Forestry Commission

Research Report

Recreational use of forests and disturbance of wildlife

Forest Research

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Recreational use of forests and disturbance of wildlife

A literature review

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Contents

Summary

Background and objectives

- The pursuit of recreational activities in UK forests is increasingly popular and provides many social and economic benefits. However, such activities can have significant impacts on the natural environment and wildlife. Land managers, especially in the public sector, have to balance the delivery of social and economic benefits with the requirement to promote nature conservation.

- This review provides an overview of wildlife and habitat disturbance issues and impacts, focusing on recreational activities undertaken in UK forests including walking and hiking, cycling and mountain biking, off-roading, horse riding, camping and nature watching.

- In this review, disturbance includes any phenomena that can impact directly on wildlife or wildlife populations (such as causing 'flight'), or that can impact indirectly (such soil erosion and other habitat changes).

Extent of evidence

- This review has identified only five published studies of recreational disturbance which draw on primary research conducted in UK forests. A search of primarily peer-reviewed literature (published mainly between 1990 and 2010) identified more than 450 generally relevant journal articles, book chapters, dissertations and reports.

- A large proportion of the literature focuses on walking, and on impacts on soils, vegetation and birdlife. Birds are the subject of 19 of the 26 UK studies (published since 1990), with seemingly few published studies on British mammals, invertebrates, reptiles or amphibians.

Impacts of recreational activities on wildlife

- The literature tends to group activities together in categories that describe the physical characteristics of disturbance, such as 'trampling'. This masks considerable likely variation between recreational users, habitat and wildlife.

- Five key generalisations can be made about the impacts of recreation on wildlife (summarised by Cole, 2004): (i) Impact is inevitable with repetitive use; (ii) Impact occurs rapidly, while recovery occurs more slowly; (iii) Impacts increase more as a result of new places being disturbed than from further deterioration of already impacted sites; (iv) The magnitude of impact depends on frequency, type and spatial distribution of use as well as environmental conditions; (v) The relationship between amount of use and level of impact is usually non-linear.

- There is a substantial body of literature on disturbance caused by walking, the most popular recreational activity in UK woods and forests. Most relates to damage through trampling, including vegetation damage/abrasion, reduced vegetation cover, reduced plant species density, decreased leaf litter biomass, and increased trail width and depth. These impacts decrease with the distance from trails.

- There is a considerable amount of research on how walking can induce an anti-predator response in wildlife ('flight'). Much of this is related to ground-nesting birds (particularly waterbirds) with only a few studies available of non-bird species. Overall, there is little available evidence to suggest that the flight response to walking has any long-term negative impacts.

- Cycling and mountain biking has expanded rapidly in recent years. Many studies focus on impacts of this activity on the environment through erosion and trampling of vegetation. Some studies show that mountain biking does cause

individual animals to use habitat differently and increases flight response. However, no long-term negative impacts have been identified and some literature suggests the there are no or few impacts on some species.

- Horse riding can affect habitat though soil compaction, trampling of vegetation, damage to surface litter and vegetation, and erosion. Most evidence suggests that horse riding occurs primarily on specifically designed bridleways, but some studies report the use of shortcuts or veering off trails to avoid obstacles.

- Evidence from the USA shows that off-road driving is one of the fastest growing recreational activities. Impacts can include compaction and erosion of soil, and animal death or injury through collisions. Indirect impacts include noise leading to abandonment of territory, raised energy consumption and increased risk of predation. Events such as car rallies may lead to some nest abandonment in birds of prey, while vehicle tracks can fragment habitats and block movements of small mammals, amphibians and invertebrates.

- Camping, nature watching and picnicking can induce behaviour change in animals which are attracted to food sources left by people. Further impacts include littering, vandalism and fires. Nature watching can be particularly intrusive, involving viewing, touching, feeding, or photographing wildlife.

- Some recreational activities can introduce harmful species or pathogens. Footwear, vehicles and bicycle tyres can carry these into forests. Horses can also potentially contribute to the spread of invasive or non-native plants or pathogens on their hooves, coat, or via their digestive tract, although most studies concur that horses are not a substantial cause of biological invasion.

- Many studies reported limited long-term impacts, although this depends on tolerance levels, and habitat variability such as soil and climate.

Recreational users' perspectives

- Few studies consider how users perceive their own and others' impacts on wildlife. There may be links between recreational activities, preferred places to visit, and visitor attitudes and behaviour; however, debate exists around whether participation in outdoor recreation increases pro-environment behaviour. Generally, users have little awareness of their impacts on wildlife and hold others responsible for negative impacts.

Managing impacts

- Only a few studies systematically address management options although many provide recommendations. Management actions can include creating new recreation areas, physical and natural barriers or screens, track alterations, temporal restrictions, information or warning signs, trail maintenance, habitat restoration, impact surveys, buffer zones or minimum approach distances. Education and social marketing approaches are also management options. The effectiveness of management actions is often poorly understood.

- There are three main categories of access restriction: buffer zones, time and site restrictions, and visual screens, all of which require some level of spatial planning.

- Social marketing involves understanding the 'customer', their needs, expectations and motivations, how they currently behave, and ways to influence this behaviour.

- Recommendations for visitor 'education' are widespread although wider literature suggests a weak relationship between information, intention and actual behaviour. There is nevertheless a substantial body of work investigating effective education.

- 'Low-impact' interpretation strategies focus on encouraging appropriate behaviour. Messages that provide a rationale for recommended behaviour are considered more effective than statements of how to minimise impact.

Challenges and research gaps

- Further information on the social dimensions of disturbance is critical. Research into the social and cultural differences between recreationists, how information is understood and acted upon, and attitudes towards impacts is very sparse. Little is known about how social and cultural norms affect recreationists' behaviour, nor how to monitor the effectiveness of management or governance mechanisms.

- We identified no studies that weigh the social benefits of public access and recreation directly against potential wildlife disturbance, although this is an overriding need for managers. More research is needed to understand the balance between positive and negative human – wildlife interactions, and to develop effective tools to help managers assess them.

- Little progress has been made in determining socially acceptable levels of impact, or the acceptability and effectiveness of various management options. More examples are needed of what management actions work and are acceptable.

- There is an compelling need for interdisciplinary studies that link ecological impact studies on wildlife with social data around recreational users. We suggest that a wide range of species and forest types are studied, not just those which have designated protection.

Introduction

The pursuit of outdoor recreational activities in forests is increasing in popularity and can have substantial societal benefits including improved mental and physical health and tourism revenue (Clawson, 1985; Cordell, Betz and Green, 2002; Jensen and Koch, 2004; Martin, 2008). However, such activities can also have significant impacts, both negative and positive, upon the natural environment and its components – soil, vegetation, wildlife and water. These impacts and the associated threat of environmental degradation have given rise to a large body of literature including the field of recreation ecology (Liddle, 1997; Hammitt and Cole, 1998; Newsome, Moore and Dowling, 2001). This literature aims to inform site and visitor management through biological investigation of the relationships between specific activities and impacts, and assessment of ecologically acceptable levels of environmental change, for example 'Limits of Acceptable Change' (LAC) (Stankey *et al*., 1985; McCool, 1996). Whole textbooks are dedicated to describing and managing these issues (see, for example, Knight and Gutzwiller, 1995), with a particular recent focus on 'ecotourism' (Buckley, 2004).

Public land managers are charged with concurrently delivering broad ecological, social and economic benefits from the land under their control, which requires that they must, among other things, balance the impacts of public access for recreation (and the capture of the associated benefits) with the requirement to conserve biological diversity (Kazmierow, Hickling and Booth, 2000). During consultation workshops in November 2009 (Marzano and Dandy, 2010) Forestry Commission colleagues expressed the need for up-to-date and specific information regarding the disturbance caused to wildlife by recreational activities in UK forests. This was considered necessary as it is felt that debates over the issue of disturbance were in danger of becoming increasingly generic with broad assumptions that all recreational activities had significant negative impacts on wildlife.

Our objective in this document is not to provide an exhaustive review of the recreation ecology and other literature pertaining to forests. To do so would require a full-length textbook, of which there are various available (cited above and in the references). Instead our focus here is to provide:

- An overview of disturbance issues and impacts relevant to recreational activities in UK forests and woodlands.
- A detailed guide to the literature on UK forests and species found in forests.
- Key references for readers to draw on if further information is needed.

Additionally, our approach differs from that adopted most commonly in the recreation ecology literature by focusing the synthesis on the recreational activities themselves, rather than particular species, habitats or taxa. We collate the sparse information relating to the social dimensions of recreational impacts from within the primarily ecological studies with a particular focus on key types of recreational activity including walking and hiking, cycling and mountain biking, off-roading and horse riding with further information on camping, nature watching and other outdoor activities. The key questions we asked were:

1. What is the level and range of disturbance impacts on flora and fauna from recreational activities?
2. Which social phenomena affect the type and scale of impacts (e.g. holiday periods, crowding, desire to go off path/trail)?
3. How do recreational users perceive their own and others' impacts on wildlife?
4. What affects recreational users' behaviour in natural areas (e.g. knowledge, understanding and perception of 'rules'; signs and interpretation)?

Background

Wildlife* management systems have been identified by Decker *et al*. (2009, p. 316, citing Giles, 1978) as involving humans, wildlife (flora and fauna), habitats and their interactions. There has been a growing awareness in recent years that inclusion of social science perspectives in wildlife management is necessary, particularly where management actions are perceived to impact on people's values, identities and relationships with the environment (Marshall, White and Fischer, 2007). Wildlife management encompasses more than the 'label' suggests as processes, outputs and outcomes often have a value or benefit for humans (Decker *et al.*, 2009). Indeed, it has been recognised that successful solutions for management need to include a focus on both humans and wildlife if they are to be socially acceptable (Baruch-Mordo *et al.*, 2009). A focus on managing wildlife in woods and forests is important as these settings are particularly valued for recreation and tourism (Sun and Walsh, 1998). In the UK, an increase in outdoor recreation is already placing considerable pressure on some woodlands and forests (Littlemore and Barlow, 2005, see also McEvoy *et al.*, 2008). However, as Newsome, Moore and Dowling (2001) have pointed out in relation to 'wildlife tourism', there is little 'hard' data on wildlife responses to tourism or recreational activity (see also Blanc *et al.*, 2006; Rodger, Moore and Newsome, 2010).

Disturbance

'Disturbance' can take myriad forms. Recreation ecology seemingly includes everything from small-scale pollution occurring completely independent of any direct response from wildlife, through to natural disasters and capture or killing of individual animals. A useful review by Blanc *et al*. (2006, p. 119) provides some definitions of disturbance. They note that the most commonly used definition is provided by the European Commission as 'any phenomenon that may cause a significant change in the dynamics of a population or the ecoethological characteristics of populations'. This review also includes non-direct impacts on flora and fauna such as impacts on the local environment, particularly soil erosion, compaction and trampling. Disturbance can further be divided into natural events and human-induced disturbances. Threatened and endangered species are considered to be particularly vulnerable to disturbance by outdoor recreation (George and Crooks, 2006 and references therein).

Animal behavioural responses to disturbance can be classified under avoidance, attraction and habituation (Newsome *et al.*, 2002). Liddle (1997) divides disturbance into three types. Type 1 disturbances are 'transient' where ephemeral activities cause animals to move, take flight or 'flush' for fear of predation. Type 2 disturbances are 'permanent' changes such as habitat destruction or modification. Trampling can cause this type of disturbance through, for example, the creation and degradation of trails and paths. Type 3 disturbances, according to Liddle, involve the capture or killing of wildlife. Hunting is the most obvious example of this type, but road traffic, off-road vehicle (ORV) driving, cycling, collecting non-timber forest products (NTFP) and walking can also have this impact on some flora and fauna. This classification is useful in some ways, but can hide considerable interesting variation and detail.

The broad range of disturbance may reflect the difficulties of directly relating recreational activities to impacts on wildlife as responses can differ, even within a species (Vaske, Decker and Manfredo, 1995). Knight and Cole (1995, p. 72-73) suggest there are four key features that influence the impact of recreational disturbance on wildlife: (1) the predictability of an activity and whether it is frequent enough to be considered non-threatening and thus requiring little response; (2) the frequency and magnitude of disturbance over and above thresholds where the activity becomes detrimental to wildlife; (3) timing, e.g. recreational disturbance is known to be damaging to wildlife during the breeding season but can also have serious effects at other times such as periods of feeding or resting; (4) locations where wildlife feels more secure.

Taylor and Knight (2003) emphasise the importance of differentiating between direct (e.g. approaching wildlife directly) and indirect (e.g. use of a road or trail nearby) disturbance and their impacts on wildlife. Several authors indicate that, generally, human presence and activities impact on large animals while smaller animals are more affected by habitat modification or other indirect impacts such as those associated with infrastructure (Hammitt and Cole, 1998; Newsome, Moore and Dowling, 2001). Plant communities are impacted more often by trampling, which reduces productivity and biomass (Newsome, *et al.*, 2002).

* The term 'wildlife' usually refers to non-domesticated members of the animal kingdom, but a broader definition also includes plants and other organisms (e.g. fungus).

Recreational activities

Various public opinion surveys (e.g. Carter *et al*., 2009; Forestry Commission, 2009) have shown that positive recreational experiences in the outdoors are associated with being able to see or hear wildlife (Newsome *et al*., 2002). Woodlands and forests are important places for recreation but there are management implications related to the amount and type of activities that take place. In urban areas, for example, where greenspaces are often limited, forests can host large numbers of recreationalists with potentially significant knock-on effects on vegetation and wildlife (Heer, Rusterholz and Baur, 2003, p. 212). Buckley (2004, p. 212) highlights how wildlife habitat 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'.

A wide range of recreational activities take place in UK woodlands and forests, but repeated visitor surveys (www.forestry.gov.uk/statistics) show that four general categories of activity form the majority – walking (very often with dogs); cycling and mountain biking; nature watching and general visits to relax, play and/or picnic. Other activities include horse riding, ORV driving, hunting,** fishing, camping, paintballing, 'outward-bounds' activities (e.g. rope trailing and orienteering), NTFP collection, and large events (e.g. car rallies and concerts).

Disturbance by recreational activities can have major impacts on flora and fauna at individual, population and community level in the short and long term. It can have direct impacts such as causing 'flight' or modifying behaviour (foraging and reproduction) and indirect impacts such as habitat change and the introduction of pests, pathogens and weeds (Knight and Cole, 1995; Taylor and Knight, 2003; George and Crooks, 2006). A wide range of social factors affect why, when and where these acts occur, and therefore it is critical to recognise these as drivers of disturbance impacts.

Scope of the review

This review identifies and discusses the literature relating to impacts caused by the disturbance of wildlife by recreational activities occurring in UK forests. We include literature relating both to direct impacts (e.g. flight, behaviour modification, injury and death) and indirect impacts - habitat change and the spread of pests, pathogens and weeds. Furthermore, it seeks to identify literature analysing why, when and where the impacts occur, including social scientific analysis.

** We do not cover hunting activities within this review. This is because although there is a considerable literature on hunting and associated disturbance of (and general impacts on) wildlife this is almost exclusively focused on non-British situations. British hunting patterns differ considerably in both scale and social structure from North American and other European patterns, thus making any comparisons problematic.

Methods

This report is based on a review of primarily peer-reviewed published literature. We searched a number of databases including Web of Science, Google Scholar, Science Direct (Elsevier), CABE, tandfonline.com (Taylor & Francis) and our own EndNote databases to identify articles that contain key words or phrases focused around key outdoor activities that take place in forests (see Table 1). We focused on papers published between 1990 and 2010 to ensure that findings were likely to still be pertinent and applicable. For a summary and review of the literature prior to 1990, see Anderson and Radford, 1992. A few older references have been included where relevant, particularly to provide contextual information or to include seminal or otherwise important texts. From these searches we compiled a reference list using EndNote software. Further literature was identified from the citations and references of these texts. This analysis highlighted substantial gaps in the evidence and we have suggested areas for future research (see Discussion).

Table 1 Search terms.

Search term	and
wildlife / recreational disturbance / forests /	forests forest roads dog walking cycling skiing birdwatching 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

Results

Our research identified more than 450 papers, book chapters, student dissertations and other published materials relating specifically to the disturbance of wildlife by walking, mountain biking, horse riding, vehicle use, camping, nature watching and a few other relevant activities. Less than one-third relate directly to forests or woodlands, and only 26 report primary research done in any habitat in the UK in the last 20 years (see Table 2). We have identified only five published studies of recreational disturbance which draw on primary research conducted in UK forests or woodlands. This reveals a continuing lack of primary studies in these environments, noted previously by Anderson and Radford, 1992. The remaining studies provide either general or contextual evidence, and/or relate to studies of species found in UK forests but conducted elsewhere. A large proportion of the literature relates to walking (including with dogs) as an activity and to soils, vegetation and birdlife. Protected and 'wilderness' areas feature prominently. This central body of the literature, relating to ecological impacts, is described in the Impacts section on p.8, subdivided into stand-alone sections on the various recreational activities of relevance to UK forests (Figure 1).

Many studies refer generically to 'disturbance' or 'human disturbance', the definitions for which can include activities far wider than recreation. In particular, there is some literature on the disturbance of forest wildlife by harvesting or other forestry operations. We have sought to avoid this literature in our study, although we have included some references where the activities are similar to recreational activities (e.g. scientific 'investigator' disturbance on foot, which is similar to walking or hiking).

UK studies replicate the wider literature's bias towards and focus on walking, and on birds (especially ground-nesting species) and open habitats. Birds are the subject of 19 of the 26 UK studies, and the Dorset heaths and Cairngorms receive relatively more attention than other areas. British mammals are the subject of only one study, with seemingly very few published studies of recreational disturbance and British invertebrates, reptiles or amphibians.

There have been a number of reviews of recreational disturbance literature and many are freely available via the internet (see Table 3).

Management recommendations permeate the literature; however, only a limited literature exists which directly or systematically addresses the management options available. Evidence relating to how recreationists understand or perceive their own and others' impacts on wildlife is also very sparse. We discuss these areas of the literature in the sections on Recreational users' perspectives (p.22) and Managing impacts (p.24).

Figure 1 Forest trails are suitable for various recreational activities.

Table 2 UK studies of wildlife disturbance by recreational activities since 1990.

First author	Date	Species/habitat	Method	
Baines	2007	Black grouse, *Tetrao tetrix*	Radio-tagging, experimental disturbance and observations of people near birds during disturbance events	
Barnard	2003	Beech woodland	Visitor numbers: automated traffic counter (ATC) Perceptions of dogs and dog walkers: observation, questionnaires	
Bayfield	1996	Mosses, grasses, forbs	3 control sites, 2 seeded, 1 left unseeded. Direct visual recording of species cover and composition over 25 years	
Beale	2007	Common guillemots, *Uria aalge* Black-legged kittiwakes, *Rissa tridactyla*	Spatially explicit model colony with simulations of visitor distribution, testing model using empirical data	
Bennett	2009	Barbastelle bats, *Barbastella barbastellus*	Simulation model SODA (simulation of disturbance activities)	
Finney	2005	Golden plover, *Pluvialis apricaria*	Data collected 1986-98, survey of bird distribution; habitat data. Secondary path use data. Distance from path – index of disturbance.	
Goss-Custard	1993	Various shorebirds/waders	15 year study. Observations of human activities (dog walking, birdwatching, walking, casual and commercial shell-fishing) during bird counts	
Haworth	1990	Various upland birds	Vegetation survey, breeding bird survey, discussions with gamekeepers, survey of features likely to disturb breeding birds	
Johnson	2000	Ancient woodlands		
Keirle	2004	Study of footpath use	Mapped observation of users passing through specified area	
Keller	1991	Eider ducklings, *Somateria mollissima*		
Langbein	1992	Red deer, *Cervus elaphus* Fallow deer, *Dama dama*	Observation of habitat use, focal animal observation, with records of disturbance events	
Langston	2007	European nightjar, *Caprimulgus europaeus*	Territory mapping, nest monitoring, vegetation measurements, observation of visitor path use	
Liley	2003	European nightjar, *Caprimulgus europaeus*	Spatial integration of existing datasets: heathland survey, national and local nightjar survey, aerial photographs of developed land and postcode data	
Littlemore	2001	(Urban fringe) Woodland ground flora and soils	Controlled experimental trampling	
Mallord	2007a	Woodlark, *Lullula arborea*	Nest location, ringing of chicks, observation	
Mallord	2007b	Woodlark, *Lullula arborea*	Territory mapping and habitat suitability, record of visitors along existing access routes at site level, no. of disturbance events within sites	
Mayer-Gross	1997	Passerines	Data from 1960-61. Record of nests at nest-building stage and exposure of nest, mimicking behaviour of nest recorder, and vegetation recording	
Murison	2002	Nightjar, *Caprimulgus europaeus*	Mapping of nightjar territory and nests, observation of nightjar breeding behaviour, postcode data	
Pearce-Higgins	2007	Golden plovers, *Pluvialis apricaria* Dunlin, *Calidris alpina*	Bird survey, nest search, radio-telemetry, visitor counts (data from 1980)	
Ruddock	2007	Various bird species	Literature review, questionnaire survey to elicit expert opinion	
Summers	2004	Capercaillies, *Tetrao urogallus*		
Summers	2007	Capercaillies, *Tetrao urogallus*	Search for capercaillie dropping, presence of raptors, wind and temperature measurements, questionnaire data from recreational users	
Taylor	2007	Stone-curlews, *Burhinus oedicnemus*	Observation of breeding sites, routes followed by 'potential disturbing agents' mapped onto aerial photographs	
Watson	2004	Ptarmigan, *Lagopus mutus*	Bird counts, territory census	
Whitfield	2007	Goldon eagles, *Aguila chrysaetos*	Based on published datasets: census of golden eagles, counts of red deer, sheep numbers, estimations of changes in forest cover, records of illegal poisoning and persecution, spatial association between Munros (and hillwalkers) and eagle territory	

	Study location	Recreational activity									
		Walking	Dog walking	Nature watching	Camping	Biking	Vehicles	Horse riding	Skiing	General	Other
	England (North Pennines)									■	
	England (Burnham Beeches NNR, Bucks)		■								
	Scotland (Cairngorm)								■		
	Scotland									■	
	England (South West)									■	
	England (Pennine Way)	■									
	England (River Exe estuary)	■	■	■							
	England (South Pennines)									■	
	England (New Forest)				■						
	Wales (Cwm Idwal, Snowdonia)	■									
	Scotland (Ythan estuary)	■	■								■
	England (Richmond and Bushy parks, London)									■	
	England (Dorset)	■	■								
	England (Dorset)										■
	England (Coventry, West Midlands)	■									
	England (Dorset)									■	
	England (Dorset)	■	■			■		■			
	England (Oxfordshire)			■							
	England (Dorset)									■	
	England (Peak District)	■									
	Scotland									■	
	Scotland (Abernethy Forest)									■	
	Scotland (Glenmore and Abernethy Forests)	■				■	■			■	
	England	■									
	Scotland (Cairngorm)								■		
	Scotland	■									

Table 3 Reviews and bibliographies of disturbance to wildlife caused by recreational activities, since 1990.

First author	Date	Title	Subject	Species/habitat
Carney	1999	A review of human disturbance effects on nesting colonial waterbirds	Human disturbance (investigators and visitors)	Waterbirds
Cessford	1995	Off-road impacts of mountain bikes: a review and discussion	Mountain biking	Various
Cole	2004	Impacts of hiking and camping on soils and vegetation: a review	Hiking Camping	Soil Vegetation Wilderness areas
Dahlgren	1992	Human disturbances of waterfowl: an annotated bibliography	Human disturbance	Waterbirds
Knight	1995	Wildlife and recreationists: coexistence through management and research	Various (including walking, horse riding, nature viewing, and vehicles) Hunting	Various
Lathrop	2003	Ecological impacts of mountain biking: a critical literature review	Mountain biking	Various
Leung	2000	Recreation impacts and management in wilderness: a state-of-knowledge review	Walking Camping	Soil Vegetation
Sidaway	1990	Birds and walkers: a review of existing research on access to the countryside and disturbance to birds	Walking	Birds
Sun	1998	Review of studies on environmental impacts of recreation and tourism in Australia	Various, including walking, camping and horse riding	Vegetation Soils
Taylor	2005	Dogs, access and nature conservation	Dog walking	Birds
Tempel	2008	Understanding and managing backcountry recreation impacts on terrestrial wildlife: an annotated reading list	Backcountry recreation	Carnivores Ungulates Small mammals Raptors Birds Reptiles Invertebrates
York	1994	Recreational-boating disturbances of natural communities and wildlife: an annotated bibliography	Boating	Various

Impacts

This section provides an overview of the literature relating to the impacts of recreational activities on forests and forest species, with an emphasis, where possible, on the UK. It is subdivided into several stand-alone sections pertaining to specific activities, which can be read without reference to each other. Having said this, there are some general principles which are usefully identified prior to addressing each activity.

First, in the literature the impacts of various recreational activities are frequently categorised as 'trampling', that is mechanical pressure on soils, flora and fauna from feet, hooves or vehicle tyres. In this sense, the literature analyses the majority of impacts together. This contributes to the generally asocial nature of much recreational disturbance literature, excluding the values, perspectives and behaviour of the people involved (see the Impacts – physically similar, socially diverse section on p.30). Torn *et al.* state 'Trampling is the most prevalent impact of recreation and nature tourism.' (2009, p. 1427). Furthermore, much recreational activity occurs on or close to designated locations, such as car parks or campsites, and defined paths, tracks, roads or other 'trails'. Thus, in the same sense as 'trampling' above, impacts caused by different activities can commonly be considered together as 'trail' or 'site' impacts. For example, Thurston and Reader assert that 'Managers of natural areas consider recreational impacts along trails and on campsites to be their most common management problem.' (2001, p. 397).

Other work indicates environmental variables that can affect the magnitude of impacts from recreational disturbance including soil type, habitat structure and

composition (e.g. shrub and tree cover), sensitivity of species, habituation of species to human presence and management measures currently in place. In his review, Cole (2004, p. 55) offers five key generalisations regarding the impacts of walking, although they are widely relevant to other forms of recreation. These are:

1. Impact is inevitable with repetitive use. Numerous studies have shown that even very low levels of repetitive use cause impact. Therefore, avoiding impact is not an option unless all recreation use is curtailed. Managers must decide on acceptable levels of impact and then implement actions capable of keeping use to these levels.
2. Impact occurs rapidly, while recovery occurs more slowly. This underscores the importance of proactive management, since it is much easier to avoid impact than to restore impacted sites. It also suggests that relatively pristine places should receive substantial management attention, in contrast to the common situation of focusing most resources in heavily used and impacted places. Finally, it indicates that rest-rotation of sites (periodically closing damaged sites, to allow recovery, before reopening them to use) is likely to be ineffective.
3. In many situations, impact increases more as a result of new places being disturbed than from the deterioration of places that have been disturbed for a long time. This also emphasises the need to be attentive to relatively pristine places and to focus attention on the spatial distribution of use. It suggests that periodic inventories of all impacted sites is often more important than monitoring change on a sample of established sites.
4. Magnitude of impact is a function of frequency of use, the type and behaviour of use, season of use, environmental conditions, and the spatial distribution of use. Therefore, the primary management tools involve manipulation of these factors.
5. The relationship between amount of use and amount of impact is usually curvilinear (asymptotic). This has numerous management implications and is also fundamental to many minimum impact educational messages. It suggests that it is best to concentrate use and impact in popular places and to disperse use and impact in relatively pristine places.

Walking and hiking (including dog walking)

Walking is the most frequent and popular recreational activity conducted in natural areas such as forests and woods (Figure 2). It is certainly the most widely reported and recorded activity on land managed by the Forestry Commission (Watson and Ward, 2010). Hiking and walking have the potential, however, to disturb wildlife in a

Figure 2 Forest roads are ideal for family walks.

number of ways including trampling, causing animal flight in response to noise and/or approach, habitat change or degradation through trail (path) and trailside management, use or pollution, and the introduction of invasive or otherwise harmful species or pathogens. Trampling associated with footpaths was the subject of much of the earliest systematic investigation in recreational ecology (e.g. Bayfield, 1971, 1973, 1979; Liddle, 1975) and Cole noted that of the approximately 1000 studies in recreational ecology conducted up until 2004 the 'majority have focused on the impacts of hiking and camping' (2004, p. 55) – particularly impacts on vegetation and soils. There exists, therefore, a very substantial quantity of information and data relating to the disturbance caused by walkers. Nevertheless, the vast majority of this evidence relates either to vegetation damage through trampling, or to flushing of ground-nesting birds (especially waterbirds) – with woodland environments and species receiving less attention.

In the UK, a high proportion of walkers using woods and forests are accompanied by dogs: Taylor *et al*. (2005) assert a figure of up to 50% in lowland areas, with fewer in upland areas (Figure 3). This can serve to increase (in some cases dramatically) the scale of disturbance (or 'sphere of influence', Taylor *et al*., 2005). The impact of dogs has received widespread attention – although again primarily in relation to ground-nesting birds (although Miller, Knight and Miller, 2001 illustrated increased disturbance of mule deer by dogs), and in non-forest environments.

Walking in forests and other natural areas can potentially disturb wildlife, with three general categories of effect. These are: (i) habitat change; (ii) 'flight'; and (iii) the introduction of invasive species, pests or diseases.

Figure 3 Dogs can increase the level of disturbance.

Habitat change

Considerable evidence has shown that the impact of walkers' footfall on the ground can have significant trampling effects in forests – with various potential impacts on flora and fauna and habitat (Figure 4). These can include vegetation damage/abrasion, reduced plant/vegetation cover, reduced plant species density, decreased leaf litter biomass, organic soil removal and compaction, reduced plant genetic and species diversity, and increased trail width and depth (Kissling *et al*., 2009; Roovers *et al*., 2004; Rusterholz, Kissling and Baur, 2009; Torn *et al*., 2009; Waltert, 2002; Weaver and Dale, 1978; Wimpey and Marion, 2010. For reviews see Leung and Marion (2000) and Cole (2004).

Figure 4 Impact can have a serious effect on vegetation.

Recent studies have confirmed earlier findings (e.g. Bayfield, 1971, 1973) that trail characteristics can have a substantial affect on disturbance, for example trail 'roughness can cause hikers to widen trails by seeking out smoother trailside hiking surfaces' (Wimpey and Marion, 2010, p. 2035). However, impacts seemingly decrease with distance away from trails. Dale and Weaver (1974) noted that vegetation more than 2 m from a trail edge is not often affected.

Indirect impact of habitat change

Impacts are not always negative. Davis' study of salamanders actually identified a beneficial relationship between trail presence and species success, noting that 'trails result in more microhabitats for salamanders around them.' (2007, p. 385). However, other analyses of human disturbance of reptiles describe some significant negative impacts; for

example the removal and accelerated decay of woody debris vital for skinks (Hecnar and M'Closkey, 1998).

Flight and behaviour change

A very substantial amount of research has focused upon measuring how and when walkers disturb wildlife through approaching them, and/or causing noise, which triggers, in essence, an anti-predator response of escape ('flight'). Within this literature there is once again, however, a very heavy focus upon birdlife (for reviews see Sidaway, 1990; Taylor *et al*., 2005), which itself focuses substantially upon ground-nesting birds (for a 'systematic review' see Showler *et al*., 2010) and disturbance by dogs accompanying walkers. Indeed, in their review of the disturbance impacts of dogs, Taylor *et al*. (2005, p. 56) conclude that 'There is *very little relevant research* that has focused on the effects of dogs *on animal groups other than birds*' (emphasis added). The central concern is that disturbance can cause birds, and other animals, to flee from cover or nests – impacting on their energy balances, feeding behaviour and the vulnerability of young, eggs or fledglings (Dahlgren and Korschgen, 1992; Fox and Madsen, 1997; Rasmussen and Simpson, 2010). Each of these potentially affects not only individuals but also populations through affecting breeding success, and can thus be a particular concern for endangered or vulnerable species of conservation interest.

Considerable attention has been given to flight responses of waterbirds (see for example Carney and Sydeman, 1999; Nisbet, 2000), but much less to forest bird species. Searches relating to the recreational disturbance of 35 'woodland bird' species found in the UK (as defined by Amar *et al*., 2006) identified very few studies (Ibanez-Alamo and Soler, 2010; Lukac and Hrsak, 2005; Fernandez-Juricic, 2000a, 2000b; Fernandez-Juricic and Telleria, 2000; Fernandez-Juricic, Jimenez and Lucas, 2001, 2002; Mueller *et al*., 2006). None of these studies were conducted in the UK and their findings are of limited relevance to UK woods in general. Five relate to empirical work in urban woodlands in Madrid, Spain, and conclusions from these studies are useful. Human disturbance was found to negatively influence the number of bird species, their persistence and guild density (Fernandez-Juricic, 2000b), along with blackbird feeding strategies, habitat selection and abundance (Fernandez-Juricic and Telleria, 2000). However, various factors affect animal's tolerance of disturbance and subsequent likelihood of flight, particularly the surrounding habitat structure and composition (Fernandez-Juricic, Jimenez and Lucas, 2001, 2002). In essence, alert distances and individual 'buffer zones'[†] vary with the presence of 'escape cover' such as shrub and tree cover. This effect is reported in the wider literature (e.g. Langston *et al*., 2007). Interestingly, Fernandez-Juricic, Jimenez and Lucas (2002) noted that blackbird buffer distances were greater in 'highly visited' parks, which the authors related to habituation.

Studies relating to other birds associated with woodlands in the UK include black grouse (*Tetrao tetrix*) and capercaillie (*Tetrao urogallus*) (Figure 5). Baines and Richardson (2007, p. 56), for example, report that 'The disturbance regimes imposed had no discernible impact upon black grouse population dynamics' (although one study revealed a considerable impact of skiing on black grouse populations in the European Alps (Patthey *et al*., 2008). An earlier study of red grouse (Picozzi, 1971) similarly showed no negative breeding impact, stating 'Grouse bred no worse on study areas on moors where people had unrestricted access, and Grouse bags showed no evidence of a decline associated with public access agreements' (p. 211). Newton, Robinson and Yalden (1981) investigated the potential impacts of recreational walkers on merlin (*Falco columbarius*) in the Peak District National Park. Their conclusion was that it was 'unlikely' to have caused the 'sharp decline in merlins during the 1950s' (p. 232), but that it could possibly slow recolonistation. Other studies of merlin (e.g. Meek, 1988) similarly suggest little negative impact by recreation, instead focusing on general habitat degradation by agriculture and pollution as the most likely causes of decline. In contrast, studies of capercaillie suggest a negative impact

Figure 5 Capercaillie are sensitive to recreational activities.

[†] Defined in Fernandez-Juricic, Jimenez and Lucas (2002) as 'the difference between the distance at which a predator is detected and the distance at which the prey flees'.

by recreational activity (Summers *et al*., 2004; Summers, McFarlane and Pearce-Higgins, 2007; Theil *et al*., 2011). Summers *et al*. (2004) and Summers, McFarlane and Pearce-Higgins (2007) draw attention to the birds' avoidance of woodland areas near tracks and suggest a causal connection between this and recreational use. Although counts of recreational visitors in this study are very low, the authors find a statistically significant difference between capercaillie use of wooded areas adjacent to tracks classified as 'high' and 'low' human use. Extrapolation from total track length led these authors to assert reduced woodland 'carrying capacity' as the species avoids using between 21 and 41% of the two forests studied.

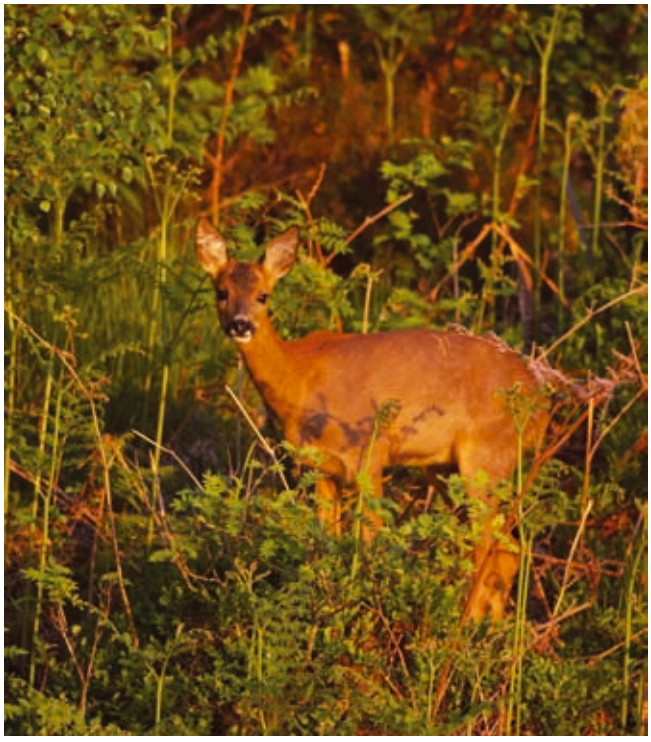
Studies of forest bird disturbance by walkers and dogs beyond the UK reveal some useful findings. In their study of 90 peri-urban (urban fringe) woodlands north of Sydney, Banks and Bryant (2007) identified a substantial, although seemingly short-term, effect of dogs on native birds – especially ground-nesters. They state 'Dog walking caused a 41% reduction in the numbers of bird individuals detected and a 35% reduction in species richness compared with untreated controls', but 'no net difference in bird diversity or abundance between areas with and without regular dog walking receiving the same treatment, suggesting that long-term impacts in this area may be small. (p. 612). In contrast, Gutzwiller *et al*. (1998, p. 497) 'found little evidence that intrusion altered vertical distributions of four passerines that nest, forage, sing, and seek refuge in subalpine forest. The minimal effects we observed indicate that the species we studied were able to tolerate low levels of intrusion.'. Similarly, in their study of nesting northern cardinals in riparian forests in Ohio, USA, Smith-Castro and Rodewald (2010, p. 130) 'found no association between nest survival and the tendency of birds to flush'.

On balance, the available evidence does not indicate significant negative impacts on UK forest birds following 'flight' responses to walking – including no clear long-term or population-level impacts.

A very few studies have attempted to assess the impacts of flight responses to walking on forest species other than birds. Some studies show, for example, that human presence on foot can in some circumstances disturb wild deer. Langbein and Putnam (1992) and Recarte, Vincent and Henison (1998) studied disturbance of British park deer, although came to different conclusions. Langbein and Putman (1992) reported significant immediate behavioural responses of deer to human presence, but these had no long-term impacts (such as on body-weights or overwinter mortality). Recarte, Vincent and Henison (1998) reported less disturbance and concluded that level of disturbance response was related to surrounding habitat and habituation. Other UK deer research includes Ward, White and Critchley (2004), who found that wild roe deer (*Capreolus capreolus)* (Figure 6) did not flee from, or otherwise change their behaviour, when disturbed by night-time ecological survey. They were found, however, to avoid paths and roads even at night when human activity was very low. In a US study, Miller, Knight and Miller (2001, p. 144) reported that 'For all species, area of influence, flush distance, distance moved, and alert distance (for mule deer) was greater when activities occurred off-trail versus on-trail' and that 'For mule deer, presence of a dog resulted in a greater area of influence, alert and flush distance, and distance moved than when a pedestrian was alone'. Studies by de Boer *et al*. (2004) and Marini *et al*. (2008) highlight a number of factors affecting the flight responses of wild deer. The structure of surrounding habitat is repeatedly identified as a major factor. In the only study of disturbance of squirrels by recreation identified in this review, Gutzwiller and Riffell conclude that 'Abundance of red squirrels at intruded [on foot] sites [in the US] did not differ significantly from that at control sites during either experiment.' (2008, p. 374).

Although immediate/short-term behaviour change may be apparent, this limited available evidence shows little or no long-term negative impacts upon UK forest mammals following 'flight' caused by walking in woodlands.

Figure 6 Roe deer maintain their behaviour when disturbed.



Introduction or spread of harmful species or pathogens

There is a small amount of evidence relating to the spread of harmful pests through walking and hiking activities in forests, although none in the UK (see also the sections on horse riding (p.14) and vehicles (p.15). In their study of hiking trails in California (Figure 7), Cushman and Meentemeyer (2008) found strong associations between human recreational trail use and the spread of *Phytophthora ramorum*. They state;

'At the local scale, we found that there was greater incidence of the pathogen in soil on hiking trails than in adjacent areas off trail. At the landscape scale, our data indicate that forests on public land open to recreation experienced greater disease severity than forests on private land closed to the public.' (p. 771)

Figure 7 Hiking can increase the spread of disease.

Jules *et al*. (2002) also identify human footfall as a vector for disease spread, although they identify vehicular spread as much more significant. Turton (2005) identifies the spread of weeds and soil pathogens by walkers and vehicles along forest paths as a key environmental impact in the tropical forests of Queensland, and recommends the 'removal of mud and soils from vehicle tyres and hiking boots before entering pathogen-free catchments' (p. 140) as a management strategy.

Cycling and mountain biking

The review of literature on environmental impacts of cycling and mountain biking include studies from the USA, Canada, Switzerland, UK and New Zealand. There is overall agreement in the literature that mountain biking in forests and wildlands has expanded rapidly (Ruff and Mellors, 1993; Symmonds, Hammitt and Quisenberry, 2000; Lathrop, 2003; Heer, Rusterholz and Baur, 2003; White *et al*., 2006) (Figure 8). In urban forests, mountain biking is reported to have exceeded walking/hiking as the main recreational activity while higher mobility has increased the area of forest under intense use (Heer, Rusterholz and Baur, 2003). As Symmonds, Hammitt and Quisenberry point out, 'In general, bikers are committed and/or have a significant amount of time available for recreation' (2000, p. 552).

Impacts from mountain biking can be classified broadly into two categories: (i) habitat change (trampling and erosion); and (ii) flight and behaviour change (Lathrop, 2003). Some literature also suggests that cycling can cause wildlife mortality.

Figure 8 Mountain biking is an increasingly popular activity.

Habitat change

Many studies focus on the erosion and trampling impacts upon soils and vegetation of cycling and mountain biking. These include, for example:

- Leaving muddy ruts in and around trails (Jacoby, 1990; Geraghty, 2000; White *et al*., 2006).
- Trampling of vegetation, uprooting plants and erosion by spinning wheels (Jacoby, 1990; Symmonds, Hammitt and Quisenberry, 2000; Thurston and Reader, 2001; Lathrop, 2003).
- Off-trail erosion and creation of impromptu paths (Cessford, 1995; Thurston and Reader, 2001). Water and mud can cause users to leave the trail (Jacoby, 1990; Littlemore and Barlow, 2005), although it is suggested that mountain bikers are generally less likely to leave trails relative to other users (Lathrop, 2003).

- Compacted soil, causing vegetation loss and erosion (Jacoby, 1990; Symmonds, Hammitt and Quisenberry, 2000; Thurston and Reader, 2001; McEvoy *et al.*, 2008).

- Trail width and incision impact increases in relation to trail slope (Wilson and Seney, 1994, White *et al.*, 2006) (Fgure 9).

Figure 9 Mountain biking can cause trail widening and vegetation loss.

Flight and behaviour change

While mountain biking literature focuses mainly on erosion and trampling of vegetation, some studies consider the behavioural impacts of mountain biking on species such as bison (*Bison bison*), pronghorn antelope (*Antilocapra americana*) and mule deer (*Odocoileus hemionus*) (Taylor and Knight, 2003), North American elk (*Cervus elaphus*) (Naylor, Wisdom and Anthony, 2009), and mule deer, bobcat (*Lynx rufus*) and coyote (*Canis latrans*) (George and Crooks, 2006). These studies are generally comparative, and show that mountain biking does disturb wildlife, in that it causes individuals to use habitat differently. They do not identify any long-term negative impacts associated with this, however.

Mountain biking can also impact on wildlife in other ways. For example:

- Mountain bikers travelling at high speed (Figure 10) and probably not talking (making noise) are less predictable for wildlife and a potential safety hazard for other humans (Cessford, 1995; Taylor and Knight, 2003; George and Crooks, 2006).

- There can be direct mortality of wildlife through impact at high speed (Lathrop, 2003). Lathrop did not find many studies but highlighted anecdotal evidence suggesting that small mammals are particularly affected.

- Disturbance can cause and increase flight response. For example, Naylor, Wisdom and Anthony (2009) found that mountain bike disturbance increased the travel time of elk, which reduced time for feeding or resting.

Some literature reports little or no impact on wildlife by mountain bikers. For example, Lathrop (2003) cites research by Stake (2000) who was studying the golden cheeked warbler (*Dendroica chrysoparia*) at Fort Hood, Texas, before the introduction of mountain biking to the area. This study reported no impacts from mountain biking on territory density, return rates or age structure of the bird population.

Figure 10 High speed riding is a danger to wildlife and humans.

Horse riding

According to Newsome *et al.* (2002) horse riding usually occurs on specifically designed bridleways. The studies investigating the impacts of horse-riding on flora and fauna have been concentrated in Australia and the USA, particularly in national parks where horse-riding holidays or treks are common. Nevertheless, horse riding is an increasingly popular forest recreational activity in many countries (Landsberg *et al.*, 2001; Newsome,Cole and Marion, 2004) including the UK.

The key impacts of horse riding are related to: (i) habitat change; and (ii) spread of invasive weeds.

Habitat change

Horse riding can affect wildlife habitat in a number of ways, including soil compaction, erosion, vegetation damage, increased trail depth and width, and sediment movement (Figure 11). Trampling can compact the soil and damage surface litter, lichens and mosses (Newsome *et al.*, 2002) and reduce populations of invertebrates (Littlemore and Barlow, 2005). Littlemore and Barlow state that 'In British woodlands, 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' (2005, p. 277–278). Landsberg, Logan and Shorthouse (2001) cite their own (Canberra Nature Park, Australia) and other studies (Summer, 1980, 1986) where they identify the terrain most vulnerable to trampling to include colluvial slopes, moraine sideslopes, wet bogs and alpine areas. Moreover, damage to trails is compounded by the use of shortcuts instead of following trails with switchbacks, or veering off the trail to avoid obstructions such as fallen trees (Landsberg, Logan and Shorthouse, 2001). Removal of vegetation can be greater when horses are going downhill (Weaver and Dale, 1978) but the level of damage is dependent on other factors such as soil type, climate, sensitivity of vegetation and management measures currently in place (Newsome, Cole and Marion, 2004).

Figure 11 Horses can cause damage to soil and vegetation.

Introduction or spread of harmful species or pathogens

As well as trampling, the potential for horses to spread invasive or non-native plants or pathogens is a concern (Gower, 2008) (Figure 12). Key aspects include the transportation of seeds or pathogens either through endozoochory (transporting seeds in the digestive tract) or epizoochory (via the horse's coat, hair or hooves) (Landsberg, Logan and Shorthouse, 2001; Gower, 2008; Pickering and Mount, 2010), and disturbance of soil providing suitable environments for the establishment of invasive species (Newsome *et al.*, 2002). Newsome *et al.* (2002) note that in protected areas in Australia invasion of the root-rotting fungus *Phytophthora cinnamomi* is a widespread problem. *Phytophthora cinnamomi* causes dieback in various tree species and can be spread through soil movement as horses move along trails (although vehicles and bicycle tyres and walkers' boots can also carry the fungus). The authors note that public appreciation of the impact of established non-native invasive species is often influenced by the fact that changes to the environment may only be discernible over a long period of time. Having said this, the limited evidence suggests that in general, horse riding in natural areas such as forests is not a substantial cause of biological invasion.

Figure 12 The risk of horses spreading non-native plants along forest trails is minimal.

Gower (2008) believes that horses are not a significant vector for invasive species as germination success on forest trails is very low. Campbell and Gibson (2001, p. 23) conclude that 'the emigration of exotic species via horse dung does not pose an immediate threat to the plant communities adjacent to trails in these forest systems'. Torn *et al*. (2009, p. 235) note, similarly, that 'alien species may be introduced to natural forests through recreational horse riding', but that 'In practice, the risk of [these] alien species to the biodiversity of natural forests may be relatively small'.

Vehicles

The main studies cited here are based on reviews of vehicle impacts from USA, Australia and France. Here, we have focused primarily on motorcycles and off-road

vehicles, which have been variously termed all-terrain vehicles (ATV), off-road vehicles (ORV) and off-highway vehicles (OHV). The types of vehicles include 4-wheel drive, snowmobiles, large tundra buggies and trail bikes (Figure 13). Buckley (2004) suggests that OHV refers to vehicles used on recognised dirt roads and tracks which are not legal highways. The most commonly used term in the literature cited is OHV. In the USA, data from 1982 to 2001 showed that off-road driving was one of the fastest growing activities and almost 10% of all visits to national forests in 2004 involved OHV use (Zielinski, Slauson and Bowles, 2008 and references therein). However, there are few studies on the impacts of OHVs in forest settings (Buckley, 2004) and only one study based in the UK was found which included this as part of its analysis (Summers, 2007).

Figure 13 Trail biking and other vehicle related activities can cause serious disturbance.

Buckley (2004) provides a useful review on impacts including compaction, erosion and trampling of soil, vegetation and fauna, transportation of weeds, and impacts on other wildlife through collisions and noise. He divides OHV impacts between plants/vegetation and vertebrates/invertebrates. Although some vegetation types are more resilient than others, generally disturbance from OHVs includes crushing and bruising of individual plants, modification of soil properties and introduction of weed seeds or pathogens. There are also risks for species in terms of habitat loss, greater energy consumption when reacting to disturbance and increased predation (Buckley, 2004).

Habitat change

Physiological damage to plants can lead to reduced growth rates and premature leaf loss (Hylgaard and Liddle, 1994 in Buckley, 2004). Bunnell, Flinders and Wolfe (2006) highlight that snowmobiles can compact snow providing greater access to predators normally restricted by deep snow (see also Zielinski *et al*., 2008).

Introduction or spread of harmful species or pathogens

Whilst motor vehicles in general have been shown to be a significant vector for the spread of plants (Schmidt, 1989; Von der Lippe and Kowarik, 2007), including during tourist activities (Lonsdale and Lane, 1994; Pickering and Mount, 2010) and in forests (Veldman and Putz, 2010), only one study was identified directly investigating the dispersal of harmful species by recreational vehicles in forests and this reported only limited dispersal (Rooney, 2005).

Flight and behaviour change

OHVs can crush animals and invertebrates, nests and burrows and collide with or run over and kill wildlife (Buckley, 2004; Burger *et al.,* 2007). Vehicle noise and speed can disturb a range of species such as songbirds, leading to displacement into potentially less favourable areas (Buckley, 2004; Blanc *et al.,* 2006). Research has also shown that wildlife will avoid areas where there are tracks and presence of human-related noise such as from OHVs. For example, Buckley (2004, p. 88 and references therein) cites studies where species such as bears, wolves, elk, deer and lizards have decreased in density. A study on great bustards in central Spain (near Madrid) found that vehicle traffic was the most common source of disturbance inducing an escape response, which not only requires increased energy but also heightened the danger of collision with powerlines, the main cause of non-natural mortality of the birds (Sastre *et al.,* 2009).

Major one-off forest events such as car rallies (Figure 14) can lead to nest abandonment, particularly in birds of prey (RSPB, 1997 in Littlemore and Barlow, 2005). Tracks left by OHVs can fragment habitat and block movement of some species of small mammals, amphibian and invertebrates (Burnett, 1992; Goosem, 1997, 2000; Forman and Alexander, 1998 from Buckley, 2004).

Figure 14 Car rallies are a source of disturbance to birds.

Camping and outdoor activities

The majority of papers reviewed here focus on camping with studies primarily from the UK and USA. Camping-related impacts can occur in areas where camping activities are intensive, including expansion of campsite areas and increasing number of sites (Leung and Marion, 2004) (Figure 15). However, some authors maintain that in fragile communities relatively low levels of use can cause significant impact (Leung and Marion, 2000 in Cole and Monz, 2003).

The main forms of impact include habitat change and flight and behaviour change (Cole and Monz, 2003; Leung and Marion, 2004; Littlemore and Barlow, 2005).

Figure 15 Intensive camping can cause habitat change.

Habitat change

Studies highlight the impacts of camping in terms of tree damage, damage and loss of vegetation through trampling, and compacted soil and erosion. Further impacts include littering, vandalism and accidental fires (Johnson and Clark, 2000), along with the removal of wood material for firewood (affecting invertebrate habitat and nutrient storage/cycling), and changes in the organic structure of soils around fires (Figure 16).

Figure 16 Camp fires can change habitats and soil structure.

Johnson and Clark (2000) discuss the impacts of camping in the New Forest, UK, where wild camping in the first half of the 20th century resulted in considerable environmental damage leading to regulations where camping was restricted to specified sites. The New Forest contains significant areas of semi-natural woodland. Despite the reduction in campsites and pitches, disturbance from campers have been documented. The authors cite a case study 'Hollands Wood' where damages to the environment over a 28-year period were recorded including: (1) 84% of the mature trees lost, reducing canopy cover by 50%; (2) 76% of the site classified as heavily disturbed ground; (3) 16% covered by roads, tracks and buildings; (4) significant

reduction in the variety and distribution of lichen flora (Cox and Rose, 1996 in Johnson and Clark, 2000, p. 98).

A study by Cole and Monz (2003) on the effect of camping on previously undisturbed sites in Wyoming, USA found that in coniferous forests with an understorey dominated by a (fragile) shrub *Vaccinium scoparium* (a species of huckleberry), even one night of camping could significantly affect vegetation cover and height.

However, Leung and Marion (2004) suggest that camping-related impacts are often less than other types of human-related disturbances. Indeed, some studies note largely neutral or no effects on wildlife from camping. Blakesley and Reese (1988, cited in Liddle, 1997) found that the presence of seven bird species was negatively correlated with campgrounds while seven were positively correlated. Cole and Monz (2003, p. 693) emphasise that the intensity and magnitude of impact depend on four factors:

1. Amount and/or frequency of use.
2. Season and/or time of use.
3. Type of user and their behaviour.
4. Durability of the campsite.

The impact of disturbance naturally depends on tolerance levels of wildlife, particularly plant communities.

Flight and behaviour change

Swensen (1979 in Littlemore and Barlow, 2005) found that proximity to camping grounds lowered breeding success of ospreys. Moreover, impacts on wildlife can occur when birds and other species are attracted to food sources left by people in and around grounds (Liddle, 1997). Marion, Dvorak and Manning (2008) note wildlife that is attracted to human food can suffer nutritionally and is more vulnerable to predators and vehicle collisions.

Watching nature

Wildlife watching – sometimes described as non-consumptive use of wildlife, wildlife tourism or as part of ecotourism – is increasingly popular (Figure 17) and can raise considerable revenue. Between 1989 and 1995 the 'ecotourism' industry grew worldwide from US $60 billion to $175 billion (Karp and Guevara, 2011) and is continuing to expand. Rodger, Moore and Newsome (2010) report that between 20 and 40% of international tourism involves some form of wildlife viewing. People expect to see wildlife (Lemelin and Wiersma, 2007). While participants in wildlife watching will have different interests and preferences (Vaske, Hardesty and Sikorowski, 2003), wildlife watching experiences can include unguided encounters in natural areas, specialised wildlife tours, managed local wildlife attractions and research, and conservation or education

Figure 17 Red kite viewing is increasingly popular.

tours (Valentine and Birtles, 2004). However, as wildlife watching has increased so have concerns around disturbance to wildlife populations and habitats (Higginbottom, 2004; Rodger, Moore and Newsome, 2010).

Flight and Behaviour change

Most reported disturbance issues around watching wildlife relate to flight and behaviour change – particularly impacts associated with approaching animals for viewing, touching, feeding and photographing (Valentine and Birtles, 2004; Green and Giese, 2004; Lemelin and Wiersma, 2007). For example, Wolf and Croft's (2010) study of tourists and kangaroos in Australia suggests that talking within the group or conversation directed towards the animal contributed to the impact of their approach on wildlife. Karp and Guevara (2011) discuss the impacts of increasing ecotourism activities on rainforest birds in Peru, particularly conversational noise, which can provoke 'predator responses' such as fleeing, increased vigilance, vocalisation cessation and moving to new territories. Although reactions to human and mechanical noise can vary among species, the authors reported a decline in abundance of forest birds in relation to average conversational noise of 50 dB. Insectivore bird species were the most affected. However, they did note that a predator response may be due to the fact that many of these species are hunted by humans in this part of the world. Further examples include human presence interfering with foraging behaviour of mammals and birds (e.g. bald eagles, ravens and woodpeckers (Figure 18)) such that they avoid preferred foraging sites with a consequent reduction in quality or quantity of food (Green and Giese, 2004). Food-conditioned wildlife can abandon territories and move to more exposed recreational sites (Marion, Dvorak and Manning, 2008). Small mammal populations can reach unnaturally high levels leading to disease transmission or starvation during the off-peak season when people (and the food they carry) are scarce (Marion, Dvorak and Manning, 2008). There is also a risk that wildlife can become aggressive towards humans.

Birdwatching is a hugely popular recreational activity in many countries and a good example of nature watching with 46 million birdwatchers reported in the USA, although only a fraction will be 'committed birdwatchers' (Sekercioğlu, 2002; Valentine and Birtles, 2004) (Figure 19). Numbers of birdwatchers in the UK vary between 10 000 and 1 million depending on how you define birdwatching (e.g. based on skills, participation in surveys). Birds are particularly popular as they are easy to see and identify but for many people birdwatching is a form of serious leisure (Stebbins, 1992; Leip, 2001; Bell, Marzano and Podied, 2010), a term that refers to leisure activities that require practitioners to invest considerable time, effort and often financial resources to attain expert knowledge and skill. The act of birdwatching can have positive or negative impacts on birds. As Sekercioğlu (2002, p. 282) has pointed out, birdwatchers represent an 'environmentally conscious segment of ecotourism' (see also Bell, Marzano and Podied, 2010). However, there are incidences where recording or photographing birds can have harmful effects, particularly in competitive birdwatching with the importance of birding 'lists' (e.g. local patch list, county list, UK list) and 'twitching' (e.g. those who travel at short notice to see a rare bird). These can impact on rare and vulnerable

Figure 18 Human activity can disturb birds such as the great spotted woodpecker.

Figure 19 Bird watching can have positive and negative impacts.

bird species and potentially the habitat in which the bird species is found (e.g. through destruction and trampling). Intrusive photography, playing bird call tapes, flushing and approaching birds, particularly during the breeding season can lead to nest abandonment and egg loss due to nest predators (Sekercioğlu, 2002).

Other activities

Other activities cited in the literature include orienteering, skiing, picnicking (Figure 20) and paintballing. Orienteering events can lead to trampling of flora and creation of new paths, erosion and disturbance of fauna if not properly managed (Anderson and Radford, 1992; Littlemore and Barlow, 2005; McEvoy *et al.*, 2008) (Figure 21). Research by Watson and Moss (2004) in Scotland on the impacts of recreation on ptarmigan found that crows attracted by the development contributed to a reduction in breeding success up to 4 km from a car park. Ski wires also led to ptarmigan deaths. A study by Patthey *et al.* (2008) on black grouse populations in the north-western European Alps highlighted the following potential impacts of disturbance from ski lifts and outdoor winter activities: habitat destruction and modification of native vegetation reducing faunal species richness, increased stress response from free-riding winter sports such as ski mountaineering, and mortality from collision with cables (see also the Walking and hiking section on p.9). The authors found that black grouse abundance was 36% lower in ski resort sites than in natural areas. Very little research has investigated the impacts of picnicking. Liddle (1997) refers to just two studies both conducted in the 1970s. These indicate that soil erosion and compaction can be significant, and affect soil moisture content in particular. However, Leney 1974 (cited in Liddle, 1997) revealed that some species (beetles and craneflies) were in fact promoted at the majority of the picnic sites in her study. Paintballing in UK woodlands became hugely popular in the late 1980s and 1990s and, although perhaps it is not as widespread as it once was, impacts include soil compaction, erosion, trampling of ground flora and base of trees, damage to regenerating trees, and disturbance of small mammals, ground-nesting birds and soil invertebrates (Hatton, 1991; Littlemore and Barlow, 2005).

Figure 20 Picnicking beside Llyn Llewelyn, Beddgelert forest.

Figure 21 Orienteering needs to be properly managed to avoid disturbance to flora and fauna.

Longevity of impacts

Understanding the longevity of impacts from recreational use on forests is critical to designing management plans. If vegetation damaged by trampling recovers quickly, forest managers may be able to address problems through short-term measures. However, long-lasting impacts are likely to require more strategic approaches. As a general rule it is clear that while impacts can and do occur rapidly, recovery is relatively much slower (Cole, 2004). However, this does not mean that recovery is slow *per se*, and many recreation ecology studies report limited long-term impacts, if any. In a study in Belgium, Roovers *et al.* (2004) show that forest vegetation recovery 'during the first year after trampling was limited in most plant communities' but that rates differed across forest community type. Kissling *et al.* (2009, p. 303) compared short- and long-term studies of impacts across a number of vegetation and soil indicators, and concluded that 'it could be problematic to use the results of short-term

trampling experiments to predict general long-term trampling effects'. Smith-Castro and Rodewald (2010) state that 'our findings suggest that the responses of birds to human use of recreational trails have only short-term effects, with no apparent effects of on nest survival'. Banks and Bryant (2007) also reported largely short-term, rather than long-term, effects of dogs on ground-nesting birds, and Thurston and Reader (2001) report quick recovery of plant stem density and species richness following high levels of impact on trails.

Comparing disturbance impacts of different recreational uses

A number of the articles reviewed provide some comparisons between impacts of various recreational uses, the most common being walking/hiking, cycling/mountain biking, horse riding and off-road vehicles (including motorcycles). Much of the comparative material is contextual, based on specific case studies and dependent on factors such as the recreational activities most common in the study area as well as the species and habitat being studied (Table 4).

In an early comparative study by Weaver and Dale (1978, p. 451) on trampling effects in the Rocky Mountains, the authors found that horses and motorcycles were more damaging than hikers. However, the authors also established that motorcycles created more damage to soil and vegetation when going uphill while hikers and horses were most damaging when going downhill. On level ground, horses were most destructive and hikers least destructive (Weaver and Dale, 1978, p. 453).

Torn *et al*. (2009) compared the impacts of hiking, skiing and horse riding on forest trails and vegetation, noting that 'Horse trails were as deep as hiking trails, even though the annual number of users was 150-fold higher on the hiking trails' (p. 1427). Thurston and Reader's (2001) study in a mature Canadian deciduous forest found little difference between impacts of mountain bikers and hikers on vegetation. Plant stem density and species richness were reduced by nearly 100% during experiments with highest intensity but can recover quickly once either use is halted (see also the Longevity of impacts section on p.20). Greatest damage occurred in the centre zone of the trail. Ruff and Mellors (1993) also maintain that there was no solid evidence suggesting that mountain biking is any more damaging to bridleways than walking or horse riding although they do acknowledge it can contribute to overuse of countryside sites.

Thurston and Reader (2001) conducted an experiment comparing the impact of mountain bikers (and hikers) on soil and vegetation. The study site in Canada was located in a mature deciduous forest with the predominant soil type being well-drained fine sandy loam. No timber harvesting was taking place. The number of passes over a particular area ranged from 1 to 500. The authors cite Cole and Bayfield (1993) who suggest that 500 passes was

Table 4 Details of selected comparative studies.

Study		Activities compared				Comparison
First author	Date	Walking	Cycling	Horse	Off-road vehicle use	
Trampling studies						
Buckley	2004	■			■	Vehicles significantly greater impact
Littlemore	2005	■			■	Vehicles significantly greater impact
Ruff	1993	■	■	■		No difference
Thurston	2001	■	■			No difference
Torn	2009	■		■		No difference
Weaver	1978	■		■	■	Vehicles and horses slightly greater impact
Wildlife disturbance studies						
Blanc	2006	■			■	Walking significantly greater impact
George	2006	■	■	■	■	Walking and biking no difference but greater impact than other activities
Lathrop	2003	■	■			Biking significantly greater impact
Naylor	2009	■	■	■	■	Vehicles significantly greater impact than all other activities
Sastre	2009	■			■	Vehicles significantly greater impact
Wolf	2010	■			■	Walking significantly greater impact

sufficient to cause a 50% reduction in vegetation cover for most vegetation types. The effects of mountain biking (and hiking) were first measured two weeks after the experiment and then after one year based on recommendations by Cole and Bayfield (1993) to identify damage and resilience of vegetation type. The study found that while vegetation loss increased with increasing pass activity, there was no significant difference between bikers and walkers in terms of pass intensity or vegetation loss.

In comparing the impact of different users one study found that there was no evidence that mountain biking should be managed any differently from hikers although it is noted that mountain bikers cover more ground (they are faster) so may disturb more wildlife per unit time (Taylor and Knight, 2003). A mountain biker travelling downhill at high speed might stress wildlife more than a hiker (Lathrop, 2003). Moreover, activities which are fast-moving but quiet such as mountain biking and jogging are less predictable for wildlife than slower activities such as hiking (Sterl, Brandenburg and Arnberger, 2008). Sterl, Brandenburg and Arnberger (2008) provide an example (from Gander and Ingold, 1997) of alpine chamois (*Rupicapra rupicapra*), which fled greater distances when encountering mountain bikers and joggers as opposed to hikers.

George and Crooks (2006) conducted a study of human recreational disturbance on coyotes, bobcat and mule deer within the Nature Reserve of Orange County, California. They found that the most common recreational activity in this area was hiking, followed by mountain biking, off–road driving and horse riding. Both bobcat and coyote activity was spatially displaced by human activity, particularly biking and hiking (but not driving or horse riding). However, in most instances walking and hiking are shown to have either similar (i.e. no worse) or less impact than other recreational activities. For example, Banks and Bryant (2007, p. 612) stated that 'Humans walking alone also induced some disturbance but typically less than half that induced by dogs'.

In relation to disturbance of North American elk, Naylor, Wisdom and Anthony (2009) found that mountain biking and hiking did not negatively impact as much as all-terrain vehicles. The authors suggest that once elk had moved away from the routes in question they could resume foraging activity but that mountain biking did increase elk travel time and decrease feeding time. The authors also found that the highest travel response of elk in north-east Oregon was related to vehicle activity (compared to hiking, mountain biking and horse riding). Nevertheless, the authors note that peak feeding time is during dawn and dusk, which will rarely coincide with high traffic. A study on great bustards in central Spain (near Madrid) found that vehicle traffic was the most common source of disturbance (escape response) followed by walkers (a group that produced a higher alert response) and was higher at weekends and holidays when recreational activities are more pronounced (Sastre *et al.*, 2009).

The impact of off-highway vehicles (OHVs) depends on driving practices and habitat and species type (Buckley, 2004). There are some differences in the literature over the extent that OHVs can cause disturbance impacts. For example, OHVs have been said to cause up to 5 to 30 times more damage to vegetation than hikers (Buckley, 2004; Littlemore and Barlow, 2005). Intuitively, one might believe that OHVs would disturb wildlife far more than other non-motorised recreational use. However, Bayfield (1986 in Newsome, Moore and Dowling, 2001) showed that in the Cairngorms the ecological impacts of OHVs were limited but social perceptions relating to potential impacts of OHVs were far greater. In a study on the impacts of tourists and wildlife watching on wild kangaroos in Australia, the authors found that flush response was lower when vehicles approached than pedestrians (Wolf and Croft, 2010). They state, 'Our behavioural observations showed that the two kangaroo species treated an approach on foot with more alarm than a vehicle approach as the time spent in vigilance behaviour, hiding or aversion movements increased by 30%'. OHVs also did not affect spatial distribution and occurrence of martens in California, USA although the authors note that as martens are nocturnal, secretive creatures, it would have been too difficult to study the direct impact of OHV disturbance on behaviour (Zielinski, Slauson and Bowles, 2008). Similarly, Blanc *et al.* (2006) maintain that vulnerable bird species in France were disturbed more by walkers, with or without dogs, than by OHVs (56.8% as opposed to 2.4%).

Recreational users' perspectives

Few studies exist on the extent to which different user groups perceive their own and others' impacts on the environment but Dorwart, Moore and Leung (2009) maintain there is a link between activities carried out, preferred places and visitor behaviour, attitudes and expectation. There are debates over whether participation in outdoor recreation increases pro-environmental attitudes and behaviour (Bright and Porter, 2001; Cordell *et al.*, 2002). However, Lemelin and Wiersma (2007) found in their study on impacts of tourism on polar bears that people can detach concerns about environmental issues from how they behave outdoors. Generally, it seems that user groups have little awareness of the impacts of their activities and hold other user groups responsible for negative impacts of

recreation on wildlife (Geraghty, 2000; Symmonds, Hammitt and Quisenberry, 2000; Taylor and Knight, 2003; Manning *et al.,* 2004; Sterl, Brandenburg and Arnberger, 2008). Interestingly, a survey carried out by Taylor and Knight (2003) on recreational disturbance to three large mammals in a US case study found that 50% of the visitors surveyed did not believe that recreation has a negative impact on wildlife. Although unintentional and intentional feeding of wildlife has been reported as a problem in places where nature watching or other activities such as camping take place, Marion, Dvorak and Manning (2008) reported that only a minority of respondents in their study on chipmunks admitted to feeding wildlife. Other studies present similar findings where recreational users do not believe their activities affect wildlife even if they see animals respond to their actions and particularly if they are obeying prescribed rules and regulations (Thompson *et al.,* 1987; Cooper *et al.,* 1981 in Klein, 1993).

Sterl, Brandenburg and Arnberger's (2008) study which investigated visitors' awareness of recreational disturbance on wildlife in an Austrian urban national park found that dog walkers believed that off-trail users impacted more on wildlife and off-trail users had similar impressions of dog walkers. However, the authors suggest that the answers given by recreational user groups such as dog walkers were influenced by their concerns over the safety of their own animals. For example, this group stated that cyclists disturb wildlife but were actually concerned about cyclists impacting on dogs that are off leash. Nevertheless, this study is particularly interesting as it focuses on a small national park which is highly used due to its urban location, network of trails and unlimited access. The main users of the park are cyclists, walkers/hikers, dog walkers and joggers, while in winter skiing is a popular activity. The study took place in the winter as this is a problematic time for wildlife such as deer species because of the lack of tree and shrub cover. Visitors (n=271) were interviewed and divided between three groups: (1) dog walkers; (2) on-trail walkers; and (3) off-trail walkers. The study's objective was to find out which activities (out of a list of 14 presented) were perceived by visitors to potentially impact on wildlife in the park, whether visitors were aware of their own potential impact and if they felt other user groups had an impact on wildlife. General results showed that off-trail biking and dog walking are perceived to have the highest impacts on wildlife. Roe deer and birds were the species most mentioned, while disturbing activities were felt to be the result of high visitor numbers, noise or dogs. However, 60% of interviewees did not believe that recreational use disturbed wildlife and only 12% of visitors stated that they had disturbed wildlife during their visit. When asked why their presence had not disturbed wildlife, 75% of respondents believed it was because they had engaged in unobtrusive behaviour, stayed on the trails and were quiet. Another perception was that wildlife had not been disturbed if they had not been seen (see also Lemelin and Wiersma, 2007). Visitors judged certain activities such as walking and cross-country skiing to have low impact on wildlife. However, the authors did point out that off-trail users could cause greater disturbance than, for example, those who stay on trails as they tend to stay in the park for longer and disperse across wider areas. Moreover, while fewer people may take part in cross-country skiing, it is a relatively quiet and fast-moving activity, which can have significant impacts on wildlife, particularly off-trail.

Taylor and Knight (2003) compared mountain bikers' and hikers' perceptions of their effects on wildlife. Respondents were asked: (1) how close they felt it was acceptable for recreationists to approach wildlife (wildlife flight distance); (2) how far they thought animals moved if they fled from recreationists (distance moved); (3) to what degree they believed wildlife was being affected by recreation; and (4) which recreational users group they felt was most responsible for causing stress to wildlife. The findings highlighted that recreationists were having a greater effect on wildlife than they thought. A key difference was that most recreationists felt they could approach wildlife at a much closer distance than wildlife would allow according to the experimental trials that were also carried out.

The emergence of mountain biking as a popular form of recreation has had a particular effect on other users over the past two decades. Previously, negative perceptions surrounding mountain biking may have arisen because they were an unfamiliar presence in the landscape (Ruff and Mellors, 1993). Thus, some found mountain biking to be out of place in the countryside (Jacoby, 1990; Cessford, 1995), possibly because users are happy to encounter 'their own kind' but do not like faster or more mechanised users (Jacoby, 1990; Cessford, 1995). Others feel that the addition of mountain biking is damaging to existing trails (Thurston and Reader, 2001). Heer, Rusterholz and Baur (2003) cite studies from Moore (1994) and Hoger and Chavez (1998) who report that hikers believed mountain bikers negatively affected the environment such as through the creation of informal trails.

In Symmonds, Hammitt and Quisenberry's (2000) study, 700 mountain bikers were asked to rate their impact on trails compared to horse riders, walkers/hikers and motorised vehicles. They rated themselves as being less damaging than horse riders and vehicles but more damaging than walkers/

hikers. The authors note that perceptions are often different from actual behaviour with 42% perceiving that they had a medium level of impact on trails and 39% a low impact. Nevertheless, 91% of mountain bikers acknowledged that mountain biking caused some degree of trail erosion with the remaining 9% stating that it had no effect (Symmond, Hammitt and Quisenberry, 2000).

A mountain-biking study conducted in the UK (Geraghty, 2000) compared the perceptions of mountain bikers, hikers and horse riders of the impact these recreational groups have on the countryside. The three user groups were represented in the study and most of the 73 participants believed that the other recreational groups caused more damage to trails than their own recreational activity. For example, horse riders were aware that horses' hooves might cause trail damage but they believed that mountain biking 'behaviour' and the fact that mountain bikers tend to concentrate in one area would have a greater impact on the environment.

Heer, Rusterholz and Baur (2003) conducted a study of perception and knowledge of mountain bikers and hikers relating to forestry, nature conservation and social conflicts in the northern Jura Mountains, Switzerland. They found that neither the type of recreational activity nor any aspect of the forest visit (e.g. how frequently they visited the forest, how long they stayed in the forest, how far they travelled etc.) had any influence on knowledge and perceptions. However, the authors did point out knowledge did not necessarily result in a change of behaviour and some of the respondents were unaware of the impact of their activities.

Only Buckley (2004, p. 83) makes reference to vehicle user attitudes suggesting that, 'there are also many recreational users of OHVs, both private and commercial, who drive them with no concern for environmental impacts and in places of high conservation value'.

Newsome *et al.* (2002) cite a US survey of environmental managers by Shew *et al.* (1986) that had received public complaints about horses including: campsite damage, tethering damage, manure on trails and associated insects and trail damage. Aside from the usual conflicts between recreational uses there appears to be some opposition to horse riding on conservation grounds, particularly in Australia and the USA (although see Miller, Dickinson and Pearlman-Houghgie, 2001 in relation to UK National Parks). Newsome *et al.* (2002) believe that 'in many cases horse-riders are indifferent to or unaware of their effects on the environment (UK CEED, 2000; D. Newsome, personal observation)'.

Taylor and Knight (2003) surveyed 640 recreationalists (hikers, mountain bikers and horse riders) on Antelope Island in Utah and revealed widespread support for the use of penalties for recreationists who chased or intentionally stressed wildlife. However, they were less supportive of closing trails seasonally and establishing minimum approach distances to wildlife. There was little support for having fewer trails on the island, requiring visitors to watch an educational video on effects of recreation on wildlife or allowing only one type of recreational use (Taylor and Knight, 2003).

Managing impacts

According to Marion, Dvorak and Manning (2008) management can be direct, such as leaving little room for individual freedom of choice, or indirect, where attempts are made simply to influence the decisions and behaviour of visitors. Higginbottom (2004, p. 218–221) in her edited volume on wildlife tourism provides two sets of management options or tools to manage recreational use. The first relates to management of wildlife tourism at sites including restriction of visitors to specific wildlife areas, dispersal of visitors to reduce impacts on wildlife and habitats at sites (although there are opposing views that suggest dispersal can cause more damage – see Cole, Petersen and Lucas, 1987), installing approach distances and temporal restrictions, and managing expectations in relation to what visitors expect to experience (e.g. handling or touching animals). The second relates to more strategic actions such as external regulations (by government), economic instruments, industry self-regulation, physical alterations to environment to withstand visitor pressure, cooperative agreements, education and marketing. Some evidence is available in relation to management of sites and is outlined below.

A range of management options have been identified in the literature relating to different recreational users. Management can involve setting aside new areas for recreation, physical and natural barriers, provision of track alterations, temporal restrictions, informational and/or warning signs, trail maintenance, habitat restoration, screening vegetation for wildlife, impact surveys, buffer zones or minimum approach distances. Various codes of conduct such as the Camping and Caravan Club Environmental Code (Johnson and Clark, 2000), UK Countryside Code and universal 'Leave No Trace' policy (Cole and Monz, 2003; Littlemore and Barlow, 2005) promote informed self-regulation.

Cole, Petersen and Lucas (1987) provide a broad view of management solutions aimed at tackling disturbance problems in natural 'wilderness' areas. Eight general 'strategies' are identified, which are then populated by more detailed 'tactics'. The strategies, some of which clearly demand social scientific knowledge, are:

1. Reduce use of the entire wilderness.
2. Reduce use of problem areas.
3. Modify the location of use within problem areas.
4. Modify the timing of use.
5. Modify type of use and visitor behaviour.
6. Modify visitor expectations.
7. Increase the resistance of the resource.
8. Maintain or rehabilitate the resource.

Tools for planning and managing recreational need with conservation requirements are available but are most easily identified in literature from the USA and Australia. There is one UK reference to Environmental Management Systems relating to integrated management that includes outdoor recreation (Font *et al.*, 2001). The most cited tools are the Recreational Opportunity Spectrum (ROS) (Clark and Stankey, 1979) and Limits of Acceptable Change (LAC) (Stankey *et al.*, 1985; McCool, 1996), but there are others such as Visitor Impact Management (Knight and Gutzwiller, 1995), Visitor Experience and Resource Protection (VERP) (National Park Service, 1997a, 1997b), Experience-based Management (Manfredo *et al.*, 2002) and Ecological Regional Framework (White *et al.*, 2006) (see Leung and Marion, 2004 for an overview). As Higginbottom (2004, p.212) has pointed out, most of these tools or models share key elements that are central for effective management of recreational disturbance. They include: clearly defined management goals and objectives, indicators and standards to show where objectives have been achieved, management actions to meet the objectives, implementation of monitoring and evaluation programmes and a clearly documented process involving all of these elements. However, Higginbottom (2004, p.219) notes the difficulties in determining the effectiveness of various management actions suggesting they are 'mostly complex and poorly understood'. Monitoring programmes are needed to records levels of use of each recreational activity, users' compliance with management constraints and impacts of recreational activities on wildlife. Below we briefly identify three broad sets of management options.

Zoning, 'set-back' distances and exclusion

Knight and Temple (1995) identify three main categories of access restriction aimed at reducing wildlife disturbance by recreational activities: buffer zones, time restrictions and visual screens (Figure 22). Establishing 'buffer zones' is a common method, the range of which can be derived from flight response and distance research (e.g. 'alert

Figure 22 Kielder Campsite screened by trees.

initiation distance'). These can be calculated according to area of influence (area or trail or line of human activity where wildlife is likely to be disturbed) or perpendicular distance, which is the shortest distance between humans carrying out an activity and wildlife (Taylor and Knight, 2003). Time restrictions include daily and seasonal access restrictions, while visual screening (e.g. through vegetation) can be effective in shielding wildlife from human activities, reducing the impact.

Management strategies have formed a large part of discussions in the camping literature, such as the use of 'dispersal' or 'containment' strategies to spread or contain the risk of camping impact (Leung and Marion, 2004; Kangas *et al.*, 2007). A definition is provided by US authors Leung and Marion (2004, p. 249–250):

'A campsite containment strategy seeks to reduce the total extent of impacts by concentrating camping use to a small number of campsites, which receive a higher frequency of use. Conceptually this approach can be applied to a temporal scale, with camping use being concentrated during specified seasons or times'.

There are still potential problems with site expansion and creation of 'social access trails' but these can be minimised by good spatial planning, which is informed by an understanding of campers' needs and activity patterns (Johnson and Clark, 2000; Leung and Marion, 2004).

Even at relatively low levels, inappropriate recreational activity can cause considerable damage, particularly to vulnerable habitats and species, and in the literature there are some doubts as to whether self-regulating systems would work, particularly in large nature reserves (Newsome *et al.*, 2002). As an example, prohibiting all horse riding opportunities is unlikely to be socially or politically acceptable, but in Australian national parks, Newsome *et al.* (2002) advise park authorities to restrict free access and authorise commercial operators to provide tours in designated areas through a permit basis, thereby enforcing low levels of use (see also Miller *et al.*, 2001). A monitoring programme of the commercial horse-riding operation is considered essential (Figure 23). Also in Australia, Landsberg, Logan and Shorthouse (2001) provide 10 principles to guide management of horse riding in peri-urban nature reserves including trail maintenance and exclusion zones.

Some authors (e.g. Newsome *et al.*, 2002) believe that restriction or rationing recreational use in vulnerable areas is a more effective management tool than 'education'.

Figure 23 Horse rider entering the Wilverley enclosure, New Forest.

Marketing

According to Moscardo and Saltzer (2004) marketing is often seen as negative due to its association with sales and commercial interests. However, one key aspect of studying tourism and recreational markets involves an understanding of who the 'customers' are, their needs, expectations and motivations, how they currently behave and ways in which this behaviour can be influenced to lesson negative impacts on wildlife. Social marketing is an approach that focuses on behaviour change for individual or societal gain (Kotler and Lee, 2008). It is essentially based on developing an understanding of what people do and providing a framework for behavioural interventions. In order to facilitate behaviour change, the interventions should be fun, easy and acceptable to a wide range of people (e.g. a social norm) (www.snh.org.uk) . A range of literature stresses the importance of understanding user perspectives and behaviour (Symmonds, Hammitt and Quisenberry, 2003; Taylor and Knight, 2003). In the UK, Littlemore and Barlow (2005) emphasise the role of stakeholder engagement in encouraging user groups to stick to specific areas or trails. They suggest contacting 'official organizations to help spread the word as a higher degree of user and owner compliance will be initiated by consultation, planning, interpretation and all understanding their roles and responsibilities' (p. 282). However, no studies have been identified which use marketing approaches to investigate recreational disturbance issues.

Education and interpretation

Management proposals in a number of the papers we reviewed often involved a recommendation for visitor

'education' programmes as it is presumed that people are unaware or unwittingly disturbing wildlife (Cole, Hammond and McCool, 1997; Sterl, Brandenburg and Arnberger, 2008). There are suggestions that managers should investigate and consider visitor perceptions when planning any actions so that visitors are more likely to understand the benefits to wildlife and be accepting of measures (Taylor and Knight, 2003). For example, education initiatives can provide information on the impacts of recreation on wildlife such as increased stress levels (Heer, Rusterholz and Baur, 2003; Taylor and Knight, 2003). Marion and Reid (2007) write about the efficacy of low-impact education programmes in protected areas. They note that visitor information (Figure 24) and education programmes (Figure 25) which aim to 'persuade' visitors to adopt low-impact behaviour are a light-handed but effective management response to reduce impacts. The focus is on encouraging appropriate behaviour rather than trying to control visitors. 'Visitors retain their freedom of choice but information that considers the consequences of their actions guides their behaviour' (p.6). The international 'Leave No Trace' programme, targeted primarily at campers but also other recreation users, is an example of awareness raising of the potential negative impact of visitor activities and providing information on the most appropriate practices to avoid or minimise impact (Marion and Reid, 2007, www.lnt.org/programs/principles.php).

Figure 24 Getting information in the forest shop at Grizedale, Cumbria.

Figure 25 A Forestry Commission education ranger conducting a networking day.

Four conceptual approaches have been identified by Marion and Reid (2007, p.10 and references therein) to understand how education may influence an individual's behaviour. The first looks at moral appeals made to visitors at different stages of moral development. The authors suggest that message delivery is important and messages which provide a rationale for recommended behaviour (i.e. why it is important) are more effective than simple statements on how to minimise impact.

However, there are limitations associated with any educational programme, not least of which is the pervasiveness of the 'knowledge deficit' concept (Durant, Evans and Thomas, 1989; Miller, 2001) where individuals are conceptualised as rational actors and certain (usually negative) behaviours are attributed to a simple lack of scientific information. Studies have illustrated the complexity of the relationship between 'lay' person behaviour and their knowledge, understanding and use of 'science' and other forms of information (e.g. Wynne, 1995). As Cynn *et al*. (2002 cited in Moscado and Saltzer, 2004, p.176) point out 'the relationship between environmental awareness, intention and behaviour is tenuous, particularly in the context of tourism' (see also Lemelin and Wiersma, 2007). It is clear, therefore, that educational programmes focused on modifying recreationists' behaviour require careful design and considerable insight into the diversity of visitors and the ways in which recreationists' understand and use information.

'Interpretation' is closely related to 'education' (they are often considered together) and can take several forms, from signage through to on-site advice direct from guides or officials (Figure 26). These methods have been shown to work differently across varied situations and audiences/social groups. Hughes and Saunders (2005) suggest that visitors' response to on-site interpretation is linked to their intended activity and those taking part in exploratory activities such as hiking and wildlife watching were more likely to be interested in conservation messages. Littlefair and Buckley (2008) report that 'minimal-impact interpretation' significantly reduced the ecological impacts of visitors to an Australian National Park/World Heritage Site (see Marion and Reid, 2007 for a review of 'low impact' education and interpretation methods). Cole, Hammond and McCool (1997) cite the work of McGuire who produced a model to identify how interpretation 'messages' are processed. The model involves six steps:

Figure 26 Visitors read the interpretation panel at Nash Carpark, Presteigne.

exposure (to the message), attention (reading the message), comprehension (understanding the message content), yielding (acceptance of the message), retention (stored in memory for later use) and behaviour (changes in accordance with message content). Cole, Hammond and McCool tested whether exposure to low-impact messages on trailside signs would increase visitors' knowledge of appropriate practices. Through various trials the authors posted between two and eight messages on a message board along with a topographical map. They noted if visitors (*n*=506), consisting of hikers (65%) or horse riders (35%) stopped to look at the messages on the bulletin board and how long they spent reading the messages. Retention of messages was assessed through a post-visit quiz (*n*=217). A key finding was that visitors exposed to eight messages did not retain any more new knowledge than those who had read just two messages even though they would spend more time reading. In addition, the authors found that while the topographic map did attract visitors to the message board, it did not facilitate attention being paid to the messages. Not surprisingly trailside message boards are not an effective means of communicating with horse riders, who will perhaps find it difficult to stop at such places. Interpretive signs are not always effective. For example, Buckley (2004) reports how Pojar *et al*. (1975) found that even illuminated and animated warning signs did not reduce roadkill of deer: drivers only slowed down when they saw dead deer carcasses on the roadside.

The development of general codes of practice can be conceptualised as an overarching dimension of education and interpretation. They can perhaps best be viewed, in Marion and Reid's terms, as 'moral appeals' to those visiting and/or using 'natural' areas. Parker (2006, p. 1), for example, describes the UK's Country Code as 'an attempt to pursue a particular moral project and an effort to influence behaviour through design of a particular regime of conduct'. Sociological analysis of such codes has noted their important role in behaviour change, but analysis of their development has highlighted how they can become a vehicle for placating various competing actors and constructing particular boundaries around citizenship (Parker, 2006, 2007), rather than providing understanding of the processes necessary to generate a widely shared vision of acceptable behaviour.

Discussion

In this section we make some observations about the limitations, strengths and framing of the evidence reviewed above, with the objective of illustrating its usefulness to forest managers.

Quality and scope of literature, and its relevance to the UK forest context

In this study we have focused our attention on literature which identifies disturbance impacts of recreational activities. Remarkably few studies have been conducted in the UK and therefore much of the evidence relating to impacts and species encountered in the UK has been generated by research done in Europe (e.g. Finland, Sweden, Switzerland, Spain and Belgium) and further afield (e.g. USA and Australia). Forest environments do receive attention, often focusing on protected areas and sensitive habitats but also including a number of studies on urban woodlands. Moreover, much of the research on recreational disturbance relates either to trampling of vegetation or there is a considerable focus on the impact on bird species. Various studies and reviews note this focus on birds (e.g. Green and Giese, 2004; Higginbottom, 2004; Taylor *et al*., 2005).

The results present a range of evidence highlighting how species are impacted through recreational use although many of the findings reported are possibly too detailed and context specific for the average manager to use meaningfully. Nevertheless, it does show that habitats can suffer from reduced plant and vegetation cover, plant damage and abrasion reducing growth and increasing premature leaf loss, reduced plant genetic and species diversity, modification of soil properties, soil removal and compaction, surface litter reduction, and damage to lichens and mosses. Wildlife can be crushed, hit and killed or disturbed through human or mechanical noise and/or close encounters. Recreational activities that interfere with feeding, breeding, travelling or resting behaviour can induce an alert or flight response affecting energy balances, social behaviour, increased vulnerability of the young or nest predation.

In some studies, human disturbance is implicated in impacts on bird species, but not observed or assessed directly. Liley and Clarke (2003), for example, analyse the relationship between nightjar density and surrogate measures of human density (such as number of buildings), which leads them to 'suggest', albeit 'tentatively', that reduced nightjar density is 'at least partly due to actual human presence on the heathlands and, as such, human disturbance is potentially a problem for this species'. Summers *et al.* (2004) move from their finding that some capercaillie tended to use trees away from tracks and roads to suggest that 'human disturbance may be displacing capercaillie and reducing the amount of woodland that can be fully occupied' (p. 66). They subsequently conclude that track removal or closure may be beneficial for capercaillie. In an older study, Jackson and Jackson (1980) infer a link between good weather and increased use of heaths by holidaymakers, and consequent 'disturbance' of lapwings. None of these studies observes or measures actual human activities, presence or disturbance in the study areas, and are therefore of limited value in understanding links between recreation and wildlife disturbance. Rather, they demonstrate that the assumption of negative relationships between recreation and wildlife are a 'default' position.

Isolating recreational disturbance from other disturbances

Forest managers need to be aware of the difficulty in isolating disturbance caused by recreation from natural disturbance and that caused by other human activities. Understanding the particular cause(s) of disturbance is, of course, essential if managers are to avoid or mitigate the impacts. The literature we have reviewed is one part of a wider set of literature describing disturbance of wildlife and natural areas by a range of human activities. Within the forestry literature there is a considerable focus on the disturbance impacts of forestry operations (e.g. timber harvesting). This general point has a number of implications for our study and the wider understanding of human disturbance. Disentangling the disturbances caused by these different activities can be problematic. In certain ways the distinction between sources of disturbance seems arbitrary, and somewhat unnecessary. For example, measuring the flight distance caused by noise generated by recreational vehicles or harvesting vehicles may be expected to yield similar results. We have included various studies of 'human disturbance' more generally within our review, but excluded many focused explicitly upon non-recreational activities. We did not identify any studies that discussed the impacts of recreation on wildlife management activities

such as accidental disturbance of deer during stalking or damage to traps. Further investigation around this topic is recommended. However, it is vital to note that the social dimensions of these activities (such as likely behaviours and/or how information is understood and used), and therefore the legitimate management responses, will vary considerably. This makes the absence of social scientific analysis of these problems particularly apparent and problematic.

Another dimension emerges from the consideration of climate change as affecting wildlife and natural areas. Not only is climate change likely to affect people's recreational activities and patterns thereof, and in some locations exacerbate existing impacts from recreation (McEvoy *et al.*, 2008), but also climate change can itself be conceptualised as a cause of 'disturbance' (perhaps Type 2 – habitat change) which has the potential to affect every environment. This raises some profound questions relating to distinctions between 'human' and 'natural' environments: a dichotomy which, philosophically, has always been at the core of recreation ecology as a field.

The conceptualisation of wildlife habitat as somehow 'natural' areas in which humans (and their effects) are out of place permeates the recreation ecology and associated literature (and environmental and conservation literature beyond). It is particularly apparent in the use of terminology such as human 'intrusion' into wildlife habitat (e.g. Gutzwiller *et al*., 1998, Gutzwiller, Riffell and Anderson, 2002; Gutzwiller and Riffell, 2008). A legitimate question is why should we treat wildlife disturbance by humans any differently from (i.e. more or less legitimate) disturbance by other wildlife? Prey species behaviour is fundamentally conditioned by predator species behaviour, a point which is perhaps made most explicitly by the ecology literature on the 'landscape of fear' concept (Laundré, Calderas and Hernández, 2009; Laundré, Hernández and Ripple, 2010; Manning, Gordon and Ripple, 2009). Anthropogenic disturbance of wildlife can be conceptualised in exactly this way and this can act to blur the boundaries around the study of 'disturbance' – and the legitimacy of responding to it.

In a corollary effect, such disturbance has been shown to have a positive effect on prey species through disturbance and displacement of *their predator* species – including a study of one UK forest species. Ibanez-Alamo and Soler (2010) conclude that disturbance by researchers ('investigators') 'significantly reduces nest predation' on blackbirds, leading them to suggest that blackbird predators may avoid disturbed places. This is an important finding, and very few studies investigate the impact of disturbance on predator behaviour. One exception, although not in a forest context, is Leighton, Horrocks and Kramer (2010), which investigated the impact of human disturbance upon the use of hawksbill sea turtle nesting habitat by an important predator species – mongooses. This study showed that human activity 'substantially decreased mongoose use of nesting habitat' and could thus reduce predation of nests by around one-third to one-half (range 29%–56%). The greatest effects were had at low visitor numbers.

Impacts – physically similar, socially diverse

Given the literature's tendency to analyse disturbance physically (i.e. by focusing on the mechanics of trampling impact and responses to noise), it is useful to consider to what extent it is productive to analyse different recreational activities as distinct from one another and, thus, what is missed by current analysis. Certainly if we adopt Liddle's (1997) classification then there are several overlapping characteristics of disturbance relating to the most popular recreational activities conducted in forests. Type 1 disturbance where activities invoke an anti-predator response are identified in the literature on walking, mountain biking, off–road vehicle use, camping, skiing, nature watching and events such as paintballing and orienteering. Type 2 disturbance involving habitat destruction or modification through, for example, trampling are a feature of all of the activities identified in this review, while mountain biking and off-road vehicle use most typify Type 3 disturbance involving the capture or killing of wildlife (we do not cover hunting in this review which can clearly have this type of impact). In this sense there is no need to analyse the walker (and their boots) separately from the cyclist (and their tyres). Walking, horse riding and off-road vehicle use are all identified as potentially spreading invasive species, pests and diseases.

However, this analytic framework, and thus field, largely misses the potentially substantial social and cultural differences between recreationalists and their activities. These factors drive behaviour and thus the impacts of recreational disturbance in forests and woodland environments, the understanding of which is so crucial for managing disturbance. People choose to pursue different activities, at different times of the day, week and year. People's perceptions of rules and regulations affect how and when they pursue activities. An individual's personal values affect what they deem acceptable behaviour and what constitutes environmental impact. As impacts on forest species vary in this way it is important to know what types of activities occur in forest settings (Sun and Walsh, 1998) and their social or 'human' dimensions. This review illustrates

that currently there is a dearth of knowledge on these dimensions and so it is difficult to make judgements on their relationship with disturbance impacts. Much more is needed here to improve understanding of social and cultural factors as drivers of impact that underpin management responses.

Balance between disturbance and benefits of recreational use

In our Introduction we noted the demand placed on land managers, particularly in the public sector, to balance various societal needs and benefits against each other. In this review, we identified no studies which sought to assess the balance between the benefits gained from outdoor recreation and the disturbance of wildlife and the potential conservation dis-benefits of this. This is an important area for further research given the already noted (often implicit) tendency within recreation ecology to frame human influences on 'natural' areas as negative (i.e. 'disturbance'; 'intrusion') and/or 'unnatural'. Clearly human presence in natural settings is not an exclusively negative phenomenon as substantial social, cultural, psychological and health benefits can be obtained.

Management frameworks, such as 'Limits of Acceptable Change' (Stankey *et al*., 1985) do recognise the need to have clear objectives for a recreational site in order to set the boundaries of acceptable management and assess its effectiveness. However, little attention, if any, has been given to assessments of, or tools for understanding, the dynamic relationship between 'costs' and 'benefits'.

Recreationalists' perceptions of behaviour and impacts

Moscardo and Saltzer (2004 citing Cordell *et al*., 1999) highlight that there are four sets of features that are associated with humans in the natural environment: (1) Interactions (e.g. the range of activities in natural environments); (2) Demand for the activities; (3) Values (e.g. that users attach to seeing wildlife); and (4) Perceptions or what people believe and know. The authors state, 'there are a number of different ways in which humans can interact with natural environments. In order to manage those interactions it is important to understand the nature and extent of the interactions and the forces that drive and shape them' (p. 170). For example, people's perceptions on how their recreational pursuits affect wildlife may influence their behaviour. Therefore, understanding user preferences and the range of perceptions, attitudes and behaviour would be relevant for managers (Symmonds, Hammett and Quisenberry, 2000; Taylor and Knight, 2003). The Recreational users' perspectives section on p.22 highlights the number of studies that attempt to compare the impacts of different recreational groups on wildlife. However, recreational users generally hold other users responsible for disturbance. Mountain bikers, horse riders and off-road vehicles were the most negatively viewed but most users were not fully aware of the impacts of their own recreational activities. Moreover, findings suggest that in some cases recreational users do not believe or care that they may be having an impact. The one study (Taylor and Knight, 2003) where potential management measures were rated showed that people were generally not supportive of restrictions on their activities. Nevertheless, Higginbottom (2004) suggests that it is most effective to target management primarily at the people rather than the wildlife. We found very little information that would usefully address important key questions around how social phenomena affect the type and scale of impacts (e.g. holiday periods, crowding), and what affects recreational users' behaviour in natural areas (e.g. knowledge, understanding and perception of 'rules'; signs and interpretation). There is a need to acknowledge that user groups are made up of individuals and there will be internal variability (i.e. all mountain bikers do not think and behave in the same way). Studies on the impacts of management responses on recreational users' perceptions of impact and actual behaviour are also needed.

Management options

A range of options have been identified which relate to management of sites (e.g. habitat maintenance, screening) and people (e.g. buffer zones and other restrictions, regulations). Broad management frameworks are provided by, for example, Stankey *et al*. (1985) and Knight and Gutzwiller (1995). Restrictive management options are unlikely to be popular with recreational users and some authors have advocated low-impact educational approaches aimed at persuading users to behave appropriately or to encourage acceptance of essential management responses. However, as Higginbottom (2004) has noted, little progress has been made on determining the effectiveness of various management actions. Interdisciplinary and integrated research is needed to identify acceptable levels of impact, and what management options are most effective in mitigating recreational user impacts on certain wildlife, as well as which of these options are considered socially acceptable, and by which individuals and groups (Kazmierow, Hicking and Booth, 2000; Rodger, Moore and Newsome, 2010). More examples are needed of what management actions work, in which context, why and how?

Future research needs

Our review has revealed considerable evidence relating to the disturbance of wildlife by recreational activities; however, substantial knowledge gaps remain. In our analysis above we focus primarily on some of the social dimensions of disturbance and go on to highlight associated evidence gaps below. However, it is critical first to note the dearth of basic ecological studies of wildlife disturbance in UK forests. We therefore remain largely ignorant in relation to some vital aspects of this debate. We have little or no knowledge regarding, for example, whether the vertical structure of forests increases or reduces disturbance. Do different densities of woodland understorey affect disturbance? In what ways are the different species assemblages associated with conifer and broadleaf forest types differently affected by recreation? A very few studies exist (or are ongoing) in relation to protected species in forests (e.g. capercaillie); however, the vast majority of species of conservation concern in UK forests remain unstudied in this regard. Little work has been done linking the success or failure of these species to the ecological conditions created by the recreational use of forests. Unless more compelling evidence is generated, debates about links between recreation and wildlife disturbance will continue to be based on uncertain, and sometimes conflicting, assumptions.

While discrete sociological and ecological research can clearly contribute positively to filling gaps in current knowledge, we would argue there is an urgent need for integrated interdisciplinary studies that link ecological impact studies on flora and fauna with social data on recreationalists' perceptions, attitudes and behaviour and support for actions in managing recreational disturbance (see Taylor and Knight, 2003). Addressing the following existing social evidence gaps would support managers in balancing public recreational access with nature conservation. We suggest that such studies are carried out across a wide range of species and forest types and not just those that have designated protection. This will widen the scope of our understanding of recreational disturbance leading to more effective visitor profiling and greater knowledge of the demand for different recreational activities and their potential or actual impacts. Suggested questions include:

1. How do specific recreational activities vary socially (i.e. change in social factors such as cultural norms) and how does this relate to disturbance?
2. How does recreationalists' knowledge and behaviour relate to wildlife disturbance?
    - Which 'knowledge networks' do people draw upon to inform themselves, if at all, of their impact on wildlife?
    - What is the role of social networks and activity groups in reducing wildlife disturbance?
    - How do these factors vary between groups?
3. How do recreationists respond to information on disturbance caused by recreation?
4. How does the existence and implementation of 'rules and regulations' relate to recreational disturbance of wildlife?
    - Which 'rules' prevent or promote disturbance of flora and fauna?
    - Can existing governance mechanisms, such as the permit system, be used more effectively to reduce disturbance?
    - What impact do less formal governance structures have on promoting behaviour that has minimal (or no) impact on wildlife?
5. How can we monitor the level of 'user compliance' (i.e. the effectiveness) of formal and less formal governance mechanisms?

Conclusion

While woodlands and forests are important places for public recreation, land managers have to balance the public benefits derived from forest-based recreation with conservation of biodiversity and other wildlife management requirements. Understanding the particular cause(s) of disturbance is essential if managers are to avoid or mitigate the impacts. Thus, the objective of this review was to gather up-to-date evidence on the impact of recreational activities on flora and fauna and habitat in UK forests. We focused our attention on literature based around disturbance impacts of recreational activities acknowledging that this is only one part of a wider set of literature describing disturbance of wildlife and natural areas by a range of human activities.

This review illustrates how recreation in forests is conceptualised by the literature as an almost purely physical phenomenon, not as a human activity. This leaves significant gaps in the understanding and knowledge resources available to forest managers charged with balancing demands for recreation, nature conservation and other needs. We found that few studies have been conducted in the UK and therefore this review relies to some degree on research from other countries but with relevance to UK forests. Moreover, although over 450 sources were identified relating specifically to the disturbance of flora and fauna by recreational activities such as walking, mountain biking, horse riding, vehicle use, camping and nature watching, the majority do not report research undertaken in forests or woodlands. Of the literature reviewed much was related specifically to walking and/or to impacts of recreational activities on soils and vegetation (e.g. trampling) and especially birdlife. However, key impacts of disturbance common among all the recreational activities were: (i) habitat change; (ii) 'flight'; or (iii) the introduction of invasive species, pests or diseases. Protected and 'wilderness' areas are a major focus of this field of research, although other woodlands also receive attention – such as those around urban areas.

The importance of understanding recreational user preferences and the range of perceptions, attitudes and behaviour has been highlighted in this review, particularly in the context of linking activities with disturbance impacts. However, the literature generally does not examine the social dimensions of recreational impact. While we were able to identify, to some extent, the level and range of disturbance impacts on flora and fauna from recreational activities, there was essentially very little that could usefully improve our understanding of why and when users recreate in particular natural environments and what influences their behaviour. Robust evidence relating to how recreational users understand or perceive their own and others' impacts on wildlife is also very sparse.

Much of the literature reviewed provided management recommendations but only a limited number of studies directly or systematically address the management options available. These were briefly discussed in the Managing impacts section (p.24) and include physical and natural barriers as well as marketing and educational programmes. However, there is little or no evidence available on the effectiveness of management activities in mitigating negative impacts of recreational use on flora and fauna or how they have influenced the behaviour of different user groups. Overall, robust social evidence on recreational users' knowledge, attitudes and behaviour and their potential impact on wildlife through disturbance is lacking, yet it is clear that such information is crucial for the development of appropriate and effective management strategies. A good starting point in a UK forestry context would be a small number of interdisciplinary case studies integrating social and ecological research across geographical contexts which encompass a range of recreational users. These should include 'typical' UK forests which feature landscape, habitat and species diversity, along with social diversity.

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Forests are popular places for recreation, but some activities can have negative impacts on wildlife. Land managers have to balance delivery of the social and economic benefits derived from outdoor recreation with nature conservation objectives. This literature review provides an overview of potential disturbance issues and a guide to the evidence on impacts from walking, cycling, horse riding, off-road vehicle use, camping, and other recreational activities that take place in forests. Greatest attention has been directed towards walking, and impacts on soils, vegetation and birdlife. Much of the literature focuses on the physical characteristics of disturbance but there is little social scientific analysis of recreational users, for example on how their values and awareness relate to disturbance, or wider social factors that influence where, when and whether impacts occur. An holistic approach to understanding and managing the interaction of recreation and forest wildlife is needed, which links ecological studies with social data.

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