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ORIGINAL PAPER

Recreationist behaviour in forests and the disturbance of wildlife

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Abstract Forests are popular locations for outdoor recreation and there is considerable evidence highlighting the positive social impacts of these activities. There is also a body of research outlining the range of potentially negative impacts of recreation on wildlife and habitats. This paper provides a summary of current social and natural scientific knowledge on disturbance caused by walking, cycling, mountain biking, horse riding, off-road vehicles use, camping, and some other recreational activities in forests. We identify more than 40 ecological studies of recreational impacts on forests. Greatest attention has been directed towards walking as an activity and the impacts upon birds, soils and flora although long-term ecological studies of wildlife or habitat disturbance are scarce. Impacts include trampling by foot, hoof and tyre, animal behaviour change and the spread of pests and pathogens. Considerably less work has been carried out on the social dimensions of recreational disturbance. In this article the authors draw on behaviour theory in an attempt to identify the key factors influencing human behaviour in the context of recreational disturbance. Cognitive theories highlight the importance of attitudes and behavioural control, whilst social practice theories emphasise the impact of behavioural routines and contexts. Management actions may be better targeted at promoting alternative behaviours rather than trying to prevent current 'problem' behaviours. We advocate greater engagement with these theories to better integrate social science with ecological studies, and improve understanding and management of interactions between recreation needs and conservation.

Keywords Recreation · Forests · Wildlife · Disturbance · Management · Integrated approach

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Introduction

Forests are popular settings for recreation with activities ranging from walking, mountain biking and horse riding to driving off-road vehicles and camping (Sun and Walsh 1998; Heer et al. 2003). While recreating in forests provides significant health and well-being benefits to individuals and society (O'Brien 2005; O'Brien and Snowdon 2007; Nilsson et al. 2011), the ecological impacts resulting from the pursuit of outdoor recreation activities are widely perceived as a significant threat to the integrity of those ecosystems in which they occur (Liddle 1997; Newsome et al. 2002; Young et al. 2005; Guillemain et al. 2007; Pickering 2010). Considerable evidence now illustrates these impacts and is the basis of a whole sub-discipline: recreation ecology. This evidence focuses primarily on the 'disturbance' of wild species and systems by physical phenomena such as 'trampling' (by foot, hoof, or tyre), noise and pollution, and has led to the development of site specific management frameworks for impact mitigation, such as the limits to acceptable change (LAC) system (Stankey et al. 1985, see also Cole et al. 1987).

The analysis and management of human–wildlife interactions such as those relating to recreation demand a focus on both humans and wildlife if they are to be effective as well as socially acceptable (Baruch-Mordo et al. 2009; Decker et al. 2009). Frameworks such as the LAC system provide useful guidance but are limited by an over-riding focus on interventions aiming to affect behaviour on-site. Whilst considerable effort has been put into parallel needs such as, for example, the design and implementation of 'conservation education' (e.g. Jacobson et al. 2006), social scientific analysis of the relationships between outdoor recreation and wildlife or habitat disturbance is limited. Even rarer is an integrated ecological and social approach to the analysis of recreational disturbance.

One consequence of focusing on ecological disturbance and affecting behaviour on-site is that broad social drivers (beyond the site) that determine when, where and why wildlife disturbance occurs are missed from the analysis. The challenges of understanding human values, attitudes and behaviour, and identifying appropriate mechanisms and interventions to influence these are widely acknowledged in the social sciences. There is a growing body of work seeking to understand human behaviour, with much of it emanating from the disciplines of psychology and sociology focusing on behaviours relating to health, transport and consumption. Recently there has been considerable interest from government and researchers in pro-environmental behaviours and how knowledge can be linked to support for certain behaviours (e.g. Darnton et al. 2006; Barr 2007; DEFRA 2008; Lucas et al. 2008; Kollmuss and Agyeman 2002). Findings from this work can be of relevance to outdoor recreation and theories and models of human behaviour may be particularly useful for guiding management responses to wildlife and habitat disturbance. Behaviour may, for example, be affected by how recreational users perceive their own and others' impacts on habitats and wildlife. Social norms, and/or other aspects of governance (formal or informal) can also structure behaviour (Newhouse 1990; Kollmuss and Agyeman 2002).

Forest managers face the difficult task of balancing the delivery of social and economic benefits with conservation requirements and priorities (Sun and Walsh 1998; Kazmierow et al. 2000; Kearsley 2000; Pickering 2010). The authors held two consultation workshops (2009) attended by 36 public sector forestry professionals to identify emerging research needs around human–wildlife interactions in state owned forests in the UK although the outcomes also have relevance for private sector forests. Attendees expressed a need for a synthesis of relevant information on recreational disturbance due to the prominence given to the public goods of biodiversity and societal wellbeing in UK and debates over whether recreational activities actually do have significant negative impacts for forests and wildlife.

In the absence of much information on the social dimensions of recreation and wildlife disturbance, we conducted a broad literature review to summarise and assess current knowledge (Marzano and Dandy 2012). Our objective was to identify relevant literature from both natural and social science studies and provide the evidence in an integrated fashion. In this paper we present a summary of our key findings, identifying a severe lack of social scientific study and resultant knowledge gaps. We then seek to progress an integrated analysis by discussing how current insights from behaviour change and pro-environmental behaviour literature can be applied to support the management of recreational disturbance in woodlands and forests.

Methods

We followed the principles of a standard approach for conducting literature reviews as established in the methodological literature (e.g. Hart 1998). At a basic level, the process consists of searching for and identifying relevant literature, reviewing identified material and providing a synthesis and summary of its main components. We searched a number of bibliographic databases—Web of Science, Google scholar, Science Direct (Elsevier), CABE, tandfonline.com (Taylor and Francis), and Springer Link (Springer) to identify articles that contain key words or phrases focused around outdoor activities that take place in forests (see Table 1).

Further to this we checked our own existing EndNote databases. Our search phase also included consultation with key staff in forestry sector organisations in order to identify unpublished evidence but much of the evidence collected was from peer-reviewed

Table 1 Search terms

Search term	And
Wildlife/recreational disturbance/forests/	Forests
	Forest roads
	Dog walking
	Cycling
	Skiing
	Bird watching
	Hunting
	Biodiversity
	Fishing
	Boating
	Off-road vehicles
	Quad biking
	Car rallies
	Motocross
	Outdoor concerts
	Walking
	Camping
	Berry/NTFP collecting
Wildlife	Visitor behaviour
	Rope trails
	Human values
	Visitor management
Outdoor concerts	Noise

published literature. Subsequent to cataloguing this initial evidence, further literature was identified from the citations and references of these texts.

In contrast to other reviews in this field our approach was to structure our searches and analysis in reference to recreational activities and their reported impacts, rather than around defined species, habitat or taxa. Studies focused on 'human disturbance' by harvesting or other forestry operations were excluded from this review. Where activities were considered to be comparable to recreation (such as scientific 'investigator' disturbance on foot, which was considered similar to walking or hiking), these studies were included. Consequently the starting point for our analysis was human behaviour, an approach via which we were able to more readily identify both socio-economic drivers of disturbance and ecological impacts. We also sought to identify management recommendations within the ecological studies.

Although the review was conducted primarily for application in advising public managers of woodlands and forests in the United Kingdom, we drew relevant evidence from many other areas such as Europe, the United States and Australia and report this broader set of evidence here. We limited our searches for primary research to contemporary work, that is material published from 1990 to 2010, consulting previous reviews (such as Anderson and Radford 1992; Knight and Cole 1995; Leung and Marion 2004; Taylor et al. 2005) to access evidence published prior to this period. Subsequent to initial reviewing some older references were included, particularly if highly cited. Evidence was collated into a reference database (using EndNote X software).

Results

Reported disturbance of wildlife by recreation

Our search identified more than 450 social and natural science publications relating to the disturbance of wildlife by walking, mountain-biking, horse-riding, vehicle-use, camping, nature-watching and other recreational activities. The review documented the available evidence on the ecological impacts of recreational activities in forests; totalling more than 40 studies (although primary research in the UK, our initial focus, is very sparse). Within this literature some studies provide brief recommendations for management actions such as physical, spatial and temporal barriers and visitor education. Table 2 lists these ecological studies.

Published evidence reports that recreational activities in woodlands and forests can have both direct and indirect impacts on wildlife. Direct impacts include behaviour modification such as 'flight' responses and altered habitat use which impact on foraging and reproduction. Indirect impacts include habitat change, for example, soil compaction, erosion and the potential introduction of pests, pathogens and weeds (Taylor and Knight 2003; George and Crooks 2006; Knight and Cole 1995). A very large proportion of the evidence (22 out of 45 of the studies on forests, see Table 1) relates to walking (including with dogs). Also considerably more attention has been given to impacts on soils and flora (17 out of 45 studies) and birdlife (12 out of 45 studies) than other elements of forest ecosystems. This bias is a reflection of the wider literature in this field of study which also features substantial material on the disturbance associated with boating which has not been analysed here due to its limited relevance in forest settings. A surprisingly high number of studies in forests have been conducted in urban contexts (18 out of 45 studies). This is in contrast to

Table 2 Studies of the ecological impacts of recreational activities in forests

	Species	Habitat	Location	Author–date
Walking—hiking—trampling—foot				
1	Birds	Urban fringe forest	Australia	Banks and Bryant (2007)
2	Birds (*Pica pica*; *Turdus merula*; *Sturnus unicolor*; *Columba palumbus*)	Urban forest park	Spain	Fernandez-Juricic (2000)
3	Birds	Forest national park Comparative (walking—climbing)	Croatia	Lukac and Hrsak (2005)
4	Birds (*Cardinalis cardinalis*)	Riparian forests	United States	Smith-Castro and Rodewald (2010)
5	Birds (*Tetrao urogallus*)	Mountain forest	Germany and France	Thiel et al. (2007)
6	Birds (*Aguila chrysaetos*)	Various	Scotland	Whitfield et al. (2007)
7	Flora; soil	National forest park	China	Deng et al. (2003)
8	Flora; soil	Urban forest	Switzerland	Kissling et al. (2009)
9	Flora; soil	Urban forest	United Kingdom	Littlemore and Barker (2001)
10	Flora; soil	Deciduous forest comparative (walking—cycling)	Canada	Thurston and Reader (2001)
11	Ground flora (*Myrtillus*)	Urban forest	Finland	Hamberg et al. (2008)
12	Flora (e.g. graminoid; dwarf-shrub)	Forest and heath	Belgium	Roovers et al. (2004)
13	Flora (*Anemone nemorosa*)	Urban Forest	Switzerland	Rusterholz et al. (2009)
14	Flora	Forest. Comparative (walking—horse riding—skiing)	Finland	Torn et al. (2009)
15	Flora (*Fagus sylvatica*)	Urban fringe forest	Switzerland	Waltert et al. (2002)
16	Soil	Deciduous forest	Turkey	Serengil and Ozhan (2006)
17	Macrofauna (soil organisms)	Mangrove forest	Australia	Ross (2006)
18	Beetles (*Coleoptera*; *Carabidae*)	Urban forest	Finland	Grandchamp et al. (2000)
19	Beetles (*Carabid*)	Urban forest	Finland	Lehvavirta et al. (2006)
20	Salamanders	Forest nature preserve	Georgia	Davis (2007)

Table 2 continued

	Species	Habitat	Location	Author–date
21	Mammals; birds; reptiles; amphibians	Urban forest park	Italy	Ficetola et al. (2007)
22	Pathogen (*Phytophthora ramorum*)	Forest landscape	United States	Cushman and Meentemeyer (2008)
Cycling—mountain-biking				
23	General	Various	United States	Jacoby (1990)
24	General	Urban fringe park	United Kingdom	Geraghty (2000)
Vehicles—off-road—motorcycles				
25	Snakes (*Pituophus melanoleucus*)	Urban forest	United States	Burger et al. (2007)
26	Herpetofauna	Floodplain woodland	United States	Hunkapillar et al. (2009)
27	Marten (*Martes americana*)	Upland forest	United States	Zielinski et al. (2008)
Horse-riding				
28	Flora	Forest	United States	Gower (2008)
29	General.	Urban forest park. Comparative (horse riding—walking—vehicle use)	Australia	Landsberg et al. (2001)
Camping				
30	Flora; soil	Forest	United Kingdom	Johnson and Clark (2000)
31	Flora; soil	Forest national park	Finland	Kangas et al. (2007)
32	Flora; soil	Forest national park	Australia	Smith and Newsome (2002)
General				
33	Birds (*Columba palumbus*; *Passer domesticus*; *Pica pica*; *Turdus merula*)	Urban forest park	Spain	Fernandez-Juricic et al. (2002)
34	Birds (*Parus gambeli*; *Regulus calendula*; *Dendroica coronata*; *Junco hyemalis*)	Subalpine forests	United States	Gutzwiller et al. (1998)
35	Birds (*Perisoreus canadensis*)	Subalpine forest	United States	Gutzwiller et al. (2002)
36	Birds (*Passer domesticus*; *Passer montanus*; *Parus major*). Recreation infrastructure	Urban forest	Spain	Remacha and Delgado (2009)
37	Birds (*Lagopus lagopus*). Recreation infrastructure	Birch and spruce forest	Norway	Støen et al. (2010)

Table 2 continued

	Species	Habitat	Location	Author–date
38	Red squirrel (*Tamiasciurus hudsonicus*)	Forest	United States	Gutzwiller and Riffell (2008)
39	Reindeer	Forest	Finland	Helle and Särkelä (1993)
40	Flora; soil	Forests; various	Australia	Sun and Walsh (1998)
41	Flora	Urban forest	United States	Loeb (1992)
42	General	Urban forests	Czech Republic	Kupka (2006)
43	General	Forests	United Kingdom	Littlemore and Barlow (2005)
44	General	Coniferous and birch forests	Finland and Sweden	Tolvanen et al. (2005)
45	General	Rainforest	Australia	Turton (2005)

the wider literature identified in the review in which protected and 'wilderness' areas feature prominently.

The breadth of possible impacts is illustrated by Buckley (2004) who highlights how wildlife and habitats may be modified through "tracks and trails; barriers; campsites and lodges; new sounds and smells; fire and weeds; provision or removal of food and water sources; and provision, removal or damage to refuges and breeding sites" (p. 212). Plants, plant communities and soils can be impacted by trampling; vulnerability to pests and diseases; vegetation damage and abrasion; reductions in ground vegetation cover, plant growth, regeneration and species richness and density; erosion; soil removal and compaction. Animal behavioural responses to recreational disturbance can include flight (anti-predator response), displacement, avoidance and other behaviour change (e.g. food conditioning). Some authors suggest that mortality may also occur through high speed recreational activities, including those involving vehicles (Lathrop 2003; Taylor and Knight 2003; Buckley 2004; George and Crooks 2006; Burger et al. 2007). All recreational activities have the potential to bring about some or all of the impacts described above. Here we provide a summary of our findings from the natural science literature under three broad categories: (i) habitat change, (ii) behaviour change, and (iii) introduction of invasive species, pests or diseases.

Habitat change

Recreation can cause forest habitat change in a number of inter-related ways including soil compaction; soil erosion; decreased biodiversity; habitat fragmentation; vegetation change; and canopy loss. A number of activities are implicated in these impacts such as walking, horse-riding, mountain-biking, camping and the use of off-road-vehicles (ORVs).

The impacts of trampling on soils and vegetation are a key feature of many studies of recreational impacts (Littlemore and Barker 2001; Cole 2004; Kissling et al. 2009). Walking and hiking are amongst the most frequent and popular recreational activities conducted in woodlands and forests and trampling through walkers' footfall can impact on habitats. Cole (2004) notes that the majority of studies in recreational ecology focused on hiking and camping, particularly in relation to changes to vegetation and soils. Camping-related impacts on habitats can occur through intensive use (Jim 1987) although in fragile habitats relatively low levels of use can also cause significant damage (Cole and Monz 2003; Leung and Marion 2004). One case study in the New Forest, UK, recorded the consequences of recreational use, particularly camping, over a 28 year period during the latter half of the twentieth century. Impacts included a reduction in canopy cover through loss of mature trees and decreasing biodiversity such as lichens and other flora due to an increase in built infrastructure and ground disturbance (Cox and Rose in Johnson and Clark 2000, p. 98).

Horse riding has been associated with heavy trampling of vegetation and soils (Weaver and Dale 1978; Landsberg et al. 2001; Littlemore and Barlow 2005). Citing Littlemore, Littlemore and Barlow (2005, p. 278) report that "heavy trampling can severely reduce the population densities of soil and litter dwelling invertebrates by up to 89 % in path centres and by 57 % at path margins when compared to undisturbed soil profiles". Trampling impacts can be compounded by the use of shortcuts or veering off the trail to avoid obstructions such as fallen trees (Landsberg et al. 2001). In some urban forests, mountain biking has overtaken walking as the main recreational activity and the associated increase in mobility extends the area of forest under intense use furthering impacts through erosion of trails, trampling of vegetation and plant life and compacted soil (Jacoby 1990; Geraghty

2000; Thurston and Reader 2001; Heer et al. 2003; White et al. 2006; McEvoy et al. 2008). Sporting activities such as orienteering can also lead to the creation of new paths and the trampling of flora if the race is not properly managed (Littlemore and Barlow 2005; Bouchet and Bouhaouala 2007). Other activities such as paintballing have been shown to damage trees and contribute to soil compaction and erosion (Webster and Adams 1989; Hatton 1991; Littlemore and Barlow 2005). There are few studies on the impacts of off-road-vehicles (ORV) in forest settings (Buckley 2004). However, those available do show that, in addition to trampling and soil erosion, tracks left by ORVs can lead to habitat fragmentation impeding the movement of some species of small mammals, amphibians and invertebrates (Buckley 2004).

Reported impacts are not always negative and there are few studies on positive impacts. For example, one study on salamander distribution identified a positive relationship between trail presence and species success through the creation of more micro habitats (Davis 2007, p. 385). Furthermore, recreational disturbance may deter nest predation, which could improve survival of vulnerable species (Ibanez-Alamo and Soler 2010).

Animal behaviour change

Changes to the normal behaviour of wild fauna are another set of impacts that can result from recreational use of forests. These can include increased alertness, 'flight' (anti-predator response), food conditioning, displacement from or avoidance of favoured habitat, and habituation to people. The central concern in relation to flight and increased alertness is that disturbance can cause animals to flee from cover or nests—impacting on their energy balances, feeding behaviour and the vulnerability of young, eggs or fledglings. As with habitat change, several types of recreation have been shown to affect animal behaviour including mountain-biking, vehicle use, wildlife-watching and other forest activities such as paintballing and orienteering. Karp and Guevara (2011) show that even average levels of conversational noise can have an impact. However, most widely reported is the disturbance caused by walking, including with dogs.

Woods and forests are extremely popular places for dog walking. Within the walking literature there is a strong focus on the disturbance of birds, with less research on other animal groups. Much of this research has concentrated on flight responses of waterbirds in non-forest environments (Dahlgren and Korschgen 1992; Fox and Madsen 1997; Carney and Sydeman 1999; Nisbet 2000; Rasmussen and Simpson 2010). Walkers have been shown to disturb forest birds (Fernandez-Juricic et al. 2002; Smith-Castro and Rodewald 2010) with related impacts on breeding and habitat use (Fernandez-Juricic 2000). Having said this, these studies show that the vertical structure of forest vegetation reduces disturbance significantly. Studies of capercaillie (*Tetrao urogallus*) highlight avoidance of woodland areas near tracks used by recreationalists potentially reducing woodland 'carrying capacity' (Summers et al. 2004, 2007; Thiel et al. 2011). The impact of walkers accompanied by dogs has received widespread attention (for a review Taylor et al. 2005), but again this is primarily in relation to ground nesting birds in heath (Langston et al. 2007). A study of 90 peri-urban woodlands north of Sydney, Australia identified a substantial, although seemingly short-term, impact of dogs on native ground nesting birds (Banks and Bryant 2007).

Studies of non-bird species indicate only limited disturbance. For example, in one study in the UK, wild roe deer *Capreolus capreolus* did not flee from, or otherwise change their behaviour, when disturbed by a night-time ecological survey. But they were found to avoid footpaths and roads even at night when human activity is very low (Ward et al. 2004).

A US study reported that walking off-trail and walkers accompanied by a dog impacted flush distance, alert distance and distance moved by mule deer *Odocoileus hemionus* (Taylor and Knight 2003). George and Crooks (2006) show significant displacement of a number of mammal species in response to walkers (including with dogs) and bikers. However, other studies on birds (e.g. Baines and Richardson 2007; Picozzi 1971; Newton et al. 1981; Gutzwiller et al. 1998), deer (Langbein and Putman 1992; Recarte et al. 1998) and red squirrels (Gutzwiller and Riffell 2008), suggest that, generally, walking as a recreational activity does not have significant long term impacts on animal behaviour.

Studies on mountain biking indicate that this form of recreation can disturb wildlife (Cessford 1995; Taylor and Knight 2003; George and Crooks 2006; Naylor et al. 2009). For example, mountain biking intensified alert and flight responses and increased travel time for elk *Cervus elaphus* (Naylor et al. 2009). However, evidence of long term negative impacts on behaviour are limited. A study on the golden cheeked warbler *Dendroica chrysoparia*, for example, reported no impacts from mountain biking—a new activity in the area—on territory density, return rates or age structure of the bird population (Stake 2000). Fast moving activities such as orienteering and paintballing also have the potential to disturb wildlife (Webster and Adams 1989; Hatton 1991; Littlemore and Barlow 2005; Bouchet and Bouhaouala 2007).

Disturbance from vehicle noise can lead to increased energy consumption through alert and flight responses and displacement into less favourable areas, potentially increasing the risk of predation (Buckley 2004; Blanc et al. 2006; Lemelin and Wiersma 2007). For example, major one-off forest events such as car rallies can result in nest abandonment (RSPB 1997 in Littlemore and Barlow 2005). Further disturbance stems from people approaching animals for viewing, photographing and/or feeding (Valentine and Birtles 2004; Green and Giese 2004; Lemelin and Wiersma 2007). This may result in the habituation of wildlife to humans leaving them vulnerable to predators. The literature also highlights the problems of wildlife attraction to food sources left by people on camping grounds (Liddle 1997). As Marion et al. (2008) have pointed out, food-conditioned wildlife can suffer nutritionally or populations can reach unnaturally high levels. Human food sources may also lead to aggression towards humans (Marion et al. 2008) and wildlife may abandon territories and move to more exposed recreational sites increasing vulnerability to predators and vehicle collisions.

Introduction of invasive species, pests or pathogens

There is a small amount of evidence relating to recreational activities and the spread of non-native plants, harmful invasive species or pathogens via vehicle and bicycle tyres, walker's boots and through horses' hooves, coat, hair or dung. In their study of hiking trails in California, Cushman and Meentemeyer (2008) found strong associations between human recreational trail use and the spread of *Phytophthora ramorum*. In the tropical forests of Queensland, the spread of weeds and soil pathogens by walkers and vehicles along forest paths has also been identified as a significant environmental impact (Turton 2005). There has been some debate over the extent to which horses are able to transport invasive seeds or pathogens although current evidence suggests they are not a significant vector (Landsberg et al. 2001; Gower 2008; Pickering 2010). The introduction or spread of harmful species, pests or pathogens can be closely linked to habitat change. For example, disturbance of soil through horse riding has been identified as contributing to the establishment of suitable environments for invasive species (Newsome et al. 2002).

Physical factors affecting the degree of disturbance

The evidence shows that the nature and degree, as well as longevity, of disturbance depends on a variety of physical factors. Some species are especially vulnerable to human presence or contact (Newsome et al. 2004). In his review, Cole (2004, p. 55) concludes that frequency of use, type of use (behaviour), season, environmental conditions, and distribution of use are the key physical factors determining the magnitude of disturbance. In an earlier review Hammitt and Cole (1998) subdivide factors affecting impacts into two broad categories: *environmental durability*, which includes characteristics of vegetation, soil, topography and wildlife, and *visitor use*, which is focused around the amount, frequency and distribution of use along with some other user characteristics. Time of day of use is also important (Knight and Cole 1995; Cole and Monz 2003). Soil type (Hammitt and Cole 1998) and climate (Ewert 1991; McEvoy et al. 2008) play a role, while physical features such as the structure and composition of the surrounding habitat and the extent to which animals can take cover in surrounding vegetation have been shown to shape wildlife responses to recreation (Fernandez-Juricic et al. 2001; de Boer et al. 2004; Langston et al. 2007; Marini et al. 2009). The condition of a trail will also influence recreational activities such that a rough surface or debris blocking the trail can lead to recreational users widening or creating new trails (Wimpey and Marion 2010).

Several studies have adopted a comparative approach in attempts to assess the relative degrees of disturbance caused by different recreational activities (Lathrop 2003; Buckley 2004; George and Crooks 2006; Blanc et al. 2006; Sterl et al. 2008; Naylor et al. 2009; Sastre et al. 2009; Weaver and Dale 1978; Ruff and Mellors 1993; Thurston and Reader 2001; Torn et al. 2009). This evidence is, however, difficult to summarise as it is often context specific such that findings will depend on the type of recreational use being compared or will be focused on specific species or habitats.

To summarise, much of the general evidence available on recreational disturbance is concentrated on settings that are particularly sensitive and/or have protected status, although in contrast the forest-related literature reports a number of urban studies. Furthermore we know very little about how the density, composition and structure of forests relate to disturbance caused by recreation (although see Gutzwiller et al. 1998). A major gap is the lack of knowledge about the longevity of impacts caused by recreational disturbance. There are significant difficulties in using short-term studies to predict potential long term effects (Kissling et al. 2009), and some studies in fact report no long-term impacts (e.g. Thurston and Reader 2001; Smith-Castro and Rodewald 2010).

Human behaviour and the disturbance of wildlife

The authors identified very little research relating to the social drivers of wildlife disturbance such as the socio-economic structures, norms and practices which determine when, where and how disturbance by recreational users occurs. Whilst some of these human dimensions have been analysed in closely related areas, such as the impact of norms on wilderness recreation experiences and behaviour (Shelby and Vaske 1991; Shelby et al. 1996; Heywood 2002), the only dimension to have undergone any sustained investigation in the recreational disturbance literature is on perceptions that recreationists have of their (and others') impacts on wildlife. Some studies have investigated whether there is a positive link between participation in outdoor recreation and concern for the environment with research into this relationship beginning in the 1970s (Dunlap and Heffernan 1975;

Geisler et al. 1977). There have been difficulties in gathering evidence to substantiate a strong, direct link but some studies have found that taking part in recreation can increase pro-environmental behaviour such as belonging to an environmental organisation, campaigning for environmental issues or participating in an environmentally friendly activity such as green consumerism (Nord et al. 1998; Bright and Porter 2001; Teisl and O'Brien 2003; Larson et al. 2011). However, there are studies which suggest that despite holding strong conservation values, people can detach concerns about the environment from how they individually behave outdoors (see for example Lemelin and Wiersma 2007). The type of recreational pursuit and preferred places to carry out that activity as well as place attachment are also said to have a bearing on environmental attitudes (Dorwart et al. 2009; Lee 2011).

A few studies have conducted social research with recreationists themselves, focused largely on wildlife, rather than habitats. For example, in a study on recreational disturbance of mammals in a US State Park, Taylor and Knight (2003) surveyed trail users, including hikers, mountain bikers and horse riders, on issues such as whether recreational activities impacted negatively on wildlife and which user group was held most responsible. Another survey (Sterl et al. 2008) carried out in an Austrian urban national park during winter investigated visitors awareness of the potential impacts of their activities on wildlife. These studies found that recreational users can be largely unaware of the consequences of their activities for wildlife, and are likely to hold other user groups responsible for negative impacts (see also Geraghty 2000; Heer et al. 2003; Symmonds et al. 2000; Manning et al. 2004). Taylor and Knight (2003) report that fifty per cent of those surveyed did not believe that recreational activities had any impact on wildlife. Sixty per cent of visitors in Sterl et al's (2008) study held the same view. Reasons for this related mostly to understandings of 'appropriate' behaviour (such as sticking to trails, following prescribed rules and being quiet), although some recreationists simply felt they were not disturbing wildlife if they did not see any (Klein 1993; Sterl et al. 2008; Lemelin and Wiersma 2007). Taylor and Knight (2003) also showed that recreational users underestimated the distance over which wildlife are disturbed (see also Symmonds et al. 2000).

Making use of behaviour theory: insights from cognitive models and social practice theory

There is clearly a significant gap in our understanding of the social dimensions of recreational disturbance. Integrating ecological impact studies with social data on recreationalists' values, attitudes and behaviour may well lead to more effective and socially acceptable management actions (see Taylor and Knight 2003). For example, there has been criticism of managers who provide information on desired behaviour but without identifying what influences behaviour in the first place (Aipanjiguly et al. 2003). However, our review identified few studies of recreational disturbance which draw directly on established behaviour theory to provide analytical guidance or framing and none that relate directly to, or presents primary data from research in, forests.

There are various ways in which human behaviour is conceptualised and studied. The most widespread perspective, based upon social psychological research, focuses on the individual who makes choices about how they behave (a cognitive perspective). They can be influenced to a greater or lesser extent by external factors such as social pressures or economic capability. Another perspective considers behaviour to be a result of the relationships between people, their environments, available technology, and other people. This perspective draws on sociological research and social practice theory.

Some cognitive models have been applied to predict recreationists' behaviour in the outdoors (e.g. Martin and McCurdy 2009; Young and Kent 1985; Bright et al. 1993; Aipanjiguly et al. 2003). The theory of planned behaviour (TPB) (Ajzen 1991) is one of the most widely cited and applied theories adopting the cognitive perspective, and claims that intention is the best predictor of actual behaviour. It posits attitudes towards a behaviour (and its outcomes), subjective norms (that is perceived social pressures), and perceived behavioural control as the three principle determinants of intention.

In terms of attitudes (that is, positive or negative evaluations of the behaviour), this theory suggests that recreational behaviours in a forest setting, such as taking the dog for a walk and letting it off its lead, are carried out because they are perceived positively—that is, as a good thing for the individual and the dog. Indeed, it is likely that dog-owners perceive that providing an opportunity for their dog to run freely, explore natural areas, and even chase wildlife is a good thing contributing to its health and well-being. This presents a significant challenge. As the reduction in wildlife and habitat disturbance may not be seen to benefit an individual directly, there may be less incentive to change behaviour if it is felt to negatively influence the recreational experience. If these behaviours are to change, not only must these positive attitudes be countered, but individuals (e.g. dog-owners, ORV drivers, and mountain-bikers) need to view the alternatives, such as keeping their dog restrained or within a restricted area, positively as well.

The other elements of the TPB such as perceived behavioural control and subjective norms may be critical. Indeed evidence suggests that perceived behavioural control, which describes whether an individual feels they have the capacity to change their behaviour and/or bring about different outcomes through their behaviour, is generally the strongest influence on individual behaviour. For example, many dog-owners may perceive it as beyond their capability to control where their dog roams. If this is the case, then a challenge facing those trying to manage 'problematic' recreational behaviour is to understand wider social expectations and norms relating to specific recreational activities. Individuals and groups also need to know what is considered to be appropriate behaviour (Newhouse 1990; Kollmuss and Agyeman 2002).

Subjective norms are often considered the weakest set of influences in studies using the TPB. Armitage and Conner (2001) suggest that this is primarily a legacy of poor methodology and measurement, and indeed there is some evidence to suggest that social norms do have a significant effect on recreationists behaviour in natural areas (Aipanjiguly et al. 2003). For example, Aipanjiguly et al. (2003) were concerned with understanding the knowledge, attitudes and behaviour of boaters in Florida in relation to manatee (*Trichechus manatus latirostris*) conservation and compliance with speeding restrictions. The authors suggested that theory of reasoned action (the precursor of the TPB) can help to explain and predict behaviours such that target audiences and their beliefs can be incorporated in the design of interventions aimed at changing or maintaining those behaviours. They also highlight that to reinforce or change behaviour, it is necessary to strengthen or change attitudes towards the enactment of that specific behaviour or the subjective/social norms surrounding it. The authors believe that observation of speeding restrictions is controlled by normative influences. They suggest increasing knowledge awareness of boaters and using normative messages highlighting societal opinions (e.g. friends and family, other boaters, law enforcers) around speeding.

Behaviour can also be understood as shared social practice rather than as an outcome of individual choice, as posited by cognitive models such as the TPB. Recent sociological analysis draws heavily on investigations of innovation and technology and focuses on the 'doing' (or 'practice') of behaviours emphasising relationships between people and the

things and ideas that surround them as they go about their 'everyday' lives (Shove et al. 2007; Shove 2010). Practices are reproduced or 'carried' by individuals (Reckwitz 2002) and are made up of an integration of materials (the physical objects which facilitate behaviour), meanings (concepts and understandings which affect when and how behaviour may occur), and procedures (skills that allow certain forms of behaviour) (see Chatterton 2011). Practices are dynamic and evolve as they are done repeatedly. As Hargreaves (2011, p. 84) notes, social practice theory focuses on "how practices form, how they are reproduced, maintained, stabilized, challenged and ultimately killed off; on how practices recruit practitioners to maintain and strengthen them through continued performance, and on how such practitioners may be encouraged to defect to more sustainable practices".

Our review identified no studies of recreational disturbance (or indeed outdoor recreation in general) from a social practice perspective. An examination of dog-walking in forests from this perspective would, however, encompass a diversity of factors analysing the relevant physical aspects of the woodland such as location, paths, car-parks, vegetation, along with, for example, the availability of outdoor clothing that enables many people to walk their dogs in all weathers and all places. It would also consider the construction of meaning around dog-ownership and walking associated with companionship, health and well-being, along with the working patterns and aesthetic and cultural perceptions of woodlands: all contributing to when, where and how this 'problem' behaviour may take place. Such an analysis of behaviour would undoubtedly be complex but by concentrating on the organisation of a mix of social practices that co-exist in daily life, any behaviour change intervention would encompass a broad range of factors that act as influential forces.

It can be extremely challenging to disentangle or draw boundaries around these different factors and identify which ones may be most influential in how people feel about, and engage in, recreational activities. Behaviour theories provide many concepts and ideas which forest managers can utilise when seeking to understand and address the disturbance of wildlife by recreationists. However, some of the concepts provide more feasible and immediate routes to understanding and affecting behaviour than others. The identification of attitudes and behavioural control by cognitive theories suggests the need to focus effort on promoting alternative behaviours as attractive and practical—rather than simply trying to prevent 'problem' behaviours. Such effort should include engagement processes that facilitate strong knowledge exchange between forest managers and a wide range of recreational groups. These could include methods used in other fields, such as demonstration of alternative recreational behaviours, leadership of accompanied activities, visualisation techniques or the use of computer-based models or games, the application of which to recreational behaviours would be novel. Sociological approaches to understanding behaviour such as social practice theory perhaps present a deeper challenge for developing practical methods to influence behaviour. Having said this it also opens up new opportunities to consider how well established forms of engagement can be used. For example, forest planning processes are now very widespread and often involve considerable stakeholder engagement, spatial analysis, and visualisation. Social practice theory enables us to reflect on these processes, their tools, and their outcomes (physical environments) and ask how they contribute to the reproduction of particular behaviours that managers may wish to promote or discourage.

Conclusions

There are significant social benefits attached to recreating outdoors and forests are popular locations for many recreational activities. However, the perception that recreation can

negatively impact on forests is widespread, although evidence of this is only partial and limited in scope and applicability to forest environments. Through our review we have found very significant gaps in both ecological and social scientific evidence. For example, few studies have been conducted in UK forests (our initial focus) and the wider evidence on recreational disturbance is narrowly focused.

Evidence to inform our understanding of the broader social drivers that influence and determine attitudes and behaviour of recreationists is particularly sparse. There are likely to be important social and cultural differences between recreational users and their favoured activities, which will drive their behaviour, determining when, where and why physical impacts occur. There are few studies of attitudes towards potential impacts from forest recreation, or the social and cultural norms that affect recreationists' behaviour in different spatial and temporal contexts. People may, for example, choose to pursue different recreational activities at different times of the day, week or year, and in varying locations.

Our interpretation of behaviour theory is that it can encourage the inclusion of a broader set of questions relating to recreation and wildlife disturbance such as the meanings attached to specific activities and the forest settings in which they take place, external factors (such as social pressures, everyday routines and materials), and the perceived legitimacy and necessity of changes that are requested of recreational users. In this paper we have sought to indicate that theory can potentially underpin an integrated approach to analysing and therefore managing the impacts of recreation on forests. Current monodisciplinary analyses generally focus on the causal relationships between physical processes and their impacts at given points in time and locations. Social analysis, particularly explanations of human behaviour provided by theory, can extend the boundaries of this analysis to include drivers of behaviour which take effect beyond a particular forest site influencing if, where and when impacts occur. A holistic approach integrating social science understanding of human behaviour together with the ecological knowledge that links these behaviours to impacts on forests and wildlife provides considerable potential for identifying opportunities for suitably targeted and effective methods of intervention at the various points where (and when) 'problem' behaviours may emerge or develop.

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