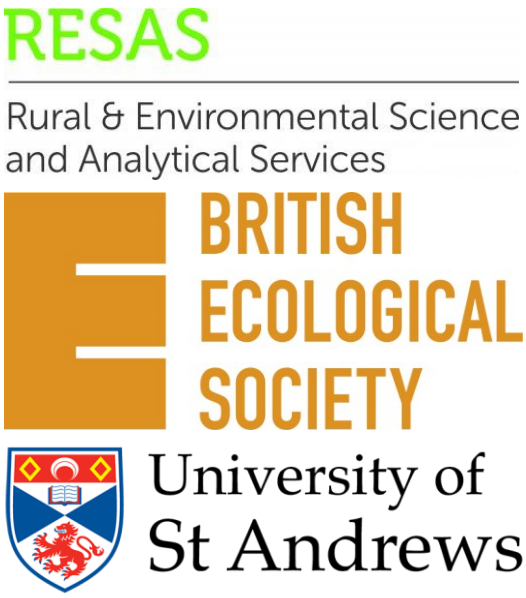
Assessing impacts of the Agricultural Reform Programme measures on biodiversity

Robert Patchett

Centre for Biological Diversity, University of St Andrews, Scotland

robertbpatchett@gmail.com



2024

Contents

Acknowledgements 2
Executive summary 3
Introduction 4
PART 1 5
Assessing biodiversity impacts of agri-environment policy measures: key considerations 5
Baseline biodiversity 5
Local context 5
Landscape configuration 6
Time to impact 6
Complementarity 6
Biodiversity at the farm- and landscape-scale 6
Different land uses are associated with different types of biodiversity 7
Land sparing and land sharing 7
Trade-offs 7
Offshoring biodiversity loss 7
How can agri-environment policy measures impact biodiversity and ecosystems? 8
Impact to species and populations 8
Impacts to landscape structure and wider ecological processes 9
Conclusion 10
PART 2 11
Evaluating how the DEFRA Qualitative impact assessment of land management interventions on Ecosystem Services (QEIA) report could be applied to the Scottish context 11
What is the QEIA? 11
What methodology was used in the QEIA? 12
Selected high-level findings from the QEIA Integrated Assessment and Executive summary 12
Other relevant points from the QEIA that could inform the ARP 13
What are the limitations of using the QEIA to understand potential biodiversity impacts of the ARP measures? 13
Using the QEIA in the Scottish context 14
Alignment of the proposed ARP measures with the QEIA actions 14
Mapping the QEIA biodiversity theme ES indicators to Scottish policy 15
Is the evidence underpinning the QEIA relevant to Scotland? 17
Are any actions in the QEIA not relevant to the Scottish context? 17

Are there any actions missing from the QEIA that would be relevant to Scotland? 17
Are there any ES indicators for biodiversity that are missing? 18
Are there evidence gaps for biodiversity? 18
Do any of the QEIA actions have variable impacts on ES indicators (i.e., benefits and disbenefits)? 19
Demonstrating how the QEIA could be used to inform the ARP 19
Brief methods 20
Summarising the ES indicator scores at the theme-level for QEIA actions relevant to the ARP measures 21
Summarising the biodiversity theme ES indicator scores for QEIA actions relevant to the ARP measures 22
Notes on interpreting results of both analyses 23
Conclusion 23
PART 3 24
Overall summary 24
Recommendations 24
References 25

Acknowledgements

This project was supported by a BES-RESAS Policy Fellowship, the University of St Andrews, and Prof Christian Rutz. I carried out this work in close collaboration with Dr Jack Bloodworth, with input from Prof Sallie Baily, Stefan Hoyte, Richard Haw (all colleagues at RESAS) and James Robinson (BES Policy Fellow, University of Edinburgh). I am grateful to Dr Tom Finch (RSPB) for general discussion on biodiversity and food production, and to Prof Bridget Emmett (UKCEH), Chris Bell (UKCEH), and Dr Tracie Evans (DEFRA) for valuable discussion on the QEIA.

Executive summary

The Scottish Government is reforming the way that farming and food production is supported in Scotland. Financial support for farmers and crofters is to be partly based on enhanced conditionality, with farmers implementing measures targeted towards 'biodiversity gain and climate mitigation and adaption'. Evaluating how these measures could impact biodiversity should assist policymakers in allocating the measures to the most suitable payment tier and help maximise the impact of the new agriculture policy on improving biodiversity. This report is intended to aid understanding of how the proposed measures could impact biodiversity and how these potential impacts could be assessed.

The first part of this report outlines the key considerations relating to the assessment of how agri-environment policy measures could impact biodiversity. During this project, DEFRA released the Qualitative impact assessment of land management interventions on Ecosystem Services (QEIA) report. In response, the second aim of the of the project '*developing a method to evaluate the potential impacts of the proposed Agriculture Reform Programme (ARP) measures on biodiversity'* was changed to '*evaluating the applicability of the QEIA for use in Scotland'*.

Biodiversity is inherently complex and the impact of agri-environment measures depends upon a range of factors including: the baseline biodiversity of the site and surrounding area; the complementarity between measures; differences between measures in the time taken for impact; whether biodiversity is being considered at a local or landscape scale; impacts to yields and potential for *off-shoring* biodiversity loss; and that some measures will benefit some species but not others. These recommendations are aimed to inform development of the ARP measures, and aid in developing an approach to assess their potential impacts on biodiversity:

1. **The biodiversity value of measures should be considered more broadly than by a single metric or indicator**, because the impact of individual measures can differ across the various components of biodiversity.
2. **Policy makers need to make decisions on what types of biodiversity to prioritise in what context.** The measures will benefit some components of biodiversity, or groups of species, but negatively impact others, so value judgements need be considered when developing the measures and their implementation.
3. **Implementing a wide range of measures, rather than a few common measures, would be more beneficial for biodiversity.** This could be achieved by (a) farms applying different combinations of complementary measures, alongside (b) coordination between landowners to create large-scale natural habitat blocks that are linked by landscape features.
4. **The QEIA can be used to inform development of the ARP.** It is the most up-to-date assessment of potential impacts of agri-environment actions on biodiversity and is largely relevant to Scotland, but its use requires caution and an understanding of its limitations.
5. **The ARP measures should be reviewed against related actions in the QEIA** to identify alternative (or additional) measures with greater potential biodiversity benefit, and to identify potential co-benefits or trade-offs with other objectives (e.g., soil, air, water, etc.). Each measure should then be clearly defined.
6. **The biodiversity impacts of the measures should be reassessed iteratively once the programme is established and more evidence is available**. This could be built into future monitoring frameworks and linked to the Whole Farm Plan biodiversity audits.

Introduction

The Scottish Government recognises that the planet is currently facing twin climate and biodiversity crises. Biodiversity is essential to support life on Earth, but is declining at an unprecedented rate (Cardinale et al., 2012; WWF International, 2020). The global food system has been identified as the primary driver of biodiversity loss, particularly the conversion of natural habitats into agricultural production (WWF International, 2020; Benton et al., 2021; Jaureguiberry et al., 2022). Meeting food production demands for the growing human population, while meeting biodiversity targets (e.g. Scottish Biodiversity Strategy to 2045 and Kunming-Montreal Global Biodiversity Framework) and United Nations Sustainable Development Goals (SDGs), requires an urgent change in our agriculture systems.

The Scottish Government are in the process of reforming agricultural payments policy with an aim to become a world leader in sustainable and regenerative agriculture. This process includes developing a future payments framework to replace EU CAP direct and indirect support payments. The proposed Future Support Framework aims to deliver four main outcomes: high quality food production; climate mitigation and adaptation; nature restoration; and wider rural development.

The proposed Future Support Framework is split into four tiers: 1) Base Level Direct Payment; 2) Enhanced Level Direct Payment; 3) Elective Payment; 4) and Complementary Support. Farmers and crofters will be able to gain financial support by applying on-farm measures to improve biodiversity, reduce greenhouse gas emissions, etc. The draft list of measures referred to in this report was developed by Scottish Government and NatureScot and was targeted towards Tier 2[1].

Financial support for farmers under the new framework is partly based on enhanced conditionality, with farmers implementing measures targeted towards 'biodiversity gain and climate mitigation and adaption'. Evaluating how the measures could impact biodiversity is important because it should assist policymakers in allocating the measures to the most suitable payment tier, help determine the value of each measure, and maximise the impact of the new agriculture policy on improving Scotland's biodiversity.

During this project, DEFRA released the Qualitative impact assessment of land management interventions on Ecosystem Services (QEIA) report. In response to this, the aim of the second part of the project '*developing a method to evaluate the potential impacts of the proposed Agriculture Reform Programme measures on biodiversity'* was changed to '*evaluating the applicability of the QEIA for use in Scotland'*.

This project aims to:

1. Outline the key considerations for assessing how agri-environment policy measures could impact biodiversity, and discuss the ways in which agri-environment policy measures could benefit biodiversity; and
2. Evaluate the applicability of the QEIA for use in Scotland.

[1] The list of measures referred to in this report was current as of October 2023.

PART 1

Assessing biodiversity impacts of agri-environment policy measures: key considerations

In general terms, biodiversity describes the variability among living organisms, including genetic, functional, species and ecosystem diversity (Cardinale et al., 2012). These multiple components of biodiversity mean that its measurement is complex, and selecting which components are assessed is important.

The draft measures included in the Scottish Agriculture Reform Programme (ARP) have been chosen for their likely benefits to biodiversity. In principle, the measures that a farmer or crofter (farmer hereafter) choose to implement should positively impact biodiversity on their farm or croft (farm hereafter). The effectiveness of the measures is likely to vary though, depending on contextual considerations such as the baseline levels of biodiversity on the farm and the surrounding landscape, landscape configuration, the time to impact of the measures, and whether combinations of measures are complementary or not. Broader considerations include the scale at which biodiversity is considered, the higher-level guidance on which types of biodiversity are considered most important for a given context, the land sparing – land sharing debate, and potential trade-offs with yield resulting in biodiversity loss being *offshored* (Figure 1). This section outlines these key considerations in more detail.

Baseline biodiversity

Baseline levels of biodiversity vary between farms, which can impact the relative effectiveness of agri-environment measures (Klein et al., 2006). Many farmers already implement nature-friendly farming practices, and many farms have existing natural or semi-natural habitats that should be maintained. Farms with low baseline levels of biodiversity will be able to improve their on-farm biodiversity more easily and by a greater margin than those that already implement nature-friendly farming or have higher levels of baseline biodiversity. Similarly, the level of biodiversity in the surrounding landscape can also impact how effective a measure will be in benefiting biodiversity. For example, set-aside management is generally more effective in less complex landscapes because the local pool of species is already at relatively a low baseline compared to more complex landscapes (Tscharntke, 2011). It is therefore important to account for biodiversity already on site and surrounding the farm when assessing the potential benefits of agri-environment measures, to avoid biasing the perceived benefit of some measures over others.

Local context

Some measures are more suited to one farm type or location over another (Whittingham, 2006). The draft ARP list of measures already includes land and habitat type categories for each measure. Selecting the measures that would most benefit biodiversity for each individual farm (or farm groups at the landscape scale) requires identification and mapping of habitat types and landscape features at the farm scale (e.g., in Scotland, land parcel habitat mapping is being developed for biodiversity audits), alongside information on biodiversity at the site and surrounding area. Land parcel habitat mapping would allow farmers to select measures designed for the habitat types relevant to their farm, while knowledge of biodiversity at the site would identify if species-focused measures would be effective. This emphasises that evaluating the impact of the ARP measures on biodiversity is highly dependent on local context.

Landscape configuration

The location where measures are applied on a farm could increase their potential benefit to biodiversity. For example, amphibians and reptiles benefit from new field margins being created near to watercourses and ditches through increased habitat connectivity (Salazar et al., 2016). This could be further enhanced by collaborative land management approaches between neighbouring farms (McKenzie et al., 2013), reducing habitat fragmentation (Samways et al., 2010), benefiting species that require large areas of habitat (Franks, 2011), and supporting ecosystem processes that operate at landscape scales (Prager, 2015).

Time to impact

The time taken for measures to benefit biodiversity is likely to differ between the measures (Watts et al., 2020). For example, biodiversity benefits accrue over several decades after woodland planting as the ecosystem structure takes time to develop (Cunningham et al., 2015), while pollinator diversity associated to within-field pollinator strips may peak after a few years and then require resowing with wild flower seed (Brittain et al., 2022). For any measure, this time lag is likely to depend upon several factors, such as the distance of source areas of biodiversity to support recolonisation of the species expected under the new conditions, the stage of vegetation succession, and the degradation of pesticides and nutrient inputs etc. (Jonason et al., 2011). There is also strong evidence that longer-term agri-environment measures host more biodiversity (Estrada-Carmona et al., 2022).

Complementarity

Some agri-environment measures may be complementary, benefitting biodiversity more when combined with each other than when implemented individually. This complimentary arises because many species depend upon multiple habitat types to provide resources for foraging, shelter, and reproduction (Dunning et al., 1992). For example, grassland invertebrate species require more than one habitat element to complete their life cycle, which may be achieved by combining measures to provide the required range of habitat elements (Staley et al., 2015); whilst a combination of hedgerow and woodland elements has been shown to double the positive effect on biodiversity compared to either hedgerow or woodland elements alone (Estrada-Carmona et al., 2022). Combining measures can also provide resilience of the intended provision to support biodiversity. For example, combining several measures to provide winter food resources for farmland birds mitigates against the impact of adverse weather causing any single measure to fail (Walker et al., 2018).

Biodiversity at the farm- and landscape-scale

The measures have the potential to impact biodiversity at different spatial scales, although most measures have been designed to be applied at the field- or farm-scale. If the same measure is implemented on neighbouring farms (and therefore covering a larger area of land), then a greater number of species could benefit from the measure because some species require larger areas of habitat than others (Dunning et al., 1992). There is a trade-off, however, between whether neighbouring farms implement the same or different measures and the resulting degree of landscape heterogeneity. Landscape-scale biodiversity should benefit from farmers implementing different measures because of the associated increase the diversity of habitats within the area of the farms. This presents a challenge when evaluating the impact of measures on biodiversity because at the landscape-scale (and even farm-scale) biodiversity will depend up the number and types of habitats in the landscape, the area that they cover, and how the habitats are

configured and connected, but most evaluations of agri-environment measures assess performance at the field- or farm-scale (Estrada-Carmona et al., 2022).

Different land uses are associated with different types of biodiversity

The measures related to nature-friendly farming practices will mostly benefit farmland species, while those related to habitat restoration will benefit species associated with the newly restored habitat types (Fenuik et al., 2019, Finch, 2023). Therefore, developing effective policy for biodiversity requires choices to be made about which habitats (or species) should be prioritised, and where.

The habitats and species that are a conservation priority could guide which measures are appropriate for a particular farm or region. For example, an arable farm in an area with a population of corn buntings could implement *delayed silage mowing* to support that target species, which would also provide secondary benefits to a range of additional species (Scottish Government, 2023). This highlights that the potential benefits of the measures to biodiversity may differ on case-by-case basis, and the important role that Scotland's Biodiversity Strategy will play in informing the most appropriate measures for each region, farm type, and local context.

Land sparing and land sharing

The debate about balancing food production and biodiversity is often framed around the land sparing–land sharing framework (e.g., see Fischer et al., 2014). Land sharing is an approach focussed on increasing biodiversity through nature friendly farming practices, while land sparing focusses on maximising crop yields on a smaller total area of land to allow nature restoration on the remaining area. In this framework, the benefits to biodiversity differ between each approach: land sharing typically benefits farmland species, while the species benefiting from land sparing depends upon the habitat that replaces the agricultural land (Finch, 2023). Although land sharing and sparing are often compared against each other, they can be considered as a continuum, with a blend of land sharing and sparing often shown to benefit biodiversity more than either sharing or sparing alone. For example, three-compartment sparing, where some land is farmed intensively to spare other land for natural habitat and low-yield farmland, is likely to be more effective overall as it maintains yields, benefits biodiversity in both agricultural and natural habitats (Fenuik et al., 2019; Finch et al., 2019), and increases overall landscape complexity.

Trade-offs

Comparing the effectiveness of agri-environment measures on how they benefit biodiversity can also depend on the impact that the measures have on other outcomes, such as impacts to food production. For example, in a comparison between on-field (organic farming) and off-field (wildflower strips) measures to benefit pollinators, wildflower strips covered 5% of the field area and supported fewer pollinators than the field-wide organic farming approach, but yields in the organic fields were reduced by 50%. On balance, over 3.5 times more pollinators would have been supported by increasing the area of the wildflower strips to match the yield losses found with organic farming in this study (Batary and Tscarntke, 2022).

Offshoring biodiversity loss

The impact an agri-environment measure has on food production can also lead to biodiversity impacts beyond Scotland. For example, Scotland's biodiversity should increase through implementing the Future Support Framework, but if this leads to decreased yields at a national scale, and consequently, increased food imports, then there is a risk of exporting biodiversity loss to other countries that produce our food (Bateman and Balmford, 2023).

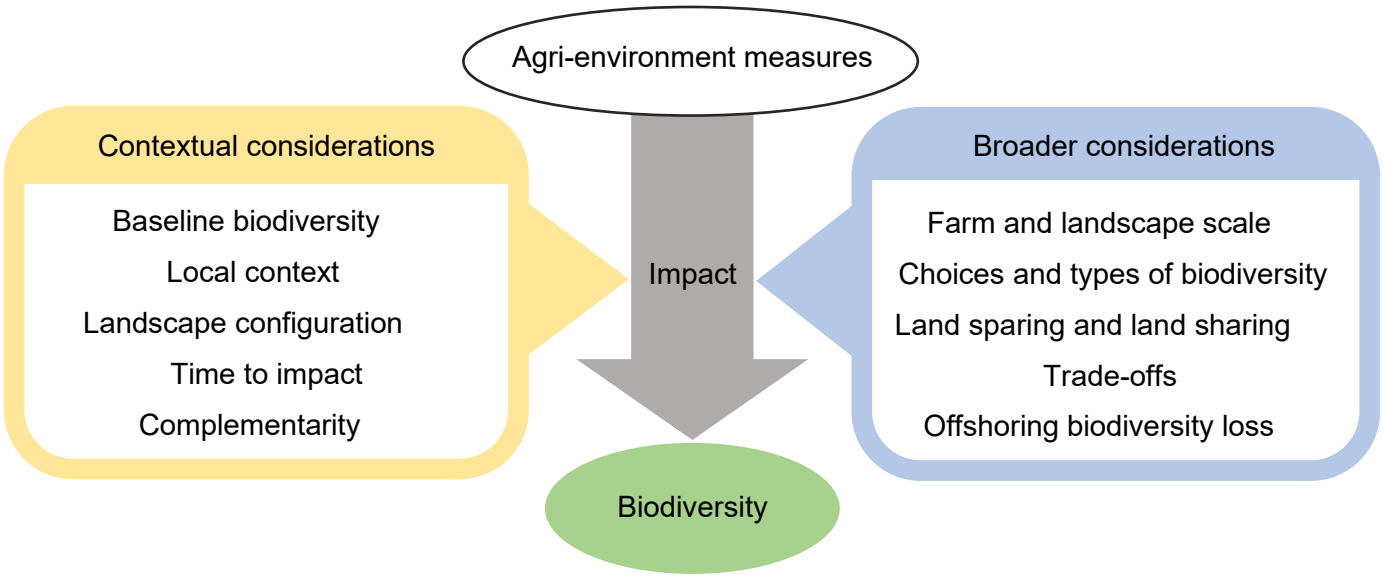


Figure 1. Understanding the potential impact that agri-environment measures have on biodiversity includes a range of considerations. These considerations can be categorised as *contextual* when they relate to how and where the measures are implemented, or they can be categorised as *broader* when they relate to higher-level decisions (e.g., the policy decision to choose what type of biodiversity to focus on and where) or wider impacts (e.g., the potential for offshoring biodiversity loss). Considerations may overlap both categories, depending on the scale they are being described at.

How can agri-environment policy measures impact biodiversity and ecosystems?

The measures are likely to impact different components of biodiversity, with direct on-farm benefits to biodiversity, indirect and off-farm benefits, and benefits from changes to landscape structure and wider ecological processes. Understanding how each of the measures impact the different components of biodiversity should aid in understanding their overall potential benefit to biodiversity, and then inform development of the approach to assessing their biodiversity benefits.

Impact to species and populations

Impact to on-farm biodiversity

At the field or farm level, agri-environment measures should directly benefit biodiversity, leading to an increase in the number of species, number of individuals of those species (e.g., Redhead et al., 2022), or a change in the type of species observed on the field or on the farm[2]. Each measure is likely to benefit a different range of species, and the effectiveness of the measures should be reflected in how many species (and the abundance of those species) they benefit. Studies that investigate the performance of agri-environment measures on improving biodiversity typically focus on groups of species, such as birds, invertebrates (often focussed on groups such as moths or pollinators), plants, mammals, reptiles and amphibians, and less frequently below-

[2] The number of species is commonly referred to as species richness, while the number of individuals of a species is referred to as abundance. The types of species recorded on a site is referred to as the community composition. There are some circumstances where the agri-environment measures main impact is a change in community composition (i.e., the types of species change).

ground (i.e., soil) biodiversity. Inevitably, it is impossible to measure and record every living thing on a farm. Some groups of species, however, are considered good indicators for biodiversity. For example, birds are used as a proxy to assess biodiversity of agricultural land across the EU (e.g. the Farmland Birds Index) because they are relatively high on the food chain and can therefore indicate the presence of other species groups.

Impact to off-farm biodiversity

Some measures are likely to impact biodiversity beyond the farm in which they are implemented. For example, buffer strips are strips of vegetation that catch and prevent nitrogen[3], phosphorus and sediment moving from cropland to watercourses. They can increase biodiversity on the farm where they are applied because they create a new habitat, but they positively impact biodiversity in the neighbouring streams, rivers and the wider catchment, by improving water quality (Borin et al., 2010).

Impacts to landscape structure and wider ecological processes

Landscape complexity

Landscape complexity describes how similar landscape units are to each other, ranging from simple (i.e., homogenous) to complex (heterogeneous). It consists of landscape composition (the number of habitat and land use types and the area that they cover) and landscape configuration (the spatial arrangement of the habitat and land use types, including linear features such as field edges, hedgerows, and watercourses, etc.). The simplification of agricultural landscapes is a major contributor to biodiversity loss (Gámez-Virués et al., 2015); more complex agricultural landscapes host more biodiversity than simplified landscapes because they include more types of habitat and associated communities of species, and so measures that increase landscape complexity should increase biodiversity (Vanbergen et al., 2020; Estrada-Carmona et al., 2022). Landscape complexity can be increased by increasing permanent habitats and features, but also from applying in-field measures such as increasing crop diversity.

Habitat connectivity and landscape permeability

Habitat connectivity describes the relative ease that species can move between habitat patches. It can be split into (a) structural connectivity, which relates to the physical connections between habitat patches, and (b) functional connectivity, which relates to the ability of species to move between patches (Baarda, 2018). Improving habitat connectivity, while proven to be beneficial in some cases, can have negative consequences in others where it increases the ranges of invasive non-native species (see NatureScot, 2023). Landscape permeability is a similar concept to habitat connectivity, but rather than focussing on connecting habitat patches through corridors etc., it takes the whole landscape into account and describes the potential for animals to move across the landscape (Singleton et al., 2002).

Agricultural intensification over time has led to the fragmentation of natural habitats through a combination of outright habitat loss and the braking apart of habitat (Fahrig 2003), reducing the overall area of natural habitat and increasing the distance between habitat patches. Overall, biodiversity is enhanced in connected patches compared to unconnected patches (Damschen, 2019), and the effectiveness of measures that have the potential to improve habitat connectivity will depend upon the existing habitats on-farm and in the surrounding landscape, and how and where the measures are deployed.

[3] Nitrogen deposition is key pressure on biodiversity (Butchart et al., 2010).

Ecosystem functioning

Ecosystem functions are an integral component of biodiversity, describing the effect that the activities of animals, plants, and microbes have on the physical and chemical environment. They include processes such as primary productivity (i.e., the production of biomass) and nutrient cycling (i.e., the biogeochemical cycle, where nutrients move between the living and non-living parts of the ecosystem) (Naeem et al., 1999). Ecosystem functioning depends upon biodiversity; for example, decreasing biodiversity reduces primary productivity and decomposition processes (Hooper at al., 2012), and so measures that have a positive impact on biodiversity should also have a positive impact on ecosystem functioning.

Ecosystem services

Ecosystem services describe the contributions of ecosystems to human well-being. This includes the provision of food, production of clean air and water, flood control, crop pollination, and a wide range of other services. Similarly to ecosystem functioning, biodiversity is inter-related to ecosystem services[4]. Many agri-environment measures are targeted towards species groups that contribute to the provision of ecosystem services such as pollination and pest control, and also benefit other components of biodiversity. For example, pollinator strips provide habitat resource for pollinators, which then contribute to crop (and wild flower) pollination; alongside this, pollinator strips provide secondary benefits by increasing overall biodiversity, protecting soils and reducing pests (Wratten et al., 2012).

Conclusion

Assessing the potential impact that agri-environment measures have on biodiversity requires consideration of several factors. The factors identified here highlight why comparing the impacts that the measures have on biodiversity is challenging – the performance of the measures depends on all of these factors and so each measure could perform differently across farms, even if the farms are in the same region. However, an assessment that evaluates the strength of evidence for how impactful the measures are across a range of biodiversity components should allow some understanding of their potential impacts to biodiversity.

At the farm-scale, biodiversity will likely be maximised by each farm applying a combination of measures which are deployed strategically with respect to the local context and species priorities. At the landscape-scale, biodiversity will likely be maximised by a mixture of agricultural land with farms applying different combinations of measures, alongside coordination between landowners to create large-scale natural habitat blocks which are linked by landscape features.

[4] Biodiversity and ecosystem services are often abbreviated together to BES, to highlight their close association (e.g., see https://www.unepfi.org/fileadmin/documents/bloom_or_bust_report.pdf).

PART 2

Evaluating how the DEFRA Qualitative impact assessment of land management interventions on Ecosystem Services (QEIA) report could be applied to the Scottish context

This project originally included an aim to design an approach for assessing the potential impacts of the ARP measures on biodiversity. The basic approach being developed was centred around using a qualitative scoring system to assess the strength of evidence and potential that the measures could have on reducing impacts of the main drivers of biodiversity loss related to food production: habitat loss, habitat fragmentation, landscape simplification, and nutrient deposition (Butchart et al., 2010).

During development of this approach the QEIA became available[5]. The QEIA was assessed as being more comprehensive than the method under development, as it covered a range of outcomes beyond those for biodiversity, and the QEIA was a complete resource. To avoid duplication of effort, further development of the 'drivers of biodiversity loss' approach was stopped, and the new aim focused on evaluating the applicability of the QEIA for use in Scotland. This section briefly summarises the QEIA and provides an example of how it could be used to inform development of the ARP.

What is the QEIA?

The QEIA was commissioned by DEFRA in 2022, made publicly available in 2024, and had three main objectives[6]:

1. To understand which land management actions[7], suitable for agricultural land in England, would contribute towards the delivery of the environmental objectives for farming.
2. To feed into value for money assessments, allowing for appraisal of land management actions and ELM schemes[8].
3. To allow for comparison across potential land management actions and therefore, provide policy with a greater understanding of the full impact of such actions.

The QEIA assessed 741 land management actions over 33 Ecosystem Services, which were further split into 53 Ecosystem Service indicators (ES indicators), 12 of which were related to biodiversity. In the QEIA, ecosystem services were broadly defined to include 'a range of environmental and cultural services, drivers and other benefits', and for the remainder of this report ES indicators are referred to as defined in the QEIA.

The QEIA consists of an integrated assessment (Emmett et al., 2023a), ten evidence reviews, a spreadsheet of data summarising the reviews (Emmett et al., 2023b), and a list of 2400+ references. Four of the reviews were on biodiversity and covered: croplands (Staley et al., 2023), improved grassland (Keenleyside and Costa Domingo, 2023), semi-natural habitats (Maskell and Norton, 2023), and integrated systems-based actions (Siriwardena, 2023). The reviews provide written accounts for groups of similar actions on: the strength of the evidence; the magnitude and

[5] See https://randd.defra.gov.uk/ProjectDetails?ProjectId=21327 for links to all reports and resources.
[6] The QEIA objectives were taken directly from https://randd.defra.gov.uk/ProjectDetails?ProjectId=21327
[7] Note that DEFRA use the term *actions,* while Scottish Government use the term *measures.*
[8] The QEIA sits alongside other work used to inform ELM schemes.

timescale of potential change; the contextual dependencies as to whether an action may work; the risk of displacement of production to other land not in scheme; potential impact of future climate change on the impact; and co-benefits and trade-offs to other services and to the farmer / land manager.[9]

What methodology was used in the QEIA?

The overarching approach was a rapid evidence assessment. This relies on the knowledge of experts and their awareness of the literature and evidence base, rather than systematic approaches which use repeatable methods to select, assess and summarise the evidence, but take substantially more time (e.g., see Conservation Evidence).

The management actions were reviewed against the ES indicators by a team of 45 experts, with the experts split among the ten review topics. They developed a systematic and consistent scoring system during a two-day workshop, and quality assurance of the scoring was undertaken by the management team to check for consistency in scoring. The evidence reviews were externally peer reviewed, with the QEIA scores being revised in response to feedback. DEFRA also conducted a quality assurance check.

The QEIA actions were assessed against each of the ES indicators using a Red-Amber-Green (RAG) system with a magnitude score of 1-3, so that the impact of an action on biodiversity could be assessed as negative, variable or uncertain, or positive. They also indicated when there was limited evidence to support the assessment, or where there was variability in an outcome (i.e., where an action had benefits for some groups but disbenefits for others) (Emmett et al., 2023a)[10].

Selected high-level findings from the QEIA Integrated Assessment and Executive summary

Many actions were identified as being context dependent

The impact of many actions depends on when and where they are carried out.

Localised effects can be small but important

Small effects can still be important for specialised species or in areas of high environmental degradation.

The impact of habitat connectivity is complex

Connecting habitat with corridors etc., can allow populations to move and disperse across the landscape, but can also have negative impacts by increasing the spread of pathogens and by creating barriers for some species.

Many actions result in trade-offs

Many actions involve trade-offs between different ES services (e.g., habitat creation actions typically trade-off with food production[11]). Actions that benefit one component of biodiversity are not always beneficial for other components.

[9] This list is taken directly from the QEIA Integrated Assessment (Emmett et al., 2023a).
[10] The QEIA annotates scored cells with contextual letter codes (L, limited evidence; D, potential disbenefit to another species group; and T, context dependence benefit or requires targeting to be effective).
[11] Note that trade-offs with yield are more likely in an arable context.

Habitat creation

Actions related to habitat creation were typically identified as having the most potential to benefit multiple ES themes.

Long-term commitment is needed to maintain impacts

The impact for many actions takes time to occur, often beyond the usual timeframe of agri-environment support.

Other relevant points from the QEIA that could inform the ARP

Some actions were split into enhance / maintain

The review team identified that the impact of some actions depended upon whether they *enhanced* or *maintained* existing habitat (i.e., enhancement implies an increase in potential benefit when compared to maintaining the condition of existing habitat). Some ARP measures could be split into create-enhance-maintain to highlight that the potential to benefit biodiversity depends on these three degrees of change. For example, the impact to biodiversity might be more beneficial if a new hedgerow is created compared to enhancing an existing hedgerow[12], which in turn could be more beneficial than maintaining an existing hedgerow[13].

Consolidating actions

The review team recommend that DEFRA consider consolidating actions to make future reviews more efficient.

Definitions of actions must be precise[14]

In the QEIA topic review *Biodiversity - Integrated System-Based Actions* (Siriwardena, 2023), the author highlights that reviewing impacts to biodiversity was challenging because the QEIA actions were defined too broadly – i.e., some actions include multiple options or ways to implement the action, each potentially impacting different groups of species in different ways. The titles of actions were also recommended to be defined more precisely, to match more obviously to "single management actions, such as would be used in an agri-environment prescription".

What are the limitations of using the QEIA to understand potential biodiversity impacts of the ARP measures?

The review team for biodiversity highlighted that the quality of best evidence for impacts to biodiversity varies widely between QEIA actions, and because of this the QEIA scores are not directly comparable between QEIA actions. This means that the QEIA scores should not be used for direct quantitative comparisons between actions and that caution is needed when interpreting the QEIA scores, or outputs that rely on them. In addition, the evidence used to assess biodiversity impacts is often limited (see 'Are there evidence gaps for biodiversity?' on page 18 of this report). The absence of available evidence for assessment of biodiversity impacts does not mean that an action is ineffective, but it highlights that the evidence base needs strengthening. Despite these limitations, the QEIA is a valuable resource that could be used alongside other resources and ongoing work to inform the ARP. For example, qualitative

[12] With the caveat that a new hedgerow will take time to establish.

[13] But some hedgerows could already be highly beneficial for biodiversity, so recognition of previous efforts to support biodiversity need to be considered.

[14] It is possible to consolidate the number of actions (previous point), while providing precise definitions.

analysis of the QEIA scores could be used highlight potential co-benefits and trade-offs between actions, or to identify additional measures to be considered for inclusion in the ARP.

Using the QEIA in the Scottish context

Alignment of the proposed ARP measures with the QEIA actions

How many QEIA actions relate to each ARP measure?

The definitions for measures in the first draft of the ARP list of measures were intentionally set to be broad and were based around Tier 2 (pers. comm. Ross Lilley, NatureScot). There are many QEIA actions that correspond or relate to most of the ARP measures (Table 1). This highlights that there may be alternative approaches to achieving the intended outcomes of the ARP measures.

Table 1. The number of QEIA actions that correspond to the proposed ARP measures[15].

ARP measures[16]	QEIA actions
Improving public access capital items menu	50
Minimum/No Till	3
Winter cover	4
Arable/ley rotations (transition from arable to arable/livestock mix)	5
Biodiversity cropping	24
Diversify crop rotation and break crop rotation period (esp. for root crop)	7
Inter-cropping, under-cropping and mixed cropping and avoid monoculture	4
Sylvo-arable systems	1
Bird friendly Crop Operations	1
Diverse sward species content and use of herbal leys	5
Regenerative grazing (mob, strip, adaptive multi-paddock) on improved grassland	4
Sylvo-pastures	6
Efficient / Reduced use of inorganic fertilisers and lime	27
Efficient / Reduced use of synthetic pesticides	18
Use of N fixing crops	3
Arable and Silage/Hay Crop Margins	4
Enhance Hedgerows	6
Retain and Enhance In Field Biodiversity Cropping and Features	14
Water Margins	14
Coastal or River embankment breaching, lowering or removal	4
Converting land at risk of erosion/flooding to low-input grassland	3

[15] The QEIA actions were mapped to the ARP measures following the author's interpretation of each measure and action. QEIA actions were linked to an ARP measure where there was either direct correspondence between the action and measure, or where actions were closely related to the measure and the intended outcome of the measure.

[16] The ARP list of measures used in Table 1 was current in October 2023, and roughly corresponds to the measures published online: https://www.ruralpayments.org/topics/agricultural-reform-programme/arp-list-of-measures/, but was in development at the time of publication (24/38 measures had a completed descriptor).

ARP measures[16]	QEIA actions
Introduction of alternative efficient watering systems	4
Introduction of sustainable drainage systems	15
Management of diffuse pollution sources	12
Management of floodplains	13
Restoring (protecting) river banks	5
Landscape scale co-operation and facilitation support	0
Control of Invasive Non-native Species	7
Create and maintain habitats specific for the target species	2
Interventions to reduce species impacts on land management activities	2
Management of deer populations to meet habitat condition targets	1
Predator control to protect priority species	1
Introduction of Small-Scale Tree and Shrub Planting	8
Manage Grazed Habitats	17
Restoration of natural habitats - peatland, natural woodlands, natural grasslands	24
Retain Traditional Cattle Small Holdings	1
Summer Hill Cattle Grazing	1

There is not an equivalent QEIA action that corresponds to the proposed ARP measure "Landscape scale co-operation and facilitation support". This may reflect a difference in how actions (QEIA) and measures (ARP) are defined, because the DEFRA ELM scheme does include support for co-operation between landowners and landscape scale projects[17].

Mapping the QEIA biodiversity theme ES indicators to Scottish policy

The QEIA includes 12 ES indicators for the biodiversity theme. These indicators are relevant to existing and in-development policy areas within Scotland. The ES indicators are presented below with relevant Scottish policy identified under each:

1. *Biodiversity adaptation - maintaining / enhancing biodiversity under a changing climate*
   This ES indicator is relevant to Scotland. 'Outcome one: Nature Connects' in the *Draft Scottish National Adaptation Plan (2024 – 2029)* acknowledges the impact of climate change to wildlife and habitats, and that biodiverse ecosystems can 'help us adapt to the changing climate.'

2. *Atmospheric deposition of N and exceedance of critical loads*
   Human agricultural and industrial activities have increased the amount of Nitrogen emitted into the atmosphere and deposited on the Earth's surface (Kanakidou et al., 2016). Atmospheric deposition is quantified as part of the Scottish Nitrogen Balance Sheet, which includes Nitrogen inputs related to food production and associated losses to the atmosphere. Critical loads have been estimated for 60% of Scottish habitats (see Britton et al., 2023).

[17] For example, see Landscape Recovery Funding.

3. *Connectivity of small 'feature' habitats*
   The concept of ecological connectivity features widely in Scottish biodiversity policy. In particular, the draft Framework for Nature Networks in Scotland (part of the wider Scottish Biodiversity Strategy Delivery Plan) explains the importance of ecological connectivity and how it will be improved under the proposed Nature Networks Framework.

4. *Favourable condition of SSSIs*
   SSSIs (Sites of Special Scientific Interest) are sites that contain important habitats or species as defined in the EU Habitat Directive and this designation is used across the UK.

   The draft Framework for 30 by 30 in Scotland considers SSSIs to contribute to the current 18.2% of land and freshwater covered by protected areas. It also uses the SSSI assessment condition terminology (see SSSI Assessment of Condition, Nature Scot) to describe "65.2% of notified features on our protected areas in favourable condition with a further 11.3% unfavourable but recovering."

5. *Enhance 6. maintain abundance and species richness of wider farmland biodiversity*
   Nature Scot are developing a farm biodiversity audit, which has a four-step approach. The third step is "manage to maintain or increase the condition of the habitats". Tackling the nature emergency: Consultation on Scotland's Strategic Framework for Biodiversity describes the intention to 'Introduce an agricultural support framework which delivers for nature restoration and biodiversity alongside climate and food production outcomes' and an action to 'Implement actions specifically benefitting farmland species as part of ongoing support and the new agricultural payments framework by 2030'. The Biodiversity Strategy to 2045 includes the Proposed EU Nature Restoration Law Targets, which cover increasing grassland butterflies and farmland birds for agricultural ecosystems.

7. *Enhance 8. maintain abundance and species richness of semi-natural habitat*
   The definition of a 'restoration measure' in the Scottish Biodiversity Strategy's Glossary of Biodiversity Terms includes the reestablishment and improvement in condition of semi-natural ecosystems. The Tackling the nature emergency: Consultation on Scotland's Strategic Framework for Biodiversity includes extensive use of the term 'enhance' when describing biodiversity outcomes.

9. *Presence of rare (red list) species, Presence of priority species*
   The Scottish Biodiversity Strategy to 2045 states that Scotland is fully committed to supporting United Nations Convention on Biological Diversity (CBD), and Global Biodiversity Framework (GBF), which uses Red List Species as one of its indicators.

   Nature Scot maintains a Scottish Biodiversity List, which contains 'animals, plants and habitats that Scottish Ministers consider to be of principal importance for biodiversity conservation in Scotland.'

10. *National species occurrence*
    This ES indicator is related to Invasive non-native species (INNS). An outcome in the Scottish Biodiversity Strategy is that by 2045 'Harmful invasive non-native species (INNS) will be managed so that established INNS no longer degrade native habitats and species or impede their restoration and regeneration and new introductions are managed quickly and effectively.' The Tackling the nature emergency Consultation on Scotland's Strategic

Framework for Biodiversity includes a Key Action: Implement Scottish Plan for INNS Surveillance, Prevention and Control.

11. *Evidence of outbreaks of pests and disease*
    This is relevant for Scotland's policy objectives around plant health in the Agriculture and Rural Communities (Scotland) Bill, which mentions 'provision of powers […] to support in the protection and improvement of plant health, for example through support for measures to control the spread of plant pests and diseases or to increase resilience to outbreaks.'

12. *Increased abundance, distribution and species richness of pollinators and seed dispersers*
    This service indicator is relevant to Scotland. The aim of The Pollinator Strategy for Scotland 2017-2027 is 'To address the causes of decline in populations, diversity and range of our pollinator species, and to help them thrive into the future.' Its first objective is 'To make Scotland more pollinator-friendly, halting and reversing the decline in native pollinator populations,' and it lists several outcomes in relation to supporting pollinators and their habitats.

Is the evidence underpinning the QEIA relevant to Scotland?

The evidence used in the QEIA is relevant to Scotland. The QEIA review team compiled a database of 2400+ published studies that informed their assessment. Scottish studies are included in the database, along with studies from the rest of the UK and Europe. The inclusion of literature from the UK and NW Europe (i.e., they used evidence from beyond England) is sensible as the farming systems, climate, and environments are relatively similar[18]. Although this is the case, there are a few exceptions that may need to be considered when using the QEIA to inform Scottish policy.

Are any actions in the QEIA not relevant to the Scottish context?

Some QEIA actions grouped under *Create and enhance access and PRoW* may be less relevant in Scotland due to differences between English and Scottish land access rights.

Are there any actions missing from the QEIA that would be relevant to Scotland?

Scotland's landcover comprises a relatively large area of upland and peatland in comparison to England. Scotland has unique habitats, such as machair, and crofting is unique to Scotland.

Uplands

Three actions specifically mention 'uplands.'

Peatland

Thirty-four actions are included in the QEIA Tier 2 management bundle "Actions for habitats with specific hydrological characteristics / Peatlands and wetlands." Of these, ten specifically target peatland.

Crofting

No actions specifically target crofts or crofting.

Machair

No actions specifically mention machair grassland.

[18] See 'Does the evidence base cover wales, scotland and northern ireland too?'

Are there any ES indicators for biodiversity that are missing?

The ES indicators in the QEIA encompass actions related to agriculture across the Objectives in the Scottish Biodiversity Delivery Plan.

Are there evidence gaps for biodiversity?

The evidence used to assess the impact of QEIA actions on the ES indicators for biodiversity is often limited, with around 60% of the QEIA actions that correspond or relate to the ARP measures being categorised as having limited evidence. This is largely consistent across the ARP measures packages (Table 2), except for QEIA actions related to the ARP package *Path infrastructure capital items,* where most of the associated QEIA actions were deemed to have no impact to biodiversity (49 of 50 actions) and for the one that did have a potential benefit to biodiversity there was limited evidence across the four associated ES indicators for biodiversity.

Table 2. Evidence limitations across the ARP measures packages for ES indicators in the biodiversity theme.

ARP Package	QEIA actions	Scored QEIA actions	QEIA ES indicators	QEIA ES indicators with limited evidence	Proportion QEIA ES indicators with limited evidence
Continuous Soil Cover	7	6	24	13	0.54
Crop Diversity - arable	41	33	201	110	0.55
Crop Diversity - grassland	16	13	79	34	0.43
Efficient / Reduced use of synthetic inputs	48	34	157	90	0.57
Landscape Restoration	-	-	-	-	-
Managing water quality and flood risk	56	14	63	25	0.40
Mostly a range of one-off capital based activities to manage the species or create habitat specific space required to host the species	13	8	49	32	0.65
Path infrastructure capital items	50	1	4	4	1.00
Restore and Manage Existing Nature Rich Habitats	51	23	144	51	0.35
Retain and Enhance Field Margins and Permanent Habitat Margins	38	20	124	55	0.44

Notes: *QEIA actions* refers to the number of QEIA actions that correspond or are linked to measures with each ARP Package. *Scored QEIA actions* includes those that were scored as red, amber or green in the QEIA. *QEIA ES indicators* refers to the total number of ES indicators for biodiversity that were scored across all QEIA actions linked to the ARP Package. *QEIA ES indicators with limited evidence* is the number of ES indicators for biodiversity across all actions for each ARP Package that were identified as having limited evidence.

Do any of the QEIA actions have variable impacts on ES indicators (i.e., benefits and disbenefits)?

The review team assessed some actions as having a variable impact on the ES indicators. For biodiversity, this means that the action could benefit some groups of species but disbenefit others. This is at least partly related to the issue of different land uses benefiting different types of biodiversity mentioned in Part 1, and further highlights that choices need to be made to decide which components of biodiversity should be prioritised in what context. Potential disbenefits appear greatest to QEIA actions within in the ARP Continuous Soil Cover package (Table 3).

Table 3. disbenefits across the ARP measures packages for ES indicators in the biodiversity theme.

ARP Package	QEIA actions	Scored QEIA actions	QEIA ES indicators	QEIA ES indicators with potential disbenefits	Proportion QEIA ES indicators with potential disbenefits
Continuous Soil Cover	7	6	24	14	0.58
Crop Diversity - arable	41	33	201	40	0.20
Crop Diversity - grassland	16	13	79	6	0.08
Efficient / Reduced use of synthetic inputs	48	34	157	14	0.09
Landscape Restoration	-	-	-	-	-
Managing water quality and flood risk	56	14	63	7	0.11
Mostly a range of one off capital based activities to manage the species or create habitat specific space required to host the species	13	8	49		0.06
Path infrastructure capital items	50	1	4	0	0.00
Restore and Manage Existing Nature Rich Habitats	51	23	144	14	0.10
Retain and Enhance Field Margins and Permanent Habitat Margins	38	20	124	20	0.16

Notes: *QEIA actions* refers to the number of QEIA actions that correspond or are linked to measures with each ARP Package. *Scored QEIA actions* includes those that were scored as red, amber or green in the QEIA. *QEIA ES indicators* refers to the total number of ES indicators for biodiversity that were scored across all QEIA actions linked to the ARP Package. *QEIA ES indicators with potential disbenefits* is the number of ES indicators for biodiversity across all actions for each ARP Package that were identified as having a potential disbenefit.

Demonstrating how the QEIA could be used to inform the ARP

The QEIA is a rich dataset that can be used to help answer a range of questions relating to the potential impacts of the ARP measures on biodiversity, air, soil and water, etc. For example, the QEIA scores can be used to identify co-benefits and trade-offs between ARP measures. This section demonstrates one way that the QEIA could help inform the development of ARP list of

measures. Specifically, the following two analyses aggregate the QEIA scores at 1) the theme-level and 2) in more detail for the biodiversity theme. The aim of these analyses is to give an overview of the data presented in the QEIA Scores spreadsheet and to help identify potential additions to the ARP list of measures. These analyses are intended to be used alongside the QEIA Scores spreadsheet and evidence reviews.

Brief methods

The QEIA methodology assesses the impacts of each action against the relevant ES indicators using a Red-Amber-Green (RAG) system with a magnitude score of 1-3 (Figure 2A); or the cells may be coloured white and coded with a letter code to indicate cases where no impact was expected, or that the action was split or merged, etc. The QEIA 'Cell contents' were summarised (see Figure 2 for visual representation of the methods, and see Annex A for detailed methods) to 1) allow a coarse comparison of potential impacts of the ARP measures on different ES themes, and 2) to allow a finer-scale comparison of the ARP measures across the 12 ES indicators in the biodiversity theme.

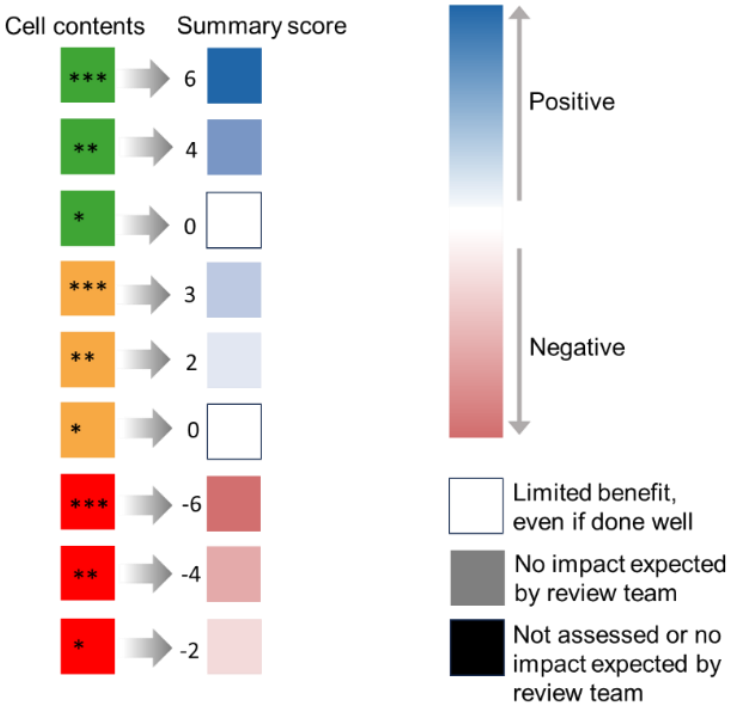


Figure 2. Data from the QEIA can be used to highlight the potential positive or negative impacts of actions on ES indicators. (A) Each action in the QEIA is assessed against 53 ES indicators, with the 'Cell contents' providing information on the potential impact. There are various ways to summarise the Cell contents. Here, the RAG and Cell Magnitude (*, **, ***) components are combined into a single value as indicated by the grey arrows to produce the corresponding *Summary score* (See Appendix A for detailed methods). (B) The Summary score is then represented as a red (negative impact) to blue (positive impact) colour to indicate the strength and direction of the potential impact. White indicates where the review team assessed the impact as 'Limited benefit, even if done well', grey indicates where the review team expected no impact of the action on the ES indicator, while black indicates either where no assessment was made, or the review team expected no impact of the action on the ES indicator.

Summarising the ES indicator scores at the theme-level for QEIA actions relevant to the ARP measures

The theme-level summary can be used to highlight where the ARP measures have potential co-benefits and/or trade-offs between the themes (e.g., see Figure 3, and Annex B for all measures).

As an example, there are seven actions in the QEIA that correspond or relate to the ARP Measure *Diversify crop rotation and break crop rotation period (esp. for root crop)*. Each of the seven QEIA actions have the potential to impact biodiversity differently. For example, the QEIA action *Use green manures within the rotation* is likely to have a limited benefit for biodiversity, whereas *Unvegetated, ploughed fallow for one year* would most likely have a positive benefit for biodiversity. This example also serves to highlight that the trade-offs differ for each QEIA action – e.g., in this case the *Unvegetated fallow* action negatively impacts yields, whereas the *Green manure* action has a limited impact to yield.

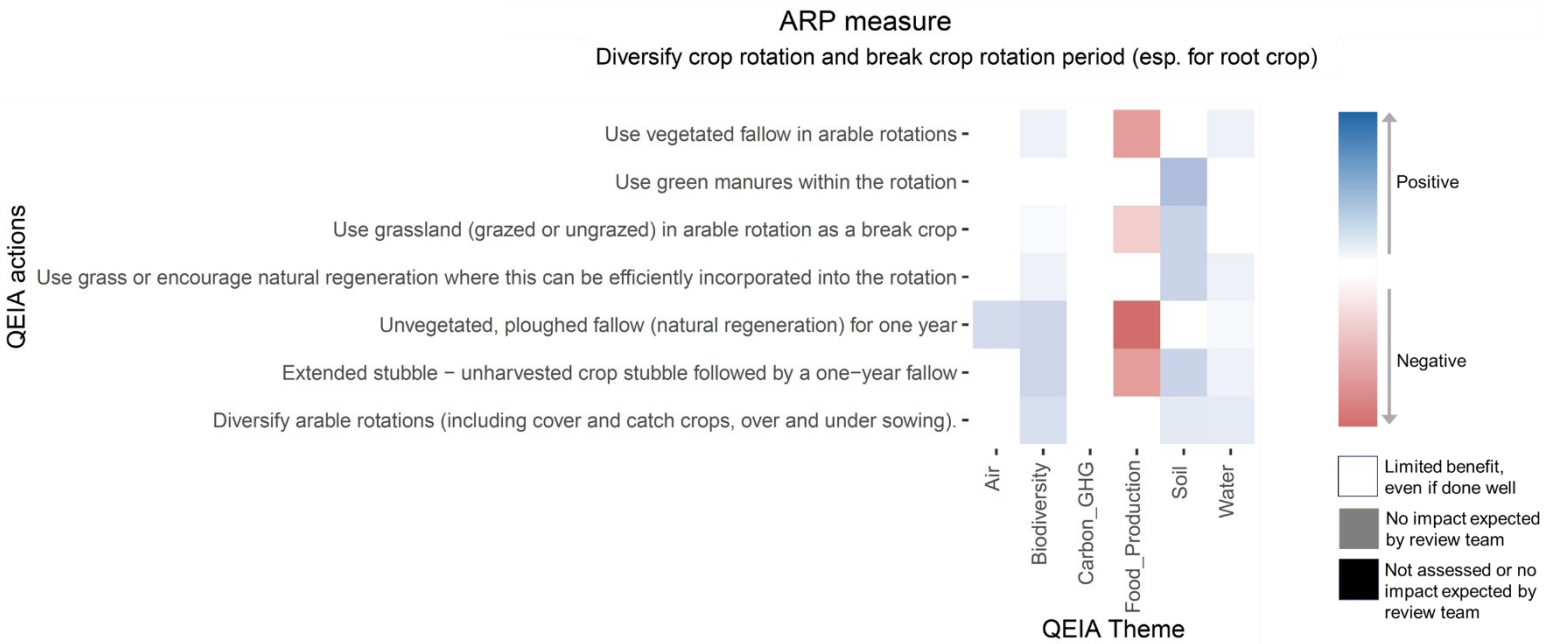


Figure 3. A theme-level summary of potential impacts for QEIA actions that correspond or relate to the ARP Measure *Diversify crop rotation and break crop rotation period (esp. for root crop).* Note that the magnitude of potential impacts are not directly comparable between the themes, and that the Cultural and Regulating themes were removed for this analysis. See Annex B for theme-level summaries of all measures.

This theme-level analysis has been undertaken for each of the ARP measures and is presented in Annex B. As a summary, 73 of the 236 QEIA actions that correspond or relate to the ARP measures include a trade-off between biodiversity and another theme. Most of these trade-offs were with *Food_Production* (66 of the 73 actions), but a few included trade-offs with the *Water* (6 actions), *Carbon_GHG* (4 actions), *Air* (3 actions) and *Soil* (3 actions) themes. Eight of the QEIA actions included trade-offs with two themes, and none had trade-offs with three or more themes. At this theme-level analysis, no actions scored positively (i.e., having major to moderate positive benefit on average) across all six themes, but one action scored positively for five themes, six actions for four themes, 32 for three themes, 75 for two themes, and 156 for one theme. This type of analysis could be used to identify potential trade-offs and co-benefits for the ARP measures.

Summarising the biodiversity theme ES indicator scores for QEIA actions relevant to the ARP measures

The summary of potential impacts within the biodiversity theme can be used to highlight how the QEIA actions differ in their impacts to biodiversity.

Using the same ARP Measure *Diversify crop rotation and break crop rotation period (esp. for root crop)* again shows a similar result: each of the QEIA actions that correspond or relate to the ARP measure have differing impacts to biodiversity. In this example, the *Diversify arable rotation* action has the potential to positively benefit the most ES indicators for biodiversity (6/12 ES Indicators), and *Unvegetated ploughed fallow* and *Extended stubble* actions have the strongest potential positive impact any single ES Indicator (Presence of rare or priority species), while still having a potential positive impact on several other ES indicators (5/12 in total) (Figure 4).

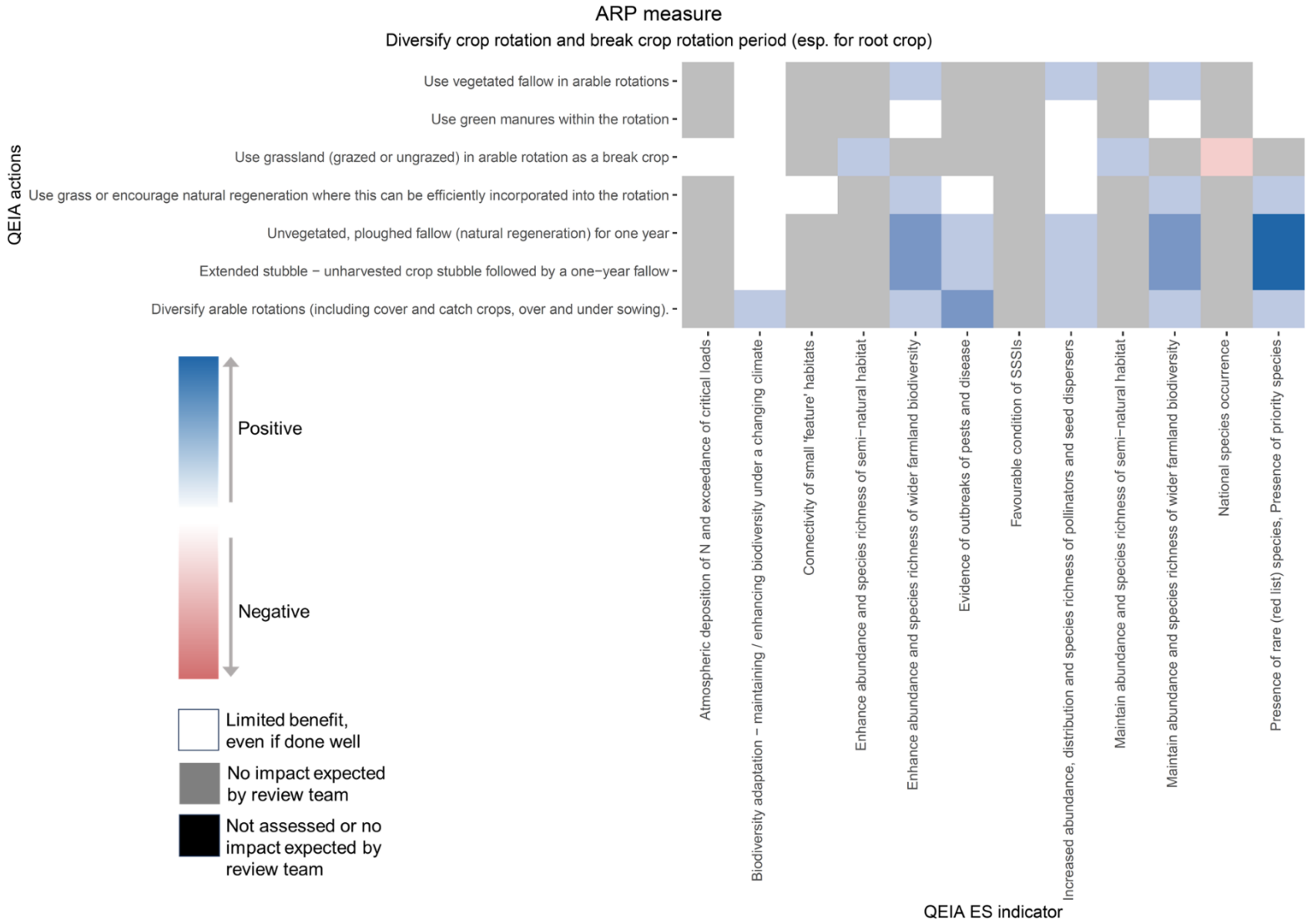


Figure 4. A summary of potential biodiversity impacts for QEIA actions that correspond or relate to the ARP Measure *Diversify crop rotation and break crop rotation period (esp. for root crop).* See Annex C for summaries of potential biodiversity impacts for all measures.

The *Use grassland as a break crop* action has a potential negative impact on one ES indicator for biodiversity (National species occurrence). This shows that an action can potentially have both positive and negative impacts on biodiversity, and that aggregating biodiversity to a single value (as in Figure 3) can mask potential trade-offs and negative impacts. Having said that, only four of the ARP measures were associated to a QEIA action with a negative impact, and in all cases, this was only for one of the 12 ES indicators for biodiversity.

Notes on interpreting results of both analyses

- Caution should be used when interpreting any outputs that use QEIA scores because the QEIA scores are not directly comparable between QEIA actions.
- These results are intended to indicate the *potential* positive or negative impact to the themes, or ES indicators for biodiversity, in a qualitative way.
- Both the theme-level analysis (Figure 3) and biodiversity theme ES indicator analysis (Figure 4) reduce the amount of information that is presented in the QEIA Scores database.
- For example, they do not explicitly include the contextual letter codes (L, limited evidence; D, potential disbenefit to another species group; and T, context dependence benefit or requires targeting to be effective) from the QEIA Cell contents in the calculation of the summary scores.
- Both levels of analysis give an overview of the data presented in the QEIA, and should be used alongside the QEIA Scores spreadsheet.
- Several evidence reviews were published as part of the QEIA and these provide more detail on the potential impacts of the actions and should be referred to alongside Annex B and C of this report.

Conclusion

Many of the ARP measures can be delivered in several ways according to the higher granularity of the QEIA actions, each having different potential impacts to biodiversity. The ARP measures need to be carefully defined so that their potential impacts to biodiversity (and for air, soil, water etc.) can be assessed. Individual measures have the potential to impact the various components of biodiversity differently, and in a few cases these impacts can include positive and negative impacts, but these potential disbenefits within the ES indicators for biodiversity appear rare for the QEIA actions that are associated to the draft ARP measures. Although caution is required when using the QEIA and interpreting outputs derived from it, the QEIA could be a valuable resource to support the ARP.

PART 3

Overall summary

This report highlights the complexity involved in understanding the impacts that agri-environment measures have on biodiversity. The QEIA could be used, alongside other available resources, to help understand the potential impacts of the ARP measures on biodiversity. For example, it could be used to highlight potential trade-offs and co-benefits between ARP measures and identify additional measures to consider for inclusion in the ARP. Future research on agri-environment scheme impacts to biodiversity should aim to fill the evidence gaps highlighted in the QEIA.

Recommendations

Identifying which measures are likely to be most effective at delivering benefits to biodiversity is important in ensuring the effectiveness of the proposed Future Payments Framework, but this is challenging because biodiversity is inherently complex. The following recommendations are aimed to inform the development of the ARP measures, and aid in developing an approach to assess and understand the biodiversity impacts of the ARP measures:

1. **The biodiversity value of measures should be considered more broadly than by a single metric or indicator**, because the impact of individual measures can differ across the various components of biodiversity.
2. **Policy makers need to make decisions on what types of biodiversity to prioritise in what context.** The measures will benefit some components of biodiversity, or groups of species, but negatively impact others, so value judgements need be considered when developing the measures and their implementation.
3. **Implementing a wide range of measures, rather than a few common measures, would be more beneficial for biodiversity.** This could be achieved by (a) farms applying different combinations of complementary measures, alongside (b) coordination between landowners to create large-scale natural habitat blocks that are linked by landscape features.
4. **The QEIA can be used to inform development of the ARP.** It is the most up-to-date assessment of potential impacts of agri-environment actions on biodiversity and is largely relevant to Scotland, but its use requires caution and an understanding of its limitations.
5. **The ARP measures should be reviewed against related actions in the QEIA** to identify alternative (or additional) measures with greater potential biodiversity benefit, and to identify potential co-benefits or trade-offs with other objectives (e.g., soil, air, water, etc.). Each measure should then be clearly defined.
6. **The biodiversity impacts of the measures should be reassessed iteratively once the programme is established and more evidence is available**. This could be built into future monitoring frameworks and linked to the Whole Farm Plan biodiversity audits.

References

Almond, R.E.A., Grooten M. and Petersen, T. (2020) Living Planet Report 2020 - Bending the curve of biodiversity loss. WWF https://www.icriforum.org/wp-content/uploads/2020/09/LPR20_Full_report.pdf

Batáry, P. and Tscharntke, T. (2022) Scale-dependent effectiveness of on-field vs. off-field agri-environmental measures for wild bees. *Basic and Applied Ecology* 62:55-60.

Bateman, I. and Balmford, A. (2023) Current conservation policies risk accelerating biodiversity loss. *Nature* 618:671-674.

Borin, M., Passoni, M., Thiene, M. and Tempesta, T. (2010) Multiple functions of buffer strips in farming areas. *European journal of agronomy* 32:103-111.

Benton, T.G., Bieg, C., Harwatt, H., et al. (2021) *Food system impacts on biodiversity loss: Three levers for food system transformation in support of nature*. Chatham House, London.

Blake, D. and Baarda, P. (2018) Developing a habitat connectivity indicator for Scotland. Scottish Natural Heritage Research Report No. 887

Brittain C., Benke S., Pecze R., et al. (2022) Flower Margins: Attractiveness over Time for Different Pollinator Groups. *Land* 11:1933. https://doi.org/10.3390/land11111933

Butchart, S.H., Walpole, M., Collen, B., et al. (2010) Global biodiversity: indicators of recent declines. *Science* 328:1164-1168.

Cardinale, B., Duffy, J., Gonzalez, A. et al. (2021) Biodiversity loss and its impact on humanity. *Nature* 486:59–67. https://doi.org/10.1038/nature11148

Cunningham, S.C., Mac Nally, R., Baker, P.J., et al. (2015) Balancing the environmental benefits of reforestation in agricultural regions. *Perspectives in Plant Ecology, Evolution and Systematics* 17:301-317.

Damschen, E.I., Brudvig, L.A., Burt, M.A., et al. (2019) Ongoing accumulation of plant diversity through habitat connectivity in an 18-year experiment. *Science* 365:1478-1480.

Dunning, J.B., Danielson, B.J. and Pulliam, H.R. (1992) Ecological processes that affect populations in complex landscapes. *Oikos* 65:169-175.

Emmett, B.A., Cosby, B.J. et al. (2023a). Qualitative impact assessment of land management interventions on Ecosystem Services ('QEIA'). Report-2: Integrated Assessment (Defra ECM_62324/UKCEH 08044).

Emmett, B.A., Cosby, B.J., et al. (2023b). Qualitative impact assessment of land management interventions on Ecosystem Services ('QEIA'). Report-2 Annex: Integrated Assessment Table (Defra ECM_62324/UKCEH 08044)

Estrada-Carmona, N., Sánchez, A.C., Remans, R. and Jones, S.K. (2022) Complex agricultural landscapes host more biodiversity than simple ones: A global meta-analysis. *Proceedings of the National Academy of Sciences* 119:e2203385119.

Fahrig, L. (2003) Effects of habitat fragmentation on biodiversity. *Annual review of ecology, evolution, and systematics* 34:487-515.

Feniuk, C., Balmford, A. and Green, R.E. (2019) Land sparing to make space for species dependent on natural habitats and high nature value farmland. *Proceedings of the Royal Society B* 286:20191483.

Finch, T., Gillings, S., Green, R.E., et al. (2019) Bird conservation and the land sharing-sparing continuum in farmland-dominated landscapes of lowland England. *Conservation Biology* 33:1045-1055. https://doi.org/10.1111/cobi.13316

Finch, T., 2020. Restoring farmlands for food and nature. *One Earth* 3:665-668.

Fischer, J., Abson, D.J., Butsic, V., et al. (2014) Land Sparing Versus Land Sharing: Moving Forward. *Conservation Letters* 7:149-157. https://doi.org/10.1111/conl.12084

Franks, J.R. (2011) The collective provision of environmental goods: a discussion of contractual issues. *Journal of Environmental Planning and Management* 54:637-660. DOI: 10.1080/09640568.2010.526380

Gámez-Virués, S., Perović, D., Gossner, M. et al. (2015) Landscape simplification filters species traits and drives biotic homogenization. *Nature Communications* 6:8568. https://doi.org/10.1038/ncomms9568

Hooper, D.U., Adair, E.C., Cardinale, B.J., et al. (2012) A global synthesis reveals biodiversity loss as a major driver of ecosystem change. *Nature* 486:105-108.

Jaureguiberry, P., Titeux, N., Wiemers, M., et al. (2022) The direct drivers of recent global anthropogenic biodiversity loss. *Science Advances* 8:eabm9982. DOI:10.1126/sciadv.abm9982

Jonason, D., Andersson, G.K., Öckinger, E., et al. (2011) Assessing the effect of the time since transition to organic farming on plants and butterflies. *Journal of Applied Ecology* 48:543-550.

Keenleyside, C.B. and Costa Domingo, G. (2023). Qualitative impact assessment of land management interventions on Ecosystem Services (“QEIA”). Report-3 Theme-5B: Biodiversity - Grassland. (Defra ECM_62324/UKCEH 08044)

Knop, E., Kleijn, D., Herzog, F. and Schmid, B. (2006) Effectiveness of the Swiss agri-environment scheme in promoting biodiversity. *Journal of Applied Ecology* 43:120-127. https://doi.org/10.1111/j.1365-2664.2005.01113.x

Maskell, L. and Norton, L. (2023). Qualitative impact assessment of land management interventions on Ecosystem Services (“QEIA”). Report-3 Theme-5C: Biodiversity - Semi-Natural Habitats (Defra ECM_62324/UKCEH 08044)

McKenzie, A.J., Emery, S.B., Franks, J.R. and Whittingham, M.J. (2013) FORUM: Landscape-scale conservation: collaborative agri-environment schemes could benefit both biodiversity and ecosystem services, but will farmers be willing to participate? *Journal of Applied Ecology* 50: 1274-1280. https://doi.org/10.1111/1365-2664.12122

Naeem, S., Chapin Iii, F.S., Costanza, R., et al. (1999) Biodiversity and ecosystem functioning: maintaining natural life support processes. *Issues in ecology* 4:2-11.

NatureScot (2023) The concern: Do networks enhance biodiversity? Website. Available at: https://www.nature.scot/professional-advice/land-and-sea-management/managing-land/habitat-networks/concerns-about-habitat-networks

Prager, K. (2015) Agri-environmental collaboratives for landscape management in Europe. *Current Opinion in Environmental Sustainability* 12:59-66.

Redhead, J.W., Hinsley, S.A., Botham, M.S. (2022) The effects of a decade of agri-environment intervention in a lowland farm landscape on population trends of birds and butterflies. *Journal of Applied Ecology* 59:2486–2496. https://doi.org/10.1111/1365-2664.14246

Salazar R., Foster J. and Thompson P. (2016) Evaluating the importance of agri-environment scheme buffer strips to widespread amphibians and reptiles [Environmental Stewardship Monitoring and Evaluation Framework Reference ECM6147]: Final report. Amphibian and Reptile Conservation (ARC) report, Report to Natural England.

Samways, M.J., Bazelet, C.S. and Pryke, J.S. (2010) Provision of ecosystem services by large scale corridors and ecological networks. *Biodiversity and Conservation* 19:2949–2962. https://doi.org/10.1007/s10531-009-9715-2

Scottish Government (2022) *Scottish Biodiversity Strategy to 2045: Tackling the Nature Emergency in Scotland.* Edinburgh: APS Group Scotland.

Scottish Government (2023) Rural Payments and Services: Supporting guidance for Corn Buntings Mown Grassland. Available at: https://www.ruralpayments.org/topics/all-schemes/agri-environment-climate-scheme/management-options-and-capital-items/corn-buntings-mown-grassland/guidance-for-corn-buntings-mown-grassland/

Singleton, P.H. (2002) *Landscape permeability for large carnivores in Washington: a geographic information system weighted-distance and least-cost corridor assessment* (Vol. 549). US Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Siriwardena, G.M. (2023). Qualitative impact assessment of land management interventions on Ecosystem Services (“QEIA”). Report-3 Theme-5D: Biodiversity - Integrated System-Based Actions. (Defra ECM_62324/UKCEH 08044)

Staley, J., Ball, S., Ridding, L. and Pywell, R. (2015) Scoping study to develop a methodology that can be used to assess the value of agri-environment scheme options in the creation and maintenance of small-scale habitat mosaics to benefit priority species. Final report for LM0202.

Staley, J.T., Botham, M.S., Broughton, R.K., Carvell, C., Pywell, R.F., Wagner, M. & Woodcock, B.A. (2023). Qualitative impact assessment of land management interventions on Ecosystem Services (“QEIA”). Report-3 Theme-5A: Biodiversity - Cropland. (Defra ECM_62324/UKCEH 08044)

Tscharntke, T., Batáry, P. and Dormann, C.F. (2011) Set-aside management: How do succession, sowing patterns and landscape context affect biodiversity? *Agriculture, ecosystems & environment* 143:37-44.

Vanbergen, A.J., Aizen, M.A., Cordeau, S., et al. (2020) Transformation of agricultural landscapes in the Anthropocene: Nature's contributions to people, agriculture and food security. In *Advances in Ecological Research* (Vol. 63, pp. 193-253). Academic Press.

Walker, L.K., Morris, A.J., Cristinacce, A., Dadam, D., et al. (2018) Effects of higher-tier agri-environment scheme on the abundance of priority farmland birds. *Animal Conservation* 21: 183-192. https://doi.org/10.1111/acv.12386

Watts, K., Whytock, R.C., Park, K.J. et al. (2020) Ecological time lags and the journey towards conservation success. *Nature, Ecology & Evolution* 4:304–311. https://doi.org/10.1038/s41559-019-1087-8

Whittingham, M.J. (2007) Will agri-environment schemes deliver substantial biodiversity gain, and if not why not? *Journal of Applied Ecology* 44:1-5. https://doi.org/10.1111/j.1365-2664.2006.01263.x

Wratten, S.D., Gillespie, M., Decourtye, A., et al. (2012) Pollinator habitat enhancement: benefits to other ecosystem services. *Agriculture, Ecosystems & Environment* 159:112-122.