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Informed debate on the use of fire for peatland management means acknowledging the complexity of socio-ecological systems

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Abstract

The effects of fire and its use on European peatlands and heaths are the focus of considerable research and debate due to the important services these ecosystems provide and the threats they face from climatic and land-use change. Whilst in some countries ecologists are actively promoting the restoration of historic fire management regimes, in the UK the debate has become increasingly acrimonious. Positions seem entrenched between continuing the intensive form of management associated with grouse moors or ceasing burning and seeking to eliminate fire altogether. In a recent paper we argued that participants' positions appeared influenced by political and philosophical beliefs associated with, for example, private land-own-

ership, hunting, and associated conservation conflicts such as raptor persecution. We also suggested there was inadequate engagement with key concepts and evidence from fire and peatland ecology. We argued that management debates should aim to be inclusive and evidence-based, and to understand the benefits and costs of different fire regimes. In a strongly-worded critique of our paper, George Monbiot (author of "Feral: Searching for Enchantment on the Frontiers of Rewilding") suggested we: i) framed our research question too narrowly; ii) made the implicit assumption that moorlands were the "right" ecosystem for the UK countryside; and iii) failed to adequately engage with arguments put forward for cessation of managed burning. Here we critically examine each of these issues to provide further insight into how adaptive, participatory land-management could develop. We argue that a productive debate must acknowledge that complex trade-offs are inevitable during ecological management. Choosing the "right" ecosystem is difficult, especially in a landscape with a long history of human influence, and the answer depends on the values and ecosystem services we prioritize. Natural resource management decisions will be improved if based on an understanding and valuation of the multiple scales and levels of organization at which ecological diversity exists, the role of disturbance in controlling ecosystem composition and function, and the need for participatory action.

Keywords
Adaptive Management, diversity, heathland, managed burning, moorland, participatory, scale

Introduction

The ecological effects of fire in European peatlands and heathlands are the focus of considerable research and debate due to the important services these ecosystems provide (Whitfield et al. 2011), their conservation importance (Thompson et al. 1995), and the threats they face from climatic (Gallego-Sala et al. 2010) and land-use changes (Acs et al. 2010). Though heathland and peatland ecosystems occur naturally in NW Europe, for instance at high elevations above the tree-line or in areas of cool temperatures and high rainfall, across much of their British range heathlands and peatlands are fundamentally anthropogenic landscapes deriving their current ecological composition, structure and function from millennia of low-intensity human management (Simmons 2003). Despite this, human interventions in the more recent past, including drainage, high rates of livestock grazing, and intensive use of managed burning have interacted with other anthropogenic impacts such as nutrient deposition, acidification and climate change to have significant ecological consequences (Holden et al. 2007). Each of these drivers can affect biodiversity and ecosystem services in their own right, but they also vary significantly in time and space and interact with each other in complex ways (e.g. Evans et al. 2014). Fire is a critical control on the current structure and function of peatlands but over time we have grown concerned that the dominant narrative in the UK surrounding the use of fire as a management tool has become antagonistic, politicised and overly-simplified. We are not alone in being concerned about the tone of upland land-management debates in the UK. Wynne-Jones (2016) recently critiqued the hyperbolic character of the debate regarding interactions between upland sheep farming, reforestation and catchment hydrology. The current debate about managed burning risks failing to adequately acknowledge the complexity associated with

multiple drivers of peatland ecosystem function, our growing global understanding of the ecological effects of fire in peatlands (e.g. Turetsky et al. 2015) and the potential flexibility of prescribed burning as a management tool (Russell-Smith and Thornton 2003). We laid out our concerns in a recent paper "The role of fire in UK peatland and moorland management: the need for informed, unbiased debate" (Davies et al. 2016), which has been the subject of subsequent discussion, debate, and no small amount of misrepresentation.

Notable amongst the coverage our paper received was the critique made by the respected author, journalist and commentator George Monbiot (Monbiot 2016a). Monbiot's comments followed newspaper reports (e.g. Webster 2016) which, without consulting us, reported on our paper before it was published and distorted our key messages. After mistakenly being placed open access on an institutional server following its acceptance, our paper was picked up by the organization "You Forgot the Birds" (YFTB) which produced a press-release based on it. In subsequent newspaper reports (e.g. Webster 2016), Monbiot and the Royal Society for the Protection of Birds (RSPB) were publicly and unfairly criticized, based on a partial reading of our work, highly selective quoting from our paper and a distortion of our conclusions. We made it clear at the time that we did not endorse any of the pre-publication coverage of our paper (Avery 2016). It is deeply ironic that our paper, which called for unbiased, informed science reporting, was used in this way given that we specifically criticized science journalism for failing to adequately engage with the authors of research papers, for not seeking or allowing pre-publication review of their articles, and for a tendency to be insufficiently critical of simplified and sometimes biased press-releases.

Given the wider issues Monbiot (2016a) raised regarding peatland and moorland ecology, we feel it is important to respond to his criticisms and to develop our arguments further. By our reading, Monbiot has three key issues with our paper: i) that we frame our question too narrowly and thus pre-empt our own conclusions to favour the continued use of current forms of burning; ii) that we make the implicit assumption that moorlands are the appropriate ecological state for large areas of the British Uplands; and iii) that we failed to read and/or understand one of his recent articles and, as a result, did not adequately engage with his criticisms of burning or his arguments in favour of "rewilding". We believe his conclusions stem from not unusual misunderstandings regarding:

1. How scientists frame research questions within the context of peer-reviewed journal publications and why we chose to focus our paper on the ecology of peatland fires.
2. The ecological, social, economic and conservation importance of peatland and heathland ecosystems.
3. The nature of ecological diversity and the importance of considering ecological patterns and processes across multiple scales.

These misunderstandings are important as they potentially influence one's attitudes regarding the role of science in the development of conservation policy and man-

agement decision-making, how one reads and interprets scientific literature and how one assesses the value of peatland and heathland landscapes and fire's role in them. Our aim here is to address each of the three points above before considering how this knowledge should influence attitudes towards land-management and the character of ecological debates.

1. Framing research questions – understanding fire effects on peatlands

A scientific paper, even a review or opinion piece, aims to shed light on a particular, focused question. Debates regarding ecosystem management and restoration are inherently complex and require an integrated understanding of socio-ecological systems. However, within these larger debates one can still identify specific process and interactions each of which often require detailed study on their own before the whole picture can be constructed (Figure 1). Arguments can often develop at cross-purposes due to misunderstandings regarding the particular element of the system being studied or debated. The objectives of our paper were to i) review recent evidence of the effects of fires (managed and wild) on moorland and blanket bog ecosystems; and ii) examine the manner in which this knowledge is communicated in scientific publications and the media. This focus is rather different from the socio-cultural debates Monbiot (2016a) primarily focused on (Figure 1). We believe our objectives were justified because as we, and others (e.g. Glaves et al. 2013), have explained, there is considerable debate about the environmental effects of managed burning and wildfires on peatland ecosystems and ecosystem services. We believe that the debate about environmental processes is being muddied by wider political, social and economic issues, and a highly simplistic view of fire management. This would have us believe that the only options are to cease or ban burning entirely, or to continue with an intensive use of fire as associated with management on some grouse moors (see Figure 1 in Davies et al. 2016a). This is a simplification of the significant variation in current and historic managed and wild fire regimes within the UK, the flexibility of fire as a management tool, and the extent to which one can manipulate its ecological effects. The objective of our paper was to elucidate the effects of fires on heathland and peatland ecosystems without taking a position regarding the wider issues associated with moorland management – our focus was solely on understanding how fire affects these ecosystems. It is essential to address this issue as it is critical in evaluation of current ecosystem management practices and the identification of future options.

Before one proposes a shift in management regime, one ideally needs to understand the range of ecosystem effects the current disturbance regime generates, and the trade-offs any changes could produce. Where such knowledge is lacking, an Adaptive Management approach (Holling 1978) should be adopted. Adaptive Management emphasizes the need for a conceptual model of inter-related ecological structures and processes; identification of areas of uncertainty; ecologically-justified, testable hypotheses about what the outcomes of management change will be given existing uncertainties; a range of potential intervention/change options that can be applied experimentally; and

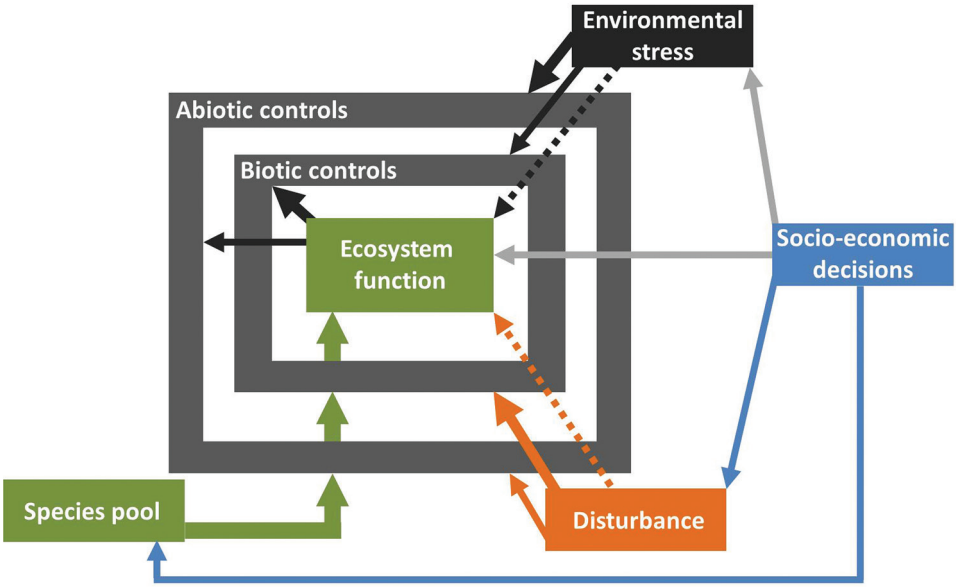

Figure 1. Ecosystem function (including species composition and ecological processes) is controlled by a series of abiotic (e.g. soil type, temperature) and biotic (e.g. species diversity and species' traits) variables. The abiotic and biotic controls also act as filters controlling the species found at a particular site out of those available from the regional (or historical) species pool. Disturbances, such as managed burning or wildfire, influence both biotic and abiotic variables and therefore ecosystem function. The nature of that influence will depend upon the characteristics of the disturbance regime and the particular ecosystem function of concern. Socio-economic decisions influence the system by impacting directly on disturbance regimes (e.g. via regulation of prescribed burning), the species pool (e.g. by re-introducing locally or regionally extinct species), and environmental stress (e.g. via anthropogenic climate change). Disturbance (fire) effects (orange) were the focus of Davies et al. (2016) whereas socio-economic decision-making (blue) were the focus of Monbiot (2016a). We argue that views in the blue region should not influence the interpretation of scientific data in the orange region. This does not mean socio-economics are not important, but these issues should be addressed in a participatory manner rather than via polemics, which assume one has a monopoly on the "right" answer about ethical, conservation and economic priorities. This diagram was adapted from Halle (2007).

mechanisms that allow the measurement of management effects and the identification of trade-offs such that the conceptual model can be updated and management options expanded or adapted if desired outcomes are not reached (Westgate et al. 2013). Adaptive Management therefore emphasizes "learning by doing" and presents an alternative to wholesale changes followed by reactive responses to problems if/when they occur. Management should not proceed by trial and error or with an unwillingness to acknowledge and account for ecological, social and economic uncertainties.

Monbiot's criticism could be taken as suggesting that scientists and managers know all they need to about the ecological effects of variation in fire regimes or the ecosystem dynamics of heathlands and peatlands, but this is very clearly not the case

(e.g. O'Brien et al. 2007, Glaves et al. 2013). Monbiot (2016a) says "Is fire good for 'landscapes that owe their existence to the use of fire as a management tool'? Er, let me get back to you on that", thus suggesting that we pre-empt the answer to our own question and that we argue that fire is "good". But there is, in fact, no clear answer to the question he has posed. Monbiot himself appears to be aware that the relationship between moorland ecosystems and fire can be complex and that, contrary to the sentiment expressed in the quote above, certain *fire regimes* can be damaging to these systems. In a previous contribution, Monbiot (2016b) highlighted degradation of moorlands as a result of interactions between fire and grazing. Degradation of peatlands or heathlands by fire is indeed possible but, as we argued in our paper, such processes are often not the sole result of one particular disturbance but rather a result of disturbances outwith the historical norm, e.g. severe wildfires (Maltby et al. 1990, Davies et al. 2012), compounded or interacting disturbances (e.g. Vandvik et al. 2005, Britton and Fisher 2006), or disputed classifications of ecosystem health (see Box 1 in Davies et al. 2016). In Monbiot's example of the decline in bog and heathland habitats on Dartmoor (Monbiot 2016b), we would suspect that inappropriate combinations of burning and grazing are more likely to be to blame than the use of burning as part of the management of the system *per se*. Previous research has shown the role that heavy grazing has played in the decline of heather-dominated moorlands (e.g. Stevenson and Thompson 1992), whilst areas which retained grouse moor management (and thus managed burning) have shown comparatively small declines compared to other land-uses (Robertson et al. 2001).

Prescribed burning has long been known to influence the behaviour of wild and domestic grazing animals (e.g. Grant and Hunter 1968, Oom et al. 2002) with grazers typically congregating on more recently burnt patches. Where the relationship between area burnt and stocking rates is out of balance this can lead to heavy grazing pressure in the years following burning and the loss of heather cover. Overstocking in general, poorly timed grazing, and burning vegetation that is either too young for the heather to have recovered after the last fire or too old for the heather to resprout can also precipitate heather loss (Anderson and Yalden 1981, Hobbs and Gimingham 1987). Significant variation can exist within and between regional fire regimes, as well as between different types of fire, such as managed burns versus wildfires (Davies et al. 2016), and even within individual prescribed fires (Davies et al. 2010). It would thus be a simplification to argue that fire, or any other disturbance, is "good" or "bad" – one has to consider it in relation to the character of the wider disturbance regime and the ecological functions or features of concern.

2. The ecological value of moorland landscapes

Monbiot clearly has strong views about what ecosystems are appropriate for the British uplands and he has been at the forefront of the nascent "rewilding" movement in the UK (Monbiot 2014a). Some of his ideas have gained a sympathetic hearing amongst

the authors here. Monbiot, however, suggests that we failed to engage with this wider debate about whether anthropogenic ecosystems, such as peatlands and heathlands, are "right" for our uplands. In his comment on our paper, and in previous writings (e.g. Monbiot 2013a, Monbiot 2013b, Monbiot 2014b, Monbiot 2015), he has questioned the ecological value of anthropogenically-derived ecosystems in general, and heathlands and peatlands specifically, in rather strong terms. Many of his contributions mix political and ecological issues in a manner we suggested in our paper was unhelpful when trying to discern the ecological effects of fire. He suggests that we started from an assumption that current conservation priorities, including statutory designation of large areas of heathland, are correct. There are undoubtedly strong arguments to be made for increasing forest and woodland cover in the British Uplands (e.g. Thomas et al. 2015), but it would be incorrect to suggest that heathlands and peatlands hold no or little ecological value, or that one has to choose between these ecosystems and forests at a national or landscape scale. Heathland and bog ecosystems have statutory conservation recognition not just in the UK but in many other regions of Europe (European Commission 2013). The report by Van der Waal et al. (2011) highlights the diverse array of provisioning, regulating and cultural ecosystem services provided by upland and heathland ecosystems in the UK. Douglas et al. (2015) pointed to the overlap between designated areas in the UK uplands and areas with a history of managed burning activity, which, in our view, highlights the role historic management has played in creating some features of conservation importance. Whether current management regimes are appropriate for maintaining the range of ecosystem services that are now desired from upland landscapes is an open question. In our paper we pointed to the fact that several other countries in Europe are actively seeking to reintroduce burning and/or grazing to protect and restore similar habitats in the absence of grouse moor management or any economic incentive from agricultural use (e.g. Keienburg and Prüter 2004, Vandvik et al. 2005, Ascoli et al. 2009). Many ecologists recognize the importance of management for early-successional habitats such as shrublands even in otherwise forested landscapes and in the face of public skepticism about their value (e.g. Askins 2001). Nevertheless, there is considerable debate about the use of fire as a management tool on moorlands and peat bogs even amongst those who believe these habitats are worthy of conservation protection.

3. Species, habitat and ecosystem diversity – the importance of scale

We would agree with previous authors (e.g. Levin 1992, Legg 1995) that management needs to consider the importance of scale in ecology and conservation, and to think about ecological processes and diversity across multiple taxonomic, spatial and temporal scales. This is particularly true when considering the effects of disturbances such as fire or grazing. Ecological responses to management vary across spatial and temporal scales including both between and within landscapes. For example, looking at the short-term effects of grazing removal on upland grasslands has shown initial declines

in species richness in some locations, but the effects were different at higher elevations where species diversity increased when stock was removed (Davies and Bodart 2015). Scale is critical here - if Davies and Bodart had been able to consider longer timescales of decades or centuries, rather than years, and a wider range of bioclimatic settings, their conclusions might have been different (Bakker et al. 2009). Unfortunately long-term and large-scale studies are in woefully short supply.

Contrary to what Monbiot (2016a) appears to suggest, it is simplistic to assume that one can choose the "right" ecosystem simply by counting the number of species a particular habitat contains (Fleishman et al. 2006). Monbiot's point that birch and pinewoods in the Cairngorms contain a wonderful diversity of species is certainly true (Shaw and Thompson 2006), though few of these are particularly rare internationally (exceptions would include endemics such as the Scottish crossbill, *Loxia scotica*). However, patch-scale (alpha) species diversity is not the only metric by which ecologists evaluate ecosystems. Diversity occurs at a variety of scales of organization and includes, in addition to the local species richness, the diversity of communities and habitats at landscape scales (e.g. Peterson et al. 1998), the diversity of ecosystems globally, as well as genetic diversity within species (e.g. Rao and Hodgkin 2002, Secretariat of the Convention on Biological Diversity 2005). Species diversity responses to management can often be rather specific. For example the response of species richness to birch colonization of moorland (as might occur during "rewilding") depends upon which species group one considers – plant species richness has been shown to decline but the diversity of *Collembola* and mites increased in the same study (Mitchell et al. 2007). The heterogeneity in habitat structure associated with burning can have important effects. For example in the study by Bargmann et al. (2016), variation in the composition of invertebrate communities meant traditional burning practices increased diversity of this group at the landscape scale. Davies and Legg (2008) found similar effects for lichen species and Velle et al. (2014) for vascular plants.

Diversity in species composition and ecosystem function is just as important as species diversity when making ecological management decisions. Temperate peatlands, including heathlands, moorlands and blanket bogs, are extremely rare in European and global terms and there have been dramatic losses in recent decades (e.g. Blackstock et al. 1995, Robertson et al. 2001). These ecosystems support important functions including carbon storage and sequestration, particularly in blanket bogs (Ostle et al. 2009), and the provision of habitat for internationally important populations of breeding birds (e.g. Stillman and Brown 1994, Thompson et al. 1995). Many of these species, such as golden plover (*Pluvialis apricaria*), lapwing (*Vanellus vanellus*), oystercatcher (*Haematopus ostralegus*), wheatear (*Oenanthe oenanthe*), red grouse (*Lagopus lagopus scotica*), golden eagle (*Aquila chrysaetos*), merlin (*Falco columbarius*) and hen harrier (*Circus cyaneus*) would likely be displaced by conversion to woodland or forest. With regard to ecosystem function, relationships with land management and vegetation structure can also be complex. For instance, shrub and tree encroachment of bogs can presage fundamental changes in their carbon balance (Walker et al. 2016) and changes to land-surface albedo means the climate change implications of forest regeneration can be complex (de Wit et al. 2014).

Making decisions about land-management in anthropogenic landscapes

We of course do not suggest the above points make grouse moors, moorlands in general, or blanket bogs the "right" ecosystem for all of the uplands. However, we know of few ecologists involved in upland management who would not agree that such ecosystems have ecological value, harbor unique species assemblages and should form part of a structurally diverse, holistically-managed landscape. Managers and policy-makers need to be aware of the inevitable trade-offs involved in management change. None of this prevents, or argues against the desirability of, alterations to "traditional" fire use strategies, woodland restoration or even "rewilding" in some parts of the uplands. In some situations win-wins may exist in addition to trade-offs. For example, in a recently published study, Gao et al. (2016) showed that restoring riparian woodland cover in peatland catchments could have important benefits for flood management. Protecting riparian corridors from fire might also mitigate some of the potential impacts of burning on aquatic ecosystems described by Rachmunder et al. (2013). The suggestion that a choice must be made between "rewilding", restoration, moorland (traditionally-managed or not), or peatlands is therefore artificial as there is significant room for a diversity of upland ecosystems some of which are presently more abundant than others. The idea that a choice must be made between natural and managed landscapes is also illogical. Disagreements about the status and value of anthropogenically-derived landscapes, such as heathlands and peatlands, may stem from differences in philosophical position regarding humans' place in the "natural world" and a desire to see naturalness as a simple binary concept rather than as a complex gradient (e.g. Machado 2004, Anderson 2005). Whatever management decisions are made in the British uplands, the resulting ecosystems will never be truly "natural", if the term is intended as "not affected by anthropogenic activities". Even in the absence of active management, our landscapes and their species pools have developed under millennia of human impacts on both biotic and abiotic conditions. Our landscapes' Anthropocene future includes biota, biogeochemical cycles, and climates heavily affected by human activities. Challenges for ecosystem management therefore include: i) understanding how species assemblages and ecosystem services are distributed along gradients of naturalness in order to protect and value the full range of ecological diversity; ii) ensuring that the diversity of human socio-cultural perceptions and priorities are reflected in management decision making; and iii) taking an Adaptive Management approach and monitoring ecosystem dynamics so that development along suitable trajectories can be ensured. The assumption that one can reintroduce species, particularly those that have been missing over evolutionary timescales, and necessarily see a "natural" ecosystem state unfold is simplistic, something Monbiot himself seems aware of (Sahn 2014). Again, this does not argue against the potential desirability of woodland restoration or "rewilding", but management decision-making should be based on ecological knowledge gained through a rigorous application of Adaptive Management.

Finding the right balance between different habitats, such as woodland and moorland, whilst maintaining or enhancing habitat connectivity and minimizing fragmentation will

require landscape-scale approaches to management. We agree with Wynne-Jones (2016), that this in turn requires trust and collaboration between diverse land-owning groups, interest groups, and individuals in making use of the best available evidence of the ecological trade-offs involved. Getting buy-in for management change requires shared knowledge and understanding of the evidence. The right balance between different ecosystems is not for us or any one person or interest to decide. It is an ecological, economic, philosophical and aesthetic decision that needs to be made by society as a whole, respecting the differing stakes and legal rights that people have in these landscapes.

Monbiot (2014a) takes one particular view about what the priorities for future landscape management should be. In his comment on our paper he questions the legitimacy of heathland and peatlands landscapes seeing them as a "reflection of cultural hegemony", which favours particular interests such as grouse moor owners (Monbiot 2016a). His ecological priorities thus appear to be at least partly politically-motivated – in our paper we specifically requested people to try to set politics aside when discussing ecosystem dynamics. That does not mean that politics and socio-economics cannot play a role in determining land-management priorities, indeed they are vital components of the socio-ecological system that needs be understood and managed in order to gain desired outcomes (Figure 1). We do however suggest that when specifically discussing ecological dynamics one should try to exercise a degree of self-awareness regarding one's inherent biases, and try and minimize the extent to which they influence interpretation of environmental data. Contrary to Monbiot's views we would argue that the fact that peatlands are cultural landscapes (*sensu* Birks et al. 2004) does not mean they are a reflection of the current culture and its associated forms of land-ownership and management. This is merely the latest (and in ecological terms fairly recent) phase in their history and evolution. The classic text by the eminent Charles Gimingham (Gimingham 1972) and the excellent volume by Ian Simmons (Simmons 2003) highlight the long (pre)history of heaths, moors and bogs in the UK. These systems are a reflection of millennia of post-glacial human modifications and climatic changes, extend along the Atlantic regions of Europe from Portugal to northern Norway, and are not simply the outcome of 19th century style grouse shooting in the UK. These are ecosystems in which species have had long enough to evolve to disturbance by fire (Vandvik et al. 2014), and they are a function of the sum total of human management and culture over the last several thousand years.

Where there is a desire to move away from existing land-uses such as grouse moor management and driven grouse shooting, trade-offs between the benefits and dis-benefits of the 'old' and 'new' forms of management need to be considered. This will need to include acknowledgement that, whatever one's view about hunting or the wider aspects of moorland management, the significant private financial investment required for any form of ecosystem management or restoration will need to be accounted for (Robertson et al. 2001, Tharme et al. 2001, Sotherton et al. 2009). We suggest that collaborative, inclusive and balanced approaches to landscape scale planning and eco-

system management will minimize conflicts and more successfully leverage the human and financial resources of heathland and peatland stakeholders. Ecological management tools, such as fire, can be used to achieve a diversity of objectives. However, as previous publications have argued (e.g. Davies et al. 2006, Penman et al. 2009), fire use should be ecologically based, bounded by clear objectives and utilized under an Adaptive Framework.

The need for informed, critical, and respectful debate remains

As we stated in our paper, we believe that the current tone of the debate about the use of fire as a management tool is overly simplistic. This is highlighted by the controversy that surrounded the pre-publication release of our paper, with several newspapers and organisations using it as an opportunity to selectively quote us in an attempt to further their own agendas – something we had specifically critiqued in our paper. The involvement of a Public Relations agency, for which YFTB appears to be a "front organization" (*sensu* Smith and Malone 2006, Beder 2014), was particularly troubling as YFTB appears to have been developed for the specific purpose of criticizing the RSPB. We do not believe using PR agencies is an appropriate approach for unbiased dissemination of scientific research nor should research be used as an opportunity to further agendas or propagate conflict.

These behaviours are symptomatic of a lack of respect between different stakeholders at the more extreme ends of the upland management debate and we would urge that further discussion takes place without resorting to language or accusations that could cause offence. Monbiot (2016a) suggested that in our paper we did not engage properly with the article of his we cited because we focused our critique on his title "Meet the conservationists who believe that burning is good for wildlife" and strapline "Our national park authorities are vandals and fabulists, inflicting mass destruction on wildlife and habitats, then calling it conservation". The relevant section of our paper was specifically focused on the need for constructive debate (it was not about the conservation implications of current or potential future management). We do not think it is unreasonable to suggest that Monbiot's headline and strapline may have caused offence to dedicated conservationists and land-managers and may not have been particularly effective in promoting a balanced, evidence-based debate. Likewise we were disappointed that the title of Monbiot's comment on our work, "Bonfire of the verities" (Monbiot 2016a), could be taken to suggest that we were somehow being dishonest in our paper. We are not alone in making such criticisms of some of his writing (Wynne-Jones 2016), though Monbiot has previously emphasized the need for inclusivity and presented his ideas with greater nuance (Stahn 2014). The need to be respectful does not mean it is not legitimate to critique and debate relevant contributions to the scientific or popular press, we just need to do so with a greater degree of respect for differing perspectives.

Conclusion – ecological, participatory, adaptive fire management

We actually think that we and Monbiot are arguing at cross purposes (Figure 1) – whilst his original article was a somewhat politically-motivated higher-level critique of heathland as a valid target for conservation, and therefore of fire as an effective means to manage the landscape, we were concerned with understanding the complex ecosystem effects of fire. In a heated debate like the one surrounding the use of fire as a management tool, it is essential for science communication to be based on facts and data, not emotions and politics. Ironically, both those opposed to burning (seemingly in general, not just in current forms), and those defending intensive grouse moor management practice (such as that can be generalized), have sought to portray our work as defending the *status quo* – something that was never our intention. Instead, we continue to argue for an ecological approach to the use of fire that is based on Adaptive Management principles, scientific evidence, and a clear understanding or hypothesis about how fire can be used to achieve specific aims. In our view, not only is the current debate unconstructive, it is also illogical – debating whether fire has either "benefits" or "impacts" is pointless as it has both, depending on the spatial and temporal scales and ecological values and ecosystem services one considers. As Reed et al. (2013) have already pointed out, we need to move towards an evidence-based assessment of the trade-offs inherent in different management regimes and mechanisms to promote participatory, landscape-scale prioritization of land use.

Unfortunately, the effect of fire on moorland and blanket bog ecosystems is likely to remain a topic of debate well into the future as its knowledge base is still far from adequate and managers are not in the position to make informed trade-offs. For instance, there is poor understanding of the complex interactions between different disturbances (such as fire, grazing, drainage, and nutrient deposition) on carbon cycling, vegetation dynamics, and wildlife habitat utilization, but management decisions have to be made nonetheless. In doing so it is vital that none of us are parochial about the evidence we use and that we do not cherry pick studies which support our own positions.

Many valuable ecosystems owe their structure, function and conservation value to human manipulation of fire regimes (Bowman et al. 2011). Nevertheless, globally, the use of fire as a management tool is not without debate and seeing ecosystems burning arouses strong emotions (e.g. Ryan et al. 2013). Understanding what makes people so passionate about the use (or not) of fire is important (McCaffrey 2006) as there is recognition that, just like conservation grazing (e.g. Plassmann et al. 2010), fire is a valuable part of the ecosystem manager's toolkit (see, for example, Russell-Smith and Thornton 2013 and references therein). Where there is conflict over management it is vital that an Adaptive Management approach is followed (Holling 1978). This emphasizes the importance of monitoring the effects of management and adapting to achieve desired outcomes rather than just ploughing on with traditional approaches, or making wholesale changes, without evidence for the benefits. Crucially, Adaptive Management also stresses the importance of constructive engagement with all stakeholders

and that all stakeholders buy into the principle of evidence-based management. The successful "Bogathon" events organized by the Moorland Association and the Heather Trust in cooperation with Natural England and others are an important example of the positive outcomes of collaboration and cross-sector cooperation (Moorland Association 2015; Natural England 2015). Everybody is entitled to hold strong views and preferences for certain ecosystems on the basis of aesthetics, emotional response, or political outlooks. At the same time, biodiversity and ecosystems are also regulated by national and international regulations and conventions, that mean managers are not completely free to choose which habitats to conserve, restore, or even create in UK landscapes. Once a decision about the conservation or restoration target for a particular area is made, there is a critical need to understand the ecological processes operating in the systems in order to make sound management decisions. We would suggest that it is possible for people from the diverse array of upland interest groups, and those with differing opinions and priorities, to engage in the important debates about the future of ecosystems without insulting each other. Afterall, a key positive conclusion that can be drawn from these exchanges is that we all care passionately about the future of these landscapes.

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