Grassland Biodiversity

A summary of research outputs supported or facilitated by the Environmental Change Programme of the Scottish Government's Portfolio of Strategic Research 2011-2016

Introduction

Grasslands cover 2.38 million hectares or 29.8 % of Scotland's land area (Countryside Survey data). They also provide most of the forage to support Scotland's 1.8 million cattle and 6.7 million sheep (2015 Agricultural Census). Their key contribution to agricultural production means there is the potential for conflict between this primary goal and the conservation of biodiversity, and also between production and other ecosystem services.

The objectives of both the Land Use Strategy and the Scottish Biodiversity Strategy focus on working with nature, responsible stewardship, protecting biodiversity and supporting healthier ecosystems. The outputs of the Strategic Research Programme summarised in this booklet address the need to support these objectives with an understanding of how grasslands are affected by change and how, in turn, their functioning supports the benefits people derive from them.

The first two articles, *Long-term changes in Scottish grassland plant communities* and *Identifying drivers of change in coastal grasslands*, highlight that both highly intensive management and a removal of grazing can lead to reductions in plant species richness. They also show the sensitivity of semi-natural grasslands to nitrogen deposition and, to a lesser extent, climate change.

The next two articles show that even when the object of management is conserving biodiversity there are problems. *Upland grassland management for biodiversity* shows that trade-offs have to be made between conservation goals for different species, whilst *Managing habitat mosaics* shows that compromises may have to be made between the conservation goals of adjacent habitats when managed as part of a mosaic.

Adapting management for other goals can also enhance biodiversity. Making upland farms more self-sufficient by reseeding to improve productivity can benefit arable weeds that survive for long periods in the seedbank (*Biodiversity benefits of reseeding inbye pastures in the uplands*). Fencing to protect watercourses can benefit a wide range of invertebrate groups, especially if management is aimed at enhancing floral diversity (*Watercourse management and the promotion of biodiversity in intensive agricultural catchments*). Floral diversity is, as *How do pollinators utilise different habitats to meet their resource requirements through space and time* shows, also important for maintaining healthy populations of pollinators. As there are strong and predictable linkages between plant and invertebrate traits, they can be used to predict the impact of management on groups such as bees and beetles (*Grassland management impacts on invertebrates*).

Finally, *Grassland management drives trade-offs for biodiversity and ecosystem services shows* that management decisions can have far reaching consequences for biodiversity and for the different benefits, such as carbon storage, that we derive from grasslands. In contrast, the analysis described in *Diversity confers resilience of production in grasslands* demonstrates that diverse systems maybe more able to deliver benefits in the face of environmental variation.

I hope you will enjoy reading these articles and please get in touch with the authors if you would like more information or wish to discuss their research.

Robin Pakeman
robin.pakeman@hutton.ac.uk

Contents

Citation:
Grassland Biodiversity (2016)
Edited by Robin Pakeman, The James Hutton Institute, Craigiebucker, Aberdeen, 24 pp.

CHAPTER 1

Long-term changes in Scottish grassland plant communities

Background

Eric Birse and Jim Robertson surveyed and studied Scottish vegetation between 1945 and 1985. As part of this work they collected almost 2000 records of vegetation composition in Scottish grasslands. Since this survey work was completed, there has been increasing awareness of, and interest in, the long term impacts of human activities on plant community composition. **The aim of this work was to identify if and how different types of Scottish grasslands have changed in community composition and species richness over the past 40-60 years and to relate this to changes in climate, pollution and land use.**

Approach

- Between 2012 and 2014 we re-visited over 600 of the grassland plots surveyed by Birse and Robertson.
- The plots were split into 6 broad types of grasslands:

  1. calcareous grasslands,
  2. acidic grasslands,
  3. mat grass (Nardus stricta) grasslands,
  4. improved (Lolium perenne-dominated) grasslands,
  5. mesotrophic (moderately fertile) grasslands,
  6. wet grasslands.

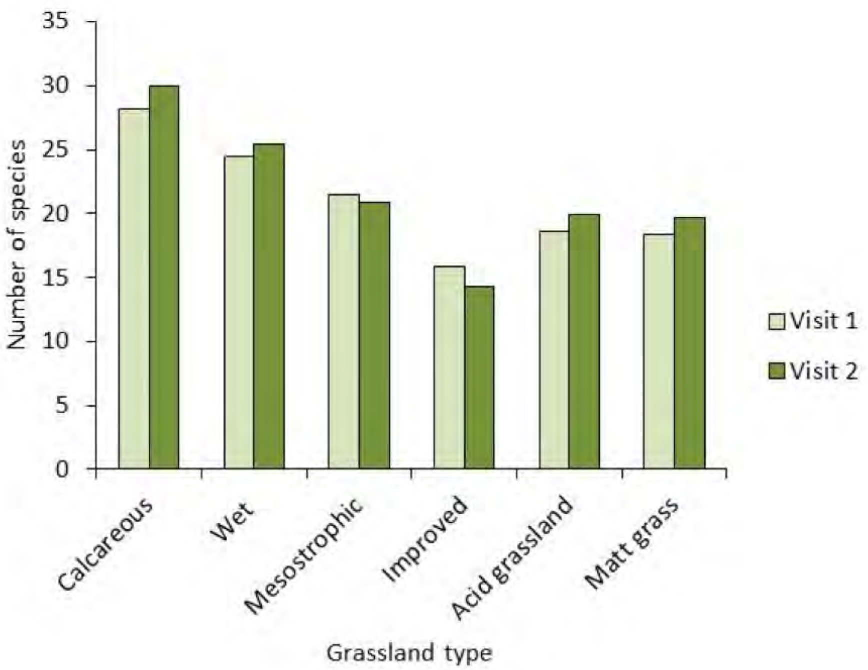


Fig. 1: Number of species in different types of grasslands in 1950-1980 (Visit 1) and 2012-2014 (Visit 2).

- Changes in species richness, taxonomic and functional composition were assessed for each grassland type over the 40-60 years between the surveys.
- Different grassland species require different growing conditions. The species recorded in this work were classified by their requirements for light, moisture, soils of different acidity and nitrogen using a scoring system called Ellenberg indicator values.

Results

- Overall, species richness increased over time but this was only in certain types of grassland (calcareous, acid and mat grass grasslands) with no increase in species richness in wet-grasslands and mesotrophic grasslands and a decline in species richness in improved grasslands (Fig. 1).
- The commonest species became more dominant with time across all types of grassland.
- Overall vegetation height remained unchanged but there were changes in individual grassland types, with height increasing in calcareous grasslands, remaining unchanged in wet, mesotrophic, acid and mat grass grasslands and declining in improved grasslands.
- Overall there was an increase in the cover of plants able to grow in moist conditions, especially in calcareous and mesotrophic grasslands. This correlates with an increase of c. 20% in rainfall at the plots surveyed over the time period between surveys; suggesting that the increase in moisture loving plants recorded by the re-survey was due to this change in climate.
- Species requiring more acidic conditions increased in wet and improved grasslands but decreased in cover in acid grassland.
- Nitrogen-loving plants increased in cover on calcareous and acid grasslands and decreased in cover in improved grasslands.

Conclusion

These changes in the types of species present in Scottish grasslands have probably been driven by combinations of changes in climate, pollution and land management (e.g. rainfall, fertiliser use and livestock grazing). Current analyses are aiming to identify the relative importance of these drivers in causing these changes.

Authors: Ruth Mitchell, Richard Hewison, Andrea Britton, Robin Pakeman, Alison Hester (and many other James Hutton Institute staff members who helped with fieldwork)

Contact: Ruth Mitchell (ruth.mitchell@hutton.ac.uk)

CHAPTER 2

Identifying drivers of change in coastal grasslands

Background

Coastal habitats are dynamic systems dependent upon the balance of erosion and deposition. They are also valuable in their provision of ecosystem services such as coastal defence and for the cultural services surrounding tourism. However, coastal habitats, and their associated biodiversity, are potentially vulnerable to a wide range of environmental drivers ranging from decreased sediment supply, climate change, atmospheric pollution and changing management. **The aim of this work was to identify which drivers were having the biggest effect on the diversity and composition of the vegetation.**

Approach

- A quadrat-based survey of 94 major sand dune and machair sites was carried out between 1975 and 1977. This was repeated in 2009-2011.
- The fates of 3862 of the original 4079 quadrats were identified.
- Changes in species richness, taxonomic and functional composition were assessed over the 34 years between the surveys.

Results

- A substantial proportion (4.9 %) of quadrats were not recorded again as they were below the high tide line, whilst 2.3 % had undergone some kind of development, such as incorporation into golf courses. There has also been a reduction in cropped area on the machair by around a half.
- Species richness changes were positive where dunes and machair have remained an integral part of the agricultural system, notably in the Inner Hebrides and North and South Uist (Fig. 1). Sites where grazing has declined have lost species.
- Sites in south east Scotland had lost species richness as a result of acidification, but climate change impacts appeared to be minimal.

Fig. 1: Species richness changes between the two surveys averaged at a site level.

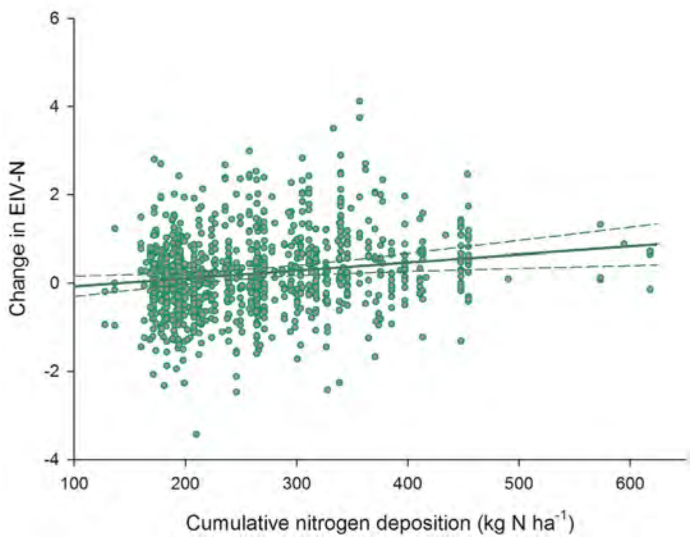


Fig. 2: Shift in community weighted Ellenberg Indicator Value for Nitrogen between 1976 and 2010 in response to cumulative nitrogen deposition for Fixed dune vegetation plots only. Fitted response shown as ——, 95 % confidence intervals shown as ---. Ellenberg's nitrogen indicator classifies species on a scale of 1 to 9.

- Nitrogen pollution has had little impact on diversity but has shifted species composition to vegetation more characteristic of nutrient rich sites (Fig. 2). The impacts of this have been particularly severe in south east Scotland. Grazing may be able to alleviate some of these impacts but it may be difficult to integrate this extensive grazing with the current intensive livestock and arable farming in eastern Scotland.

Conclusions

Reintroduction of grazing to coastal areas where it has been removed appears to be the most amenable driver to influence by changing agri-environmental incentives. Falling levels of atmospheric pollution will be beneficial but timescales for recovery are uncertain. Coastal planning that allows for realignment, as sediment supply decreases and sea levels rise continues, will also be necessary.

Author: Robin Pakeman *(James Hutton Institute)*
Contact: Robin Pakeman (robin.pakeman@hutton.ac.uk)

CHAPTER 3

Upland grassland management for biodiversity

Background

Grazing is the major influence on the composition and biodiversity of Scotland's uplands. Despite a long history of studies looking at the short-term impacts of grazing on individual species, there is a lack of mechanistic understanding about the cascading impacts that changes in grazing management can have on biodiversity. **To understand how changes in agricultural support affect upland biodiversity we need to understand how grazing impacts all parts of the system.**

Approach

- A large-scale grazing experiment was established in Glen Finglas, Stirlingshire, in 2002.
- Four treatments were established and replicated six times (Fig. 2): "low sheep": a continuance of previous grazing management (0.9 sheep $ha^{-1}\ yr^{-1}$); "high sheep": a tripling of grazing (2.7 sheep $ha^{-1}\ yr^{-1}$); "low sheep and cattle": the same offtake as low sheep but using a mixture of sheep and cattle (0.9 sheep $ha^{-1}\ yr^{-1}$); "no grazing": no livestock grazing (0 sheep $ha^{-1}\ yr^{-1}$).
- Plots have been monitored regularly for vegetation structure and composition, invertebrate numbers and meadow pipit nesting density. Monitoring has also been carried out for voles and foxes.

Fig. 1: Impact of the grazing treatments on vegetation height and density.

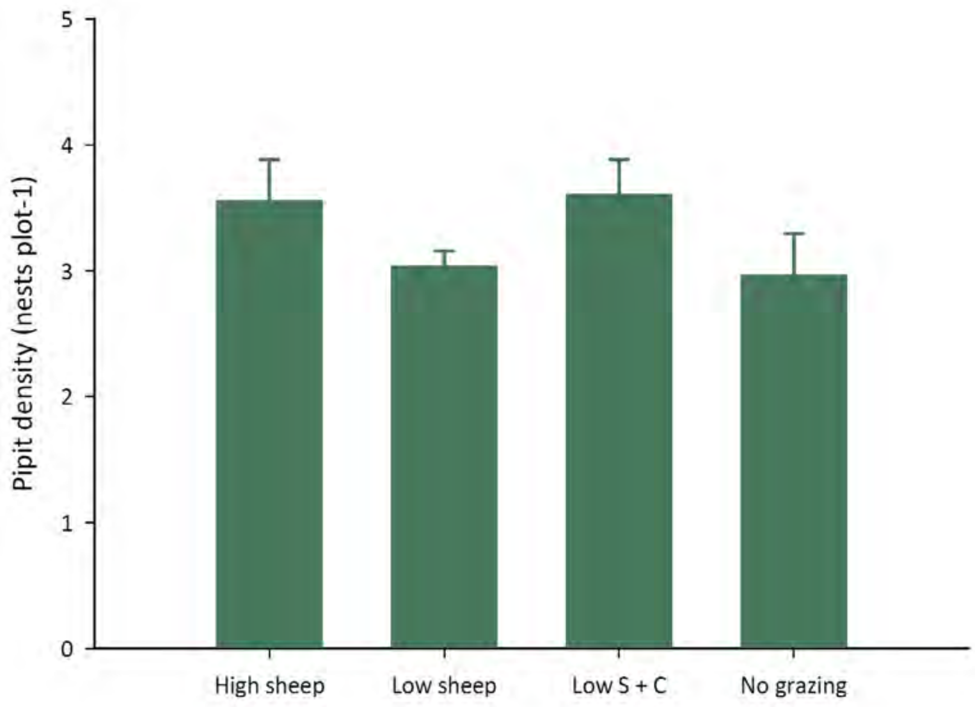


Fig. 2: Mean pipit densities for treatments averaged from 2003 to 2011.

Results

- Grazing reduced vegetation height and density, whilst partly replacing sheep grazing by cattle increased the heterogeneity of the vegetation structure. So far grazing has had little impact on the composition of the vegetation.

- Lower plant biomass cascaded across trophic levels, with fewer invertebrates and small mammals, as well as less fox activity, on the high sheep plots. Vole populations cycled in all treatments, but reached much higher peaks in population size in the ungrazed plots compared to the heavily grazed plots.

- Meadow pipits performed best in the high sheep and low sheep and cattle treatments (Fig. 1). Detailed analysis showed that higher vegetation heterogeneity, which broke up the vegetation, allowed them access to their invertebrate food in denser patches of vegetation.

Conclusion

The choice of a grazing management regime for upland grasslands can have significant effects on the plants and animals present. The bottom-up impact of removing vegetation by grazing cascaded through the system altering food availability for other herbivores, including both voles and herbivorous insects, habitat structure as shelter for voles and as foraging habitats for meadow pipits and foxes. Only some of the amenable parts of this system have been monitored – so these cascades could have far reaching implications for less easily monitored parts of the system such as upland birds like curlews which nest at much lower densities than can be covered by an experiment such as this one. The implications of changing agricultural support payments and the profitability of upland farming will have long-term implications for upland biodiversity with both winners and losers likely.

Authors: Debbie Fielding, Nick Littlewood, Gabor Pozsgai, Robin Pakeman *(James Hutton Institute)* and Darren Evans *(University of Hull)*

Contact: Robin Pakeman (robin.pakeman@hutton.ac.uk)

CHAPTER 4

Managing habitat mosaics

Background

Grazing is a commonly used tool in environmental management and many plant communities depend on it for their continued good condition and the maintenance of species diversity. However, many plant communities exist in a mosaic of different types, each with their own response to grazing. **In order to promote the conservation of habitats in a mosaic we need information on how grazing animals respond to different amounts and distributions of multiple habitats in a landscape.**

Approach

- Habitat Impact Assessment data from the Isle of Rum National Nature Reserve were assessed in term of how the vegetation was impacted by grazing.
- Impact was modelled in terms of deer density, elevation and the proportion of the preferred habitat, species-rich grassland, in the neighbourhood (up to 1 km).

Results

- Impact was positively correlated with deer density, though the effect was not strong.
- Impact for the less preferred vegetation types, including blanket bog (Fig. 1), dry heath and wet heath, was higher where there was more of the preferred vegetation, grassland, in the vicinity.
- Impact on the more preferred vegetation type, species-rich grassland, decreased when there was more grassland in the vicinity (Fig. 2).

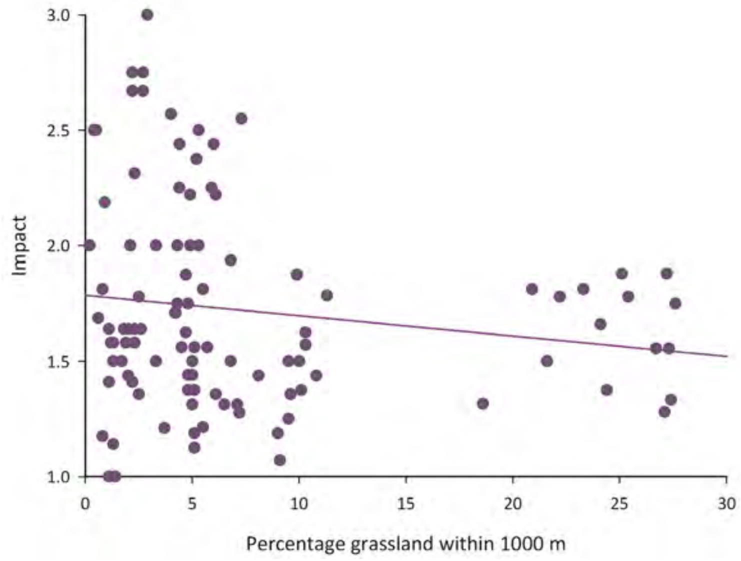


Fig. 1: Fitted relationship between grazing impact score of blanket bog and the percentage of grassland within 1000 m.

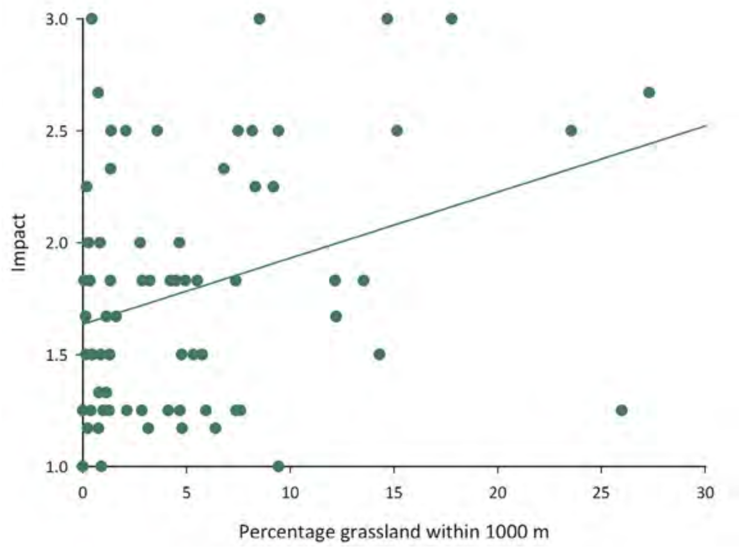


Fig. 2: Fitted relationship between grazing impact score of species-rich grassland and the percentage of grassland within 1000 m.

Conclusions

The results indicate that where there are large amounts of the preferred community, then the associated less preferred habitats nearby in the mosaic will likely be grazed at a more than desirable level. However, in the same circumstance patches of grassland in the mosaic where there is a preponderance of grassland in the vicinity may be grazed at less than optimum levels. Thus there is an inherent conflict between the aims of the grazing sensitive, less preferred communities and the more resilient preferred communities.

Managing mosaics is inherently difficult: in this situation higher deer numbers are needed to ensure that the grassland remains open and species rich, but in doing so there is a spill-over effect that results in higher than desirable impact on the heaths and bogs. Consequently, a trade-off or prioritisation has to be made between the conservation objectives of the different communities. In mosaic situations it is unlikely that all habitats can be managed so that they remain in good condition.

Authors: Emily Moore and Josephine Pemberton *(University of Edinburgh),* Glenn Iason and Robin Pakeman *(James Hutton Institute)*

Contact: Robin Pakeman (robin.pakeman@hutton.ac.uk)

CHAPTER 5

Biodiversity benefits of reseeding inbye pastures in the uplands

Background

The small amount of productive, inbye grassland on many hill farms is used to provide vitally important winter feed. As regular reseeding has declined since the 1970s and 1980s, productive species like Perennial Rye-grass and White Clover have been lost and the nutritional value of the pastures has declined.

The recent push for more sustainable agriculture has seen increasing interest in improving inbye grassland productivity and reducing the amount of bought-in feed. Research has focused on the impact of reseeding techniques on soil greenhouse gas emissions, productivity and farm economics. **This has enabled assessment to be made of the implications of reseeding old permanent pastures on biodiversity (particularly 'weed' diversity).**

Approach

At SRUC's Hill and Mountain Research Centre farm near Crianlarich, an old permanent pasture that had not been reseeded since 1989 was selected for study and split into five treatment plots in 2012:

1) Minimum till - grass/clover reseed
2) Conventional plough - grass/clover reseed
3) Conventional plough - stubble turnip/rape forage crop
4) Minimum till - stubble turnip/rape forage crop
5) Permanent pasture (control)

Results

- Ploughed plots were characterised by a number of annual arable weeds (shown in red in Table 1), indicating the long history of cultivation of this field and the ability of seeds of these species to survive dormant in the soil for decades.

- Weed species in the minimum till plots were mainly perennial weeds; dominated by Creeping Buttercup, Meadow Buttercup and Broad-leaved Willow-herb. One weed abundant in the ploughed plots was the Large-flowered Hemp Nettle (*Galeopsis speciosa*); an archaeophyte, an ancient introduced species that has declined markedly throughout the British Isles as a result of modern methods of cultivation and weed control.

- The two forage plots were also important as winter feeding areas for a number of birds not previously recorded as using the inbye fields; including Golden Plover and Skylark.

Abundance within the plots: Frequent / Occasional / Scarce					
'Weed' Species	**Mini. Till - Grass**	**Plough - Grass**	**Plough - Forage**	**Min. Till - Forage**	**Permanent Pasture**
Meadow Buttercup	Frequent			Frequent	Frequent
Broad-leaved Willowherb	Frequent			Frequent	
Common Sorrel	Frequent				Occasional
Daisy	Occasional			Occasional	Scarce
Common Nettle	Occasional				Scarce
Common Groundsel	Scarce				
Broad-leaved Dock	Occasional	Occasional			
Creeping Buttercup	Frequent	Frequent	Frequent	Frequent	Frequent
Wavy Bitter-cress	Frequent	Frequent	Frequent	Frequent	Scarce
Common Mouse-ear	Frequent	Frequent	Frequent	Frequent	
Common Chickweed	Frequent	Frequent	Frequent	Frequent	
Blinks		Frequent	Frequent	Frequent	
Toad Rush		Frequent	Frequent	Scarce	
Common Hemp-Nettle		Frequent	Frequent	Scarce	
Large-flowered Hemp-Nettle		Frequent	Frequent		
Redshank		Frequent	Frequent		
Pineapple-weed		Occasional	Occasional	Scarce	
Marsh Cudweed		Occasional	Occasional	Scarce	
Knotgrass		Scarce			
Pale Persicaria		Scarce			
Fat Hen		Scarce			
Wild Radish		Scarce			
Corn Spurrey			Scarce		
Green Field Speedwell				Scarce	
Creeping Thistle					Scarce

Table 1:' Weed' abundance within the ploughed, direct drilled and permanent pasture plots. Annual arable weeds are shown in red; biennials and perennials in black.

Fig. 1: Many of the 'weeds', such as the Large-flowered Hemp Nettle shown here, provided nectar and pollen for a range of invertebrates including the Heath Bumblebee *(Bombus jonellus).*

Conclusions

The ploughing and reseeding resulted in a rich assemblage of arable weeds, most of which did not occur elsewhere on the farm. As the plants are annuals, this was only a temporary spike in diversity, but one that provided nectar and pollen for bumblebees (Fig. 1), hoverflies and soldier flies. Cultivation and reseeding of inbye pastures may be useful for both the sustainability and biodiversity of upland farms.

Author: John Holland *(SRUC)*

Contact: John Holland (john.holland@sruc.ac.uk)

CHAPTER 6

Watercourse management and the promotion of biodiversity in intensive agricultural catchments

Background

There is an increasing focus within the Common Agricultural Policy to balance food production and environmental goals at the landscape level. Establishing fenced buffer strips next to watercourses is a recognised approach to reducing diffuse pollution from agriculture. **This research investigated whether such buffer strips could also provide additional benefits through restoring ecological connectivity and promoting biodiversity.**

Approach

- A series of experiments were conducted to determine how the location, width, vegetation composition and management of buffer strips impacted on biodiversity.
- This collaborative research was conducted at the landscape scale on commercial farms in five river catchments differing in agricultural management intensity.
- The riparian field margins selected encompassed a range of botanical (vegetated and forested) and structural (e.g. unfenced margins and narrow and wide buffer strips) attributes. Flowering plants, ground beetles and insect pollinators were monitored.

Fig. 1: Impact of riparian management on biodiversity. The number and colour of symbols represents the abundance and diversity of that taxa. One symbol and one colour represents low numbers and diversity, respectively, whilst three symbols and three colours represents high numbers and diversity, respectively.

Results

- While the impact of fencing was taxa specific, a wider suite of species were favoured by the erection of fences, with the greatest benefits being derived when the resultant buffer strips were over five metres wide (Fig. 1).

- In contrast to the situation within agricultural fields, pollinator assemblages in riparian field margins (i.e. fenced and unfenced) were comparatively rich. Fencing only had positive impacts on pollinators when the resultant buffer strips were wider than five metres.

- Fencing did not on its own influence floristic diversity within the buffer strips. This indicates that management to enhance botanical diversity may further enhance the value of buffer strips to pollinators.

- Buffer strips over five metres wide provided stable habitats favouring flightless ground beetles and created harbourage (e.g. grassy tussocks) for beetles that overwinter as adults.

- Forested buffer strips, while tending to support fewer species across all taxa, supported large ground beetles typical of woodland habitats, indicating their potential to restore woodland connectivity.

Fig. 2: Small tortoiseshell butterfly *(Aglais urticae).*

Conclusions

Wide buffer strips create a greater barrier against the management practices of the adjacent fields with positive implications for both diffuse pollution and biodiversity goals. Management (e.g. restricted grazing or mowing) to open up the vegetation structure and prevent scrub encroachment is likely to enhance the botanical diversity of riparian buffer strips which will in turn benefit a range of invertebrates, including insect pollinators (Fig. 2). Spatial modelling at the landscape level can improve the placement of riparian woodlands or buffer strips to ensure that the inherent complexity of riparian habits is maintained (or restored) and to optimise the benefits derived (e.g. diffuse pollution mitigation, biodiversity enhancement, flood management and ecological connectivity).

Authors: Lorna J Cole *(SRUC)* and Jenni Stockan *(James Hutton Institute)*

Contact: Lorna Cole (lorna.cole@sruc.ac.uk)

CHAPTER 7

How do pollinators utilise different habitats to meet their resource requirements through space and time?

Background

Agricultural intensification and the associated losses of botanical diversity have been identified as major drivers of insect pollinator declines globally. Insect pollination increases both the yield and quality of many crops and pollinators have been valued to be worth in excess of £600 million to the UK economy annually. Many pollinators are highly mobile and will move between different habitats to meet specific resource requirements. **This research investigated how pollinators utilise different habitat components and how utilisation changes throughout the season.**

Approach

- This survey was conducted in an intensive grassland landscape. A range of agricultural and semi-natural habitats were selected for survey.
- Insect pollinators (i.e. bumblebees, hoverflies and butterflies) and floral resources were monitored using standardised transect walks throughout their main activity period.
- The influence of habitat type and the availability of floral resources on pollinator diversity were explored.

Results

- Insect pollinators were strongly influenced by floral resource variables (i.e. area and richness of flowers), with habitat effects for bumblebee richness being purely driven by floral resource variables.
- Road verges and riparian buffer strips supported the richest assemblages of bumblebees and hoverflies and also provided key habitats for butterflies (Figs. 1 and 2).
- Bumblebees and hoverflies were more abundant in riparian buffer strips early in the season and in road verges later in the season (Fig. 3). This indicates that pollinators responded to resources at the landscape scale and changed their foraging patterns accordingly.

Fig. 1: Ringlet butterfly (*Aphantopus hyperantus)* foraging in a riparian buffer strip.

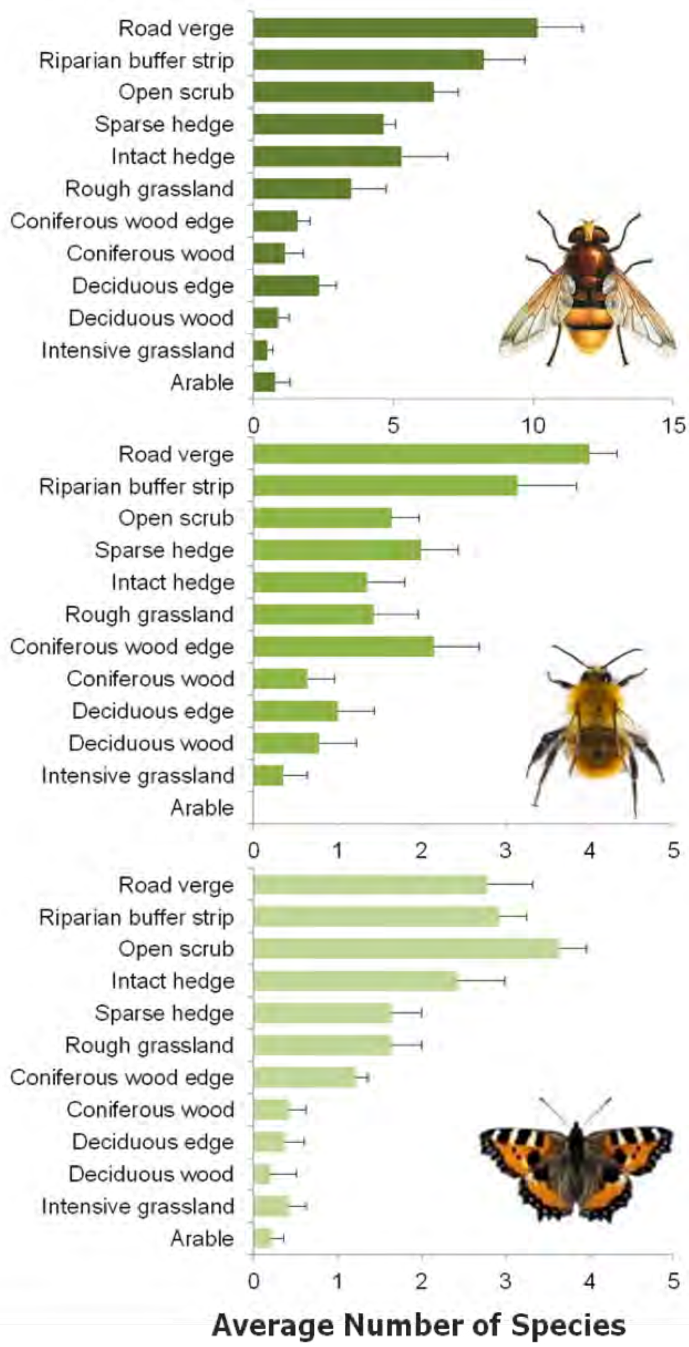


Fig. 2: Impact of habitat on the number of species of hoverfly (top), bumblebee (middle) and butterfly (bottom) species.

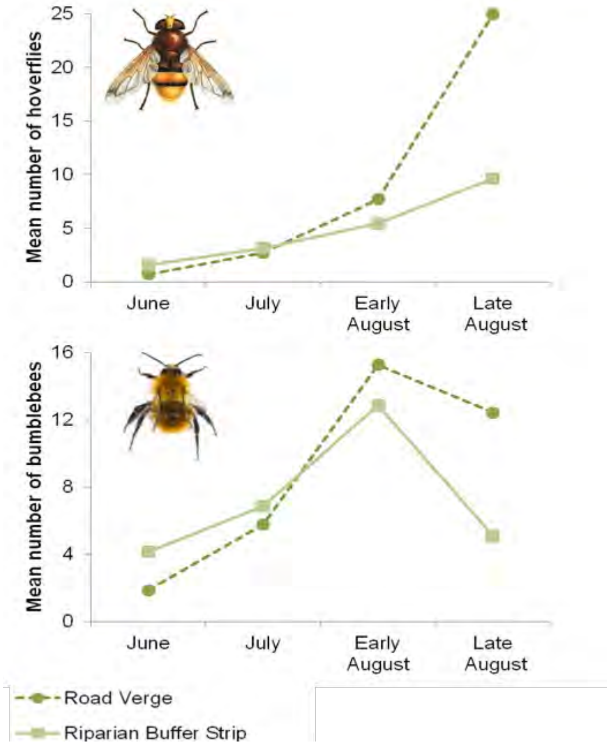


Fig. 3: Temporal variation in habitat utilisation by hoverflies (top) and bumblebees (bottom).

Conclusions

Semi-natural habitats provide important resources for insect pollinators within intensively managed agricultural landscapes. Few pollinators were observed in woodland transects as woodlands in the catchment typically provided dense shaded environments. Management to create woodland clearings and widen rides could enhance their value to pollinators. Different habitats also provided temporal complementarity in resources. Maintaining and restoring habitat diversity at the landscape scale therefore has a vital role to play in the conservation of insect pollinators in intensive agricultural systems.

Author: Lorna J Cole *(SRUC)*

Contact: Lorna J Cole (lorna.cole@sruc.ac.uk)

CHAPTER 8

Grassland management impacts on invertebrates

Fig. 1: Red-tailed bumblebee *(Bombus lapidarius)*

Background

Research has shown that plant functional traits can be used to predict the response of vegetation to environmental drivers such as climate and land management. If linkages exist between plant traits and those of other trophic levels then it should be possible to predict management impacts throughout the system. **Establishing these linkages then simplifies the task of predicting the effect of changing environmental drivers on ecosystem function and hence the delivery of ecosystem services.**

Approach

- Thirty sites on the west coast of Scotland were surveyed in terms of their plant species composition, beetle (carabids) and bumblebee (Fig. 1) assemblages, as well as soil and management activities. Plant and beetle functional traits were assembled from databases.
- Plant traits and species composition were used to model the traits and species composition of the beetles.
- Plant traits, taxonomic information and species composition were used to model bee abundances.

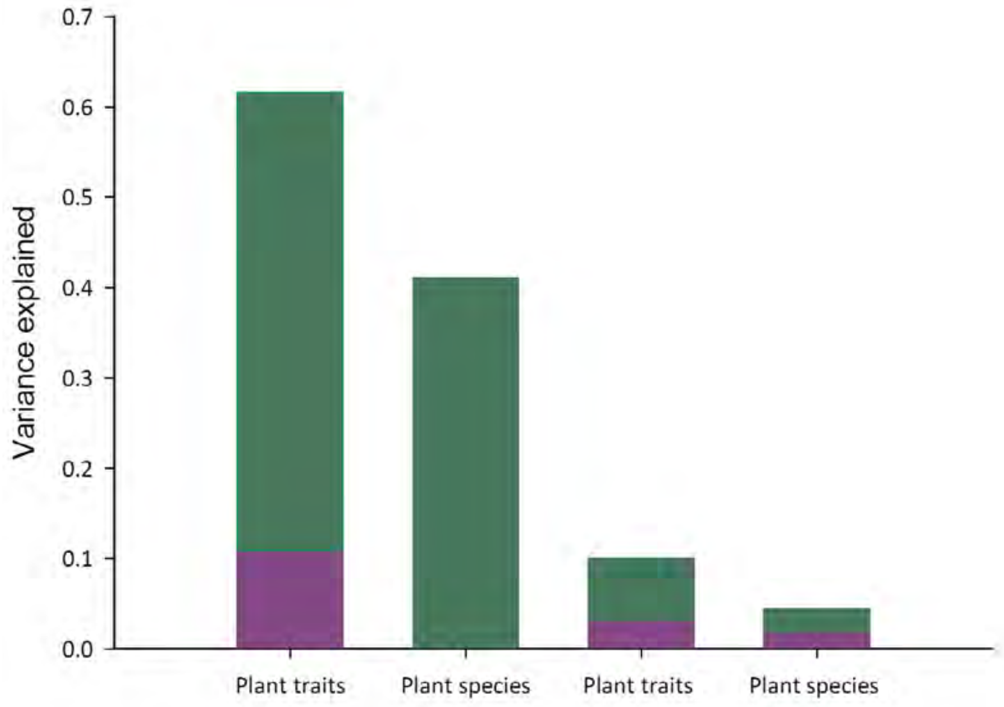


Fig. 2: Proportion of variance explained by plant traits or composition individually ■ and in association with management and soil drivers ■.

Results

- Beetle traits were consistently better explained by plant traits and composition than was beetle assemblage composition (Fig. 2). The explanatory power of plant traits was considerably higher than that of plant species composition.
- Bee numbers were best explained by plant family (proportion of variation explained: 0.51) and flower colour (0.50). Even a subset of plant families proved to be a useful predictor of bee numbers; including information whether the plant was of the daisy or legume family only reduced the proportion of variance explained to 0.30. Plant traits were less effective, for instance the Forage Index (a measure of relative visitation) explained only 0.18.

Conclusion

There was a strong linkage between the traits of the plants present and those of the beetles suggesting a strong functional linkage between these two groups. This is despite the great majority of the beetles being predatory species at these sites and therefore not directly consuming the plants present; it is likely acting through vegetation structure and resource provision for the herbivorous beetles that form the beetles' prey.

The analysis showed that phylogenetic information was successful at predicting bee foraging distributions, but that there is a need to develop more specific plant functional traits that are of direct relevance to bees. Specifically, more information is needed on nectar composition and production as well as on pollen quality (protein content). Without this specific information, functional approaches are currently a poor substitute for information on species composition.

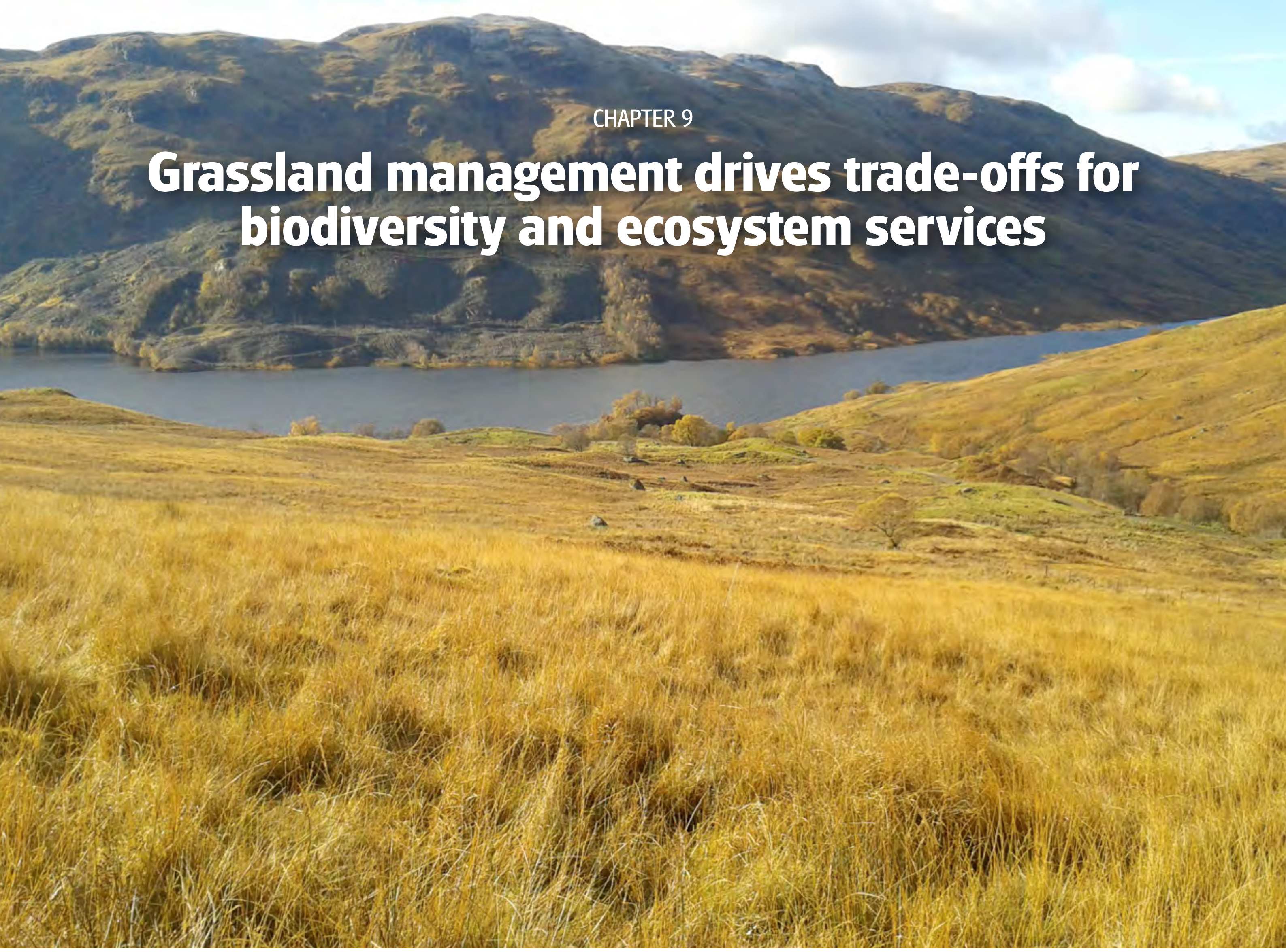
This trait framework offers potential to functionally link trophic levels and thus provide a means to assess how environmental and management changes will propagate through a system and affect a range of ecosystem services.

Authors: Jenni Stockan and Robin Pakeman *(The James Hutton Institute)*

Contact: Robin Pakeman (robin.pakeman@hutton.ac.uk)

CHAPTER 9

Grassland management drives trade-offs for biodiversity and ecosystem services



Background

Grassland management by grazing usually has the main goal of providing food and, to a much lesser extent, other products such as wool and leather. However, there is increasing appreciation that land management has to deliver against a wider range of objectives than food production alone. **Evidence is needed to make quantitative judgements about grassland management so that all the implications of changing management can be assessed.**

Approach

- The Glen Finglas experiment described in Chapter 3 was analysed to look for trade-offs between different aspects of biodiversity.
- The experiment has also been assessed in terms of the carbon sequestration potential of the upland grasslands present. Trade-offs were examined between this key ecosystem service, livestock production and the cultural service of natural heritage conservation.

Results

- Even at the simplest level there are trade-offs between different aspects of biodiversity. Comparing Figs. 1 and 2, it is immediately apparent that the graph of pipit density has the complete opposite pattern than moth species richness.
- Comparing the graphs of livestock production (Fig. 3) and carbon storage (Fig. 4) shows a similar trade-off – the more agricultural production from the grasslands the less carbon is stored in the soil.

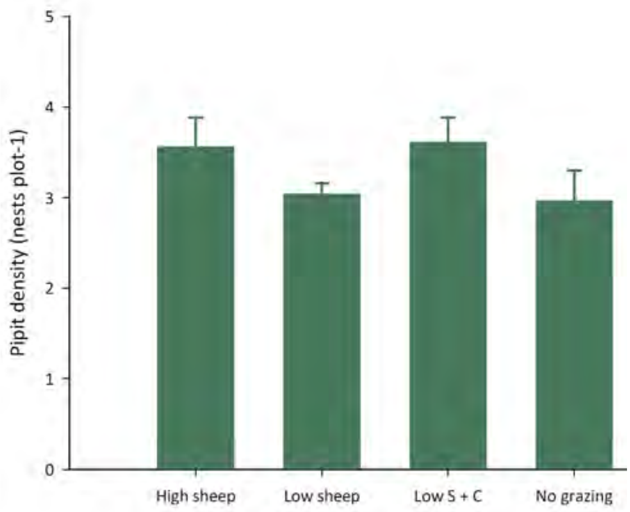


Fig. 1: Mean pipit densities for treatments averaged from 2003 to 2011: "low sheep" = 0.9 sheep ha^{-1} yr^{-1}, "high sheep" = 2.7 sheep ha^{-1} yr^{-1}, "low sheep and cattle" equivalent to 0.9 sheep ha^{-1} yr^{-1}, "no grazing" = 0 sheep ha^{-1} yr^{-1}.

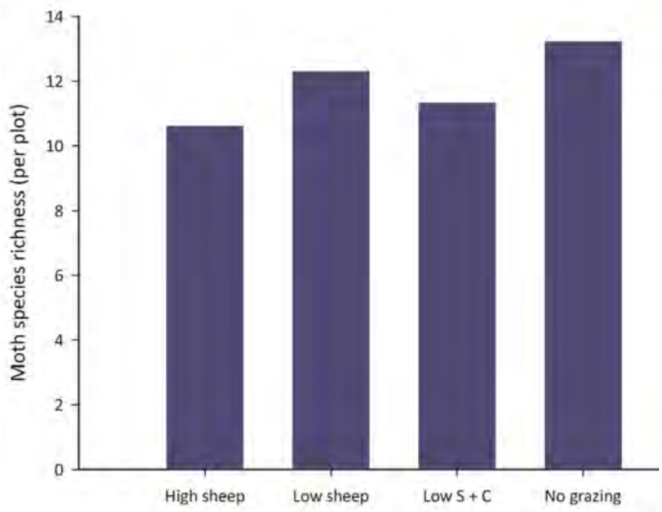


Fig. 2: Moth species richness 2007.

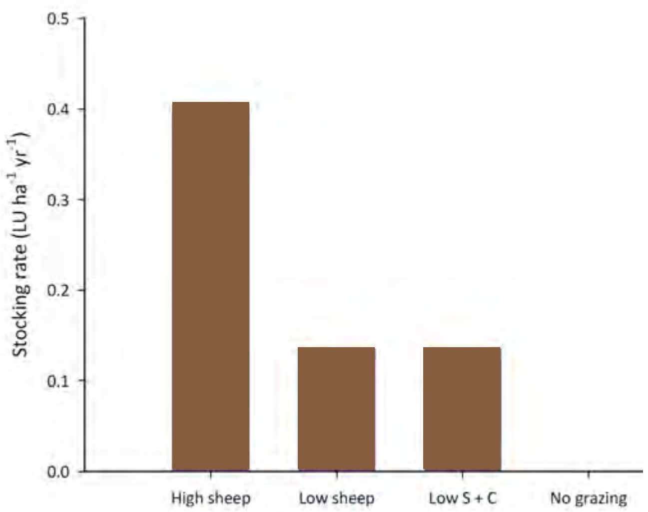


Fig. 3: Stocking rate in Livestock Units (LU).

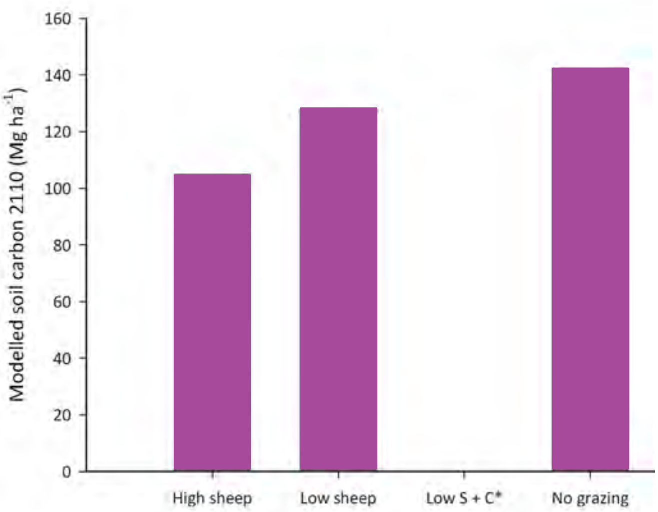


Fig. 4: Modelled soil carbon content (to a depth of 15 cm) for 2110. *No data available.

Conclusion

It is immediately apparent from this simple analysis that there is no win-win scenario for this system. There appears to be a trade-off between production and meadow pipits on the one hand and carbon and moths on the other. It seems that in this system the low sheep and cattle treatment, whilst rarely the 'best' treatment for any variable, is maybe the best in delivering multiple benefits. However, it should be noted that even a long-term experiment such as the one at Glen Finglas only provides a small number of data points on an axis of grazing intensity, so it is difficult to extrapolate from it.

In consequence, management decisions have to include the values land managers and wider society place on the individual services supplied by grasslands as well as the uncertainties caused by an incomplete or imprecise understanding of the system. It may be that wider issues such as climate change or food security drive land management choices, but it is clear that there are repercussions across the system for whatever choice is made.

Authors: Robin Pakeman, Debbie Fielding, Nick Littlewood, Gabor Pozsgai *(James Hutton Institute)* and Stuart Smith *(Norwegian University of Science and Technology)*
Contact: Robin Pakeman (robin.pakeman@hutton.ac.uk)

CHAPTER 10

Diversity confers resilience of production in grasslands

Background

To manage ecosystems to maintain ecosystem services for the long-term, we need to understand how their various characteristics contribute to controlling ecosystem processes. Concerns surrounding food security mean that maintaining the productivity of grasslands is important for livestock production and part of this maintenance is ensuring that they can continue to provide foraging resources under future more variable climates. **To assess this we need to identify which plant traits drive productivity and whether their diversity also affects this productivity.**

Approach

- A meta-analysis of nine Scottish grazing experiments was carried out. All had detailed records of vegetation and stocking rates.
- Stocking rates were modelled as functions of plant traits, the functional diversity of plant traits and weather conditions. Functional diversity represents the distribution of species in functional space.
- The inter-year variability in production was also modelled as a function of these variables.

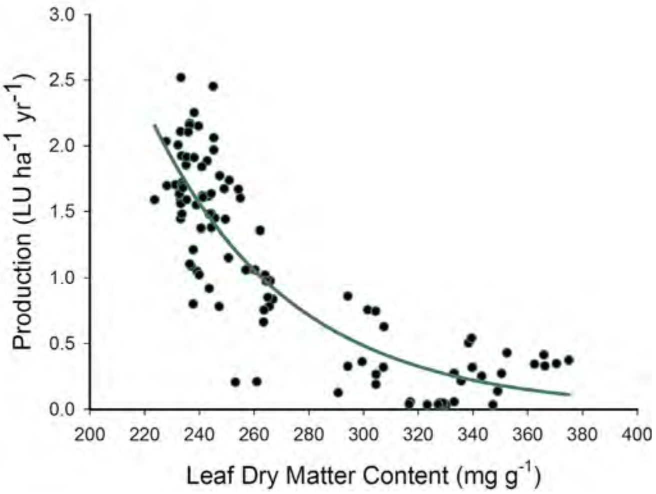


Fig. 1: The relationship between community weighted leaf dry matter content of the grassland and its productivity.

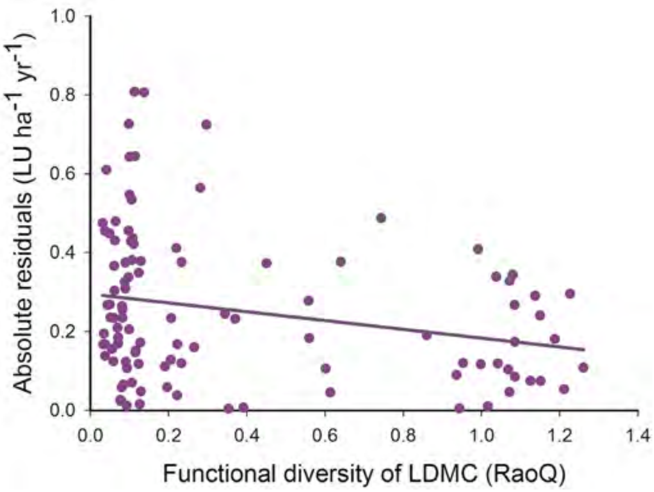


Fig. 2: Relationship between the functional diversity of leaf dry matter content (as Rao's Q) and the absolute size of the residuals from the fitted model of productivity as a function of LDMC and rainfall.

Results

- Productivity was highly dependent on one leaf trait: leaf dry matter content (LDMC, Fig. 1), as well as rainfall.
- Functional diversity was only poorly correlated to productivity compared to the leaf traits tested.
- The diversity of leaf dry matter content present in the grasslands was negatively correlated to variation unexplained by LDMC and rainfall. Grasslands with a higher functional variability present were more able to maintain production under more extreme weather conditions (Fig. 2).

Conclusion

One leaf trait, leaf dry matter content, proved to be a robust predictor of ecosystem productivity. Whilst a very simple trait, it reflects the balance in investment between leaf structural tissue and cellular contents, and thus a fundamental axis of growth strategies between a slow, conservative growth strategy represented by species with a high LDMC; and species with a low LDMC which are fast growing and have fast leaf turnover rates. LDMC is, in reality, a good measure of digestibility.

The negative correlation between the functional diversity of LDMC and the unexplained variance in productivity indicates that more functionally diverse swards are better able to maintain their productivity under environmental stress; less functionally diverse swards showed greater fluctuations in productivity. As high functional diversity has to follow from high species richness, then long-term resilience in production is better guaranteed by more species-rich swards. However as functional diversity is often reduced at high levels of grassland productivity, it appears that there is a trade-off between productivity and the resilience of productivity in the face of environmental variation.

Author: Robin Pakeman *(James Hutton Institute)*

Contact: Robin Pakeman (robin.pakeman@hutton.ac.uk)

This booklet summarises some of the key findings concerning grassland biodiversity and management that have arisen from the Scottish Government Rural and Environment Science and Analytical Services Division's Environmental Change Programme. The research programme ran from 2011 to 2016 and involved researchers from

- Biomathematics and Statistics Scotland
- The James Hutton Institute
- Royal Botanic Garden Edinburgh
- Scotland's Rural University College

This programme receives financial support from RESAS