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Research article

Can digital reinvention of ecological monitoring remove barriers to its adoption by practitioners? A case study of deer management in Scotland

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ABSTRACT

Monitoring is one of the key tools employed to help understand the condition of the natural environment and inform the development of appropriate management actions. While international conventions encourage the use of standardised methods, the link between the information monitoring provides and local management needs is frequently overlooked. This problem is further exacerbated when monitoring is employed in areas where there are divergent interests among stakeholders in land use and management. Such problems are found in the management of wild deer across Scotland, where monitoring, in the form of habitat impact assessments, have been introduced as an innovation in sustainable deer management. However, the uptake of habitat impact assessments has been limited. We used deer management in Scotland as a case study to explore whether reinventing habitat impact assessments, and hosting the system on a familiar digital platform (a mobile phone) could help to remove perceived barriers to the implementation of assessments. Using the diffusion of innovations as a theoretical framework three sets of workshops were conducted with participants representing different stakeholder interests. While the proposed digital system did address perceived barriers to the conduct of habitat monitoring, in addition it revealed underlying concerns on the use and purpose of habitat monitoring as a tool in land management. Such concerns indicate friction between scientific and management perspectives, which need to be considered and addressed if monitoring is to become more widely acceptable as a tool to inform the management of natural resources.

1. Introduction

Since the 1980s, there has been an 'explosion of monitoring' in the management of resources across organisations and institutions (Power, 1997; Mol, 2008). Within the environmental arena, a number of international conventions promote the monitoring of ecological condition (e.g. Convention on Biological Diversity, Ramsar Convention, and Bonn Convention). Monitoring obligations under these international conventions are realised in national policies that promote the use of standardised methods, for example, the Joint Nature Conservation Committee's *Common Standards Monitoring* for designated sites in the UK (Williams, 2006). Yet, there is a growing body of evidence that points to problems with current environmental monitoring approaches, with criticism being made of unclear objectives (Legg and Nagy, 2006; Lovett et al., 2007; Holland et al., 2012), poor consideration of eventual analysis (Field et al., 2007) and methodological design being affected by resource constraints (Couvet et al., 2011; Reynolds et al., 2011).

To overcome some of these problems, more flexible and innovative approaches to monitoring natural resources focussed on local engagement have been proposed (Funder et al., 2013; Aceves-Bueno et al., 2015; Vugteveen et al., 2015). Adaptive monitoring encourages the evolution of methods as new information becomes available, or as management objectives change (Lindenmayer and

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Likens, 2009). However, adaptive monitoring has faced criticism that shifting protocols affect the ability to identify long-term data patterns (Hutto and Belote, 2013:186), make it difficult to address broader scientific questions (Haughland et al., 2010) and result in the documentation of trends without the capability to determine underlying causes (Holland et al., 2012: 95). In nature conservation such criticisms can exacerbate the problem of monitoring as an activity aimed at informing policy, but isolated from informing management decisions (Sutherland et al., 2004; Pullin et al., 2004; Westgate et al., 2013).

Yet, to inform policy habitat monitoring needs to occur at a landscape scale, beyond designated areas (Adams et al., 1994; Ostermann, 1998; Nagendra et al., 2013), where land is still composed of important habitats and species. This in turn requires the input of multiple stakeholders with differing management perspectives and objectives (Quinn et al., 2010; Hughes et al., 2011). Such an approach will require innovative approaches to habitat monitoring to address the associated complications that come with the involvement of multiple stakeholders, such as tension in the collation, use and sharing of data (Pocock et al., 2015; Young et al., 2016). However, the advent of digital tools to collect data in recent years has provided opportunities in some areas of environmental monitoring to open up the data collection process. Nature conservation in particular has seen a growth of digital innovation that promotes the collection of data from numerous individuals (e.g. citizen science, Arts et al., 2015; Newman et al., 2012). Such inclusive digital technologies present new opportunities for the involvement of multiple stakeholders in ecological monitoring and decision-making (Arts et al., 2015).

Here we present an experimental approach to the digital reinvention of a monitoring tool: habitat impact assessments, which are used to assess the impact of wild deer populations on vegetation across Scotland. Increased data collection, through habitat impact assessments, has previously been promoted in wild deer management to increase collaborative natural resource management (Davies and White, 2012; Fiorini et al., 2011). The assessments are completed on paper forms and the methods derived from ecological approaches to monitoring impacts. The uptake of assessments has faced problems (Dandy et al., 2014) with criticism due to lack of understanding, practical constraints and concerns of trust in relation to data access (Maffey et al., 2013). In this study we presented three potential user groups, representing divergent stakeholder interests, with a proposed alternative digital system to conduct habitat impact assessments. We reinvented habitat impact assessments by using a familiar digital tool, a mobile phone, to host a data collection platform that reduced the time required to collect and collate habitat condition data. In addressing some of the practical constraints to habitat impact assessments (time required for collection and collation of data) we were able create the opportunity for broader critical reflection on environmental monitoring approaches. We subsequently ask: to what extent can digital reinvention of ecological monitoring remove barriers to adoption? We answer this research question by conducting workshops with three different stakeholder groups. The stakeholder groups were identified from previous studies on the use of habitat impact assessments in deer management, which indicated that it was the younger generation that would be those integrating such methods into standard management practices (Maffey et al., 2013), and a three step approach to the study was adopted:

i) *Triangulation*: critical reflection is used to consider the current purpose and function of habitat assessments, as well as potential barriers to its conduct - in line with previous research (Maffey et al., 2013);
ii) *Introduction*: a potential technical fix (reinvention) is introduced in the form of a digital data collection system; and,
iii) *Reflection*: participants compare the proposed digital system against their knowledge and/or experience of the current paper-based data collection system, providing additional reflection on barriers, reinvention and overall adoption.

2. Case study and theoretical frame

In the Highlands of Scotland, a diverse range of management interests exists among multiple private and public landowners (Austin et al., 2013; Glass et al., 2013), especially in relation to deer management. Deer present a particular problem as, on the one hand they are valued as an economic resource (MacMillan and Leitch, 2008; Phillip et al., 2009), whereas on the other high densities of deer can have a negative impact on habitats and species therein (Putman et al., 2011). As a result, attempts have been made to introduce (standardised) methods for habitat monitoring, in the form of habitat impact assessments, as an innovative tool to inform decision-making in deer management across Scotland. Habitat impact assessments require that landowners/managers establish assessment plots (quadrats) to record and monitor vegetation types and indicators of herbivory; the plots are revisited every two years. Currently methods for the conduct of assessments are outlined in the *Best Practice Guidance on the Management of Wild Deer in Scotland* (SNH, 2011), together with data collection forms. The assessments were derived from broader ecological monitoring methods for those working on large areas of privately owned land across Scotland. The methods are taught as part of college qualifications in gamekeeping and wildlife management to encourage increased uptake across the sector. The use of these methods is also promoted under the voluntary *Code of Practice on Deer Management* (SNH, 2012), which was developed in compliance with the Wildlife and Natural Environment (Scotland) Act 2011, and implies an expectation that regional deer management groups should regularly conduct habitat assessments. However, for those involved in deer management who have limited ecological training habitat assessments are an innovation that is policy, rather than management led and the subsequent uptake of habitat impact assessments among many land managers has been limited (Dandy et al., 2014). Several barriers to adoption have been identified (Maffey et al., 2013), including problems with the complexity of the data collection protocol, the time data collection takes, and the costs of conducting habitat impact assessments.

In our case study we used the 'diffusion of innovations' theoretical framework – a theory that was originally developed in the 1950s and considers the introduction of an innovation, whether an idea, theory or product, across a community (Rogers, 2003). We were interested in the process of innovation adoption by a community – categorised as the implementation stage of the diffusion of innovations framework. The framework refers to different elements that can influence the uptake of an innovation during the implementation stage; three elements were of particular interest – core elements, reinvention and familiarity. The role of the three elements in the context of the framework and deer management is explained below.

2.1. Core elements

Following early criticisms that the diffusion of innovations model failed "to view innovations as dynamic and reciprocal" (German et al., 2006: 356), the model was refined to incorporate reinvention (see Section 2.2). Yet, in order to understand how much potential there is for adaptation of an innovation, it is necessary to

identify the different elements that the innovation is composed of Kelly et al. (2000). Some of these compositional elements can be considered core elements that underpin the innovations' purpose and function. These core elements are unlikely to change, whereas other non-core elements may be adaptable depending on contextual influences.

2.2. Reinvention

Reinvention is thought to largely occur at the point of implementation, as early adopters customise the innovation to their specific needs (Von Hippel, 1976), particularly if an innovation is complex (Larsen and Agarwal-Rogers, 1977). Reinvention by early adopters can make the innovation more applicable to later adopters, increasing the likelihood of adoption across the community and making the adoption process faster (Westphal et al., 1997; Hays, 1996; Majchrzak et al., 2000).

When "greater heterogeneity" exists amongst adopters (Rogers, 2003: 186) reinvention is more likely to occur. Considerable heterogeneity can be observed in the range of land management objectives and interests that exist in relation to deer management in Scotland (Toogood, 1995; Lorimer, 2000), which may provide instances where peer influence can challenge accepted norms (Prell et al., 2010; Davies and White, 2012). Educational institutions do provide an opportunity for training in different approaches to land management, however this does not change the role of habitat assessments as an ecology derived, policy led initiative. The need for reinvention of habitat impact assessments to improve their utility for management more broadly has also previously been identified (Maffey et al., 2013). Currently, a voluntary agreement (*Code of Practice on Deer Management* – SNH, 2012) encourages the use of impact assessments in deer management through methods outlined in *Best Practice Guidance on the Management of Wild Deer in Scotland* (SNH, 2011). Extensive non-compliance with this voluntary code of practice could result in revised legislation that enforces the compulsory uptake of methods such as habitat impact assessments. This situation could put further strain on collaborative approaches to natural resource management and hence places the onus on reinvention of the tool.

2.3. Familiarity

Initially innovations can have a slow rate of uptake, as they are an unfamiliar tool or concept. In the case of deer management in Scotland, habitat impact assessments may be a new concept with consequent barriers to their uptake (Maffey et al., 2013). These barriers exist despite investment in channels of mass communication (i.e. *Best Practice Guidance on the Management of Wild Deer in Scotland* literature and events – SNH, 2011), which in accordance with diffusion of innovations literature should increase the familiarity of habitat impact assessments across the deer sector (Valente and Rogers, 1995; Wejnert, 2002; Conde, 2004).

In this study, we attempted to link the less familiar innovation (habitat impact assessments) with existing and readily used digital technology in order to increase the familiarity of the innovation. When interviewing individuals about the perceived barriers to the uptake of impact assessments they were also asked for their views on the use of digital tools. It was found that the most prevalent pieces of digital equipment used by those working on estates (areas of privately owned land in Scotland) consisted of a computer, a mobile phone (often carried for health and safety reasons) and a GPS. The mobile phone was the most readily used and easily portable piece of equipment, and was therefore the most suitable to host an alternative data collection system. We were hereby able to evaluate whether linking an unfamiliar process (i.e. habitat impact assessments) with a more familiar tool, could decrease the complexity of the assessment methods and aid adoption.

3. Methodology

To investigate the attitudes towards habitat impact assessment methods in deer management and the potential for reinvention in the innovation process, we held three workshops with groups studying courses that required the use of habitat impact assessments. The groups were selected in compliance with previous research that identified the 'next generation' as the target audience for increased adoption of habitat impact assessments (Maffey et al., 2013). Groups were also chosen to reflect divergent stakeholder perspectives on habitat assessments according to their educational background. Group 1 were college students studying for a Higher National Certificate in gamekeeping with wildlife management; Group 2 were final year university students taking a module on wildlife conservation and management; and Group 3 were registered students taking an online course in sustainable deer management. As all groups were linked to educational establishments, every participant had a basic understanding of habitat impact assessments. In addition, the majority of participants also had practical experience, although the level of experience varied within each group (as indicated by the participants themselves at the start of the workshops). As such, we recognised that each group contained a degree of stakeholder diversity, but viewed each group as a whole for the purpose of analysis (cf. Barreteau et al., 2010).

The workshops were run by facilitators (at least 1 facilitator to 10 participants) and consisted of three phases. In phase one, participants were initially asked two questions to critically reflect on habitat impact assessments in relation to land management, namely: "*what are habitat assessments?*" and "*why are habitat assessments conducted?*" Participants were able to write points down and discuss ideas amongst themselves. At the end of the first phase of the workshop participants were asked: "*what are the barriers to conducting habitat assessments?*" after which groups discussed and created their own prioritised list of barriers. In phase two of the workshop, participants were provided with a demo of a proposed alternative data collection system, and subsequently given the time to try the system themselves where practical. The proposed system used open source software (FrontlineSMS) to support data entry on a mobile phone. Users were able to download the software to the phone and received a digital version of the paper habitat impact assessment form (sent via SMS), which could be completed multiple times. Once the form was uploaded on the phone, no mobile reception was required for the form to be operational. Completed forms could then be uploaded remotely (via SMS) to a central database.

To ensure that the system was compatible with current assessment schemes, the digital forms met the data collection requirements outlined in the *Best Practice Guidance on the Management of Wild Deer in Scotland* (SNH, 2011). Following the demo, in phase three of the workshop, participants were asked: "*what are the pros and cons of the proposed system?*" This encouraged a deeper reflection on habitat impact assessments and the potential for reinvention, as participants compared the current paper-based data collection with the proposed digital reinvention.

3.1. Workshop participants

Group 1 was made up of 12 students and 2 lecturers on a Higher National Certificate course in gamekeeping and wildlife management (all male – with the majority of students being in their late teens to early twenties). This course was composed of theoretical and practical components studied together as a group, with

extensive practical application of topics, conducted on individual estates that each student was partnered with. The estates represented a range of management interests, including but not limited to, management for game birds, deer stalking and forestry. The students all had practical experience of conducting habitat impact assessments on their course, with some having a high level of experience through conduct on their partner estate. To ensure sufficient depth of study Group 1 was split into two sub-groups, with each sub-group containing 6 students and 1 lecturer plus a facilitator. The workshops were carried out on the same day with one group taking part in the morning and one in the afternoon. Each workshop lasted for approximately 3 h, including a short break held after the first phase of the workshop.

Group 2 was composed of 27 final year students taking a module on Wildlife Conservation and Management: Concepts and Practice in Biological Sciences (11 male, 16 female – with the majority of students being in their early twenties). The students, supported by previous studies, all had a prior understanding of habitat monitoring and attended a three-hour lecture and practical that explored issues in deer management three days before the workshop, as well as being provided with supplementary reading material. Students that had attended the preparatory lecture and practical were split into five working sub-groups, containing a maximum of six students. Some of the students present also had practical experience of habitat impact assessments due to involvement in previous research projects. The workshop itself followed the same format as Group 1. Three facilitators were present throughout the course of the workshop.

Group 3 was made up of seven students taking an online course in sustainable deer management (4 male, 3 female – with all the students aged above 25). This group was the most varied as the course was offered both as a module of an MSc course and as a stand-alone course for continuing professional development. Therefore, some individuals were actively involved in practical estate management and/or had studied previously on other wildlife management courses. The course was conducted entirely online and the workshop took place over a two-week period. In the first week, students watched a short introductory video that presented the same information as was given at the beginning of the workshop to groups 1 and 2, before answering the first three questions of the workshop. In the second week students watched a second demonstration video that presented a review of the questions addressed in the previous week before answering the final question. Students answered the questions on a closed forum that was accessible only by the students, the course lecturer and the facilitator. Students were therefore able to discuss answers at length among themselves as well as with the facilitator, just as was the case for groups 1 and 2.

3.2. Data analysis

The data collated from the three workshops consisted of written answers and recorded audio discussions prompted by the questions posed, as well as written comments in the case of group 3. Audio discussions from groups 1 and 2 were transcribed and printed, and all responses were then classified using different colours according to whether the answers came from groups 1, 2 or 3, to trace discussions. The responses from all groups were then separated according to the question they addressed. Each question was manually and openly coded; this involved texts being categorised according to the topics that they addressed, with subsequent 'axial coding' to understand the relationships between the coded categories (Corbin and Strauss, 1990; Walker and Myrick, 2006). The coded data was subsequently analysed using the Diffusion of Innovations as a theoretical frame.

4. Results

Throughout the results section, quotation marks are used to indicate phrasing that comes directly from the participants in the workshops, and italics to represent themes that emerged from the analysis.

4.1. Core elements of the innovation

During the initial phase of the workshops, participants were asked to discuss their perceptions on what habitat impact assessments were and why they were conducted. The initial question "*what are habitat assessments?*" revealed a series of themes that represented relatively simple flows of argumentation in each of the workshops (Fig. 1). In the biological sciences workshop (group 2), habitat impact assessments were viewed as an *assessment* that considered the *condition* and/or the *diversity* of species in an environment. In the sustainable deer management (group 3) and gamekeepering (group1) workshops, the arguments followed a somewhat similar flow. The sustainable deer management workshop predominantly referred to habitat impact assessments as a "useful" or "valuable" *tool* used to assess the condition or presence of species on the land. Likewise, the gamekeepering workshop referred to the importance of using *consistent methods* (both in terms of methods learnt, and consistency of application year on year) to consider the diversity of species present and grazing pressure on the land. However, both the sustainable deer management and gamekeepering workshops contained an additional step in the argument flow beyond those recognised in the biological sciences workshop. In this step, participants referred to the role of using information collected on habitat condition or species presence to *aid* or inform future *management* decisions.

When considering "*why are habitat assessments conducted?*" four themes were commonly identified in all of the workshops: *assessment, management decisions, policy* and *justification* (Fig. 1). These four themes demonstrate the elements of habitat impact assessments that underpin the innovations' perceived purpose and function (Section 2.1). The first two themes (*assessment* and *management decisions*) largely elaborated on the initial argument flows in Fig. 1, and although slightly different terminology was used across the workshops, overall discussions were similar. Participants in all workshops referred to the need to use *assessments* in order to "identify", "record" or "see" any "change", "impact" or "damage" at sites of interest. All of the workshops discussed the role of habitat impact assessments to inform *management decisions*, whether in relation to conservation or wider land management objectives. In addition, dialogue around *management decisions* also explored how habitat assessments could be used to reflect on the effectiveness of previous management decisions; this idea was repeatedly returned to during the gamekeepering workshop.

Discussions in the workshops differed noticeably when considering the final two themes (*policy* and *justification*). All three workshops referred to the role of *policy* as a reason to conduct habitat assessments. In the biological sciences workshop, habitat monitoring were considered as an activity in "compliance" with national legislation. However, in the sustainable deer management and gamekeepering workshops, *policy* was also discussed in terms of funding for management schemes of which habitat assessment might be a component. In the gamekeepering workshop, one participant argued that if policies were not in place then the individual would not monitor in the first place. There was also a considerable amount of discussion in the gamekeepering workshop around habitat impact assessments as a *justification* for management. Participants referred to habitat assessment as a way to provide evidence for why management decisions had been made, or as

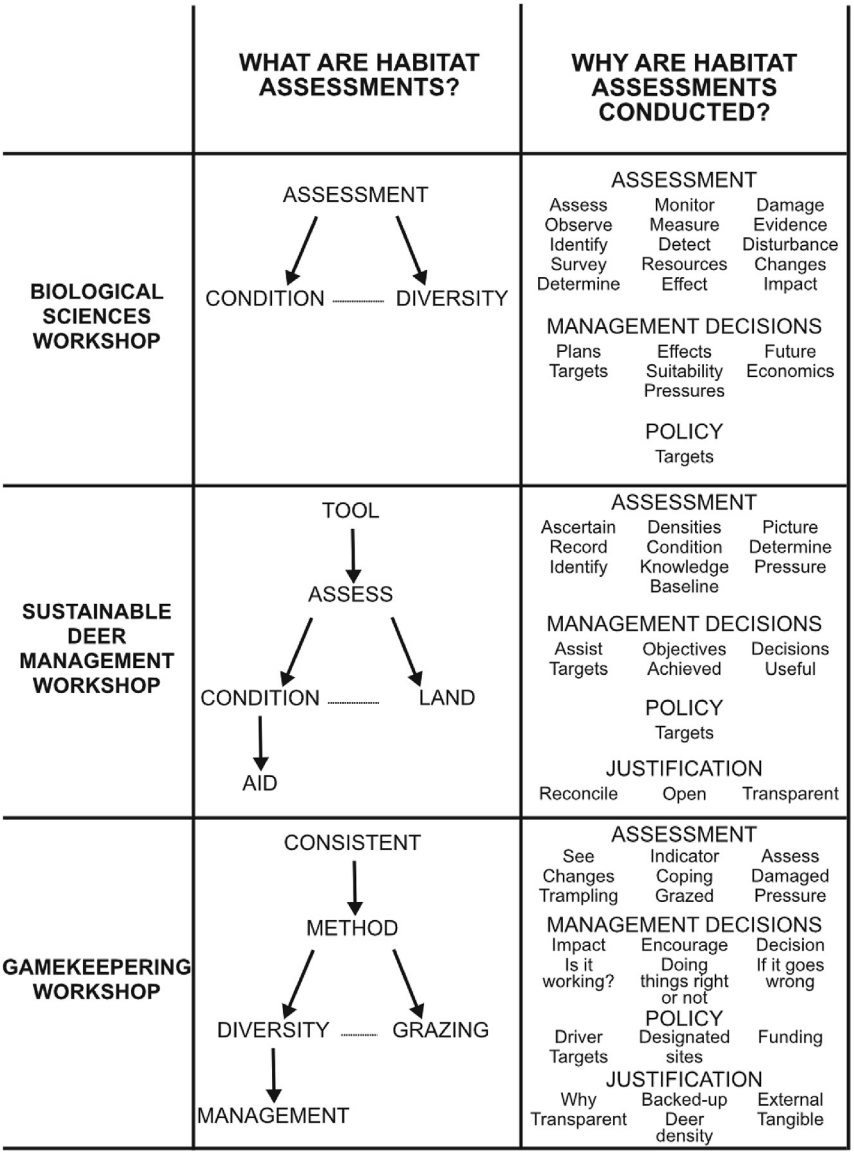

Fig. 1. Themes identified from the initial discussions on habitat assessments. The flow of argumentation during each workshop following the question "what are habitat assessments" is represented, with dotted lines denoting linked themes. Four themes that emerged following the questions "why are habitat assessments conducted?" are also shown (capitalised), with associated terminology listed underneath.

a way to produce "transparent" results on habitat condition that could be viewed by external parties. This final point was also briefly raised in the sustainable deer management workshop.

4.2. Triangulation of recognised barriers

As a final part of phase one of the workshop, participants were asked what barriers there were to the uptake of habitat assessment across the deer management community. This encouraged critical appraisal of the assessment process and triangulated information with that previously highlighted by representatives of the deer management community (Maffey et al., 2013), confirming the workshop groups' understanding of the issues being discussed. While all of the barriers identified by previous interviewees were also collectively recognised by workshop participants (*time, funding, interpretation, understanding,* and *generation*), additional barriers were identified in the workshops (*interest, accessibility, vulnerability,* and *health and safety)*, as shown in Table 1.

Time was consistently identified as a barrier to undertaking assessments, and predominantly referred to two constraints: the actual time taken to carry out assessments in the field; and the subsequent "paperwork" that went with data collection. A lack of "manpower" to conduct assessments was also felt to place additional pressure on time available for other management activities. In the gamekeepering workshop in particular, it was noted that assessments could "come into conflict with important tasks", indicating that habitat assessments may be considered an additional, rather than a central, management activity. *Funding* was commonly associated with time constraints during the workshops, either due to a lack of funding available to support the conduct of habitat assessments, or due to the cost of an employee's or a contractor's time. Interestingly, although discussed in the gamekeepering workshop, funding was not something that participants perceived to be a key barrier to conducting assessments. It was instead felt that funds would be found if estates had a "vested interest" in conducting assessments.

Table 1
Barriers to the uptake of habitat impact assessments as themes identified by representatives of the deer management community during previous interviews (Maffey et al., 2013) and present workshop participants. The size of the ticks in the workshop columns represents the extent of discussion around the theme in each workshop.

	Professional deer managers (Maffey et al., 2013)	Biological sciences workshop	Sustainable deer management workshop	Gamkeepering workshop
Time taken to carry out assessments	✓	✓	✓	✓
Funding and resources to carry out assessments	✓	✓	✓	
Interpretation of data collated from assessments	✓	✓	✓	✓
Understanding of how to conduct assessments	✓	✓	✓	✓
Interest in conducting assessments		✓	✓	✓
Generation (age) involved in conducting assessments	✓		✓	✓
Accessibility to areas that require assessing		✓	✓	✓
Vulnerability of areas that require assessing		✓	✓	
Health and Safety requirements during assessments		✓		

As found in the interviews (Maffey et al., 2013), workshop participants shared concerns over how assessment data could be understood, or as one participant put it, there was a worry that "opposing parties may interpret results differently". Linked to *interpretation*, was the potential barrier of *understanding*. Participants in the biological sciences workshop in particular discussed the "knowledge" and "education" required to carry out assessments effectively. The sustainable deer management and gamekeepering workshops also discussed the problem of "traditional" approaches to management, and how this could make it especially difficult to introduce new ideas to older *generations* of gamekeepers.

In addition to the barriers previously identified through interviews (Maffey et al., 2013), four further barriers were brought out during the workshops: *interest, accessibility, vulnerability* and, *health and safety*. The latter three referred directly to physical sites being monitored, with concerns that some areas may be difficult to *access* due to "geography", "weather", "seasons" and "tenancy agreements"; that sites could be *vulnerable* and assessments could have negative impacts; and that there could be associated *health and safety* implications for those conducting habitat assessments due to the location of sites. The fourth point (*interest*) was raised during all three workshops, and indicated that there was potentially no *interest* in conducting habitat assessments from those expected to do the actual assessment work. When discussed in the biological sciences workshop, this was because it was thought that habitat assessments were, or could be perceived to be "boring". In the gamekeepering and the sustainable deer management workshop it was felt that if it was not "estate policy", or an individual was not concerned with deer management, then there would be no *interest* in conducting assessments. In the gamekeepering workshop it was further explained by participants that habitat impact assessments are a recent introduction to estate management and that currently it is "not a major concern". However, participants in the sustainable deer management workshop felt that a lack of *interest* or "willingness" to conduct assessments could be associated with a lack of "expertise" in, or "knowledge" of, how to conduct assessments.

4.3. Perturbation of habitat assessments – digital reinvention

During the second phase of the workshop, participants were introduced to an alternative, mobile phone based system for collecting habitat assessment data. The electronic system addressed some of the technical issues previously identified by interview participants (Maffey et al., 2013), and in the final phase of the workshop participants were asked to discuss the pros and cons of the proposed alternative. Reflecting on the different assessment systems enabled participants to compare the two systems, which revealed underlying problems with the application of habitat impact assessments in different contexts (Fig. 2).

4.3.1. Barriers addressed

Across the workshops, four themes were unanimously identified as pros of the alternative electronic data collection system: *immediate, simple, backed-up* and *eco-friendly*. The *immediacy* of the system was viewed as a key advantage in that "less paperwork" and the automation of data transfer onto a computer removed a lengthy manual step in the process, and subsequently brought "interpretation [of the data] closer". For the sustainable deer management and gamekeepering workshops, it was felt that the system could help to make habitat assessment part of the management process, rather than as an additional activity. The *simplicity* of the proposed mobile phone based system was perceived to be important as it meant assessments were "less hassle" to conduct as "it could be used by anyone". The biological sciences and sustainable deer management workshops discussed the fact that data was *backed-up* in a "paper-less" electronic system reducing the potential loss of data, and also felt that the idea of reduced paper use made the system more *eco-friendly*.

A number of the themes identified were perceived to be both pros and cons by the workshop participants: *time, cost, collaboration* and *access*. The proposed electronic system was perceived to have "time saving" qualities because there was "no annual input of data". These qualities also linked *time* to the previously listed theme *immediate*. However, despite these benefits, the proposed system still meant that a dedicated amount of time had to be spent on the actual collection of data in the field. Also associated to the *time* theme was the *cost* of the system. Participants in the biological sciences workshop felt that savings were made as it was not necessary to "pay professionals to input data", while in the sustainable deer management and gamekeepering workshops it was felt that if the system costs were low and resulted in a time saving, then estates would be more likely to adopt it. Despite this, it was recognised in all the workshops that the purchase costs of new or additional equipment could be a disadvantage of the system. The sustainable deer management and gamekeepering workshops also raised overall concerns of the amount of time and associated cost that would be required to set up and maintain habitat impact

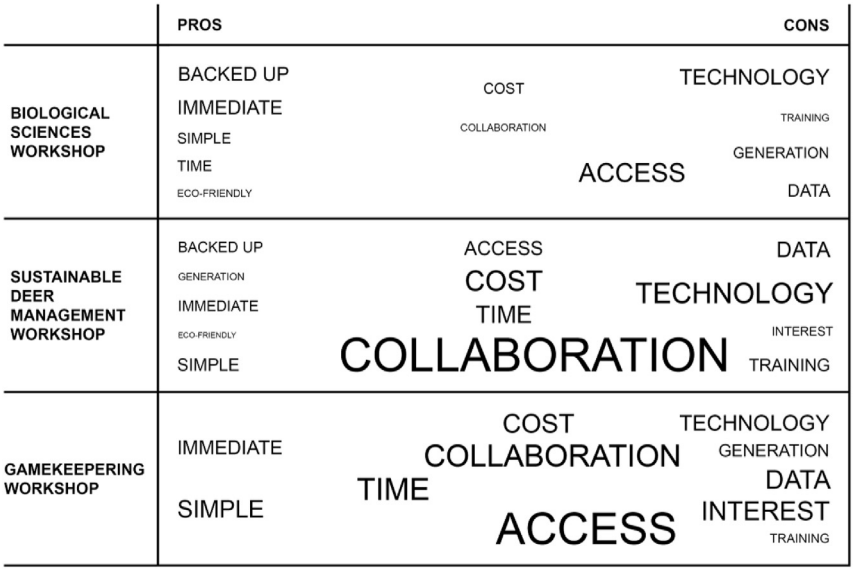

Fig. 2. Pros and cons of the proposed digital reinvention as identified by workshop participants. The size of the text indicates the extent of discussion around each theme to provide a guide to where discussion occurred. The position of the text shows whether the theme is considered a pro, a con or both.

assessment schemes in general (not just with a digital system) on an estate.

In the sustainable deer management workshop, it was felt that the proposed system would help with *collaboration* between estates on management decisions. However, this was not directly because of the system itself but the potential for the submission of data to a "central database" where results could be "shared" with neighbouring estates or more widely. In both the biological sciences and the gamekeepering workshops, *collaboration* was briefly referred as an advantage in relation to the "clarity" and the "reliability" of the data if it was typed rather than handwritten. However, *collaboration* was more readily discussed as a disadvantage in all the workshops. This was largely related to issues of "trust", for example who would have access to such data, whether this be other estates, NGOs, government bodies or the wider public. The system was also criticised as it did not "assist with interpreting results" once the data was collected. In the sustainable deer management and the gamekeepering workshop, there were additional concerns over who would have access to the data, and that there may be requests for data from public bodies and Deer Management Groups. It was felt that many estates "may not wish to share the data", especially if public bodies, for example, could use this data "against the [data] collector", and intervene with management practices. Finally, there was the theme of *access* that was raised in all the workshops. Although it was perceived to be advantageous that the electronic system was "lightweight" and could be used in different "weather conditions", equally there were potential practical problems if the system got wet or ran out of "battery life" when working in remote areas. The gamekeepering workshop especially felt that there might still be connectivity issues, despite the system being shown to operate without mobile telephone signal in the demonstration. It was suggested that a system that would work on multiple platforms (i.e. via broadband satellite connection) would be more appropriate in these areas, linking to notions under the theme *technology* below (Section 4.3.2).

4.3.2. Additional barriers

Two disadvantages of the proposed system were raised, which had not been noted when considering the original system: *technology* and *data*. Both of these themes related to the use of a digital system. Issues with the *technology* itself included: equipment required to operate the system; the overall reliability of the respective software; whether additional components (such as GPS) could be included; and, if it would ever be possible to completely get rid of the paper-based system and rely solely on a digital one. In addition to this, concerns were raised in all the workshops relating to the potential "loss of data" due to "technical faults" with equipment, and loss of *data* quality because it was less convenient to "add notes" in the proposed system.

4.3.3. Underlying concerns

Importantly, the exposure to an alternative electronic system and comparison with the paper-based approach brought out underlying flaws with habitat impact assessments overall, captured by the themes *training, interest* and *generation*. While the majority of the discussion around *interest* and *generation* occurred in the sustainable deer management and gamekeepering workshops, all of the workshops referred to the need for *training* in assessment methods. This was discussed in relation to how to use the proposed data collection system, but frequently extended beyond this to consider habitat impact assessments methods in general. Participants felt that *training* in the conduct of habitat assessments was necessary, particularly if they were only conducting them once a year or less, as well as *training* to help people to understand how to interpret the data once collected.

Actual *interest* in conducting habitat assessments was discussed in the sustainable deer management and, repeatedly, in the gamekeepering workshops. As noted by one participant in the sustainable deer management workshop: "I don't see this system addressing the main reason for not carrying out [habitat impact assessments] – a lack of interest in them as a decision support tool". Another participant in the sustainable deer management workshop felt so strongly about the inadequacy of the current habitat impact assessment methods, that this participant advocated a complete overhaul of the system, not just how data was collected. In the gamekeepering workshop, *interest* was considered from the perspective of the overarching management objectives of an estate. It was felt that because these habitat impact assessments were targeted at deer management, they were not applicable for those who were not actively interested in deer management. This

resulted in a recurring cyclic argument throughout the final phase of the workshop as – when other pros or cons were considered – participants would frequently return to the point of whether an estate was actually interested in conducting habitat assessments in the first place.

Finally, some participants in the sustainable deer management workshop noted the use of mobile phones by different *generations* of gamekeepers. They saw the attachment of habitat assessments to a mobile phone as something that would appeal to "the younger generation of estate worker" as they "[loved] electronic gadgets". However, this point was more commonly identified as a con in the other workshops. In the biological sciences workshop, this was because of "technophobes" that would not be willing to use technology. This problem was also identified in the gamekeepering workshop, but elaborated to indicate problems of getting senior gamekeepers (who were deemed less inclined to use a mobile phone) on board when implementing the system.

5. Discussion

The workshops conducted provided insight into the extent to which making use of digital technology could remove one of the key barriers to the uptake of habitat impact assessments to inform land management, and help to reinvent the process. One of the main differences between the workshops was the importance of *interest* in conducting habitat assessments (Table 1). The gamekeepering and sustainable deer management groups in particular emphasised the need to support the development of habitat impact assessments as a tool to inform management decision-making (Fig. 1). The final phase of the workshop followed the introduction of a proposed digital reinvention of the tool. This phase clarified that digital reinvention was perceived to have addressed some of the technical barriers to habitat impact assessments. However, through the presentation of an alternative digital system, it was clear that there are underlying limitations to habitat impact assessments as both a method and a concept (Fig. 2), which holds implications for the use of such a tool in wider land management.

5.1. Identification of core elements and triangulation of barriers

The recognised purpose and function of habitat impact assessments was essentially the same across the workshops: to assess the diversity and abundance of species present and, or, the condition of the habitat. Two of the themes identified in the initial phase of the workshops (*assessment* and *management decisions*) largely aligned with the generic objectives of habitat impact assessments previously outlined by Chapman (2012). As such, they can be considered as the core elements of habitat impact assessments, which are responsible for the effectiveness of its implementation (Kelly et al., 2000). In other words, according to the participants, assessments should provide information to determine habitat condition and to inform management decisions.

However, two additional themes, *policy* and *justification*, were also identified (Fig. 1). These two themes represent the importance of policy and legislation as drivers in the adoption of assessments, but also demonstrate a shift from the role of habitat impact assessments as a tool within environmental monitoring, to one that informs broader land management decision-making. Consequently, *policy* and *justification* should be considered as additional elements of the innovation that are context dependent (Rogers, 2003). Considering *policy* and *legislation* as context dependent elements may help to recognise disparities in decision-making and ensure that monitoring is not isolated from informing management decisions (Sutherland et al., 2004; Pullin et al., 2004; Westgate et al., 2013).

The theme of *interest* identified by workshop participants (Table 1) indicates two potential problems for the use of assessments in management. In one sense, it reflects the fact that while there is an increasing trend in policy to adopt a more holistic approach to land management (Grumbine, 1994; Borgström et al., 2015) this has not yet been fully reflected in practice. Put differently, it indicates that the data collected from habitat impact assessments is largely a policy driven exercise, and is not necessarily perceived as complementary to traditional management approaches in the wider countryside. Addressing this gap will likely require consideration of how frameworks for assessment schemes can be better designed to address local management interests, while adhering to (inter)national policy and legislation (Legg and Nagy, 2006; Lengyel et al., 2008; Lindenmayer et al., 2011; Lindenmayer and Likens, 2011).

5.2. Reinvention

Workshop participants were asked to critically reflect on a proposed digital reinvention of the current habitat impact assessments data collection system. While the proposed system did not address all of the original barriers raised by interviewees (Maffey et al., 2013), it did go some way to improving technical issues such as *time, funding* and *understanding*. In addition, some concerns with *accessibility* that were only raised by workshop participants were also addressed. However, a number of general disadvantages with habitat impact assessments were identified (Fig. 2). These disadvantages (*training*, *generation* and *interest*) go beyond the technical barriers addressed through reinvention, and reveal fundamental problems that underpin the use of habitat impact assessments in management.

One of the key problems with using habitat impact assessments in deer management is the conflict between management objectives according to social context, (Marshall et al., 2007); for example divergent interests that stem from management objectives for forestry, stalking or conservation. It has been pointed out that assessments require knowledge and expertise (Reynolds et al., 2011), and this is often attributed to ecological field staff. The current simplified habitat impact assessment methods under *Best Practice Guidance* (SNH, 2011) allow those who are not fully trained in ecological methods to collect data. However, assessments are only conducted every two years on an individual estate, opposed to the more regular conduct of different monitoring methods across multiple locations undertaken by ecologists. In the case of deer management it may be necessary to also consider technology as an aid, for example by including guidance to aid users in the conduct of assessment methods. This could help to increase familiarity and translate theory and teaching into practice, as is currently encouraged in a growing number of citizen science projects. Such projects use websites and mobile device apps to facilitate the monitoring of species of concern – such as Beewatch (an online crowd-sourcing platform for bumblebee identification, Van der Wal et al., 2015) or apps developed by Nature Locator (to collect crowd-sourced data for biological surveys e.g. iRecord Ladybirds; Planttracker; Aqua Invaders). In developing countries digital platforms have been used to host environmental monitoring interfaces (e.g. cybertracker – that uses icons for expert non-literate trackers to enter information, Liebenberg, 2003; Maffey et al., 2015).

In addition, consideration also needs to be made as to how these data collection methods sit within a management framework (Lindenmayer et al., 2011). The workshops demonstrated patterns that have also been noted by Sutherland et al. (2004), Pullin et al. (2004) and Adams and Sandbrook (2013) in the fact that monitoring data is not subsequently used to inform conservation management. In this instance university students with ecological

training viewed monitoring predominantly as scientific exercise, without initially recognising it as a tool to inform management decision making.

One limitation of the study was that we were unable to follow the integration of habitat impact assessments into land management networks, such as deer management groups. However, the next generation of gamekeepers had originally been identified as the target audience for adopting tools such as assessments in estate management. Consequently it was determined that this group would have a vested interest in the potential digital reinvention of habitat impact assessments. Workshop participants reflected on this and raised concerns that although a digital system could be attractive to younger audiences, it could equally alienate older audiences. This has repercussions for adoption as land management in Scotland operates in a complex hierarchical structure (Glass et al., 2013; Fiorini et al., 2011), with influences on management decisions likely to come from senior keepers, landowners and estate policy, not junior keepers. The current onus on the next generation to pilot ecological tools in land management could result in a particularly slow rate of adoption, and it may be necessary to consider the development of initiatives beyond *Best Practice Guidance* (SNH, 2011), such as habitat impact assessment demonstration sites to increase the understanding of such tools (Davies and White, 2012).

Interest in habitat impact assessments has been a persistent theme throughout the workshops. It is evident that assessments are currently viewed as an additional and onerous activity rather than a support tool for management planning and decision-making (Chapman, 2012; Holland et al., 2012). This may be due in part to the value judgement attributed to the interpretation of assessment results, which determines whether areas are found to be in 'favourable' or 'unfavourable' conservation status (Putman et al., 2011). It is also clear that this view is exacerbated by the narrow use of impact assessments in relation to deer management. It was readily discussed during the gamekeepering workshop that other species (including other game species) could also have impacts on natural resources, so "why not consider more species than just deer?" The accommodation of considerations such as these, from diverse interests in management, will further influence the reinvention of habitat impact assessments. This inevitably shifts the discussion on habitat impact assessments away from the uptake of methods towards questions of what the data collected from environmental monitoring is for; who should be responsible for its collection; and, how to balance assessments for local relevance and assessments to meet higher policy objectives.

6. Conclusion

The three-step approach (triangulation, introduction and reflection) used during the workshops demonstrated friction between how habitat impact assessments are used from a scientific and from a natural resource management perspective. Digital reinvention did address some of the previously identified barriers to the adoption of assessments from a management perspective (Maffey et al., 2013). However, it primarily served as a perturbation, through which we were able to identify two key issues: although the habitat assessment methodology has been agreed upon for the deer management sector, it has not been sufficiently adapted from its ecological roots to be useful for managers; in addition there needs to be consideration of the wider social context (Marshall et al., 2007) to ensure that such tools can be used effectively to support decision-making in land management.

More broadly, the findings of this research caution against rapid, large-scale deployment of mobile digital technologies in the land use sector without careful consideration of local socio-cultural contexts. The proposed approach, tested and illustrated via the deer management case study, may provide a useful methodological template for scoping the development and deployment of future innovations in digital technology in this sector. By adopting a three-step approach we were able to triangulate existing perspectives, introduce new concepts and critically reflect on habitat assessments with target users and other stakeholders. This approach provided valuable feedback about far more than just the technology and revealed broader concerns about the use of habitat assessments as a monitoring tool, which would need to be addressed prior to the development of any future technologies. Addressing such concerns through further reinvention in collaboration with and between end user groups will go some way to move beyond just 'monitoring', to a more considered 'monitoring and management' approach to decision-making.

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