This is the pre-peer-reviewed version of the following article: Davies A.L., Colombo S. & Hanley N. (2014) Improving the application of long-term ecology in conservation and land management. *Journal of Applied Ecology*, 51, 63-70, which has been published in final form at http://dx.doi.org/10.1111/1365-2664.12163.

# TITLE: Valuing multiple sources of evidence in ecosystem management

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RUNNING TITLE: Valuing evidence in ecosystem management

WORD COUNT: Summary (221), main text (4135), acknowledgements (25), references (2002), tables (425), total (6956)

NUMBER OF TABLES: 3

NUMBER OF REFERENCES: 62

## Summary

1. Significant effort is being made to develop more inclusive and systematic decision-making frameworks in ecology, but these have yet to include palaeoecology which addresses critical questions about long-term ecological processes (data spanning >50 years).
2. This paper uses a choice experiment format to present long-term data alongside three established sources used in decision-making: ecological monitoring, research and stakeholder participation. This allows researchers, policy-makers and practitioners to consider how evidence outside current frameworks might affect management decisions and outcomes. We use the method to estimate the relative weights that they place on differing types of ecological information, using two UK upland case studies.
3. The responses provide the first quantitative indication that ecologists perceive a potential value in longer-term records as an additional source of evidence when making UK upland management decisions. They value both site-specific and broader syntheses of long-term evidence.
4. ***Synthesis and applications***: Two opportunities are identified to create more effective, constructive links between ecological, palaeoecological and practitioner interests: (1) participatory approaches currently used to improve the alignment of interests in ecology could be applied to identify common priorities relating to longer-term factors; and (2) the increased availability of databases and interpretative metrics could allow hypothesis-testing and the development of integrative research strategies. These would improve approaches to decision-making by using the full breadth of ecological knowledge.

**Keywords**: choice experiment, decision-making framework, evidence-base, integrative ecology, long-term ecology, palaeoecology, stated preference, upland management

## Introduction

The state of the environment and effectiveness of management depend not just on the quality of the evidence, but also on choices in the decision-making process (Sutherland *et al.* 2004; Mathevet & Mauchamp 2005; Kass *et al.* 2011). Many conservation ecologists recognise the need for decision-making frameworks that accommodate new perspectives and multiple sources of evidence to manage ecosystems for multiple benefits while adapting to uncertainties that lie outside recent experience (Pullin *et al.* 2004; Heller & Zavaleta 2009; Peters 2010; Polasky *et al.* 2011). While progress is being made towards more integrative, multi-disciplinary decision-making in some areas (Sutherland *et al.* 2011), this is not the case for all disciplines relevant to conservation management.

Long-term ecology (spanning >50 years) has the potential to make significant contributions to these frameworks, but has yet to be routinely recognised in ecological research, policy or practice (Willis & Bhagwat 2010; Rull & Vegas-Vilarrúbia 2011). Davies and Bunting (2010) suggest that answering 54 of the 100 questions of UK conservation importance (Sutherland *et al.* 2006) requires consideration of processes acting over multiple years or of conditions in the past and present. Many palaeoecological papers address themes raised by these 100 questions (*e.g*. Willis *et al.* 2007; Vegas-Vilarrúbia *et al.* 2011), indicating the relevance of long-term data to conservation priorities on an international level. However, only 16% of studies published in the *Journal of Applied Ecology* in 1999 addressed timescales greater than a decade (Ormerod, Pienkowski & Watkinson 1999), and no key biodiversity assessments published between 1998 and 2005 used records longer than 50 years (Willis *et al.* 2005). The lack of long-term perspectives in ecological policy and research is more than an issue of academic recognition: it has implications for the effectiveness of management interventions and investment. For example, in marine ecosystems, omission of historical data results in overly optimistic assessments of conservation status, lower recovery targets and higher fisheries quotas (McClenachan, Ferretti & Baum 2012).

In addition to numerous barriers to the uptake of unfamiliar methods (see Context), there is a lack of basic empirical evidence on the attitudes of those involved in conservation management towards multiple sources of evidence, including long-term ecology (LTE). To establish the willingness of researchers, policy-makers and practitioners to incorporate less familiar forms of evidence into decision-making, this paper uses a choice experiment (Hensher, Rose & Greene 2005) to assess the relative merits of four sources of information on ecosystem functioning: ecological monitoring, ecological research, LTE and stakeholder participation. This allows the relative value of each source to be assessed and quantified, as perceived by conservation managers and scientists. We apply this method to a case study on UK upland conservation issues. The two ecosystems used as the context for this study are sensitive to climatic and management change, and provide many ecosystem services, with beneficiaries well beyond the geographical limits of the uplands (Holden *et al.* 2007, Reed *et al.* 2009). Reliance on partial information has potentially significant and widespread implications for the long-term supply of these ecosystem services.

The results provide a first quantitative assessment of how LTE is regarded by ecologists who contribute to the evidence-base, implement conservation management and inform policy-makers, relative to more familiar sources of evidence. We use the responses to suggest ways of developing a more inclusive framework of shared priorities and integrative research strategy, drawing on measures being used to improve the alignment of interests across conservation research, policy and practice (Sutherland *et al.* 2011).

## Context: challenges and limitations in valuing diverse knowledge

The main barriers to knowledge exchange relevant to LTE are outlined before describing the value of choice experiments for understanding attitudes towards unfamiliar sources of evidence.

Three interrelated sets of issues limit knowledge exchange between researchers, practitioners and policy-makers within and between ecology and palaeoecology. First, a lack of availability or awareness of relevant long-term and neo-ecological information contributes to differing priorities and a misalignment of interests (Sutherland *et al.* 2009). This is due to insufficient evidence, a shortage of accessible or coordinated data, and insufficient communication or evaluation of the effectiveness of existing information (Pullin *et al.* 2004; Willis *et al.* 2007; Newton *et al.* 2009; Davies & Bunting 2010). Second, infrastructural and technical obstacles reduce opportunities for exchange and learning. These include the lack of a support framework and accessible measures for exchange, collation and evaluation of knowledge (Sutherland *et al.* 2004; Newton *et al.* 2009). A lack of time, education and training to provide exposure to relevant ideas from other fields, and differences in the ways that various methods record information can further restrict data comparability (Davies & Bunting 2010). This includes the challenge of translating data into understandable, meaningful formats for other audiences without compromising levels of detail or uncertainty. Finally, attitudes and preconceptions influence the reception of unfamiliar evidence. This includes the perception that longer records are time-bound, purely descriptive and of little use in conservation practice (Willis *et al.* 2007), or failure amongst some palaeoecologists to consider conservation ecology as a relevant audience and frame their data accordingly (Birks 2012). It can include uncertainty over data precision or accuracy, and reluctance to use data that do not arise from well-controlled experiments (Dietl & Flessa 2011). There may also be cultural resistance to changing established thinking and a tendency to defend established approaches (*e.g*. Carrion & Fernandez 2009, and responses thereto), or to focus on the shortcomings of differing sources rather than developing strategies to overcome them (Froyd & Willis 2008).

There are few opportunities for researchers, policy-makers and practitioners to simultaneously consider how information from different sources might affect management decisions and their environmental outcomes. Unless the actual and perceived relevance of other sources is assessed, there is a risk that knowledge exchange networks will remain biased towards a subset of established views, rather than accommodating multiple insights (Sutherland *et al.* 2004). This paper uses a choice experiment (CE) as a structured format for deriving participant preferences towards different sources of knowledge. CEs have several strengths relevant for assessing the relative weight that researchers, policy-makers and practitioners place on LTE in decision-making. First, CEs have been widely used to value ecosystem attributes that are unfamiliar to many stakeholders and lack easily defined market values. This includes being used to assess how complex concepts like biodiversity are understood and valued by the general public (Christie *et al.* 2006). A variant of the method has also been used to assess how unfamiliar evidence, like the extent of historical woodland change, affects preferences for future changes in tree cover (Hanley *et al.* 2009). Second, CEs take into account the fact that complex decisions are based on multiple decision-relevant criteria by facilitating simultaneous consideration of multiple dimensions of conservation problems, such as changes in raptor populations and local employment under alternative management regimes on sporting estates (N. Hanley, unpublished data). Third, the method enables researchers to estimate the relative values of multiple attributes of ecological change in a manner consistent with well-established principles in decision science (Louviere, Hensher & Swait 2000). Finally, CEs can be used to assess how individuals make trade-offs when multiple, competing benefits and values are involved, as for example in managing ecosystem services (Birol *et al.* 2009).

Most CEs have been carried out with members of the public in order to inform policy-makers about preferences held by tax-payers, rather than with ‘professional’ participants like ecologists (Burgess, Clark & Harrison 2000) or policy makers (Carlsson, Kataria & Lampi 2011). In contrast, recent efforts to improve policy-making relating to conservation and ecology have involved researchers, practitioners and policy-makers to identify common priorities and emerging issues (Sutherland *et al.* 2011). By involving ecological researchers and practitioners, this paper bridges a gap in CE applications and extends the conservation decision-making literature by considering the relative merits of longer-term perspectives alongside established sources of evidence.

## Materials and methods

### Construction of a comparative evidence-base

CEs are a stated preference technique developed in market research, but now used in a range of applications (Bateman *et al.* 2002). Respondents are required to make a series of choices between alternative scenarios to identify their preferences and the trade-offs that they are willing to make between different "attributes" of a policy option or consumer good. Choices are specified in terms of a number of attributes, each of which is available at different levels. Experimental design consists of selecting attributes and levels, and combining them into a series of choice tasks which respondents complete. In this case, participants considered four types of evidence within an upland management context (Table 1). The following attributes used in the experimental design:

1. *Ecological monitoring* is used to detect trends and evaluate management effectiveness. Monitoring frequency depends on resources and objectives, including species and ecosystem response rates. Three levels were included in the CE: 3 years, 6 years (the approximate interval in site condition monitoring, the standard approach for monitoring designated sites) and 12 years.
2. *Ecological research* provides the basis for understanding ecosystem behaviour and the underpinning mechanisms, from genome to biosphere scales. Two attribute levels were included in the CE: none (monitoring evidence is sufficient), and diverse (encompassing a broad range of ecological insights, including climate modelling, genetics or carbon chemistry, for example).
3. *Long-term ecological data*: Since many ecosystem processes operate over long periods, baselines may shift between each generation of policy-makers, researchers and managers who see only part of the process. This has direct consequences for species and ecosystem management (McClenachan, Ferretti & Baum 2012). In this context, 'long-

term' refers to records spanning >50 years. Three attribute levels were included: none, syntheses (broad-scale) and region- or site-specific data (finer spatial scale).

4. *Stakeholder engagement***:** Translating evidence into effective policy and practice requires locally adapted planning and implementation (Heller & Zavaleta 2009). Stakeholder participation is increasingly advocated as a means of generating more adaptive and acceptable management decisions (Reed 2008) and can improve synergies between research, policy and practice (Sutherland *et al.* 2011). Three attribute levels were included to reflect different levels of participation: none, guidance (stakeholder knowledge or preferences used to implement pre-determined research, policy or management strategies), and collaboration (co-generation of research agendas, management or policy approaches).

CEs usually incorporate a price attribute to assess how much participants are willing to pay to maintain particular landscape characteristics or to support a change in management, for example. Monetary costs are not appropriate for valuing different forms of knowledge directly, but time is included as a fifth attribute to represent the costs associated with changing or broadening the evidence-base used to support management decisions. These costs are prospectively incurred by in acquiring new information, through the time taken to gain a basic understanding of additional sources, keep abreast of developments in a wider range of fields, or take part in meetings or projects in order to obtain additional types of evidence. Three time costs are included in the CE: one day/quarter, one day/month and one day/week. This cost relates to how much working time would be allocated within a participant's organisation, rather than the level of the individual involved in the CE.

To provide a real-world context, information on each attribute was presented to participants before the choice cards relating to two practical UK conservation issues: the management of peatlands and the management of upland woodlands, in each case with the aim of maintaining ecosystem viability. These contexts were selected because their management incorporates a range of biotic and abiotic interactions, with scope for broad disciplinary and knowledge input. They also provide a wide range of ecosystem services (Bonn, Allott & Hubacek 2008) and include values arising from a complex palimpsest of cultural activities and environmental changes on recent to millennial timescales (Tallis 1998).

In applying a CE to evaluate how information provision influences participant preferences, the clarity, relevance and acceptability of that evidence is paramount. Therefore information on each attribute was drawn from peer-reviewed literature and best practice guidance (Appendices S1-S3 in Supporting Information). Feedback was obtained from two upland ecologists on a draft version and via a pilot CE. The information aimed to summarise the current state of knowledge with a focus on ecosystem process and function, in the context of key management issues (e.g. Holden *et al.* 2007; Hopkins & Kirby 2007; Sutherland *et al.* 2006, 2010).

### Experimental design and implementation

The CE was designed and implemented in two stages. A pilot was conducted with a small number of participants to improve the statistical efficiency and ease of use of the final design. The pilot set of 18 choice cards, which presented different combinations of the attributes and levels described above, was designed using online software, based on the method of Street and Burgess (2007). Attribute levels were combined orthogonally to allow an estimate of the relative value of each attribute to the overall preferences of respondents. Respondents were asked to respond to both case studies (peatland and woodland). The pilot included post-CE questions on the amount, relevance and clarity of information presented.

The full survey was developed using a mixed design, combining multi-nomial logit and mixed multi-nomial logit panel designs. A D-optimal design (Rose & Bliemer 2009) was used to combine the attributes offered to respondents. Such design requires explicit incorporation of prior information about respondents' preferences. This was obtained from the mean and standard deviations of the estimated attribute coefficients from the pilot survey, on the assumption that respondent preferences for the full survey sample will lie within this range. Coefficients which were not significant in the pilot were assigned a fixed zero value. Participants were asked to select the context (woodland or peatland) with which they were most familiar before completing the full CE. Each participant completed 18 choice cards.

The survey was completed by professionals with experience of the habitats and issues described. Participants were recruited via personal contacts, email invitations to members of UK upland policy and research networks, and additional participants suggested by these respondents, incorporating a range of government agencies and non-governmental organisations, and UK researchers and practitioners. The main survey was conducted via an online format, with the option for email responses. All responses were treated anonymously.

## Results

Sixteen completed responses were received for the main survey, including one NGO ecologist, one policy-maker, three practitioners, five researchers (including one long-term researcher) and six agency ecologists, drawn from England, Wales, Scotland and the Irish Republic.

A random parameter logit model using normally distributed preferences provided the best fit for both CEs. In the peatland CE (Table 2), for the non-random parameters in each respondents' preference, ecological research is significantly valued relative to no such research input to decision-making, as is LTE at both "synthesis" and "specific" levels, with a slight preference for the former. Time commitments to information processing are not significant determinants of choice. Preferences vary significantly across respondents for ecological monitoring and stakeholder inputs. Preferences for ecological monitoring at 3 year intervals do not differ from those at 6 year intervals, but respondents respond negatively to a change to monitoring at 12 year intervals. Both stakeholder guidance and collaboration were valued relative to no such involvement, with a higher value placed on collaboration than guidance. Preferences for all four information attributes display significant heterogeneity, as standard deviation estimates are strongly significant.

In the woodland case study (Table 3), the model fit is not as strong as for the peatland CE (pseudo $R^2$ of 0.38 relative to 0.52: values of 0.2-0.4 are equivalent to $R^2$ of 0.7-0.9 in standard linear models). In contrast with the peatland CE, there is no significant preference for ecological monitoring intervals differing from a 6 year frequency, since parameter estimates for 3-year and 12-year intervals are insignificant. All respondents consider ecological research to be valuable. Both synthesis-level and more specific LTE data are preferred to none. The larger coefficient for site-specific (1.59) over synthesis LTE data (1.36) reveals that the former is slightly preferred. Stakeholder involvement is preferred relative to none, with collaboration preferred (0.86) over guidance (0.69). The lowest time demand (once/4 months) is preferred over monthly or weekly time inputs, and in contrast to the peatland CE, both these measures of time demand are of significance to respondents, as shown by statistically significant negative parameter estimates for both the 1 day/month and the 1 day/week attribute levels. There is statistically significant heterogeneity in values attached to the frequency of ecological monitoring and to ecological research as inputs to management decision-making.

## Discussion

The CE results and their potential wider applicability are discussed before considering opportunities and methods of creating more integrative ecological decision-making frameworks.

### Preferences towards long-term ecology in the upland evidence-base

Unsurprisingly, participants place a statistically significant value on ecological research, but the CE results provide the first quantitative indication that ecologists perceive a potential value in longer-term records as an additional source of evidence when making management decisions. This can be seen from the positive and significant parameter estimates for the LTE attribute, relative to none being provided. Variations in the value placed on synthesis-level compared to region- or site-specific LTE may reflect the supporting information presented to participants, which summarised the current state of knowledge: regional variations in the timing and extent of range shifts are more pronounced for UK woodlands (Appendix S2) than peatlands (Appendix S1), albeit with significant dynamism in both habitats. A preference for site-specific and broad-scale woodland data may reflect current management concerns, like the continuing contraction of old-growth woodland (Hopkins & Kirby 2007) compared with the relative stability of moorland extent since the 1990s (Countryside Survey 2007). Concerns nevertheless persist over the condition of both ecosystems and their ability to provide ecosystem services (Quine *et al.* 2011). Similar factors may explain the preferences towards ecological monitoring, in that participants have no statistically significant preferences for changes from the current *c*.6 year interval for woodlands, but viewed 12 year intervals as less desirable than 3- or 6-year intervals on peatlands. This could reflect more rapid response rates in peatland species (*e.g.* to restoration and burning management), compared with slower growth rates and generation times for trees.

Preferences towards stakeholder engagement varied between participants, but some level of involvement was significantly preferred over none. In both case studies, collaboration was preferred to using stakeholder knowledge to help implement pre-determined strategies. Finally, for peatlands, time costs within a participant's organisation were not viewed as a significant factor. For woodlands, the lowest time demand (one day/quarter) was preferred to higher levels. In the case of peatlands, this suggests that changes are not seen as significantly different from current requirements, or that it is difficult to estimate on an organisational rather than individual level, so that participants chose not to focus on this attribute when making their choices. For woodlands, participants clearly viewed an increase to one day/week for acquiring new information as a significant and undesirable burden.

While the small sample size and inability of participants to query the dataset or discuss reasons for their choices restrict the wider inferences that can be drawn from the data, the consistency of the results across a range of participant positions (government agency and policy, academics and practitioners) suggests that these preferences could have broader relevance and applicability, at least within UK upland management.

## Building an integrative approach

As discussed earlier, three common barriers restrict knowledge exchange and the alignment of interests between palaeoecologists, ecologists, policy-makers and practitioners: a lack of availability and awareness, technical and infrastructural barriers, and attitudes and preconceptions. This CE contributes to the first and last of these by allowing respondents to simultaneously consider evidence from different disciplines, assess their attitudes toward a broader evidence-base, and consider the relative values of different types of information relevant to conservation management. Although the results suggest a willingness to accept LTE alongside ecological research, monitoring and stakeholder inputs, this evidence has yet to be incorporated into the evidence-base or decision-making frameworks, such as recent priority-setting and horizon-scanning activities (Sutherland *et al.* 2008). More proactive approaches may therefore be needed to shift current conventions (*cf*. Turnpenny 2012). The remainder of the discussion assesses how the trend towards more systematic and inclusive frameworks in ecology and conservation, methodological developments and ecological comment on long-term trends could be used to bring about closer integration of timeseries datasets.

The CE format allowed different sources of knowledge to be considered simultaneously, but the online application method did allow discussion or debate. Participatory processes like those used in recent ecological priority-setting and horizon-scanning exercises (Sutherland *et al.* 2011) can help identify shared priorities and gaps in knowledge or understanding, and frame long-term messages around key ecological and policy questions to increase interdisciplinary relevance and awareness (Davies & Bunting 2010; Dietl & Flessa 2011). Generating open debate over the values and preconceptions that influence decision-making can challenge mutual assumptions, encourage lateral thinking across disciplinary boundaries and so stimulate collaboration and more effective knowledge exchange (Willis *et al.* 2007; Froyd & Willis 2008; Sutherland *et al.* 2008, 2011). This approach is currently being developed to establish the most pressing questions in palaeoecology for addressing key ecological issues in the Anthropocene. Based on the CE results, collaborative priorities could incorporate both habitat-specific implications (Chambers, Mauquoy & Todd 1999) and broader, thematic priorities like biodiversity (Willis *et al.* 2007). At the site level, identifying common interests could stimulate palaeoenvironmental analyses at existing long-term ecological monitoring sites to encourage interdisciplinary hypothesis-testing (Froyd & Willis 2008). Site-level interaction between palaeoecologists, managers and practitioners could allow differing perspectives to fulfil complementary roles: LTE, empirical records and ecological modelling inform our understanding of processes and assist in predicting future responses, while experimental data, systematic surveys and experiential knowledge help indicate the management tools needed to achieve desired longer-term outcomes (Davies 2011).

In addition to collaborative priority-setting initiatives, additional recent trends in ecology suggest a window of opportunity for connecting across ecological timescales. These include the increase in ‘revisiting’ studies which assess the extent of change over the course of the 20th century (Hopkins & Kirby 2007; Kapfer *et al.* 2011; Newton *et al.* 2012), the emergence from established monitoring networks of biophysical trends spanning multiple decades (Monteith & Evans 2005; Morecroft *et al.* 2009; Youngblood & Palkin 2011) and the growing number of ecological papers stressing the relationship between past management and current conservation status (Gustavsson, Lennartsson & Emanuelsson 2007; Wyatt & Silman 2010).

To help overcome technical barriers, databases for storing and disseminating the growing volume of ecological and palaeoenvironmental data (Dengler *et al.* 2011, Fyfe *et al.* 2009) and systematic reviews (Pullin & Stewart 2006) provide accessible, standardised tools for coordinating a more inclusive multi-scale evidence-base (McMahon *et al.* 2011; Sergeant *et al.* 2012). For example, systematic, accessible archives combined with statistical tools allow hypothesis-testing across spatial and timescales (McMahon *et al.* 2011). Many ecological and environmental insights are communicated using indices and models to quantify the extent and rate of environmental change and to represent aspects of ecosystem structure and function (*e.g*. Gritti *et al.* 2004; Newton *et al.* 2012). As methods for representing system complexity, these could help communicate and compare insights from different analytical methods (*e.g*. Jeffers *et al.* 2011) and stimulate further development of cross-scale metrics (Polly *et al.* 2011) to address issues of data accessibility and comparability (Froyd & Willis 2008; Davies & Bunting 2010) which prevent direct comparisons of proxy (palaeo), observational and instrumental records.

## Conclusions

Publications discussing the value of long-term ecology (>50 years) for conservation policy and management make a strong case for their inclusion alongside other ecological inputs, but this has yet to become established in practice and it is unclear how these long-term messages are received by an ecological or policy audience. By providing a format in which different knowledge sources could be concurrently assessed, the choice experiment discussed in this paper suggests that participating researchers, practitioners and policy advisors value long-term ecological insights alongside empirical and predictive ecology, ecological monitoring and stakeholder knowledge for UK upland management. This includes site-specific and broader syntheses of long-term evidence. By engaging 'professional' respondents with a direct stake and high level of involvement in the production and use of the evidence-base, rather than the general public, this CE addresses aspects of ecosystem complexity and recognises the difficult choices involved in decision-making. To develop this potential, collaborative exercises currently used to identify common priorities in ecology provide the logical next steps for generating dialogue and building more integrative frameworks between these communities. There is also an opportunity for palaeoecologists to build on the multi-decadal trends emerging from established long-term monitoring and survey networks. Incorporating long-term datasets into conservation and management frameworks presents challenges, but continuing to overlook information on longer-term ecosystem function and process represents an even greater risk to the future effectiveness of management decisions. Given the mounting pressures on ecosystems and time delays between information gathering, policy development and implementation, more proactive approaches are needed to apply the full breadth of existing knowledge.

## Acknowledgements

This research was funded by the Economic and Social Research Council through the Rural Economy and Land-Use Programme (RES-229-27-0003). Thanks to choice experiment participants.

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Table 1. A sample ‘choice card’, showing how different levels of the attributes were combined to provide three hypothetical alternatives from which participants were asked to select their most preferred (or least disliked) option

| **Source** | **Alternative 1** | **Alternative 2** | **Alternative 3** |
|---|---|---|---|
| Ecological monitoring | Every 12 yrs | Every 6 yrs | Every 3 yrs |
| Ecological research | None | Diverse | Core |
| Long-term research | None | General | Specific |
| Stakeholder preferences | None | Bottom-up | Top-down |
| Time commitment | 1 day/4 months | 1 day/month | 1 day/week |
| **Choice:** | | | |

Table 2. A model for peatland CE responses, showing coefficient estimates for each attribute and their associated standard errors, along with standard deviation estimates for attributes modelled as being randomly distributed across respondents

| **Attribute** | | |
|---|---|---|
| *Random parameters in utility functions- mean effects* | **Coefficient** | **SE** |
| Ecological monitoring 3 years (relative to 6 years) | 0.668 | 0.553 |
| Ecological monitoring 12 years (relative to 6 years) | -4.439*** | 1.117 |
| Stakeholder guidance (relative to none) | 2.719*** | 0.747 |
| Stakeholder collaboration (relative to none) | 4.639*** | 1.310 |
| *Non-random parameters in utility functions* | **Coefficient** | **SE** |
| Ecological research (relative to none) | 4.132*** | 1.093 |
| LT research synthesis (relative to none) | 4.087*** | 1.098 |
| LT research specific (relative to none) | 3.829*** | 1.097 |
| Time 1 day/month (relative to 1 day/quarter) | -0.443 | 0.463 |
| Time 1 day/week (relative to 1 day/quarter) | 0.287 | 0.378 |
| *Distributions of random parameters (standard deviation estimates)* | **Coefficient** | **SD** |
| Ecological monitoring 3 years | 4.054*** | 1.139 |
| Ecological monitoring 12 years | 4.832*** | 1.407 |
| Stakeholder preference guidance | 2.163*** | 0.675 |
| Stakeholder preference collaboration | 3.523*** | 1.098 |
| *Log likelihood at convergence* | -84.91 | |
| *Pseudo* $R^2$ | 0.52 (52%) | |

Note: ***, **, * denote significance at 1%, 5% and 10% levels, respectively

Table 3. A model for woodland CE responses, showing coefficient estimates for each attribute and their associated standard errors, along with standard deviation estimates for attributes modelled as being randomly distributed across respondents

| **Attribute** | | |
|---|---|---|
| *Random parameters in utility functions* | **Coefficient** | **SE** |
| Ecological monitoring 3 years (relative to 6 years) | -0.066 | 0.550 |
| Ecological monitoring 12 years (relative to 6 years) | -0.582 | 0.512 |
| Ecological research (relative to none) | 2.356*** | 0.655 |
| *Non-random parameters in utility functions* | **Coefficient** | **SE** |
| LT research synthesis (relative to none) | 1.370*** | 0.421 |
| LT research specific (relative to none) | 1.592*** | 0.503 |
| Stakeholder guidance (relative to none) | 0.692*** | 0.339 |
| Stakeholder collaboration (relative to none) | 0.868*** | 0.342 |
| Time 1 day/month (relative to 1 day/quarter) | -0.534* | 0.308 |
| Time 1 day/week (relative to 1 day/quarter) | -1.254*** | 0.329 |
| *Distributions of random parameters (standard deviation estimates)* | **Coefficient** | **SD** |
| Ecological monitoring 3 years | 1.257*** | 0.487 |
| Ecological monitoring 12 years | 0.798** | 0.417 |
| Ecological research | 1.177** | 0.616 |
| *Log likelihood at convergence* | -98.79 | |
| *Pseudo* $R^2$ | 0.38 (38%) | |

Note: ***, **, * denote significance at 1%, 5% and 10% levels, respectively

## Supporting Information

Additional Supporting Information may be found in the online version of this article:

**Appendix S1.** Supporting information on peat- and moorland function & ecosystem services for choice experiment.

**Appendix S2.** Supporting information on upland woodland regeneration and habitat continuity for choice experiment.

**Appendix S3**. References cited in peatland and woodland case studies.