely reduce
- ◯ No change
- ◯ Small increase (small number of extra sites)
- ◯ Significant increase (10 or more additional sites)

16. What are the THREE main barriers to expanding the area of grass managed for biodiversity in your local authority?

Tick all that apply.

- [ ] No significant barriers
- [ ] Lack of commitment from senior management
- [ ] Lack of knowledge/skills within workforce
- [ ] Lack of willingness to change current methods
- [ ] Lack of necessary equipment
- [ ] Concerns of increased costs and time
- [ ] Distance/lack of relationship between conservation staff and grounds maintenance dept
- [ ] Concerns regarding complaints from residents
- [ ] Other: _____

17. What would help you most in overcoming the barriers to change in your local authority?

Tick all that apply.

- [ ] National campaigns on benefits of managing for biodiversity
- [ ] Local campaigns on benefits of managing for biodiversity
- [ ] Specific targets from the Welsh Government
- [ ] More direct funding for conservation/maintenance teams
- [ ] More project-based funding
- [ ] Examples of business cases for change from other local authorities
- [ ] Sharing of best practice
- [ ] Other: _____

18. Could you provide an example of a successful grassland biodiversity project or best practice carried out by your local authority? Please provide brief outline, link to website/blog/article or email a file to 1905575@student.uwtsd.ac.uk

Appendix 6 NPMS data

	5m x 5m plots	Cae Tegerianau (donor meadow)				Cae Gwair (green hay applied 2019)							Cae Derwen (green hay applied 2016)				
		Plot 1	Plot 2	Plot 3	Plot 4	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
		02/07/2021	02/07/2021	02/07/2021	02/07/2021	26/05/2021	26/05/2021	18/06/2021	18/06/2021	18/06/2021	18/06/2021	23/06/2021	26/05/2021	23/06/2021	23/06/2021	23/06/2021	23/06/2021
							no green hay					no green hay					
SW corner		SN 53532-18255	SN 53507-18260	SN 53461-18240	SN 53459-18256	SN 52566-18058	SN 52657-18094	SN 52660-18043	SN 52607-17990	SN 52534-18000	SN 52568-18079	SN 52626-18078	SN 52347-17324	SN 52425-17323	SN 52423-17345	SN 52325-17404	SN 52332-17388
slope		N	NW	NW	NW	N						NW					
steep		Mod	Mod	Mod	Mod	Flat	Flat	Flat	Flat	Flat	Flat	Mod	Flat	Flat	Flat	Flat	Flat
Veg height	<10cm	1	1	1	1	1		1	1	1	1				1		
	11-30cm	1	2	2	2	3	1	3	3	3	3	2	3	3	3	3	3
	31-100cm	1	2	2	1	1	3	1	1	1	1	3	1	1	1	1	1
	1=1-33% 2=34-66% 3=67-100%																
Dactylorhiza fuchsii	Common Spotted Orchid	2	3	2	3											1	2
Dactylorhiza maculata	Heath Spotted Orchid		2	1	2										1		
Dactylorhiza praetermissa	Southern Marsh Orchid	1	2		3										1		
Platanthera chlorantha	Greater Butterfly Orchid	3	2	2	3			1					1	1	2		3
Agrostis capillaris	Common Bent	4	3	4	4		6	5	4	5	4	4	2	4	4		4
Anthoxanthum odoratum	Sweet vernal grass	9	8	8	8	8	5	7	7	8	8	8	8	8	7	5	7
Cynosurus cristatus	Crested Dogstail	3	4	2	3									3	3	3	3
Dactylis glomerata	Cocksfoot			2	2							3	2	4	3		
Festuca rubra	Red Fescue		3	4	4		4							3		2	3
Holcus lanatus	Yorkshire Fog	4	5	3	3	3	4	4	4	3	3	5	2	4	4	3	4
Lolium perenne	Perennial Ryegrass							4	4	5	4	3		3			
Luzula campestris	Field Wood-rush				2	4			4		4		3				
Poa pratensis	Smooth Meadowgrass																
Poa trivialis	Rough Meadowgrass											2					
Alopecurus pratensis	Meadow Foxtail						4					3	2	3	2	2	3
Holcus mollis	Creeping soft grass											4					
Phleum pratense	Timothy											3					
Juncus effusus	Soft rush															6	
Achillea millefolium	Yarrow					3				3	2						
Centaurea nigra	Common Knapweed	1		3	1										5	4	7
Cerastium fontanum	Common Mouse-ear					2			1				2				
Cirsium arvense	Creeping thistle											1					
Cirsium palustre	Marsh thistle					1		2		2						1	
Cirsium vulgare	Spear thistle																
Conopodium majus	Pignut			2	2	2					2						
Euphrasia ssp	Eyebright	8	7	2	4	3		3	3	6	6		2	3	7	5	7
Heracleum sphondylium	Hogweed												3	1			
Hyacinthoides non-scripta	Bluebell																
Hypochaeris radicata	Cat's Ear	4	4	4	4	2		3	3	2	2		2		2	3	4
Leontodon hispidus	Rough hawkbit																
Lotus corniculatus	Common bird's foot trefoil		3										1	3	4	4	3
Lotus pedunculatus	Greater bird's foot trefoil																3
Odontites vernus	Red Bartsia																
Plantago lanceolata	Ribwort plantain	6	6	4	5	1			3	2	2		5	5	4	4	3
Ranunculus acris	Meadow Buttercup	4	4	3	2	3	1	4	3	4	4	2	2	4	4	6	4
Ranunculus bulbosus	Bulbous Buttercup					3							2				
Ranunculus repens	Creeping Buttercup					1	1	4		5	4						
Rhinanthus minor	Yellow Rattle	8	7	6	7	7		8	8	8	8	1	4	7	7	5	5
Rumex acetosa	Commen sorrel	1	2	2	2	2		5	4	4	3	4	1	3	3		
Rumex obtusifolius	Broad-leaved dock											2					
Taraxacum officinale	Dandelion	3	3	2	2	1	2	2	4	3	3		2	4	4	2	2
Trifolium dubium	lesser trefoil	3	2		2						3					4	3
Trifolium pratense	Red clover	5	5	4	4	1				2	2		2	3	5	5	5
Trifolium repens	White Clover	4	5	4	4	3		4	3	4	5						
Vicaria verna	Lesser Celendine						3						2				
Senecio jacobaea	Common ragwort		3														
Stellaria graminea	Lesser stitchwort				1									2			
Myosotis discolor	Changing forget-me-not					1											
Quercus sp	Oak seedling									1						1	
Prunella vulgaris	Selfheal													3	4	3	3
Carum verticillatum	Whorled caraway															5	
Senecio aquaticus	Marsh ragwort															1	
Sanguisorba officinalis	Greater burnet															1	2

Domin scale	1	2	3	4	5	6	7	8	9	10
% cover	1-2 indivs	<1% sev indiv	1-4%	5-10%	11-25%	26-33%	34-50%	51-75%	76-90%	91-100%

Appendix 7 Tablefit Data

Sample Teg1 Parameters = All sp Domin Sp & c

E2.112 MG 5 56 | 74 82 45 67| Cynos cris-Centaur nigr

E2.112 MG 5a 54 | 73 83 42 67| Cynos cris-Centaur nigr Lath pratensis

E2.242 MG 3b 53 | 56 81 55 77| Anthox odo-Geran sylv Briza media

E1.72 U 4b 50 | 69 53 63 49| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

E2.111 MG 6b 49 | 78 57 50 50| Lolium per-Cynos cris Anthox odorat

Sample Teg2 Parameters = All sp Domin Sp & c

E2.112 MG 5 68 | 85 80 60 72| Cynos cris-Centaur nigr

E2.112 MG 5a 66 | 83 80 57 72| Cynos cris-Centaur nigr Lath pratensis

E2.112 MG 5b 58 | 75 74 54 65| Cynos cris-Centaur nigr Galium verum

E2.242 MG 3b 58 | 60 75 63 76| Anthox odo-Geran sylv Briza media

E3.41 MG 8 57 | 72 56 73 55| Cynos cris-Caltha palu

Sample Teg3 Parameters = All sp Domin Sp & c

E2.242 MG 3b 72 | 70 92 74 93| Anthox odo-Geran sylv Briza media

E2.112 MG 5 65 | 85 86 49 85| Cynos cris-Centaur nigr

E2.112 MG 5a 63 | 83 87 46 84| Cynos cris-Centaur nigr Lath pratensis

E1.72 U 4b 58 | 79 56 65 64| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

E2.242 MG 3 57 | 77 79 42 80| Anthox odo-Geran sylv

Sample TEG4 Parameters = All sp Domin Sp & c

E2.242 MG 3b 74 | 74 81 79 82| Anthox odo-Geran sylv Briza media

E2.112 MG 5 65 | 88 77 55 73| Cynos cris-Centaur nigr

E2.112 MG 5a 63 | 87 76 51 72| Cynos cris-Centaur nigr Lath pratensis

E2.112 MG 5b 57 | 77 68 51 65| Cynos cris-Centaur nigr Galium verum

E1.72 U 4b 55 | 85 51 65 55| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

Sample GWA1 Parameters = All sp Domin Sp & c

E2.242 MG 3b 49 | 65 90 34 93| Anthox odo-Geran sylv Briza media

E1.72 U 4b 47 | 81 58 37 62| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

E2.242 MG 3 43 | 69 75 22 79| Anthox odo-Geran sylv

E2.112 MG 5 37 | 66 70 16 67| Cynos cris-Centaur nigr

E3.41 MG 8 37 | 66 56 26 55| Cynos cris-Caltha palu

Sample GWA2 Parameters = All sp Domin Sp & c

E1.72 U 4b 68 | 51 78 88 89| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

B3.31 MC 9e 56 | 56 70 65 80| Fest rubra-Holcu lanat Anthox odorat

E1.72 U 4 46 | 43 61 57 81| Fes ovi-Agr cap-Gal sax

E2.111 MG 6b 46 | 48 73 49 80| Lolium per-Cynos cris Anthox odorat

E2.111 MG 7c 43 | 68 75 26 58| Lol pere flood-pasture Lol-Alop-Fes pr

Sample GWA3 Parameters = All sp Domin Sp & c

E2.111 MG 6b 57 | 70 66 62 60| Lolium per-Cynos cris Anthox odorat

E1.72 U 4b 55 | 61 59 78 56| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

B3.31 MC 9e 43 | 61 48 56 49| Fest rubra-Holcu lanat Anthox odorat

E2.111 MG 6a 42 | 80 58 38 36| Lolium per-Cynos cris Typical

E3.41 MG 8 41 | 52 60 46 58| Cynos cris-Caltha palu

Sample GWA4 Parameters = All sp Domin Sp & c

E1.72 U 4b 65 | 83 81 61 57| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

E2.111 MG 6b 63 | 89 83 50 58| Lolium per-Cynos cris Anthox odorat

E2.242 MG 3b 50 | 54 100 48 85| Anthox odo-Geran sylv Briza media

E2.242 MG 3 50 | 64 94 38 77| Anthox odo-Geran sylv

B3.31 MC 9e 47 | 74 58 50 45| Fest rubra-Holcu lanat Anthox odorat

Sample GWA5 Parameters = All sp Domin Sp & c

E1.72 U 4b 62 | 79 68 73 52| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

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E2.111 MG 6b 59 | 78 67 61 55| Lolium per-Cynos cris Anthox odorat

E2.112 MG 5a 47 | 69 89 30 64| Cynos cris-Centaur nigr Lath pratensis

E2.112 MG 5 45 | 68 83 29 59| Cynos cris-Centaur nigr

E2.111 MG 6a 45 | 85 59 44 33| Lolium per-Cynos cris Typical

Sample GWA6 Parameters = All sp Domin Sp & c

E1.72 U 4b 56 | 85 65 54 51| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

E2.111 MG 6b 54 | 78 61 57 52| Lolium per-Cynos cris Anthox odorat

E2.242 MG 3b 50 | 60 87 44 74| Anthox odo-Geran sylv Briza media

E2.112 MG 5a 50 | 74 84 32 62| Cynos cris-Centaur nigr Lath pratensis

E2.112 MG 5 48 | 72 81 32 60| Cynos cris-Centaur nigr

Sample GWA7 Parameters = All sp Domin Sp & c

E2.111 MG 7d 47 | 90 60 37 46| Lol pere hay-meadow Lol per-Alo pra

E1.72 U 4b 46 | 51 50 56 78| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

E2.111 MG 6b 46 | 65 61 38 76| Lolium per-Cynos cris Anthox odorat

E2.111 MG 7c 44 | 83 68 22 49| Lol pere flood-pasture Lol-Alop-Fes pr

B3.31 MC 9e 43 | 54 42 56 68| Fest rubra-Holcu lanat Anthox odorat

Sample DER1 Parameters = All sp Domin Sp & c

E2.242 MG 3b 58 | 70 92 46 98| Anthox odo-Geran sylv Briza media

E2.112 MG 5 51 | 80 78 26 82| Cynos cris-Centaur nigr

E2.112 MG 5a 48 | 78 79 22 79| Cynos cris-Centaur nigr Lath pratensis

E2.242 MG 3 43 | 70 75 21 88| Anthox odo-Geran sylv

E1.72 U 4b 39 | 76 54 22 70| Fes ovi-Agr cap-Gal sax Hol lan-Tri rep

Sample DER2 Parameters = All sp Domin Sp & c

E2.112 MG 5 70 | 90 88 53 80| Cynos cris-Centaur nigr

E2.112 MG 5a 68 | 87 90 51 81| Cynos cris-Centaur nigr Lath pratensis

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E2.242 MG 3b 64 | 61 81 70 86| Anthox odo-Geran sylv Briza media

E2.112 MG 5b 61 | 78 81 51 72| Cynos cris-Centaur nigr Galium verum

E2.212 MG 4 60 | 71 86 54 75| Alopec pra-Sangui offi

Sample DER3 Parameters = All sp Domin Sp & c

E2.112 MG 5 64 | 85 84 48 72| Cynos cris-Centaur nigr

E2.112 MG 5a 61 | 83 85 45 72| Cynos cris-Centaur nigr Lath pratensis

E2.242 MG 3b 57 | 60 79 61 72| Anthox odo-Geran sylv Briza media

E2.112 MG 5b 54 | 73 76 45 64| Cynos cris-Centaur nigr Galium verum

E2.212 MG 4 49 | 63 77 44 64| Alopec pra-Sangui offi

Sample DER4 Parameters = All sp Domin Sp & c

E2.112 MG 5 53 | 79 70 41 59| Cynos cris-Centaur nigr

E2.112 MG 5a 51 | 77 71 38 62| Cynos cris-Centaur nigr Lath pratensis

E2.212 MG 4 45 | 66 73 35 56| Alopec pra-Sangui offi

E2.242 MG 3b 43 | 51 63 50 58| Anthox odo-Geran sylv Briza media

E2.112 MG 5b 42 | 67 63 35 50| Cynos cris-Centaur nigr Galium verum

Sample DER5 Parameters = All sp Domin Sp & c

E2.112 MG 5 58 | 85 80 40 68| Cynos cris-Centaur nigr

E2.112 MG 5a 56 | 83 80 37 68| Cynos cris-Centaur nigr Lath pratensis

E2.242 MG 3b 53 | 56 72 63 64| Anthox odo-Geran sylv

E2.112 MG 5b 52 | 73 72 43 60 | Cynos cris-Centaur nigr Galium verum

E2.212 MG4 49 | 67 78 41 56 | Alopec pra-Sangui offi

The management of grassland for biodiversity in Welsh Local Authorities by Laura Davies

11 responses

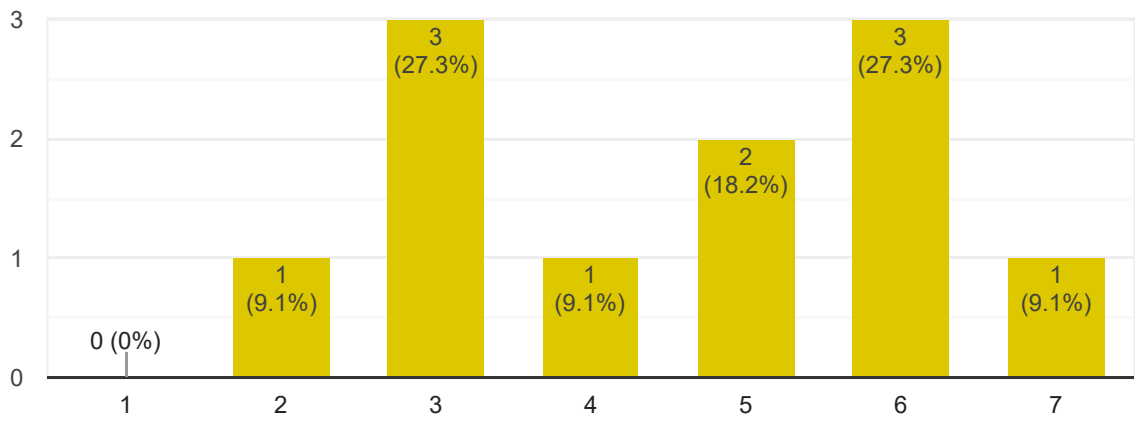
Publish analytics

Management of Roadside Verges

How often does your local authority use the TIMING OF CUTS to manage verges for biodiversity?

Copy

11 responses



How often does your local authority use CUT & COLLECT to manage verges for biodiversity?

Copy

11 responses

How often does your local authority use WILDFLOWER SEED (including yellow rattle) to manage/improve verges for biodiversity?

Copy

11 responses

Has your local authority used WILDFLOWER TURF to manage/improve verges for biodiversity?

Copy

11 responses

Has your local authority used 'GREEN HAY' to manage/improve verges for biodiversity?

Copy

11 responses

Has your local authority used any method not listed for the management/improvement of verges for biodiversity?

7 responses

local interest groups to monitor floral interest

Scarification plus local provenance wildflower seed; (re) Creation of denuded grassland using improted soil and seed

Planting wildflowers grown from local provenance seed (Currently planted out over 7,000 plants with community groups). Lots of our grassland management has been focused on public realm sites, which are often away from verges.

Scarifying

We have some 'late-cut verges' - species rich verges cut at the end of the mowing season so they can flower and set seed. It is questionable whether they work in the long term as we cannot cut and collect.

We are starting to use local provenance seed from local meadows collected by our seed harvester to enhance verges for biodiversity

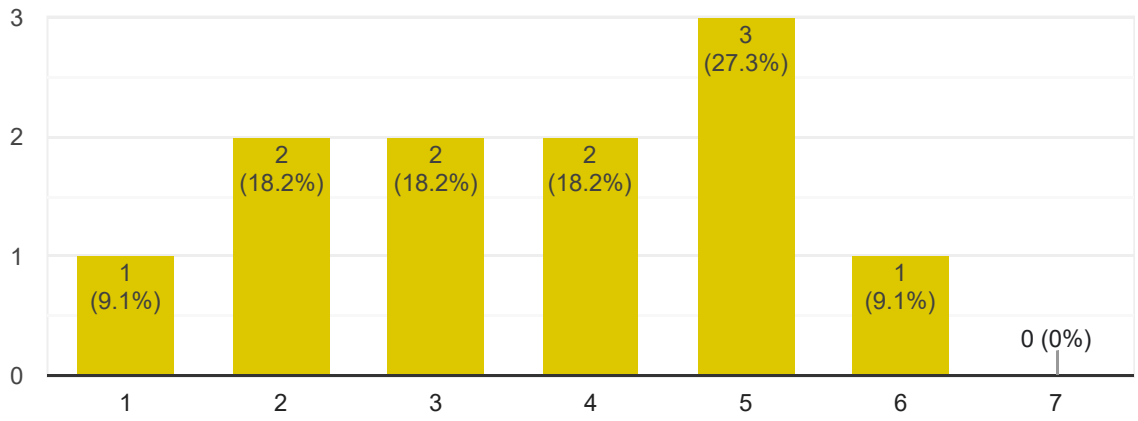
Will be trailing turf stripping and seeding

Management of Amenity Grassland

How often does your local authority use the TIMING OF CUTS to manage/improve amenity grass for biodiversity?

Copy

11 responses



How often does your local authority use CUT & COLLECT to manage/improve amenity grass for biodiversity?

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11 responses

How often does your local authority use WILDFLOWER SEED (including yellow rattle) to manage/improve amenity grass for biodiversity?

Copy

11 responses

How often does your local authority use WILDFLOWER TURF to manage/improve amenity grass for biodiversity?

Copy

11 responses

Has your local authority used 'GREEN HAY' to manage/improve amenity grass for biodiversity?

Copy

11 responses

Has your local authority used any method not listed for the management/improvement of amenity grass for biodiversity?

3 responses

Local provenance wildflower planting

Rabbits!

One county park is cattle grazed

Use of Green Hay

What do you regard as the THREE main challenges to using green hay to improve biodiversity?

Copy

11 responses

Barriers to Change

Over the past five years do you feel your local authority has expanded the area of grass managed for biodiversity?

Copy

11 responses

Over the next five years do you feel your local authority will expand the area of grass currently managed for biodiversity?

Copy

10 responses

What are the THREE main barriers to expanding the area of grass managed for biodiversity in your local authority?

Copy

11 responses

What would help you most in overcoming the barriers to change in your local authority?

Copy

11 responses

Could you provide an example of a successful grassland biodiversity project or best practice carried out by your local authority? Please provide brief outline, link to website/blog/article or email a file to 1905575@student.uwtsd.ac.uk

7 responses

Clobryn Road Biosite, Llysfaen and Police Head Quarters Colwyn Bay

This has been the main focus of our (Denbighshire County Council) conservation work for a number of years. We manage 78% of road verges with a single cut after the 1st August. We also have nearly 100 sites in the public realm, managed with cut and collect equipment which total nearly 50 acres. We developed a monitoring and survey tool, which we have shared with other local authorities throughout the UK, and we recently set up a tree nursery site with facilities to grow at least 5,000 wildflowers per year (https://www.denbighshirefreepress.co.uk/news/19949741.st-asaph-nursery-gives-new-growth-biodiversity-project/) , and purchased a seed brush harvester to collect our own seed mix from a 4 acre meadow we created at the site using local provenance green hay.

A recent video of our project work can be seen here: https://www.youtube.com/watch?v=LOoKD2RN2MY . We would be very happy to discuss our work with you further if you have any specific questions (joel.walley@Denbighshire.gov.uk)

We're only just trying to purchase a cut and collect machine so it will be a while before we have any examples/projects led by the local authority. However, what has been successful here is when Town Councils or community groups help with management by raking up cuttings afterwards: https://en.powys.gov.uk/article/9196/Resurgence-of-wildflowers-for-Powys-roadsides

https://www.facebook.com/PresteigneLife/posts/1195176380825549

https://www.facebook.com/onthevergetalgarth/

There's still the issue of disposing of the cuttings afterwards though.

Llanbadarn Cemetery - will follow by email

Will try and remember to send you an example!

Fforest Community Park in Barry where the Parks and Open Spaces changed the mowing regime, took a cut and collect, seed was harvested from a proposed housing development site that had SINC quality grassland with additional harvested seed from the National Trust at Dyffryn Gardens and spread by the local community. 30+ Pyramidal orchids were also rescued from the development site and will be transplanted.

https://carboncopy.eco/initiatives/blaenau-gwent-and-torfaen-local-nature-partnership-grasslands-network

Google Forms