Journal of Environmental Management 377 (2025) 124541

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Comparing stakeholder perspectives and biodiversity models in assessing scenarios of management change

Robin J. Pakeman [a,*], Alba Juárez-Bourke [a], Scott Herrett [a], Alice Hague [a], Anja Byg [a], Altea Lorenzo-Arribas [b], Anke Fischer [c], Laura MacLean [a], Keith Marshall [a], Gillian Donaldson-Selby [a], Alison J. Hester [a], Antonia Eastwood [a]

[a] The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK
[b] Biomathematics and Statistics Scotland, The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH, UK
[c] Sveriges Lantbruksuniversitet, Inst för stad och land, Box 7012, 75007, Uppsala, Sweden

ARTICLE INFO

Keywords:
Community engagement
Contextualised knowledge
Dialogue
Scientific knowledge
Woodland management

ABSTRACT

Bringing together local, contextualised knowledge with generalised, scientific knowledge is seen as best practice in decision making for biodiversity management. However, there is the potential for conflict if predictions from these different viewpoints do not concur. We tested whether the predictions of stakeholders for biodiversity changes agreed with or differed from those based on simple models based on biodiversity data and species' ecological preferences - for this we used six sites to test the impact of four different woodland management scenarios on two proxies (spring flowers, dominant weed species). The scenarios were: "Management Plan" based on the current goals for site management, "Biodiversity Conservation" where the main goal for site management focussed on improving habitats and species conservation, "People Engagement" where site management encouraged the use of the woodland and its resources and "Low Budget" where resources were constrained to keeping the site safe for access. Stakeholder predictions were elicited during workshops involving deliberative discussions and repeated scoring of scenario effects. The biodiversity occurrence data model was developed using species occurrence data and predicted responses to disturbance based on habitat preferences.

Worksop scorings were relatively consistent across sites ranking the scenario Biodiversity Management just ahead of Management Plan and People Engagement, with Low Budget scoring consistently much lower. The modelling spread the predicted results of the scenarios, so that for spring flowers Management Plan ranked substantially lower than Biodiversity Conservation and People Engagement reflecting the lower levels of disturbance under the former. For dominant weed species, "People Engagement" ranked lower than Biodiversity Management and Management Plan reflecting the reduced concentration on dominant weed species control under the former scenario. As for the stakeholder scorings, the Low Budget" scenario ranked much lower than the others.

Effective decision-making requires taking account of different sources of knowledge. The study described here highlights the general similarities between local, contextualised knowledge and a more generalised, ecological approach to predicting change, though there were important differences. Customising models to the site level is likely to be unrealistic in terms of the resources needed, so there is likely to be a tension between different sources of knowledge and reconciling these will remain a challenge. This reconciliation will be helped by developing appropriate workshop questions to cover the multi-faceted nature and responses of biodiversity.

1. Introduction

Frameworks set up to analyse the benefits and disbenefits of changing land use or land management such as the Ecosystem Approach (Kay et al., 1999) and Nature-based Solutions (Keesstra et al., 2018) have embedded within them the necessity of effective engagement with stakeholders. The embedding of stakeholders within the Ecosystem Approach was put in place by the Convention on Biological Diversity

* Corresponding author.
E-mail address: robin.pakeman@hutton.ac.uk (R.J. Pakeman).

https://doi.org/10.1016/j.jenvman.2025.124541
Received 30 May 2024; Received in revised form 23 January 2025; Accepted 10 February 2025
Available online 19 February 2025

(CBD SBSTTA, 2000) in order to ensure both sustainable and equitable use of land, water and other resources (Waylen et al., 2014). Similarly, the development of Nature-based Solutions has aimed to be collaborative and inclusive of a diverse range of actors rather than taking a top-down, technological approach (Cohen-Shacham et al., 2019; Nesshöver et al., 2017).

Common to both frameworks are that they are used to identify appropriate strategies to achieve future goals: the restoration of biodiversity and the improvement of ecosystem services. Stakeholders are embedded in the process, in part to test acceptance of different scenarios of change, but also to make use of their knowledge as what might be the endpoints of different management options under local conditions (Bélisle et al., 2018; Persson et al., 2018). This has led to research focussing on identifying and resolving conflicts between stakeholders (e.g., Marshall et al., 2007; Pouwels et al., 2011; White et al., 2009).

One other potential conflict in the development of projects within these frameworks is disagreement between the assessments of stakeholders and the experts involved. To a degree this can be seen as a potential conflict between local knowledge and, especially, knowledge of local context, versus more generalised knowledge that results from integration across a scientific discipline and from many contexts (Brugnach and Ingram, 2012; Larsen and Nilsson, 2017). Conflicts between such knowledges have a long history (Clark and Murdoch, 1997) and many examples could be given where one or other side has been right; livestock managers in Utah assessed bison as the primary competitor for cattle whilst evidence identified jack rabbits as more important (Ranglack et al., 2015), but in the Western Ghats of India, misplaced afforestation attempts dating from colonial times have resulted in the planting of invasive species into long managed, natural forest-grassland mosaics (Joshi et al., 2018). Fisheries management is one clear example of where stakeholder and expert predictions of the impact of management often diverge (e.g., Ford and Stewart, 2021; Hare, 2020). In recognition of this type of issue, a key component of many projects is the attempt to integrate local, contextualised knowledge with generalised, scientific knowledge before decisions are taken (e.g., Ainsworth et al., 2020; Brook and McLachlan, 2008). The challenges in integrating different knowledges include the way knowledge is categorised, language differences and perceptions about the quality of knowledge (Raymond et al., 2010). If different views need to be reconciled it may be that in practice greater weight is given to expert knowledge (Alberts, 2007).

A fundamental issue in integrating local, contextualised knowledge and scientific, generalised knowledge, or in deciding between them (in situations where, for instance, a nature-based solutions project is planned) is that they are both making predictions about the future. Hence, it is a decision based on “models” of how the world works and whether predictions from those “models” concur or diverge (Lamarque et al., 2011). Knowledge of where there might be disagreement would be helpful in pre-empting conflicts in objectives and would help focus discussion on similarity and differences between what local, contextualised knowledge and what generalised, scientific knowledge might predict. A further issue to overcome in integrating different knowledge systems is that it may be impractical to ask the same question. Where multiple species or habitats, for instance, are the focus of restoration it may be difficult to engage local stakeholders with such complexity. This is further compounded if the target is all encompassing such as “improving biodiversity”. Simplifications have to be made in the process of integration and this increases the opportunity for disparity to arise between both local and scientific knowledge, but also between the simplification and the overall information available to the scientists.

Using scenarios to elicit stakeholder views about different policies has a long history for predicting impacts or benefits to landscape and biodiversity (Burt et al., 2021; Kiatkoski Kim et al., 2022). For instance, they have shown that stakeholders from different countries in Europe hold similar views about the management of mountain landscapes (Soliva et al., 2008) and have been shown to be useful at assessing the palatability of different land sparing or land sharing strategies (Karner et al., 2019). In contrast to considering only the views of stakeholders, purely model-based assessment of different scenarios of land use or land management are common in the literature from global (e.g., Alkemade et al., 2009; Rosa et al., 2020) to regional (e.g., Sharma et al., 2018; Wamelink et al., 2003) and to local scales (e.g., Halkos and Jones, 2012; Sweet et al., 2019). The joint use of biological models and stakeholder knowledge to assess futures is rarer and often takes the form of integrating stakeholder preferences or knowledge into models (e.g., Blattert et al., 2020; Lexer and Seidl, 2009) or developing models or model scenarios together with stakeholders (e.g., Eggers et al., 2020; Lagabrielle et al., 2010). There is a need to identify potential conflicts or agreements between stakeholder and expert views about the impacts of management change to have confidence about predictions of impacts in situations where one or other source of information is unavailable. This study complements the few studies that have compared stakeholder and expert views of management impacts.

As part of a wider study comparing stakeholder perceptions of ecosystem service delivery under different woodland management scenarios (Eastwood et al., 2024), we tested whether stakeholder predictions of the impact of four different woodland management scenarios on two proxies for biodiversity agreed with or differed from those based on simple occurrence data models based on biodiversity data and species' ecological preferences. The wider study addressed a suite of potential woodland ecosystem services including timber production as a provisioning service, carbon sequestration and flood regulation as regulating services as well as mental restoration and place attachment as cultural services and how they might be affected by different management scenarios. We tested if simplifying the likely impacts of management change into two questions for stakeholders corresponded to the model predictions based on a wider view of likely biodiversity change based on the ecology of species present at each site. Comparisons were made across six sites, two in each of three different regions of Scotland to provide a range of contexts and different stakeholder groups to add generality to the conclusions. As an additional aim, we used the biodiversity occurrence data models to investigate how the different scenarios affected the likely impacts on alien species (species non-native in the British Isles) and species of conservation interest – specifically species on the Scottish Biodiversity List (https://www.nature.scot/doc/scottish-biodiversity-list). Elicitation of stakeholder views and perceptions on biodiversity and ecosystem services is increasingly important in developing management strategies and policy (Hölting et al., 2020; MacLeod et al., 2022), but it is important to understand how those views and perceptions relate to the actual impact of management or policy on those biodiversity and ecosystem services.

2. Methods

2.1. Sites

The study was conducted at six sites spread over three different regions of Scotland; Clunes and Loch Arkaig in the Highlands approximately 20 km north-east and north of Fort William, Cumbernauld Glen and Forest Wood in Cumbernauld, North Lanarkshire, and Glasdrum and Glen Creran in Argyll and Bute approximately 20 km north-east of Oban. The sites were chosen to cover a broad range of ownership models and levels of community engagement with management. Clunes is owned by the local community, Loch Arkaig by the same community and the Woodland Trust (an environmental charity), Cumbernauld Glen and Forest Wood are owned by the Scottish Wildlife Trust (an environmental charity), Glasdrum is owned by NatureScot (the Scottish nature conservation agency) and Glen Creran by Forestry and Land Scotland (a part of Scottish Government). Further details are given in Appendix 1 with locations shown in Fig. S1.

2.2. Stakeholder workshops

All day stakeholder workshops were held at each site (from April 2018 to August 2021, Eastwood et al., 2024). Participants were chosen for their knowledge of the site and the surrounding local area. We deliberately sought participants with potentially differing knowledges, views and experiences of, and about, the site, for example, a local ranger, a local business owner, a community engagement officer and a local volunteer. We limited the number of participants to a maximum of 10 to ensure sufficient time for in depth deliberation (actual numbers ranged from five to nine). Four of the workshops (Glen Creran, Glasdrum, Cumbernauld Glen and Forest Wood) were held face-to-face whilst those at the Loch Arkaig and Clunes were conducted on-line using a virtual whiteboard (Miro). Further details are given in Appendix 1.

Before each workshop (Eastwood et al., 2024) participants were asked to score 11 indicators of ecosystem service delivery (Employment and income, Target species -spring flowers, Target species – dominant weeds, Timber, Carbon sequestration, Mental restoration, Spirituality, Knowledge, education, skills and training, Landscape quality and character, Place attachment and Natural flood management) across six scenarios (see below). The scenarios were developed by the research team using past and present management plans, site visits, ecological survey reports, socio-economic studies and archival documents. They were created by the research team rather than participants so that they covered all sites and allowed participants to use their time deliberating on outcomes (Eastwood et al., 2017; Waylen et al., 2015). Following deliberative discussion participants were given the opportunity to revise their scores at the end of the workshop but were not expected to come to consensus. For the purpose of this analysis, we focussed only on the four scenarios assessing potential future site management: maintaining the management set out in the current "Management Plan", shifting management to focus on "Biodiversity Conservation", where habitat improvement and species conservation were prioritised, or "People Engagement", where use of the site and its resources was maximised, and a final scenario where funding was minimised "Low Budget". We did not consider the "Past" and "Present" scenarios as they were not focussed on future site management. Also, we considered only the stakeholder responses to the two ecosystem services directly relating to biodiversity: the positive cultural associations of "spring flowers" and the negative impacts of "dominant weed species". The latter included both alien species such as *Rhododendron ponticum* and native species such as *Pteridium aquilinum* (bracken).

2.3. Occurrence data

To contrast with the stakeholder predictions in the workshops, we developed a simple occurrence data model based on the records for all species from the 10 km × 10 km Ordnance Survey grid squares (hectad) that overlapped each site (Fig. S1). These were downloaded from the Atlas of the National Biodiversity Network (https://nbnatlas.org/) for the 20-year period 2000 to 2019 (Table 1). Taxonomy was standardised at the species level to reduce bias. As many species have been recorded at only a 10 km × 10 km or 2 km × 2 km (tetrad) resolution, it was necessary to weight species occurrence data to give greater weight to records that could be (nearly) unambiguously allocated to a site. So, records for the 1 km × 1 km squares (monads) overlapping each site were weighted 1, records for tetrads overlapping the site were weighted 0.5 and records only available at the hectad level were weighted 0.1. Multiple records of many species were present within each hectad, so the final weight for each species in the analysis was the maximum weight recorded for it. The final list for each site was then reduced to woodland and woodland ride/clearing species by removing species from other habitats, e.g., montane, aquatic, marine etc.

Table 1
Site locations, 10 km × 10 km Ordnance Survey grid squares used to download data from the National Biodiversity Network (https://nbnatlas.org) and date and time of downloads. Full citations are available in the Supplementary Material file "Citation.xlsx".

Site	Latitude and longitude	10 km × 10 km OS grid square	Download details from NBN Atlas
Clunes	56°57′10″N, 4°57′27″W	NN28	*NBN Atlas occurrence download at* https://nbnatlas.org *accessed on Thu Nov 19 12:31:22 UTC 2020.*
Cumbernauld Glen	55°57′46″N, 3°57′42″W	NS77	*NBN Atlas occurrence download at* https://nbnatlas.org *accessed on Mon Mar 06 15:56:50 UTC 2017.*
Forest Wood	55°57′01″N, 3°56′38″W	NN77	*NBN Atlas occurrence download at* https://nbnatlas.org *accessed on Mon Mar 06 15:56:50 UTC 2017.*
Glasdrum	56°33′37″N, 5°15′40″W	NM94, NN04	*NBN Atlas occurrence download at* https://nbnatlas.org *accessed on Wed Mar 22 08:58:58 UTC 2017.*
Glen Creran	56°35′27″N, 5°11′49″W	NN04, NN05	*NBN Atlas occurrence download at* https://nbnatlas.org *accessed on Wed Mar 22 08:58:58 UTC 2017.*
Loch Arkaig	56°57′12″N, 5°05′23″W	NN08, NN09, NN18, NN19	*NBN Atlas occurrence download at* https://nbnatlas.org *accessed on Tue Jun 09 16:12:25 UTC 2020.*

2.4. Scenarios and species' behaviours

To represent the generalised, scientific knowledge, species' behaviour under each scenario were assessed by predicting individual species likely responses to the changed disturbance regime under each scenario. For all plants, lichens and many invertebrate groups there are data sources that include habitat preferences, and scores were developed so that species sharing the same habitat preferences had the same scores (Britton et al. unpublished; Hill et al. 2004, 2007; Webb et al., 2017). The scoring focussed on the species responses to changing light levels – which would be the main impact of changing woodland management on individual species. Full details of these are in Appendix 2 and individual scores in Supplementary Material file "SpeciesResponse.xlsx". Scores were developed individually for other groups using the following information sources: birds (Hume et al., 2020), fungi (host plants in https://www.bioinfo.org.uk/and habitats from http://fungi.myspecies.info/), mammals (Harris and Yalden, 2008) and molluscs (http://www.habitas.org.uk/molluscireland/index.html). Ad hoc searches were carried out for Acari, amphibia and reptiles and species not listed under other information sources.

As two of the scenarios, maintaining the current management plan and active management to enhance biodiversity, both included specific actions targeted at weed species, the scores were adjusted for these species to reflect this.

To link the stakeholder workshops' focus on two specific biodiversity questions, two sets of species were selected from the species occurrence data a list of spring flowers and list of dominant weed species. The former included *Allium ursinum, Anemone nemorosa, Dactylorhiza fuschii, D. maculata, Ficaria verna, Galanthus nivalis, Hyacinthoides non-scripta, Mercurialis perennis, Oxalis acetosella, Primula vulgaris, Silene dioica, Viola riviniana*. The latter was composed of *Pteridium aquilinum*, *Rubus fruticosus* agg. and *Rhododendron ponticum*.

2.5. Analysis

The predicted impact of each of the four scenarios on the biodiversity of the six sites was assessed in two ways. Firstly, a comparison was made between the scoring in the workshops with both the selected species groups and the overall data. Scores for the dominant weed species groups from the occurrence data were multiplied by −1 so that an increase in these species corresponded to a low score in the workshops. This was followed by adjusting the scores to cover the same range (1–10) using with the minimum and maximum scores across all four scenarios for each of the scoring types (i.e., workshop scores or occurrence scores weighted by probability of occurrence and predicted trend). These scores were then subject to two-way analysis of variance (lm from *base* in R, R Core Team, 2024) with the type of scoring and the scenarios as factors, and the focus on whether the interaction between scoring type and scenario was significant, i.e., a mismatch between scoring in the different approaches.

Secondly, the predicted trends of species were tabulated for each site across each scenario in terms of (a) the number of alien species (species non-native to the British Isles except for archaeophytes which arrived in the UK prior to 1500 AD) and (b) the categories in which species sit in the Scottish Biodiversity List - Conservation Action Needed, Avoid Negative Impacts or WB Watching Brief Only (https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy/scottish-biodiversity-list). Species were tabulated in terms of the overall balance of increasing and decreasing species weighted occurrence probability and predicted trend. Alien species responses were multiplied by −1 so that desirable outcomes are consistently seen as positive scores. Differences between sites and scenarios were tested in a two-way analysis of variance without an interaction term.

3. Results

3.1. Stakeholder workshop results

The workshop scoring was relatively consistent across the six sites and the two biodiversity scores (Table 2). Biodiversity Conservation was the most highly rated for both scores (mean score 7.75), though at individual sites it frequently shared the highest ratings with either Management Plan (mean score 6.88) or People Engagement (mean score 6.83). It was slightly exceeded by Management Plan at one site (Cumbernauld Glen). Some communities were more pessimistic about the Management Plan including Clunes and Glen Creran, whilst others were more pessimistic about the People Engagement scenario, including Forest Wood, Glasdrum Loch Arkaig. The exception to this pattern was Forest Wood, where Management Plan scored highest. Low Budget consistently scored lowest (mean score 2.29) and was clearly seen as a poor scenario for spring flowers, and it also was seen as likely to lead to an increase in dominance of key dominant weed species.

3.2. Comparisons between scoring methods

There was a clear difference in the scoring of the impact on spring flowers between the four scenarios across the different scoring methods - stakeholder workshops, from the short list of species and for the overall biodiversity assessment (Table 3). However, the significant interaction between scenario and method clearly indicated that the modelled responses of the spring flower species to the Management Plan were more pessimistic that the workshop scoring. This follows from the suggested greater level of disturbance to the canopy suggested in the Biodiversity Conservation and People Engagement scenarios put forward. There was a good agreement between the workshop assessment and the overall species assessment.

Similarly, there was a clear difference in the scores for dominant weed species between the scenarios, with Biodiversity Conservation scoring highest and Low Budget lowest for all three methods (Table 4). There was, however, a significant interaction between method and scenario, with the dominant weed species modelled scores for People Engagement being much lower than the other two methods. This reflects the focus in both the Management Plan and the Biodiversity Conservation scenarios on dominant weed species control. The agreement between the workshop scores and the overall score was better than between the workshop scores and the dominant weed species-specific scores.

3.3. Aliens and species of conservation interest

The modelled outputs across all species suggest that the net positive impact of Biodiversity Conservation was highest, followed by People Engagement and then Management Plan (Table 5a). Low Budget had a

Table 3
Standardised scores from the biodiversity assessment of the stakeholder workshops, from the short list of species and for the overall biodiversity assessment for the impacts of management change on spring flowers. Results from a two-way analysis of variance are also shown.

Scenario	Workshop	Scores	Overall
Management Plan	7.56	3.33	5.33
Low Budget	1.03	3.27	2.09
Biodiversity Conservation	8.72	6.42	8.09
People Engagement	7.56	5.34	6.18
Factor	df	F	p
Method	2,60	8.037	<0.001
Scenario	3,60	51.96	<0.001
Scenario*Method	6,60	11.53	<0.001

Table 2
Scores for the two biodiversity scenarios from the stakeholder workshop for the six sites against the four scenarios of change.

	Management Plan	Low Budget	Biodiversity Conservation	People Engagement
Clunes				
Spring flowers	5	3	8	8
Weed suppression	6	2	8.5	8
Cumbernauld Glen				
Spring flowers	8.5	2	8	8
Weed suppression	8	3.5	7.5	7.5
Forest Wood				
Spring flowers	8	3	8	6
Weed suppression	7	2	8	6
Glasdrum				
Spring flowers	7	2	7	6
Weed suppression	8	2	8	6
Glen Creran				
Spring flowers	5	2	7	7
Weed suppression	4	1	6	6
Loch Arkaig				
Spring flowers	8	4	8	6.5
Weed suppression	8	1	9	7

Table 4
Standardised scores from the biodiversity assessment of the stakeholder workshops, from the short list of species and for the overall biodiversity assessment for the impacts of management change on dominant weed species. Results from a two-way analysis of variance are also shown.

Scenario	Workshop	Scores	Overall
Management Plan	7.29	7.42	5.33
Low Budget	1.15	0.77	2.09
Biodiversity Conservation	8.54	9.23	8.09
People Engagement	7.19	3.19	6.18
Factor	df	F	p
Method	2,60	3.231	0.046
Scenario	3,60	110.3	<0.001
Scenario*Method	6,60	7.289	<0.001

net negative impact on the woodland species present. The results were consistent across the six sites.

There was similar consistency across the six sites for the impact of the scenarios on alien species (Table 5b). However, in this case Biodiversity Conservation and then Management Plan scored positively, and Low Budget and People Engagement scored negatively and similarly. The highest scores, both positive and negative, were for the central belt sites at Cumbernauld, Cumbernauld Glen and Forest Wood.

There was a high consistency between sites for both species classified in the Scottish Biodiversity List as Conservation Action Needed (Table 5c) and species classified as Avoid Negative Impacts (Table 5d). For both groups of species Biodiversity Conservation showed the highest positive scores followed by People Engagement, and Management Plan scoring negatively but not as negatively as Low Budget. The highest positive and negative scores were at the two west coast sites Glasdrum and Glen Creran.

Table 5
Balance of the total number of species in each category affected by each scenario weighted by occurrence weight and species response to each scenario for (a) all species, (b) alien species, and species listed in the Scottish Biodiversity List (https://www.nature.scot/scotlands-biodiversity/scottish-biodiversity-strategy/scottish-biodiversity-list) as (c) Conservation Action Needed or (d) Avoid Negative Impacts. Results from a two-way, unreplicated analysis of variance across the scenarios are also shown.

Site	Management Plan	Low Budget	Biodiversity Conservation	People Engagement
(a) All species				
Clunes	75.4	−296.3	313.9	123.7
Cumbernauld Glen	12.1	−183.6	197.5	90.5
Forest Wood	6.8	−74.0	89.7	39.7
Glasdrum	2.9	−251.9	327.4	106.7
Glen Creran	4.0	−97.7	109.3	40.6
Loch Arkaig	81.8	−367.5	379.0	160.8
Mean	30.5	−211.8	236.1	93.7
Scenario	df = 3,15	F = 21.05	P < 0.001	
Site	df = 5,15	F = 0.171	P = 0.969	
(b) Aliens				
Clunes	2.1	−2.4	2.5	−2.3
Cumbernauld Glen	10.2	−14.9	18.6	−12.8
Forest Wood	5.7	−8.6	10.5	−6.5
Glasdrum	2.1	−4.1	5.5	−7.8
Glen Creran	3.9	−5.0	7.3	−5.1
Loch Arkaig	5.4	−7.4	7.9	−7.5
Mean	4.9	−7.1	8.7	−7.0
Scenario	df = 3,15	F = 16.98	P < 0.001	
Site	df = 5,15	F = 1.174	P = 0.998	
(c) Conservation Action Needed				
Clunes	−1.7	−4.0	4.2	4.1
Cumbernauld Glen	0.6	−1.8	2.5	0.6
Forest Wood	0.2	−1.0	2.2	0.2
Glasdrum	−2.9	−14.2	14.5	5.1
Glen Creran	−1.0	−9.5	10.7	1.6
Loch Arkaig	−0.1	−3.3	4.3	2.3
Mean	−4.9	−33.8	38.4	13.9
Scenario	df = 3,15	F = 8.125	P = 0.002	
Site	df = 5,15	F = 0.005	P = 0.999	
(d) Avoid Negative Impacts				
Clunes	−0.2	−2.9	5.2	2.4
Cumbernauld Glen	0.8	−2.7	3.6	0.2
Forest Wood	0.4	0.8	3.3	−1.1
Glasdrum	−1.9	−12.6	13.1	4.2
Glen Creran	0	−15.2	15.7	3
Loch Arkaig	0	−4.6	5.4	2.5
Mean	−0.2	−6.2	7.7	1.9
Scenario	df = 3,15	F = 8.242	P = 0.002	
Site	df = 5,15	F = 0.008	P = 0.999	

4. Discussion

4.1. Stakeholder workshop results

What was universal across all the sites, was that the stakeholders all viewed a lack of management intervention under the Low Budget scenario as being of limited benefit for the two biodiversity scores. This suggests the possibility that a clear link was made by the stakeholders between the requirement of spring flowers for light through some measure of disturbance as well as the ability of weed species to spread in the absence of intervention. It may have been affected by an overall negative view of removing management as might be done under a rewilding plan. Alternative questions may have elicited a completely different view of each scenario (see below).

4.2. Comparisons between scoring methods

There were clear disparities between scoring methods, revealed by both differences in overall scores and by significant interaction terms (Tables 3 and 4). For the spring flower question (Table 3), the scoring by the occurrence data model was relatively more pessimistic than the workshop for the Management Plan, with the model ranking it very similar in terms of benefit to Low Budget, which actually scored higher in the model than the average across workshops. Without external evidence the disparity between the workshops and the occurrence data model can come from either, or both, a consistent lack of discrimination between the scenarios by the workshops or by incorrect assumptions in the occurrence data model concerning the response of individual species to the different scenarios. The latter could be improved by developing more specific models for the behaviour of spring flowers.

In contrast, the main disparity between the workshop and occurrence data model scores concerned the impact of the People Engagement scenario. Stakeholders clearly had a more optimistic view of how community engagement in management and other woodland activities would reduce the impact of dominant weed species compared to the model-based evaluation. Scores had higher variances and were lower at sites where *Rhododendron ponticum* was already a significant issue, namely Glasdrum, Glen Creran and Loch Arkaig.

There was, however, little difference between the workshop scores and the overall scores for biodiversity from the occurrence data model for both spring flowers and dominant weed species, though the model did separate out Biodiversity Conservation as more positive than either Management Plan or People Engagement compared to the workshop scores where they were very similar. This correspondence may represent workshop participants assessing Management Plan and People

Engagement as more optimistic about improving biodiversity than is likely given the varying woodland management strategies set out in the scenarios given to them. Careful choice of questions to represent the multi-dimensional issue (Heydari et al., 2020; Naeem et al., 2016) of what might happen to biodiversity if management changes have to made will be necessary if this is considered an appropriate way of engaging stakeholders into the future (Durham et al., 2014; Webb and Raffaelli, 2008). This is in contrast to other questions posed which were more one-dimensional, such as “will the change in management improve carbon stocks” or “change the amount of timber extracted”. Across the diversity of sites used in the study it was challenging to come up with universal questions that were specific enough to create useful deliberation between the participants, general enough to be useful at summarising management impacts on biodiversity at a site level and not requiring deep background knowledge about species ecology. However, most stakeholders understood what was meant by it and the questions created dialogue in the workshops. More general questions such as “how will this affect biodiversity” would be harder for the stakeholders to deliberate given that each site is home to hundreds to thousands of recorded species and the deliberations would quickly either focus on a small number of species of importance to the stakeholders or disintegrate without agreement on what constituted relevant biodiversity (Durham et al., 2014; Hesselink et al., 2007). We felt that the questions used were appropriate in being at the right level of detail to focus deliberation, represent site level impacts and yet be relevant to the experience and knowledge of the participants.

As done in this study, basing decision making on combining generalised, scientific evidence and contextualised stakeholder knowledge through dialogue and deliberation is important for robust decision making (de Barros et al., 2022; Chopin et al., 2019; Jones-Walters and Cil, 2011). Should a similar approach be adopted elsewhere, having an additional round of deliberation, in which stakeholders discuss the differences between their assessments and the results of the modelling, could provide further insights to their locally-informed interpretations, providing a more complete knowledge for decision-making.

4.3. Aliens and species of conservation interest

The modelled responses showed a clear ranking between the scenarios Biodiversity Conservation > People Engagement > Management Plan > Low Budget or all species (Table 5a). This shows that more woodland species have ecological preferences for some level of disturbance as against little or none. Classic examples are butterflies such as Heath Fritillary (*Melitaea athalia*) and its foodplants Common Cowwheat (*Melampyrum pratense*), Ribwort Plantain (*Plantago lanceolata*), Germander Speedwell (*Veronica chamaedrys*) (Hodgson et al., 2009) or moths such as the Large Yellow Underwing (*Noctua pronuba*) and its foodplants foxgloves (*Digitalis purpurea*) and annual meadow grass (*Poa annua*) (Broome et al., 2011). Many woodland species are promoted by some level of disturbance (Buckley, 2020)

The modelled response of alien species differed from the other modelled responses as the ranking was Biodiversity Conservation > People Engagement > Management Plan > Low Budget (Table 5b). This reflected the focus written into management plans but highlights that this is an issue that should be addressed if management was focussed more on use by the community. The central belt sites around Cumbernauld show the highest net scores indicating that these sites have the highest numbers of alien species – potentially a result of the higher level of local population and good communication links – road, rail, canal and river corridors. The method, of course, does not model the impact of the alien species, so it misses the high degree of concern over *Rhododendron ponticum* invasion for the Argyll and Bute sites, Glasdrum and Glen Creran.

The two categories of species in the Scottish Biodiversity List, Conservation Action Needed and Avoid Negative Impacts (Table 5c and d, respectively), both showed the same pattern as overall biodiversity. This suggests that, on balance, a higher level of woodland disturbance would be beneficial to species of conservation concern. It is also clear that Glasdrum and Glen Creran harbour many more Scottish Biodiversity List species than the other two areas, reflecting the more diverse woodland types present and their continuity in the landscape.

4.4. Conclusions

The development of complex models of biodiversity, ecosystem service(s) or landscape change requires considerable resources. Choices have to be made between generality, which effectively translates into low cost per site assessed but potentially low accuracy for each site, and specificity, effectively high cost per site but high accuracy (e.g., Bamford et al., 2009; Smith, 1988). The combined approach taken in this study shows that stakeholder assessments are often well correlated with the simple but relatively comprehensive modelling approach adopted which becomes more cost-effective as more sites are modelled (fewer new species added to the species behaviour matrix as new sites share species with previously modelled sites). The results add further evidence that stakeholder-based decision making is often effective (Beierle, 2002; MacLeod et al., 2022; Sterling et al., 2017) and that integrating stakeholder views with modelling outputs is a useful approach in decision making (Kaim et al., 2021). Bringing together different type of stakeholders to model the impact of scenarios outperforms the results from homogenous groups and care should be taken to ensure stakeholder groups are representative to gain the greatest benefit from involving them (Aminpour et al., 2020; Gray et al., 2020). However, developing appropriate questions to ensure that they are representative of site level biodiversity and are covered by the knowledge of the participants will be a crucial part of stakeholder workshop planning if similar approaches are adopted elsewhere in future. The combined approach of eliciting stakeholder views and simple occurrence data modelling is a potentially powerful tool for decision making at a local level.

CRediT authorship contribution statement

Robin J. Pakeman: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Alba Juárez-Bourke:** Writing – review & editing, Investigation. **Scott Herrett:** Writing – review & editing, Investigation. **Alice Hague:** Writing – review & editing, Investigation. **Anja Byg:** Writing – review & editing, Investigation. **Altea Lorenzo-Arribas:** Formal analysis. **Anke Fischer:** Writing – review & editing, Project administration, Investigation, Funding acquisition. **Laura MacLean:** Writing – review & editing, Investigation. **Keith Marshall:** Writing – review & editing, Investigation. **Gillian Donaldson-Selby:** Writing – review & editing, Investigation. **Alison J. Hester:** Writing – review & editing, Investigation. **Antonia Eastwood:** Writing – review & editing, Project administration, Investigation.

Declaration of competing interest

The authors have no interest to declare.

Acknowledgements

We would like to thank all the participants in the stakeholder workshops and particularly the site managers who gave freely of their time in discussing scenarios and identifying participants. The work was funded by the Scottish Government's Rural and Environmental Science and Advisory Services' 2016-2022 Strategic Research Programme (1.3.2).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2025.124541.

Data availability

The authors do not have permission to share data.

References

Ainsworth, G.B., Redpath, S.M., Wilson, M., Wernham, C., Young, J.C., 2020. Integrating scientific and local knowledge to address conservation conflicts: towards a practical framework based on lessons learned from a Scottish case study. Environ. Sci. Pol. 107, 46–55.

Alberts, D.J., 2007. Stakeholders or subject matter experts, who should be consulted? Energy Policy 35, 2336–2346.

Alkemade, R., Van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M., Ten Brink, B., 2009. GLOBIO3: a framework to investigate options for reducing global terrestrial biodiversity loss. Ecosystems 12, 374–390.

Aminpour, P., Gray, S.A., Jetter, A.J., Introne, J.E., Singer, A., Arlinghaus, R., 2020. Wisdom of stakeholder crowds in complex social–ecological systems. Nat. Sustain. 3, 191–199.

Bamford, A.J., Monadjem, A., Anderson, M.D., Anthony, A., Borello, W.D., Bridgeford, M., Bridgeford, P., Hancock, P., Howells, B., Wakelin, J., Hardy, I.C., 2009. Trade-offs between specificity and regional generality in habitat association models: a case study of two species of African vulture. J. Appl. Ecol. 46, 852–860.

de Barros, K.M.P.M., Marchini, S., Bogoni, J.A., Paolino, R.M., Landis, M., Fusco-Costa, R., Magioli, M., Munhoes, L.P., Saranholi, B.H., Ribeiro, Y.G.G., de Domini, J. A., 2022. Best of both worlds: combining ecological and social research to inform conservation decisions in a Neotropical biodiversity hotspot. J. Nat. Conserv., 126146

Bélisle, A.C., Asselin, H., LeBlanc, P., Gauthier, S., 2018. Local knowledge in ecological modeling. Ecol. Soc. 23, 14.

Beierle, T.C., 2002. The quality of stakeholder-based decisions. Risk Anal.: Int. J. 22, 739–749.

Blattert, C., Lemm, R., Thürig, E., Stadelmann, G., Brändli, U.B., Temperli, C., 2020. Long-term impacts of increased timber harvests on ecosystem services and biodiversity: a scenario study based on national forest inventory data. Ecosyst. Serv. 45, 101150.

Britton, A.J., Mitchell, R.J. & Riach, D. (unpublished). A Database of Lichen Attributes and Traits.

Brook, R.K., McLachlan, S.M., 2008. Trends and prospects for local knowledge in ecological and conservation research and monitoring. Biodivers. Conserv. 17, 3501–3512.

Broome, A., Clarke, S., Peace, A., Parsons, M., 2011. The effect of coppice management on moth assemblages in an English woodland. Biodivers. Conserv. 20, 729–749.

Brugnach, M., Ingram, H., 2012. Ambiguity: the challenge of knowing and deciding together. Environ. Sci. Pol. 15, 60–71.

Buckley, P., 2020. Coppice restoration and conservation: a European perspective. J. For. Res. 25, 125–133.

Burt, G., Mackay, D., Mendibil, K., 2021. Overcoming multi-stakeholder fragmented narratives in land use, woodland and forestry policy: the role scenario planning and 'dissociative jolts'. Technol. Forecast. Soc. Change 166, 120663.

CBD SBSTTA (Convention on Biological Diversity, Subsidiary Body on Scientific, Technical and Technological Advice), 2000. Recommendation V/10 Ecosystem approach: further conceptual elaboration. Recommendations Adopted by the SBSTTA Fifth Meeting, 31January–4 February 2000, Montreal. Available from: https://www.cbd.int/doc/recommendations/sbstta-05/full/sbstta-05-rec-en.pdf.

Chopin, P., Bergkvist, G., Hossard, L., 2019. Modelling biodiversity change in agricultural landscape scenarios-A review and prospects for future research. Biol. Conserv. 235, 1–17.

Clark, J., Murdoch, J., 1997. Local knowledge and the precarious extension of scientific networks: a reflection on three case studies. Sociol. Rural. 37, 38–60.

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C.R., Renaud, F.G., Welling, R., 2019. Core principles for successfully implementing and upscaling Nature-based Solutions. Environ. Sci. Pol. 98, 20–29.

Durham, E., Baker, H., Smith, M., Moore, E., Morgan, V., 2014. The BiodivERsA Stakeholder Engagement Handbook. BiodivERsA, Paris, p. 108. https://www.biodiversa.eu/wp-content/uploads/2022/12/stakeholder-engagement-handbook.pdf.

Eastwood, A., Fischer, A., Byg, A., 2017. The challenges of participatory and systemic environmental management: from aspiration to implementation. J. Environ. Plann. Manag. 60, 1683–1701.

Eastwood, A., Juárez-Bourke, A., Herrett, S., Hague, A., Byg, A., Lorenzo-Arribas, A., Fischer, A., MacLean, L., Marshall, K., Donaldson-Selby, G., Hester, A.J., Pakeman, R.J., 2024. Exploring the impacts of woodland management on ecosystem services – a deliberative method. Ecosystems and People 20, 1. https://doi.org/10.1080/26395916.2024.2322638.

Eggers, J., Räty, M., Öhman, K., Snäll, T., 2020. How well do stakeholder-defined forest management scenarios balance economic and ecological forest values? Forests 11, 86.

Ford, E., Stewart, B.D., 2021. Searching for a bridge over troubled waters: an exploratory analysis of trust in United Kingdom fisheries management. Mar. Pol. 132, 104686.

Gray, S., Aminpour, P., Reza, C., Scyphers, S., Grabowski, J., Murphy Jr, R., Singer, A., Baltaxe, D., Jordan, R., Jetter, A., Introne, J., 2020. Harnessing the collective intelligence of stakeholders for conservation. Front. Ecol. Environ. 18, 465–472.

Halkos, G.E., Jones, N., 2012. Modeling the effect of social factors on improving biodiversity protection. Ecol. Econ. 78, 90–99.

Hare, J.A., 2020. Ten lessons from the frontlines of science in support of fisheries management. ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 77, 870–877.

Harris, S., Yalden, D.W. (Eds.), 2008. Mammals of the British Isles. Handbook, fourth ed. The Mammal Society, Southampton.

Hesselink, F., Goldstein, W., van Kempen, P.P., Garnett, T., Dela, J., 2007. Communication, Education and Public Awareness (CEPA) A Toolkit for National Focal Points and NBSAP Coordinators (Secretariat of the Convention on Biological Diversity and. IUCN, Montreal, Canada. https://www.cbd.int/cepa/toolkit/2008/doc/CBD-Toolkit-Complete.pdf.

Heydari, M., Omidipour, R., Greenlee, J., 2020. Biodiversity, a review of the concept, measurement, opportunities, and challenges. Journal of Wildlife and Biodiversity 4, 26–39.

Hill, M.O., Preston, C.D., Roy, D.B., 2004. PLANTATT. Attributes of British and Irish plants: status, size, life history, geography and habitats for use in connection with the new Atlas of the British and Irish flora. Biological Records Centre. NERC Centre for Ecology and Hydrology.

Hill, M.O., Preston, C.D., Bosanquet, S.D.S., Roy, D.B., 2007. BRYOATT. Attributes of British and Irish Mosses, Liverworts and Hornworts with Information on Native Status, Size, Life Form, Life History, Geography and Habitat. NERC Centre for Ecology and Hydrology and Countryside Council for Wales.

Hodgson, J.A., Moilanen, A., Bourn, N.A.D., Bulman, C.R., Thomas, C.D., 2009. Managing successional species: modelling the dependence of heath fritillary populations on the spatial distribution of woodland management. Biol. Conserv. 142, 2743–2751.

Hölting, L., Komossa, F., Filyushkina, A., Gastinger, M.M., Verburg, P.H., Beckmann, M., Volk, M., Cord, A.F., 2020. Including stakeholders' perspectives on ecosystem services in multifunctionality assessments. Ecosystems and People 16, 354–368.

Hume, R., Still, R., Swash, a., Harrop, H., Tipling, D., 2020. Britain's Birds: an Identification Guide to the Birds of Great Britain and Ireland, second ed. Princeton University Press, Woodstock.

Jones-Walters, L., Cil, A., 2011. Biodiversity and stakeholder participation. J. Nat. Conserv. 19, 327–329.

Joshi, A.A., Sankaran, M., Ratnam, J., 2018. Foresting the grassland: historical management legacies in forest-grassland mosaics in southern India, and lessons for the conservation of tropical grassy biomes. Biol. Conserv. 224, 144–152.

Kaim, A., Bartkowski, B., Lienhoop, N., Schröter-Schlaack, C., Volk, M., Strauch, M., 2021. Combining biophysical optimization with economic preference analysis for agricultural land-use allocation. Ecol. Soc. 26, 9.

Karner, K., Cord, A.F., Hagemann, N., Hernandez-Mora, N., Holzkämper, A., Jeangros, B., Lienhoop, N., Nitsch, H., Rivas, D., Schmid, E., Schulp, C.J., 2019. Developing stakeholder-driven scenarios on land sharing and land sparing–Insights from five European case studies. J. Environ. Manag. 241, 488–500.

Kay, J.J., Regier, H.A., Boyle, M., Francis, G., 1999. An ecosystem approach for sustainability: addressing the challenge of complexity. Futures 31, 721–742.

Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., Cerdà, A., 2018. The superior effect of nature based solutions in land management for enhancing ecosystem services. Sci. Total Environ. 610, 997–1009.

Kiatkoski Kim, M., Álvarez-Romero, J.G., Wallace, K., Pannell, D., Hill, R., Adams, V.M., Douglas, M., Pressey, R.L., 2022. Participatory multi-stakeholder assessment of alternative development scenarios in contested landscapes. Sustain. Sci. 17, 221–241.

Lagabrielle, E., Botta, A., Daré, W., David, D., Aubert, S., Fabricius, C., 2010. Modelling with stakeholders to integrate biodiversity into land-use planning–Lessons learned in Réunion Island (Western Indian Ocean). Environ. Model. Software 25, 1413–1427.

Lamarque, P., Tappeiner, U., Turner, C., Steinbacher, M., Bardgett, R.D., Szukics, U., Schermer, M., Lavorel, S., 2011. Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. Reg. Environ. Change 11, 791–804.

Larsen, R.K., Nilsson, A.E., 2017. Knowledge production and environmental conflict: managing systematic reviews and maps for constructive outcomes. Environ. Evid. 6, 17.

Lexer, M.J., Seidl, R., 2009. Addressing biodiversity in a stakeholder-driven climate change vulnerability assessment of forest management. For. Ecol. Manag. 258, S158–S167.

MacLeod, C.J., Brandt, A.J., Collins, K., Dicks, L.V., 2022. Giving stakeholders a voice in governance: biodiversity priorities for New Zealand's agriculture. People and Nature 4, 330–350.

Marshall, K., White, R., Fischer, A., 2007. Conflicts between humans over wildlife management: on the diversity of stakeholder attitudes and implications for conflict management. Biodivers. Conserv. 16, 3129–3146.

Naeem, S., Prager, C., Weeks, B., Varga, A., Flynn, D.F., Griffin, K., Muscarella, R., Palmer, M., Wood, S., Schuster, W., 2016. Biodiversity as a multidimensional construct: a review, framework and case study of herbivory's impact on plant biodiversity. Proc. Biol. Sci. 283, 20153005.

Nesshöver, C., Assmuth, T., Irvine, K.N., Rusch, G.M., Waylen, K.A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., 2017. The science, policy and practice of nature-based solutions: an interdisciplinary perspective. Sci. Total Environ. 579, 1215–1227.

Persson, J., Johansson, E.L., Olsson, L., 2018. Harnessing local knowledge for scientific knowledge production. Ecol. Soc. 23, 38.

Pouwels, R., Opdam, P., Jochem, R., 2011. Reconsidering the effectiveness of scientific tools for negotiating local solutions to conflicts between recreation and conservation with stakeholders. Ecol. Soc. 16, 17.

R Core Team, 2024. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL. https://www.R-project.org/.
Ranglack, D.H., Durham, S., du Toit, J.T., 2015. Competition on the range: science vs. perception in a bison–cattle conflict in the western USA. J. Appl. Ecol. 52, 467–474.
Raymond, C.M., Fazey, I., Reed, M.S., Stringer, L.C., Robinson, G.M., Evely, A.C., 2010. Integrating local and scientific knowledge for environmental management. J. Environ. Manag. 91, 1766–1777.
Rosa, I.M., Purvis, A., Alkemade, R., Chaplin-Kramer, R., Ferrier, S., Guerra, C.A., Hurtt, G., Kim, H., Leadley, P., Martins, I.S., Popp, A., 2020. Challenges in producing policy-relevant global scenarios of biodiversity and ecosystem services. Global Ecology and Conservation 22, e00886.
Sharma, R., Nehren, U., Rahman, S.A., Meyer, M., Rimal, B., Aria Seta, G., Baral, H., 2018. Modeling land use and land cover changes and their effects on biodiversity in Central Kalimantan, Indonesia. Land 7, 57.
Smith, E.A., 1988. Realism, generality, or testability: the ecological modeler's dilemma. Behav. Brain Sci. 11, 149–150.
Soliva, R., Rønningen, K., Bella, I., Bezak, P., Cooper, T., Flø, B.E., Marty, P., Potter, C., 2008. Envisioning upland futures: stakeholder responses to scenarios for Europe's mountain landscapes. J. Rural Stud. 24, 56–71.
Sterling, E.J., Betley, E., Sigouin, A., Gomez, A., Toomey, A., Cullman, G., Malone, C., Pekor, A., Arengo, F., Blair, M., Filardi, C., 2017. Assessing the evidence for stakeholder engagement in biodiversity conservation. Biol. Conserv. 209, 159–171.
Sweet, L.C., Green, T., Heintz, J.G., Frakes, N., Graver, N., Rangitsch, J.S., Rodgers, J.E., Heacox, S., Barrows, C.W., 2019. Congruence between future distribution models and empirical data for an iconic species at Joshua Tree National Park. Ecosphere 10, e02763.
Wamelink, G.W.W., Ter Braak, C.J.F., Van Dobben, H.F., 2003. Changes in large-scale patterns of plant biodiversity predicted from environmental economic scenarios. Landsc. Ecol. 18, 513–527.
Waylen, K.A., Hastings, E.J., Banks, E.A., Holstead, K.L., Irvine, R.J., Blackstock, K.L., 2014. The need to disentangle key concepts from ecosystem-approach jargon. Conserv. Biol. 28, 1215–1224.
Waylen, K.A., Martin-Ortega, J., Blackstock, K.L., Brown, I., Uribe, B.E.A., Hernández, S. B., Bertoni, M.B., Bustos, M.L., Bayer, A.X.C., Semerena, R.I.E., Quijano, M.A.F., 2015. Can scenario-planning support community-based natural resource management? Experiences from three countries in Latin America. Ecol. Soc. 20.
Webb, J., Heaver, D., Lott, D., Dean, H.J., van Breda, J., Curson, J., Harvey, M.C., Gurney, M., Roy, D.B., van Breda, A., Drake, M., Alexander, K.N.A., Foster, G., 2017. The Pantheon Database: Habitat Related Traits, Conservation Status and Taxa Associations for Invertebrates in England. NERC Environmental Information Data Centre. https://doi.org/10.5285/2a353d2d-c1b9-4bf7-8702-9e78910844bc.
Webb, T.J., Raffaelli, D., 2008. Conversations in conservation: revealing and dealing with language differences in environmental conflicts. J. Appl. Ecol. 45, 1198–1204.
White, R.M., Fischer, A., Marshall, K., Travis, J.M., Webb, T.J., Di Falco, S., Redpath, S. M., van der Wal, R., 2009. Developing an integrated conceptual framework to understand biodiversity conflicts. Land Use Policy 26, 242–253.

Workshop reports are available for each site:

MacLean, L., Hague, A., Eastwood, A., Marshall, K., Lorenzo-Arribas, A., Herret, S., 2022. Clunes and the Tom an Eirannaich woodland: exploring the perceived impacts of different management interventions on woodland benefits. The James Hutton Institute. https://sefari.scot/document/clunes-and-the-tom-an-eireannaich-woodland.