

Chapter 23:

Health Values from Ecosystems

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Key Findings*

Observing nature and participating in physical activity in greenspaces play an important role in positively influencing human health and well-being¹. 'Green exercise', comprising of activity in green places (in the presence of nature), is associated with positive health outcomes, which exceed those experienced from exercising in environments lacking nature^a.

¹ well established
^a virtually certain

Ecosystems provide three generic health benefits: i) direct positive effects on both mental and physical health²; **ii) indirect positive effects** which facilitate nature-based activity and social engagement (by providing locations for contact with nature, physical activity and social engagement), all of which positively influence health, and provide a catalyst for behavioural change in terms of encouraging the adoption of healthier lifestyles (improving life pathways, activity behaviour, consumption of wild foods)²; **iii) a reduction in the threats of pollution and disease vectors** to health via a variety of purification and control functions, such as local climate regulation, noise reduction, and scavenging of air pollutants^b.

² established but incomplete
^b very likely

Ecosystems can be a direct provider of threats to human health¹. These threats include infectious agents (e.g. *Lyme borreliosis*, *Cryptosporidium*, *Plasmodium* that cause malaria); physical threats from wild animals (although this is not generally a factor in the UK), domestic livestock and dogs; pollutants or contaminants from plants (e.g. bracken spores, volatile organic compounds (VOCs), pollen); elemental threats through extremes of temperature or UV radiation.

¹ well established

All eight UK NEA Broad Habitats contribute to all three positive and the one negative class of health-related ecosystem services². However, there is limited evidence to indicate that habitats with more biodiversity have a greater effect on health, even though they may encourage greater use^c. The UK NEA Broad Habitat that has received the greatest empirical study in terms of its effects on health is Urban, mainly because the presence of greenspace is clearly a contrast to the majority of the built environment.

² established but incomplete evidence
^c likely

Local greenspaces or nearby natural habitats are vital for all individuals³. There is a clear link between the amount of accessible greenspace and psychological well-being. The more frequent the visits to nearby green spaces, the lower the incidence of stress^c.

³ competing explanations
^c likely

Access to nature can encourage participation in physical activity (green exercise)²: individuals with easy access to nature are three times as likely to participate in physical activity and, therefore, are 40% less likely to become overweight or obese.

² established but incomplete evidence

Green exercise in all habitats results in significant improvements in both self-esteem and mood¹; however, those habitats with open water produce a significantly larger degree of improvements in mental well-being^b. The greatest effects for self-esteem and mood occurred within the first five minutes of activity. The improvement in both of these measures appears to be larger in green settings compared to exercising in areas lacking nature¹. The greatest health outcomes are experienced by those with mental health problems, suggesting that exercise in ecosystems can be therapeutic for specific cohorts of people.

¹ well established
^b very likely

Nature-dominated drives increase recovery from stress². Commuters both recover quicker from stress and reduce the likelihood of experiencing future stresses after nature-dominated drives, compared to urban-dominated drives.

² established but incomplete evidence

There is a growing use of 'green care' in many contexts in the UK, including therapeutic horticulture, animal-assisted therapy, ecotherapy, green exercise therapies and wilderness therapy². Green care produces health, social and educational benefits, but these have not yet been widely evaluated³.

² established but incomplete evidence
³ competing explanations

* Each Key Finding has been assigned a level of scientific certainty, based on a 4-box model and complemented, where possible, with a likelihood scale. Superscript numbers and letters indicate the uncertainty term assigned to each finding. Full details of each term and how they were assigned are presented in Appendix 23.1.

Recent experience using smartphones (*Mappiness*) has shown increased happiness levels are associated both with vigorous outdoor pursuits, such as sports, running and exercise, and walking and hiking, and with less energetic activities, such as gardening, birdwatching and nature-watching². On average, respondents are happiest outdoors and least happy indoors, and report intermediate happiness levels when in a vehicle. All green or natural habitat types were linked with higher happiness levels than the continuous urban environment. ² established but incomplete evidence

Experiencing nature has been demonstrated to have a significant positive impact upon heart rate and blood pressure². Green settings have a relaxing effect on autonomic functions, thus decreasing heart rate and blood pressure measurements. Green settings lead to a greater increase in parasympathetic nervous system activity and a greater decrease in sympathetic nervous activity than built environments^c. ² established but incomplete evidence ^c likely

Humans depend on exposure to the sun for the synthesis of adequate amounts of vitamin D; a lack of vitamin D absorption, or vitamin D deficiency, is associated with a number of health problems². Concerns over skin cancer, combined with a decrease in the opportunities for people to access green places, is reducing exposure to sunlight and, therefore, contributing to the development of chronic diseases^b. Sensible exposure to sunlight for approximately 5–10 minutes three times per week helps to protect against the development of skin cancer and is highly likely to be beneficial to physical health. ² established but incomplete evidence ^b very likely

Green settings offer opportunities for the building of social capital, which, in turn, benefits health². The presence of trees and grass in urban areas also has a substantial effect upon social engagement and neighbourhood ties. Areas with trees and grass encourage individuals to utilise outdoor space and increases the likelihood of social interaction. Green places can also increase social engagement and interaction through conservation activities and initiatives. By protecting nature, individuals can obtain social contact and derive value from being in the presence of nature^b. ² established but incomplete evidence ^b very likely

Ecosystems provide wild foods which can have a direct effect on health¹. Today, wild foods act as a supplement to purchased foods, as opposed to providing the sole means of nutrition, and interest in wild foods is growing. ¹ well established

Ecosystems not only affect immediate health and well-being, but also affect health throughout life². Healthy behaviours may be followed as a direct result of an individual's surroundings, although there is no guarantee of uptake. If 1% of the sedentary population moves to a healthy pathway, 1,063 lives and £1.44 billion will be saved each year. The earlier this shift occurs during life, the greater the impact upon health and society³. ² established but incomplete evidence ³ competing explanations

Contact with nature at any age can derive a whole number of benefits for physical and mental health, **contact with nature during youth can directly impact upon healthy adult behaviours².** Research indicates that the frequency of visits to green places during childhood significantly correlates to the number of visits during adulthood. A lack of experience of nature as a child may directly result in a lack of contact during adulthood. ² established but incomplete evidence

23.1 Ecosystems and Health

23.1.1 Overview

The term 'health' is generally taken to incorporate physical health, mental or emotional health, social health, spiritual health, lifestyle and functionality. The World Health Organization's definition of health is still the most widely cited and states that: "health is a state of complete physical, mental and social (individual) wellbeing, and not merely the absence of disease or infirmity" (WHO 1948). A universal definition of 'well-being' is not available, as many sources interpret it differently. However, well-being is generally considered in a broader context, and Defra (2007) has collaborated with other government departments and stakeholders to develop a shared understanding of the meaning of well-being within a policy context (Defra 2007;

Box 23.1).

Ecosystems comprise a multifaceted set of relationships between the living organisms, resources (including plants, animals, fish, birds and microorganisms, water sources, soil, rocks, minerals and the local atmosphere) and habitats of an area, which function together as a unit. Ecosystem services support our health and well-being in a variety of ways. These include the provision of resources for basic survival, such as clean air, water and genetic resources for medicines, along with the provision of raw materials for industry and agriculture. However, ecosystem services also contribute to better mental and physical well-being by providing accessible urban and rural spaces for recreation and interaction with nature. Both observing natural ecosystems and participating in physical activity in greenspaces play an important role in positively influencing human health and well-being (Table 23.1).

It is well-known that regular physical activity improves both physical and mental health (CDC 1996; DH 2005a; Foresight 2007; Sandercock *et al.* 2010), and can improve the survival of the elderly and their quality of life (Lim & Taylor 2005). There is also increasing evidence to show that exposure to nature and greenspace positively affects health and well-being (Maas *et al.* 2006; Pretty *et al.* 2006; Van den Berg *et al.* 2007; Hansen-Ketchum *et al.* 2009; Barton & Pretty 2010). Thus 'green exercise'—physical activity undertaken in green places in the presence of nature—leads to positive

Box 23.1 Shared understanding of well being. Source: Defra (2007).

"Well being is a positive physical, social and mental state; it is not just the absence of pain, discomfort and incapacity. It requires that basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals and participate in society. It is enhanced by conditions that include supportive personal relationships, strong and inclusive communities, good health, financial and personal security, rewarding employment, and a healthy and attractive environment. Government's role is to enable people to have a fair access now and in the future to the social, economic and environmental resources needed to achieve wellbeing. An understanding of the effect of policies on the way people experience their lives is important for designing and prioritising them."

health outcomes (Table 23.1). Green exercise has been shown to be more effective than comparable activities (which reflect the exercise component only) undertaken indoors (Thompson Coon *et al.* 2011). Participating in physical activity in green settings is associated with decreased feelings of tension, confusion, anger and depression, while exhibiting greater feelings of revitalisation (Thompson Coon *et al.* 2011). Outdoor experiences are rated as more restorative (Hug *et al.* 2009) and more effective in improving mood and vitality (Ryan *et al.* 2010). In comparison, indoor activity is associated with increased frustration, anxiety, anger and sadness (Teas *et al.* 2007). Research shows that health benefits arise in all urban and rural ecosystems tested, ranging from deep wilderness to domestic gardens and allotments, and including open countryside, forests, woodlands, national or country parks, nature or wildlife reserves, urban parks, grasslands, hills and valleys.

Existing research studies can be grouped into one of two prevailing categories. The first involves experimental research which has predominantly focused on stress reduction and attention restoration, often by inducing stress within the experimental setting. These types of studies often administer pre- and post-intervention measures to assess the immediate short-term health benefits of active or passive exposure to natural and urban ecosystems. They often take place within a controlled setting to limit confounding variables and attempt to isolate the ecosystem as the key variable influencing health measures. The second type comprises epidemiological research studies which primarily report correlations between ecosystem use and health benefits. However, the difficulty with this type of analysis is that it is very challenging to establish causality and often relationships can only be described, not explained. Although these associations regularly emerge from such experiments, determining causality is not straightforward and further research is required to establish any direct cause-effect relationships. Demonstrating a link between ecosystems and health is not the same as proving that exposure to ecosystems produces positive health outcomes. Yet evidence of causality would provide a powerful argument for a change in existing policies. Although interpretation of the causal structure of these relationships is challenging due to the complexity of the system, it remains an important finding in its own right.

Ecosystems provide three generic health benefits (Figure 23.1):

- i) Direct positive effects
 - a) Mental health (Kaplan 2001; Pretty *et al.* 2005; Pretty *et al.* 2007).
 - b) Physical health (Laumann *et al.* 2003; Kampman *et al.* 2007; Pretty *et al.* 2007)
- ii) Indirect positive effects
 - a) Facilitating nature-based activity and social engagement (by providing locations for contact with nature, physical activity and social engagement), all of which positively influence health (Coley *et al.* 1997; Kuo *et al.* 1998; Ward Thompson 2002).
 - b) Providing a catalyst for behavioural change in terms of encouraging the adoption of healthier lifestyles (improving life pathways, activity behaviour and the

Table 23.1 The health and well-being benefits of contact with nature.

Health and well-being benefit	Evidence
Provides opportunities for 'green exercise' and associated improvements in self-esteem and/or mood	Hartig <i>et al.</i> (1991), Ulrich <i>et al.</i> (1991), Hartig <i>et al.</i> (1996), Hartig <i>et al.</i> (2003), Van den Berg <i>et al.</i> (2003), Morita <i>et al.</i> (2006), Pretty <i>et al.</i> (2005), Hine <i>et al.</i> (2007), Pretty <i>et al.</i> (2007), Barton <i>et al.</i> (2009), Barton & Pretty (2010), Bowler <i>et al.</i> (2010)
Reduces stress	Parsons (1991), Ulrich <i>et al.</i> (1991), Lohr <i>et al.</i> (1996), Rubinstein (1997), Parsons <i>et al.</i> (1998), Hartig <i>et al.</i> (2003), Laumann <i>et al.</i> (2003), Fredrickson & Branigan (2005)
Promotes ecological knowledge	Pilgrim <i>et al.</i> (2007), Pilgrim <i>et al.</i> (2008), Pretty (2011)
Fosters social bonds	Kawachi <i>et al.</i> (1997), Takano <i>et al.</i> (2002), Ward & Thompson (2002), Brugha <i>et al.</i> (2003), Barton <i>et al.</i> (2011), Pretty (2011)
Reduces levels of crime and violence	Kuo & Sullivan (2001a), Kuo & Sullivan (2001b)
Provides outdoor classrooms	Kaplan & Kaplan (1989), Kahn & Kellert (2002)
Delivers cognitive benefits	Berman <i>et al.</i> (2008), Hansen-Ketchum <i>et al.</i> (2009)
Influences behavioural choices	Kuo <i>et al.</i> (1998a), Maas <i>et al.</i> (2006), Mitchell & Popham (2008), Barton <i>et al.</i> (2011)

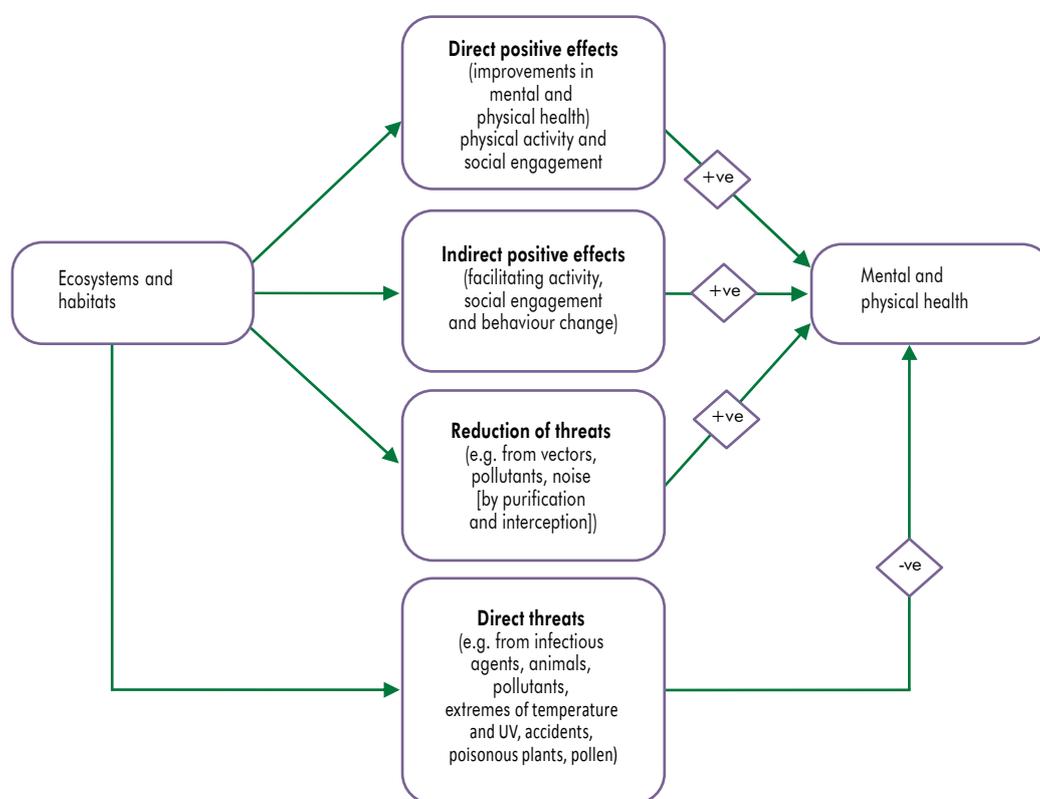


Figure 23.1 Health benefits and threats from ecosystems.

consumption of wild foods) (Wells & Lekies 2006; Pretty *et al.* 2009).

- iii) Reducing the threats and incidence of pollution and disease vectors via a variety of purification and control functions such as local climate regulation, noise reduction and scavenging of air pollutants (Morecroft *et al.* 1998; Pitcairn *et al.* 1998; Bignal *et al.* 2004).

However, ecosystems can also be a direct source of threats to human health including: infectious agents (e.g. *Lyme borreliosis*, *Cryptosporidium* species, *Plasmodium* species that cause malaria); physical threats from animals, pollutants or contaminants from plants (e.g. bracken spores,

volatile organic compounds (VOCs), pollen); and elemental threats through extremes of temperature or UV radiation (Frumkin *et al.* 2004).

Health outcomes depend on the types of ecosystems and the services they provide, as well as the choices people have and decisions they make. If individuals do not engage with the natural world, either by observation or undertaking physical activity in green settings (including urban greenspace), then they will not derive the specific mental or physical health benefits nature can provide. Such choices are affected by location of dwelling, proximity of, and access to, nature, and individual choices and environmental behaviours (DH & DCSF 2009).

Access to nature often varies according to cohort demographics. For example, wealthier individuals are able to access certain places more readily because they own a car; it is common for the most biodiverse ecosystems not to be served by public transport, which excludes the poorest individuals and other minority groups. Thus, access is dependent on the socioeconomic characteristics of the potential beneficiaries and not solely on the ecosystem qualities. Yet having access to nearby greenspace can eradicate the health inequality levels in areas of deprivation (Mitchell & Popham 2008). This highlights the importance of providing health-promoting, accessible greenspaces to reduce socioeconomic health inequalities.

Behaviours can also influence correlative relationships identified between ecosystem exposure and health outcomes, which contributes to the challenge of interpreting the causal structure. In effect, health outcomes of ecosystems are not independent of people's demographics, choices and behaviours. Health benefits are, therefore, a function of the ecosystem type, ease of access to nature and frequency of use of green places.

23.1.2 Health Benefits According to UK NEA Broad Habitats

All eight UK NEA Broad Habitats contribute to all three positive and the one negative class of health-related ecosystem services. However, there is limited empirical

evidence to indicate that habitats with more biodiversity have a greater effect on health (Fuller *et al.* 2007). One UK study has shown positive associations between urban greenspace species richness and improved well-being (Fuller *et al.* 2007), although the authors acknowledge the challenge of deciphering causality. There is also empirical evidence to indicate that, after rehabilitation, Urban greenspace attracts more users, providing a greater health service (Barton *et al.* 2009; Barton & Pretty 2010). In a similar way, it could be hypothesised that habitats with greater biodiversity or particular rare or distinctive species (e.g. nature reserves, Sites of Special Scientific Interest (SSSIs)) may attract more visitors and, therefore, deliver a greater aggregate health benefit; this hypothesis would fit with the findings of Fuller *et al.* (2007).

The UK NEA Broad Habitats provide potential places for people to engage in physical activity (green exercise) and social interaction. If these habitats are used, they would have positive direct effects on health, and reduce threats from disease vectors, pollutants and noise; but they could potentially provide a variety of direct threats to health (**Table 23.2**). The provision of positive health benefits is dependent not only on the intrinsic biological characteristics of the ecosystems, but also on location. An ecosystem which is close to a densely populated area will provide many more health benefits than a physically identical ecosystem in a remote area, because it is accessible to more individuals.

Table 23.2 Health-related ecosystem services (positive and negative) from the eight UK NEA Broad Habitats.

UK NEA Broad Habitats	Health-related ecosystem services			
	Provide places for physical activity and social engagement	Direct positive effects on health	Reduce threats from disease vectors, pollutants, noise	Direct threats to health
Mountains, Moorlands and Heaths	Considerable provision; access generally good	Considerable provision; wild foods	Purification of water and air	Bracken, accidents, temperature extremes
Semi-natural Grasslands	Considerable provision; access often limited	Considerable provision; wild foods	Purification of water and air, flood regulation	Zoonoses and vectors, livestock accidents
Enclosed Farmland	Limited access except by footpaths and bridleways	Considerable provision; wild foods from hedgerows	Purification of water and air, flood regulation	Zoonoses and vectors, livestock accidents
Woodlands	Considerable provision; access generally good	Considerable provision; wild foods	Purification of water and air, flood regulation, climate regulation (shading and cooling)	Pollen-causing asthma, VOCs, Lyme disease
Freshwaters – Openwaters, Wetlands and Floodplains	Considerable provision; access generally good	Considerable provision; wild foods from fishing	Purification of water and air	Waterborne diseases (<i>Cryptosporidium</i> , Weil's disease), red tides from eutrophication, accidents
Urban*	Considerable provision; access limited	Provision where access is available from homes and workplaces; foods from domestic gardens and allotments	Purification of water and air, interception of noise and water, reduction of heat island effect	Accidents
Coastal Margins	Considerable provision; access generally good	Considerable provision; wild foods (birds, shellfish, samphire)	Sea defences	Red tides, accidents
Marine	Limited access	Limited provision (as limited access)	Limited	Accidents

*Urban greenspace includes, for example, parks, gardens, allotments, street trees; does not include the built environment.

Therefore, the aggregate health benefit is not solely reliant on type of habitat, but ease of access.

The UK NEA Broad Habitat that has received the greatest empirical study in terms of its effects on health is Urban, mainly because the presence of nature and greenspace is clearly a contrast to most of the built environment. In addition, the majority of people reside in urban areas and are, therefore, more able to access Urban habitats. Some 3.5% of England is urbanised (428,000 hectares), and these environments contain 52,000 hectares of greenspace in the form of parks, allotments, city and community farms, cemeteries, golf courses, nature reserves, street trees and green roofs (not counting private gardens) (CABE 2010).

23.2 Direct Positive Effects on Mental Health

23.2.1 Observing Ecosystems

The importance of observing nature is becoming increasingly recognised. Viewing nature through a window can help to increase recovery from mental fatigue and improve mental well-being (Kaplan 1992; Maller *et al.* 2006). Natural views in hospitals help to increase recovery from illness (Diette *et al.* 2003), while access to nature in the workplace is associated with lower levels of perceived stress and greater job satisfaction (Kaplan & Kaplan 1989; Maller *et al.* 2006; Hine *et al.* 2007). Furthermore, research suggests that prison inmates whose cell has a view of nature have a lower frequency of stress and psychological symptoms when compared to those inmates who lack such a view (Moore 1982). The view from the home is also known to be important (Kaplan 2001; Taylor *et al.* 2002). For children, green views have a positive effect on cognitive thinking and concentration, while also aiding self-discipline (Taylor *et al.* 2002).

The positive effect of viewing nature even occurs if the view is not of living nature; pictures of nature can also elicit improvements in mental well-being (Pretty *et al.* 2005). Several studies have compared the effects on mental well-being of viewing photographic scenes of both nature and built environments. The results suggested that the natural scenes, especially those depicting water, had a more positive effect on measures of emotional well-being such as sadness and happiness, than viewing built environments (Ulrich 1981). Indeed, viewing built environments led to a decline in attention and interest. In 2005, Pretty *et al.* (2005) examined the mental health benefits of viewing urban and rural scenes while performing physical activity. Participants took part in five exercise conditions: exercise only; exercise while viewing unpleasant urban scenes (cityscapes lacking greenspaces); exercise while viewing pleasant urban scenes (buildings with surrounding nature); exercise while viewing pleasant rural scenes; and exercise while viewing unpleasant rural scenes (landscapes spoilt with rubbish, abandoned cars, or pipes carrying effluents). The results indicated that all exercise conditions led to a significant improvement in self-esteem;

however, the unpleasant conditions reduced the positive effects of the physical activity, while the pleasant conditions led to the greatest improvements. The improvement for both urban and rural scenes was comparable, highlighting the importance of urban nature. Mood was also significantly affected by viewing the different scenes. Both the urban and rural pleasant conditions led to significant reductions in fatigue and tension, and a significant increase in vigour. Pleasant urban scenes also led to a significant decrease in depression. Both urban and rural conditions can improve mental well-being; however, those scenes that depict threats to the natural environment lead to a reduction in self-esteem and mood (Pretty *et al.* 2005).

Parsons *et al.* (1998) reported similar results when reviewing the literature on commuter stress in car drivers and the effect of the surrounding environment. The evidence indicated that commuters who participated in nature-dominated drives experienced quicker recovery from stress, and a reduction in the likelihood of experiencing subsequent stress, than those who took part in an urban-dominated drive (Parsons *et al.* 1998).

23.2.2 Contact with Nearby Nature

Local greenspace and accessible nature are vital for all individuals, whether it is an urban park or an area of rural wilderness (Barton & Pretty 2010). Being in the presence of 'nearby nature' (whether or not it is incidental to some other activity, such as walking to work or sitting on a bench) plays an important role in human well-being (Pretty *et al.* 2005; Hine *et al.* 2007). Research suggests that there is a link between the amount of accessible greenspace and psychological well-being (Takano *et al.* 2002; De Vries *et al.* 2003), as contact with nature can help individuals to recover from stress, protect them from further stress and improve concentration (Maller *et al.* 2002). Furthermore, the more frequent the visits to nearby natural spaces, the lower the incidence of stress (Grahn & Stigsdotter 2003).

Nearby nature is also important for the mental well-being of children (Kaplan & Kaplan 1989; Thomas & Thompson 2004; Ward Thompson *et al.* 2008). Evidence suggests that the well-being of children is closely linked to their ability to access natural settings close to their homes (Thomas & Thompson 2004). Wells (2000) conducted a longitudinal study with children of low-income urban families and assessed the effects of nature on their cognitive functioning. When the families were relocated to houses with more nearby nature they had higher levels of cognitive functioning and their ability to direct attention continued for several months after moving. However, these findings should be treated with caution because it could be argued that these types of families were able to select these types of preferred homes. Therefore, cause and effect can be difficult to disentangle and decipher (Wells 2000).

In addition, Wells and Evans (2003) found that children with easy access to nature were more able to cope with stressful life events and were generally less stressed individuals than those in urban habitats lacking greenspace (Wells & Evans 2003). However, the issue of cause and effect is still indeterminate as it remains unclear whether having contact with nature aids the development of stress-coping

mechanisms which are used in later life; whether nearby nature provides the opportunity for stress recovery and replenishes attentional fatigue; whether greenspace provides the opportunity to play with other children (social contact); or whether it is a combination of many factors. However, access to nature during youth is of great importance, particularly as childhood experiences of nature predict contact during adulthood (Ward Thompson *et al.* 2008).

In health care settings, gardens are of particular importance to mental well-being (Ulrich 2002). Gardens in hospitals have a number of positive effects on individuals by helping them to feel more relaxed and able to cope, reducing stress, and improving mood (Cooper-Marcus & Barnes 1995; Whitehouse *et al.* 2001). Even short visits of five minutes in duration to these gardens have been demonstrated to have a positive effect on the mental well-being of patients (Cooper-Marcus & Barnes 1995; Whitehouse *et al.* 2001).

23.2.3 Green Exercise

Natural ecosystems can provide an environmental setting for green exercise (Pretty *et al.* 2005; Bowler *et al.* 2010). Both physical activity and exposure to nature have separately been demonstrated to provide benefits for mental well-being, thus, by combining the two, green exercise has synergistic health benefits (Pretty *et al.* 2003; Pretty *et al.* 2005; Pretty *et al.* 2007; Hine *et al.* 2007; Peacock *et al.* 2007; Barton *et al.* 2009; Barton & Pretty 2010; Barton *et al.* 2011). For instance, walking in greenspaces is more effective at enhancing self-esteem and mood than walking indoors, suggesting a greater amalgamated health benefit than either component provides alone (Mind 2007; Peacock *et al.* 2007).

Pretty *et al.* (2007) examined the psychological health benefits of participating in ten different green exercise activities (including walking, fishing, horse riding, cycling and conservation activities) in four different regions in the UK. The results of the study found that green exercise led to significant improvements in self-esteem and mood, especially in the mood subscales of anger, confusion, depression and tension (Pretty *et al.* 2007). Furthermore, improvements in self-esteem and mood were not affected by the type, intensity or duration of the exercise, or by the different regions themselves (Pretty *et al.* 2007).

Barton *et al.* (2009) examined the mental well-being effects of walking in four UK national heritage sites (Dunwich Heath, Suffolk; Flatford Mill, Suffolk; Hatfield Forest, Essex; Wicken Fen, Cambridgeshire). In line with the results produced by Pretty *et al.* (2007), both self-esteem and overall mood were significantly enhanced as a result of participating in the green exercise (Barton *et al.* 2009). Furthermore, feelings of anger, confusion, depression, fatigue and tension were reduced as a result of the green exercise, while feelings of vigour were increased (Barton *et al.* 2009). However, in contrast to the results of Pretty *et al.* (2007), the study suggested that there was a relationship between the duration of the green exercise and the degree of improvements in mental well-being: participants walking for the longest period of time displayed the greatest improvements in mood (Barton *et al.* 2009).

Barton and Pretty (2010) undertook a meta-analysis on the mental health outcomes of many different types of green

exercise in different habitats, for varying lengths of time, and by different age cohorts and gender. Habitats included woodland, forests, watersides, urban green areas, farmland and natural habitats, and the activities included walking, horse riding, sailing and gardening (Barton & Pretty 2010). Green exercise in all habitats resulted in significant improvements in both self-esteem and mood; however, those habitats with open water produced a significantly larger degree of improvement in mental well-being. Furthermore, self-esteem and mood was most improved during the first five minutes of activity, but this effect gradually deteriorated if the exercise lasted between 10 minutes and half a day (Barton & Pretty 2010). Nevertheless, the effectiveness of the green exercise in improving mental well-being increased again if the activity lasted for a whole day. The results are in contrast to those produced by Pretty *et al.* (2007), implying a need for further research in this area.

The meta-analysis also revealed that the effectiveness of the green exercise was influenced by its intensity (Barton & Pretty 2010). For self-esteem, light intensity exercise produced the greatest improvements, with the effects deteriorating as the intensity of exercise increased; a similar response was noted for mood. However, the lowest effect on either measure was seen during moderate exercise; the effects increasing once again for vigorous exercise.

With regards to the different age cohorts of participants, the meta-analysis revealed that the fewest health outcomes occurred for the elderly, while the greatest health outcomes were experienced by those with mental health problems, suggesting that exercise in ecosystems can be therapeutic for specific cohorts of people (Barton & Pretty 2010).

Essentially, the evidence implies that there is a synergistic health benefit from exercising in areas containing nature (including urban greenspace) compared to exercising in urban areas lacking nature or indoor environments. All types of habitat are beneficial, from experiences in deep wilderness to gardening in local allotments. The optimal dose of green exercise may be dependent on many variables, but it is clear that both urban and countryside habitats can provide the ideal setting to facilitate activity and afford greater health benefits.

23.2.4 Green Care

'Green care' is an inclusive term for many complex and diverse nature-based interventions that use nature and the natural environment as a framework in which to create health and well-being benefits for vulnerable groups of people (Sempik *et al.* 2010). Green care has emerged from the idea that contact with nature could be effective in therapeutic applications (**Figure 23.2**) (Pretty 2006; Peacock *et al.* 2007; Hine *et al.* 2008a). In the UK, there is a growing movement towards green care in many contexts ranging from social and therapeutic horticulture, animal-assisted interventions, ecotherapy, green exercise therapies as a treatment option, and care farming (Sempik *et al.* 2003; Sempik 2007; Hine *et al.* 2008a). Green care is different to green exercise in that it is used as a therapy or intervention for specific groups, such as psychiatric patients, people with learning disabilities, disaffected youth and several other at-risk populations, while green exercise is more of a therapeutic experience (Pretty

2006; Hine *et al.* 2008a). The aim of green care is to produce health, social and educational benefits (Hine *et al.* 2008a).

There are six key types of green care options:

- i) **Social and therapeutic horticulture** is defined as “participation by a range of vulnerable people in groups and communities whose activities are centred around horticulture and gardening. It is distinct from domestic gardening because it operates in an organised and formalised environment” (Sempik *et al.* 2003; Samson & Pretty 2005). Social and therapeutic horticulture has been demonstrated to promote psychological well-being and has also been utilised in the treatment of disease.
- ii) **Animal-assisted interventions** involve the use of animals in the rehabilitation and social care of humans (Kruger & Serpell 2006; Bokker 2006). Companion animals can also play a therapeutic role for people with psychiatric disorders, physically ill people, those with emotional disorders, the elderly and children (Fine 2006). Like human relationships, animal-human relationships can help to buffer against stress responses and illness (McNicholas & Collis 2006).
- iii) **Care farming** is defined as the therapeutic use of agricultural landscapes and farming practices (Hassink 2003; NCFI 2011) and its use is increasing both within the UK and Europe (Hine *et al.* 2008a). On care farms, components of either the whole or part of the farm environment are utilised to provide health, social or educational care services through a supervised, structured programme of farming-related activities. Results from studies into the mental health benefits of

these care farms within the UK have found that their use can result in significant improvements in both self-esteem and mood, with significant alterations in all mood factors (Pretty 2006; Peacock *et al.* 2007; Hine *et al.* 2008a).

- iv) **Green exercise therapy** is defined as facilitated green exercise activities. Evidence suggests that these activities may have therapeutic applications (Pretty *et al.* 2007; Peacock *et al.* 2007); for example, they may provide an effective treatment for mild to moderate depression through reconnection with nature and the positive mental health benefits that come hand in hand with this (Samson & Pretty 2005; Pretty *et al.* 2007). Currently, approximately 21% of general practitioners use exercise as a therapy in the treatment of mental disorders (Mental Health Foundation 2009). Green exercise therapy may be even more effective than exercise alone and could, therefore, be utilised as an alternative or complimentary treatment therapy to antidepressants (Samson & Pretty 2005).
- v) **Ecotherapy** encompasses all nature-based methods aimed at the re-establishment of human and ecosystem reciprocal well-being (Sempik *et al.* 2010). Contact with natural ecosystems enhances physical, psychological and social health for people, communities and ecosystems. Ecotherapy encourages reconnection with nature and therefore facilitates behavioural and social changes which can directly influence mental health and well-being (Burls 2008).
- vi) **Wilderness therapy** is described as an “experiential programme (e.g. Outward Bound) that takes place in wilderness or a remote outdoor setting” (Conner 2007). It

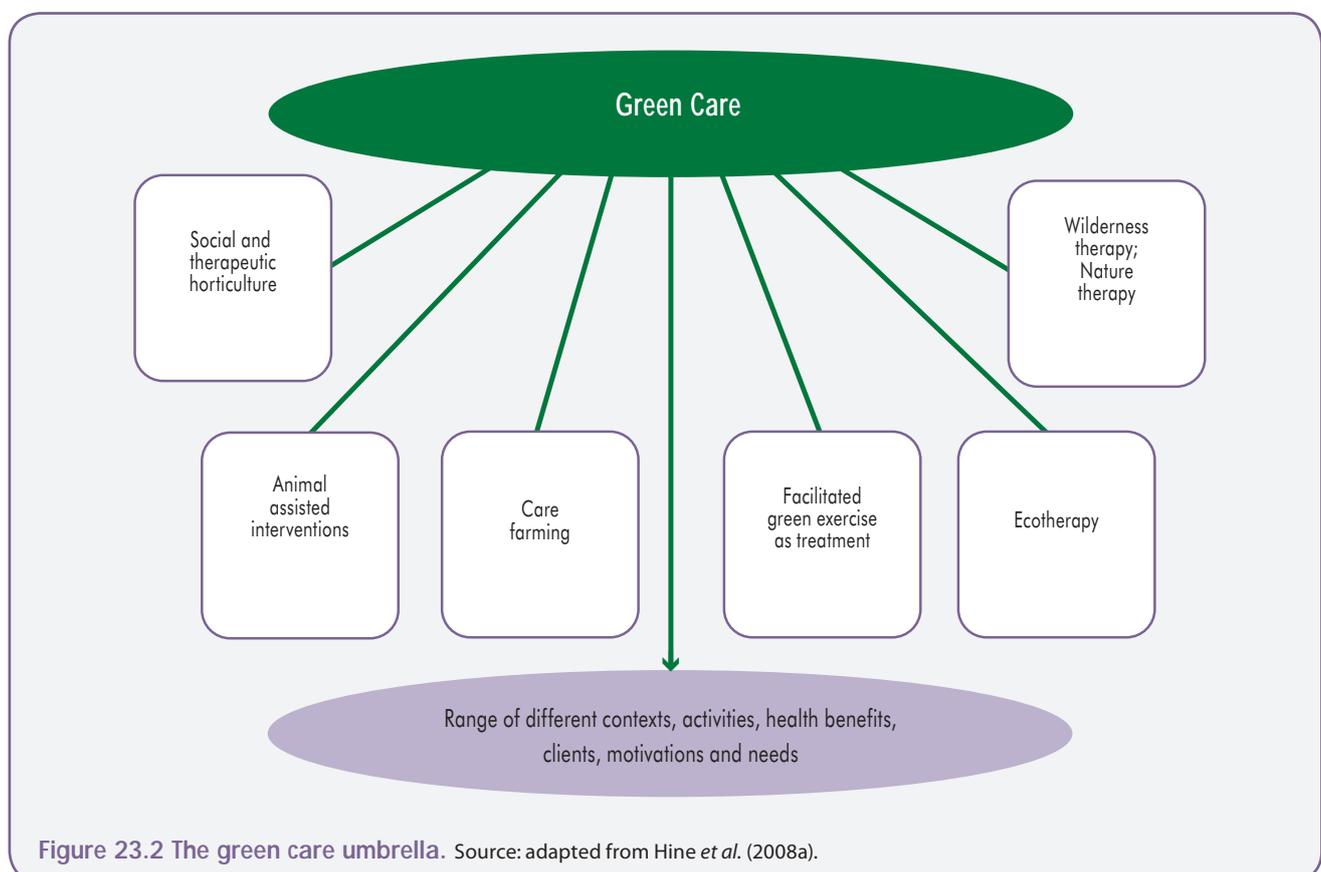


Figure 23.2 The green care umbrella. Source: adapted from Hine *et al.* (2008a).

has been widely used in the USA for many years, but is a relatively new concept in the UK and is most commonly used for adolescents with behavioural problems (Pretty *et al.* 2009) and adults with mental health issues (Hine *et al.* 2011). Programmes provide healthy exercise and diets, group and individual therapy sessions, and separate participants from daily negative influences, placing them in a safe outdoor environment. Evidence regarding the benefits of wilderness therapy has indicated that it can facilitate behaviour change, address problem behaviours, improve mental well-being and self-esteem, reduce Body Mass Index (BMI) and provide opportunities for emotional growth (Moote & Wadarski 1997; Hans 2000; Russell & Phillips-Miller 2002; Samson & Pretty 2005; Russell 2006; Conner 2007; Hine *et al.* 2009; Bharucha & Pretty 2010; Godfray *et al.* 2010; Hine *et al.* 2011).

23.2.5 Mappiness Research for Well-being

Subjective well-being is related to happiness and has become increasingly important to economists (Layard 2005; Dolan *et al.* 2008; Frey 2008; Mourato & MacKerron 2010; MacKerron & Mourato 2011). The established influences on happiness include income (positively correlated with subjective well-being); the incomes of others, rivalry (negative) and/or ambition (positive); an individual's own lagged income;

and reduced responses due to habituation (negative). Further factors include unemployment; separation, divorce and widowhood; and poor health (all negatively correlated). Social capital indicators and relational goods are important, such as membership of interest groups or friendly relations with neighbours; trust; and belief in a god (all positively correlated). Important environmental quality parameters include climate, noise, air quality, and access to greenspaces. Mourato and MacKerron (2010) investigated well-being in the UK by using a satellite geo-located, large-scale, smartphone-based Experience Sampling Method study (*Mappiness*) to explore links between instantaneous mood states and the immediate environment.

On average, respondents were happiest outdoors and least happy indoors, and reported intermediate happiness levels when in a vehicle. Increased happiness levels were associated both with vigorous outdoor pursuits, such as 'sports, running and exercise' and 'walking and hiking', and with less energetic activities such as 'gardening' and 'birdwatching and nature watching'. High energy pursuits, such as sports, running and exercise, were associated with a 6% increase in happiness, and more contemplative activities, such as nature watching, were linked with a 3% increase in happiness. Respondents were happiest when neither at home nor at work, least happy at work, and reported intermediate happiness when at home. When outdoors, higher happiness levels were associated with higher temperatures, while rain and wind are linked to lower happiness. Importantly, there was a clear link between being outdoors in particular habitat types and happiness levels. Almost all habitat types (with the exception of inland bare ground) were linked with higher happiness levels than urban habitats. Marine and Coastal Margins, Mountains, Moorlands and Heaths, and Coniferous Woodlands were associated with the highest increases in happiness. The key findings from *Mappiness* are summarised in **Table 23.3**.

Table 23.3 Summary findings from an analysis of subjective well-being (Mappiness). Significance: *** p < 0.001, ** p < 0.01, * p < 0.05, + p < 0.1. Source: MacKerron & Mourato *et al.* (2011); Mourato & MacKerron *et al.* (2010).

Explanatory variable	Difference in explanatory variable	Associated difference in happiness response
Walking, hiking	Not doing compared with doing this activity	+2.6%***
Sports, running, exercise		+6.1%***
Gardening, allotment		+2.5%***
Birdwatching, nature watching		+2.9%***
Outdoors	Being indoors compared with being outdoors	+1.4%***
Marine and Coastal Margins	Being outdoors in 'continuous urban' land cover compared with being outdoors in the listed land cover type	+5.2%***
Freshwater – Openwaters, Wetlands and Floodplains		+1.7%+
Mountains, Moorlands and Heaths		+4.0%***
Semi-natural Grasslands		+1.2%**
Enclosed Farmland		+2.1%***
Coniferous Woodland		+4.5%***
Broad-leaved/ Mixed Woodland		+2.3%***
Suburban/rural developed		+1.0%***

23.3 Direct Positive Effects on Physical Health

23.3.1 Heart Rate and Blood Pressure

Experiencing nature has been demonstrated to have a significant impact upon heart rate and blood pressure. Laumann *et al.* (2003) demonstrated that viewing nature led to a significant reduction in heart rate from the baseline level. However, viewing urban landscapes did not significantly reduce the participants' heart rate. Blood pressure is also reduced as a result of viewing nature (Pretty *et al.* 2005). Pretty *et al.* (2005) showed that mean arterial blood pressure (MABP) significantly reduced five minutes after exercising at a moderate intensity. However, when engaging in the same intensity of exercise while viewing pleasant rural scenes, a greater reduction in MABP was recorded (Pretty *et al.* 2005). Viewing unpleasant rural scenes also led to reductions in MABP; but viewing urban scenes, both unpleasant and pleasant, did not reduce blood pressure and, in fact,

increased the measurements relative to the exercise-only control. Thus, viewing nature can have a relaxing effect on autonomic functions (the unconscious regulation of internal bodily activity), decreasing heart rate and blood pressure measurements (Laumann *et al.* 2003; Pretty *et al.* 2005). Spending time in green settings leads to a greater increase in parasympathetic nervous system activity (the slowing of autonomic functions at rest) and greater decrease in sympathetic nervous activity (accelerated functions associated with the fight-or-flight response) than spending time in urban settings (Li *et al.* 2007).

23.3.2 Encouraging Physical Activity

Nature can encourage participation in physical activity: individuals with easy access to nature are three times more likely to participate in physical activity than those with poorer access and, therefore, 40% less likely to become overweight or obese (Wells *et al.* 2007; Bowler *et al.* 2010). The issue of cause and effect is difficult to identify as individuals may choose to live near habitats which facilitate activity if they enjoy exercising in greenspaces. Therefore, this cohort may engage in more activities simply because they chose to reside close to that type of habitat, rather than adopting new active behaviours because greenspace became accessible. However, by encouraging physical activity through participation in green exercise, such habitats can provide a whole number of physical health outcomes.

Physical activity can reduce the risk of developing Cardiovascular Disease and the associated risk factors, such as hypertension, high blood lipids and elevated blood pressure, and can also reduce the likelihood of developing Type 2 Diabetes (Blair & Connelly 1996; Biddle *et al.* 2004; DH 2004). Furthermore, individuals who regularly partake in green exercise are less likely to become overweight or obese, and may also have better bone health and a reduced risk of developing Osteoporosis (Biddle *et al.* 2004; DH 2005b). Thus, the natural environment supports physical health through the provision of opportunities for exercise (Wells *et al.* 2007).

Urban habitats are less encouraging of physical activity than other habitat types and often restrict access to nature (Wells *et al.* 2007). Urban design and planning sometimes reduces opportunities for individuals to participate in physical activity, contributing to large increases in physical inactivity and the prevalence of overweight and obese individuals (Wells *et al.* 2007). Nonetheless, urban parks promote healthy living for residents of Urban habitats by encouraging participation in green exercise activities such as walking and cycling (Ross 2000; Berrigan & Troiano 2002; Craig *et al.* 2002; Handy *et al.* 2002; Parks *et al.* 2003). In the UK, urban parks attract 2.5 billion day visits per year (DLTR 2002), so as urban sprawl continues, the importance of access to nearby nature is paramount. Urban life exposes people to many stressors, such as traffic noise, crowding and fear of crime (Van den Berg *et al.* 2007), and often access to nature and greenspace is limited or of poor quality. The type of nature close to where people live and work, in the form of parks, gardens, tree-lined streets, communal squares and allotments, is strategically important for the quality of life of urban dwellers and for the sustainability of towns and cities

(Chiesura 2004). Hence, individuals need easy access to nature and greenspace, as these encourage physical activity and result in a number of benefits for physical health.

23.3.3 Vitamin D and Latitude

Humans depend on exposure to the sun for the synthesis of adequate amounts of vitamin D. Some 90% of the human requirement for vitamin D comes from the sun (Hollick 2005; Kampman *et al.* 2007). Ultraviolet B (UVB) radiation is absorbed by dehydrocholesterol in the skin, which is transformed and further converted to vitamin D₃. This is then metabolised by the liver to its active form (Hollick 2005). Outdoor contact with nature allows humans to absorb the vitamin D required in the human body. However, a lack of vitamin D absorption, or vitamin D deficiency, is associated with a number of health problems.

Vitamin D deficiency can lead to poor bone health, increasing the likelihood of the development of diseases such as Osteoporosis and Osteomalacia. Vitamin D deficiency has also been associated with the development of Rickets in children. Furthermore, a lack of vitamin D can lead to cancer cell growth, an increased risk of heart failure and Cardiovascular Disease, Arthritis and Type 1 Diabetes (Hollick 2005; Kampman *et al.* 2007). In a study following children from age 1 into adulthood, those individuals who received adequate vitamin D decreased their risk of developing diabetes by 80% (Hollick 2005; Kampman *et al.* 2007).

Latitude can also have an impact upon physical health. Areas at high latitudes have been associated with a reduced risk of developing Multiple Sclerosis and also a reduced risk of developing cancer (Hollick 2004; Kampman *et al.* 2007). However, Norway appears to be an exception to this finding. This is likely to be the result of increased summer outdoor activities in childhood, which have been demonstrated to protect against Multiple Sclerosis (Hollick 2004). Contact with nature and sunlight are essential to physical health. However, concerns over skin cancer, combined with the reduction in the opportunity to access nature, are reducing exposure to sunlight and contributing to the development of chronic diseases (Hollick 2004)(Hollick, 2004). Sensible exposure to sunlight for approximately 5–10 minutes three times per week helps to protect against the development of skin cancer and is highly likely to be beneficial to physical health (Hollick 2004).

23.3.4 Recovery from Illness and Immunity

Access to nature can also aid recovery from illness (Kaplan 2001). A study revealed that hospital patients with a view of nature from their hospital room recovered from surgery and illness faster than those who had a view of a built environment (Maller *et al.* 2006). They spent less time in hospital and nursing staff also reported fewer negative comments in their medical records. Furthermore, those patients with a view of nature required fewer painkillers for their illness and had less post-operative complications. A similar pattern was noted in prison environments: those inmates with a natural view from their cell reported a lower frequency of stress symptoms, including digestive illness and headaches, and had an overall reduced number of sick

calls (Moore 1982; West 1985). Access to nature can also help to reduce the requirements of the health care services (Kaplan 2001).

There is evidence to suggest that some habitats may help to enhance immunity to disease (Li *et al.* 2007; Park *et al.* 2010). Spending time in a forest environment has been demonstrated to increase natural killer T cell activity, a vital component in the rejection of tumours and cells infected by viruses. Contact with forest environments also increase levels of perforin, a substance found in the presence of natural killer T cells, and granulysin which destroys infected body cells (Park *et al.* 2010). Additionally, studies have noted an increase in the induction of intracellular anti-cancer proteins in subjects that spend time in forest environments (Park *et al.* 2010).

23.4 Indirect Positive Effects

23.4.1 Facilitating Nature-based Activity

Access to nature, via any of the three levels of engagement (view from the window; functional engagement; active participation), can help to facilitate nature-based activity. If nature is within close proximity, there are health benefits from simply viewing it through a window (Ulrich 1984; Pretty *et al.* 2005), being in its presence (De Vries *et al.* 2003), or actively taking part in green activities and wilderness trails (Davis-Berman & Berman 1989; Hartig *et al.* 2003; Pretty *et al.* 2007). Research suggests that individuals who are readily able to access greenspaces, whether they are vast areas of wilderness or urban parks, are three times more likely to participate in physical activity than those that cannot access it so easily (Wells *et al.* 2007; Bowler *et al.* 2010). Furthermore, the nature-based activities associated with the two latter levels of engagement can, in turn, lead to a number of health benefits. Activities such as walking, gardening, fishing, hunting and horse riding not only provide those health benefits associated with contact with nature, but also provide benefits through participation in physical activity (Pretty *et al.* 2007; Barton & Pretty 2010).

23.4.2 Facilitating Social Engagement

High levels of social capital can have a direct effect on markers of individual and community well-being (Kawachi *et al.* 1997; Pretty & Ward 2001; Wood & Giles-Corti 2008). Social capital captures the idea that social interaction and social norms are an important part of the basis for sustainable livelihoods and communities (Pretty & Ward 2001). Levels of social interaction can be directly influenced by the availability of greenspace (Coley *et al.* 1997; Ward Thompson 2002). Modern Urban habitats lacking greenspace tend to restrict social contact as individuals are not attracted to their surrounding environments so tend to stay indoors, away from others (Coley *et al.* 1997). However, urban greenspace, in the form of parks, streets and allotments, can facilitate social contact and give rise to stronger neighbourhood ties (Coley *et al.* 1997; Kuo *et al.* 1998; Ward Thompson 2002). Evidence suggests that the presence of trees and grass in

urban areas encourages individuals to utilise outdoor space, increasing the likelihood of social interaction. The higher the number of trees and vegetation in an area, the more people that use it and the more time they spend within it (Coley *et al.* 1997; Kuo *et al.* 1998). Urban parks give individuals the opportunity to meet new people—an opportunity that is not so readily provided elsewhere in modern society (Ward Thompson 2002).

Social engagement and interaction can also be increased through participation in outdoor conservation and development activities and initiatives (Pretty & Smith 2004; Parliamentary Office of Science and Technology 2007). These activities can connect people through groups and networks, and build stronger communities, particularly in Urban areas where greenspace such as woodlands are generally declining (Pretty & Smith 2004; Parliamentary Office of Science and Technology 2007). By protecting nature, individuals can obtain social contact and derive value from being in the presence of nature (Pretty & Smith 2004).

23.4.3 Providing Wild Foods

Ecosystems provide wild foods that can have a direct effect on health. For many thousands of generations, farmers, hunter-gatherers, fishers and foragers have utilised, managed and amended wild foods from their surrounding habitats in order to provide a source of nutrition for themselves and others (WHO 2005; Bharucha & Pretty 2010). Historically, wild plants and food were the sole source of nutrition for hunter-gather and forager cultures, and so, have long-standing cultural value as well.

Today, wild foods help to link people to local habitats and increase social engagement, thus impacting upon health. The Food and Agriculture Organization of the United Nations estimates that one billion people use wild foods in their diet at some time during a typical year (Aberoumand, 2009). In many parts of the world, wild foods remain important to health: the mean use of wild foods by agricultural and forager communities in 22 countries of Asia and Africa (36 studies) is 90–100 species per location (Bharucha & Pretty 2010). In the UK, however, they now tend to be no more than a supplement to purchased foods (Bharucha & Pretty 2010). Yet older generations can still recall when the wild harvest had a critical nutritional value and products ranged from autumn berries and nuts, to rabbits, wildfowl and birds' eggs.

The use of wild foods and the prevalence of traditional ecological knowledge appear to be declining in industrialised countries (Mabey 1996; Pilgrim *et al.* 2008). In New Zealand, however, more than 60 species are still in common use, largely because of traditions of Māori groups. These include muttonbird (sooty shearwater, *Puffinus griseus*), seagull, possum, rabbit, deer, wild pig, goat, salmon, trout, eel, watercress, sea lettuce, gorse and many berries (Newman & Moller 2005; Stephenson & Moller 2009). In the Wallis Lake catchment, Australia, 88 species are in general use (Gray *et al.* 2005). In the swamps of Louisiana, USA, large numbers of people still hunt and fish regularly for their own food (Roland 2006). With regards to Europe, Pieroni (1999) suggests that the geographical isolation of the upper Serchio Valley in Tuscany has “permitted a rich popular knowledge

to be maintained”, and, as a result, gastronomic traditions have survived from pre-Roman times: 120 species still form a well-preserved pharmacopoeia of food and medicine (Pieroni 1999). In other regions of continental Europe, wild food use persists: 123 edible species are still used in Spain (Tardio *et al.* 2003); and in many Mediterranean countries, wild foods are still prevalent enough to be considered an important part of local diets (Leonti *et al.* 2006).

In the UK, wild foods remain an important cultural link to certain habitats. Wildfowling was very common in coastal communities, for example, until the mid-20th Century (Tennyson 1949; Wentworth Day 1949, 1950), and duck decoys were an important source of both food and income during the 18th Century (Heaton 2001). At their height, there were 29 duck decoys in Essex, 14 in Suffolk and 26 in Norfolk, and each could harvest 5,000 birds per year. The last working duck decoy in East Anglia closed in 1968. Yet wildfowling remains an important activity and food for small groups in coastal areas (Pretty 2011). In some communities, the wild harvest remains a significant cultural event. For example, for generations men from the fishing village of Ness on the Isle of Lewis, Scotland, have travelled 60 km each August to the island of Sula Sgier to gather young gannets (*Morus bassanus*) (Pretty 2011). Some 2,000 of these *guga* (Gaelic for young gannet) are collected from nests on the rock faces and killed; they are later salted and stored for local consumption as the meat is a highly valued. There is no evidence that the gathering has any adverse effect on the overall population of the gannet colony.

There is some evidence that wild foods are now receiving greater prominence in butchers and supermarkets, with venison (deer), rabbits and game becoming increasingly available and being purchased. In the UK, deer numbers are increasing because of growing woodland cover, warmer winters, improved urban habitat management, and the development of more golf courses. Over the past 20 years, the area of woodland in the UK has increased by 600,000 hectares to some 2.6 million hectares, and there are now thought to be 500,000 roe (*Capreolus capreolus*), 360,000 red (*Cervus elaphus*) and 100,000 fallow (*Dama dama*) deer, along with 50,000 muntjac (*Muntiacus reevesi*), sika (*Cervus Nippon*) and Chinese water (*Hydropotes inermis*) deer. Due to their grazing habits, which can decimate plant growth, in many habitats, numbers of deer have to be controlled, and this provides a ready source of venison. Such hunting and shooting also brings income and people into the countryside.

In addition, each year, some 20 million pheasants (*Phasianus colchicus*) and 400,000 mallards (*Anas platyrhynchos*) are raised and released for shooting in and around woodlands and wetlands in the UK. It has been shown that landowners who both hunt and maintain gamebird stocks conserve 7% of their farms as woodland, whereas those who do neither keep less than 1% as woodland (Oldfield *et al.* 2003).

23.4.4 Providing a Catalyst for Behaviour and Lifestyle Change

Contact with nature not only affects immediate health and well-being, but also health throughout life. Life courses and pathways, through which all lives are shaped, can be

mapped out into a ‘funnel’. **Figure 23.3** represents the two extreme pathways, healthy A and unhealthy B. However, there are numerous pathways that lie in between, consisting of varied configurations and patterns of behaviours (Pretty *et al.* 2009).

In pathway A, the healthy pathway, people tend to live longer and have a better quality of life (Pretty *et al.* 2009). This increase in life expectancy and quality of life is a direct result of increased levels of physical activity, a greater connection to people and society, contact with nature, and the consumption of healthy foods (Pretty *et al.* 2009). These healthy behaviours may be followed as a direct result of an individual’s surrounding environment. The ability to access green settings has been demonstrated to encourage contact with nature and participation in physical activity, both of which encourage the adoption of other healthy lifestyle choices such as social engagement and consumption of healthy foods (Wells *et al.* 2007; Pretty *et al.* 2009; Bowler *et al.* 2010). The availability of greenspace is, therefore, critical to healthy behaviours. On the healthy pathway, individuals have a better level of mental health, engage with nature regularly, are more resilient to stress, are members of social groups and keep learning (Foresight 2008; Pretty *et al.* 2009).

By contrast, the second life course in **Figure 23.3**, pathway B, is the unhealthy pathway. In this pathway, individuals have a lower life expectancy and a poorer quality of life, resulting from inactive and sedentary behaviour, disconnection from society and people, a lack of connection with nature, and the consumption of energy-dense and unhealthy foods (Pretty *et al.* 2009). Individuals on the unhealthy pathway also have more stressful jobs, a lower socioeconomic status, live in areas where active travel is difficult, and have an increased likelihood of being mentally ill, overweight or obese (Foresight 2007; Pretty *et al.* 2009).

In an increasingly urbanised society, the likelihood of following this pathway is becoming increasingly likely. As urban areas continuously grow and diffuse into rural areas, individuals rely heavily on cars for transportation, and are separated from neighbouring communities (Pretty *et al.* 2009). In modern human history, inactivity, disengagement from nature, consumption of unhealthy foods and social isolation are common behaviours. Urban areas do not provide vast opportunities for physical activity or active transport (e.g. cycling), and greenspace is continuously decreasing (Biddle *et al.* 2004; Louv 2005; Pretty *et al.* 2007; Pretty *et al.* 2009). The unhealthy behaviours encouraged by more modern urban environments are resulting in poor health and well-being (Pretty *et al.* 2009) and some environments may be considered as obesogenic (Foresight, 2007).

Although an individual may spend some time on a particular life pathway, it is possible to change behaviour and take an alternative pathway (Pretty *et al.* 2009). Individuals may move to a more healthy pathway as a direct result of adopting healthy behaviours that require spending time outdoors. For example, an individual may take part in a wilderness trail or activity away from their normal environment, but may continue to have contact with nature even when the trail has finished. This change in behaviour may also lead them towards the adoption of other healthy

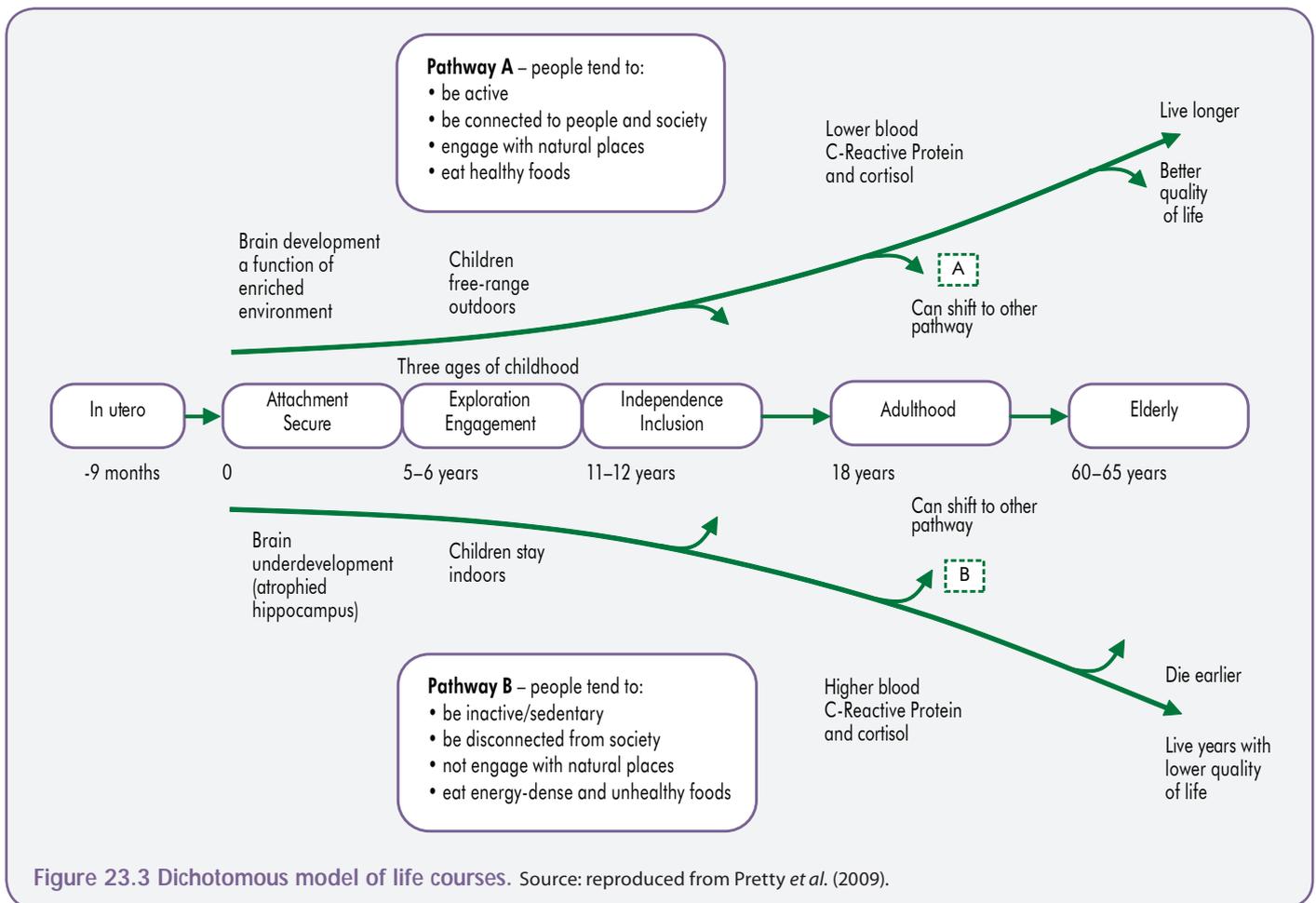


Figure 23.3 Dichotomous model of life courses. Source: reproduced from Pretty *et al.* (2009).

behaviours, such as physical activity. However, individuals may also move from a healthy to an unhealthy pathway as a result of a particular experience. Yet resilient individuals, who regularly perform physical activity and have contact with nature, are more likely to be able to cope with these stressful life events and will, therefore, continue on the healthy pathway (Pretty *et al.* 2009).

By moving from an unhealthy to a healthy pathway, individuals will experience significant improvements in quality of life and well-being. Furthermore, this shift will save society approximately £2,423 per person per year in health care costs (Pretty *et al.* 2009). Indeed, if just 1% of the sedentary population moves to a healthy pathway, 1,063 lives and £1.44 billion will be saved each year (NICE 2009). The earlier this shift occurs during life, the greater the impact will be upon health and society.

23.4.5 Childhood Experience and Behaviour

Experience of nature during childhood can impact upon adult behaviour and life pathways. Although contact with nature at any age can derive a whole number of benefits for physical and mental health, contact with nature during youth can directly impact upon healthy adult behaviours. Research indicates that the frequency of visits to green places during childhood significantly correlates to the number of visits during adulthood (Ward Thompson *et al.* 2008; Pretty *et al.* 2009). Therefore, a lack of experience of nature as a child

may directly result in a lack of contact during adulthood. Being disconnected from nature is characteristic of an unhealthy life pathway and may reduce the opportunities for adopting other healthy behaviours (Pretty *et al.* 2009).

Contact with nature during childhood can also influence environmental attitudes and behaviours during adulthood. Evidence suggests that children who participated in nature-based activities before the age of 11 are much more likely to express pro-environment attitudes and engage in pro-environment behaviours (Figure 23.3). Experience during childhood can, therefore, have a significant impact upon an individual's attitude towards the environment, a factor that could potentially impact upon environmental conservation (Wells & Lekies 2006).

Despite the evidence that adults who have high levels of contact with nature during youth have an increased likelihood of adopting a healthy life pathway and exhibiting environmentally friendly behaviours (Wells & Lekies 2006; Pretty *et al.* 2009), opportunities for the children of today to play and engage in green settings are continually diminishing. Less than 10% of children ever play in natural areas, compared to the 40% of today's adults who did so as children. Children are spending less time outdoors than they used to, and have a reduced understanding of the natural environment (Louv 2005; Bird 2007). If the children of today continue to be disconnected from nature, it is increasingly likely that they will embark on an unhealthy life pathway throughout their lives and, hence, have a reduced quality of life and life expectancy (Pretty *et al.* 2009).

23.4.6 Epidemiological Studies

Epidemiological studies often show associations between the proximity of greenspace to the home and positive health outcomes (Maas *et al.* 2006; Mitchell & Popham 2007, 2008). A direct link between the amount of accessible local greenspace and health has been evidenced using large-scale epidemiological studies in Japan, Netherlands and Sweden, which we have reviewed here (Takano *et al.* 2002; De Vries *et al.* 2003; Grahn & Stigsdotter 2003).

In Tokyo, Japan, tree-lined streets, parks and other greenspaces play a key role in the increased longevity of residents, and decrease the risk of mental health issues (Takano *et al.* 2002). A longitudinal study compared access to local greenspaces within walking distance of home and mortality rates in elderly people over a period of five years. After controlling for demographic and socioeconomic variables, Takano *et al.* (2002) found that, out of 3,100 Tokyo citizens born between 1903 and 1918, 71% were still alive in 1992, and that the probability of their living for an additional five years was linked to their ability to walk in a local park or tree-lined street (Takano *et al.* 2002). However, the issue of causality is not clear as it is possible that the more affluent individuals, who often live longer anyway, represented those who lived in the greener neighbourhoods (Adams & White 2003).

In the Netherlands, self-reported health data from over ten thousand Dutch urban residents was correlated with national environmental data characterising the type and quantity of blue and green spaces present in their neighbourhood. Socioeconomic and demographic characteristics were controlled for selection effects and the study reported that people living in greener neighbourhoods enjoyed better general health (De Vries *et al.* 2003). The type of greenspace did not seem to alter effectiveness; the total amount of greenspace in the living environment seemed to be the most relevant predictor. However, environmental characteristics were separated into neighbourhoods, and all individuals within that particular area were classed as having equal access to greenspaces. This measure does not acknowledge that exposure to greenspace may vary considerably between residents of the same neighbourhood and that durations of exposure may also differ.

In a Swedish study, Grahn and Stigsdotter (2003) examined the relationship between the use of urban greenspaces and health, and found that the level of self-reported stress showed significant relationships with the proximity of urban greenspaces, the frequency of visits to those greenspaces, and the duration of the stay. The findings implied that the more frequent the visits, the lower the incidence of stress-related illnesses. Having access to a public or privately owned garden adjacent to their place of residence was another principal factor, which has implications for both policy and urban landscape planning (Maas *et al.* 2006; Mitchell & Popham 2007, 2008).

Perceived neighbourhood 'greenness' is also strongly associated with better mental and physical health (Sugiyama *et al.* 2008). Respondents who perceived their neighbourhood as highly green were 1.37 and 1.60 times more likely to have better physical and mental health respectively, in comparison with those who perceived it as low in greenery. The degree

of species richness in urban greenspaces has also been positively associated with the psychological well-being of visitors (Fuller *et al.* 2007), emphasising the importance of locally managed biodiversity in providing a sense of place and an object for reflection.

Despite these findings, it is also important to acknowledge potential selection or causation mechanisms (De Vries *et al.* 2003). Selection processes would suggest that healthy people move to green surroundings (selective migration), whereas causation mechanisms would imply that living in green environments promotes good health and well-being. So do green environments make people healthier and affect individual behaviour, or do those particular areas attract healthy people? If a person resides in a green area, do they spend more time being physically active outdoors? Even if the natural environment did not affect physical activity patterns, would the health of those living in greener surroundings improve solely from the increased exposure to nature? Although all of these studies have attempted to address the possibility of selective migration, it cannot be categorically ruled out. The studies are also cross-sectional in nature, as opposed to longitudinal. Cross-sectional studies are valuable and provide a good starting point (Wells *et al.* 2007) by establishing relationships among correlates or covariates (Bauman *et al.* 2002). However, longitudinal studies are necessary to establish causality, which is an important outcome for informing policy and practical recommendations. Although longitudinal studies are time intensive, the advantage of exploring causality makes them a creditable goal.

23.5 Reducing the Incidence of Pollution and Disease Vectors

Ecosystems provide important services by reducing threats to health through purification, dampening and consumption functions. Processes include local climate regulation, noise reduction, scavenging of air pollutants and the control of vectors of disease.

23.5.1 Air Purification Through the Reduction of Pollution

Ambient air pollution has long been implicated as a contributor to adverse health effects. The House of Commons Environment Audit Committee reported that up to 50,000 people a year in the UK may be dying prematurely because of air pollution (Defra 2007). The Government's 2007 Air Quality Strategy estimates that the health impact of particulate matter alone costs the UK between £8.5 billion and £20.2 billion a year (Defra 2007). This is very likely to be an underestimate as it ignores the impact on morbidity, costing only mortality. In addition, air pollution has wide-ranging environmental impacts including loss of biodiversity, reduced crop yields and contributing to climate change.

Rehdanz and Maddison (2008) found that perceived levels of air pollution are negatively related to well-being in Germany. Welsch (2006) examined average well-being in relation to average air pollution values, and found significant negative associations in each case. Brereton *et al.* (2006) and Ferreira & Moro (2010) working with individual-level data on air pollution and other Environmental Quality parameters in Ireland, also found negative associations between air pollution and well-being; and MacKerron & Mourato (2010) arrived at the same conclusion using air pollution data for London.

Numerous studies have shown how ecosystems can play a significant role in reducing air pollution.

Rowe (2010) recently reviewed the use of green roofs to reduce pollution. He concluded that they have significant potential to reduce air pollution directly and emissions indirectly. The major hurdle to their widespread utilisation is the considerable cost barrier between green and conventional roofs (Rowe 2010).

Urban forests can either reduce air pollution by increasing dry deposition, or increase it through emissions of enhanced biogenic volatile organic compound (BVOC), which can act as precursors of secondary air pollutants. Many reports have shown that trees in urban areas provide a significant contribution to the reduction of air pollutants (Yang *et al.* 2005; Nowak 2006; Escobedo & Nowak 2009). Escobedo *et al.* (2011) argue the forests should be managed within the parameters of urban sustainability and, at the same time, promoted to policy makers and citizens as a means of mitigating pollution, so they can be used to improve human quality of life throughout the cities of the world (Escobedo *et al.* 2011).

There is little guidance on optimum locations in which to plant trees in urban areas. In New York, locations for tree planting have used indicators such as hospitalisation and asthma rates (Grove *et al.* 2006). This earlier work has now been developed into a planting priority index that spatially considers air pollution concentrations, human population density and tree cover. On the other hand, the placement of trees may also increase pollution concentrations at street levels, especially in valleys where they impact on the dispersion processes (Buccolieri *et al.* 2009).

On a global scale, BVOCs emitted from vegetation are more reactive than, and exceed, anthropogenic VOCs. Emission rates of BVOCs are strongly dependent upon temperature, so it is expected that they will increase in the future as a result of climate change. Emissions also vary from species to species, so selective planting of low-emitting species may be beneficial. Donovan *et al.* (2005) developed an urban tree air quality score that ranks trees in order of their potential to improve air quality. They concluded that pine, larch and silver birch had the greatest potential to improve air quality. In contrast, if planted in large numbers, oaks, willows and poplars had the potential to decrease air quality downwind (Donovan *et al.* 2005).

23.5.2 Interception of Noise and Water

In recent years, noise pollution has become an increasingly important environmental problem which can have adverse effects on human health (Ozer *et al.* 2008). Traffic-generated noise is one of the main sources of noise pollution, with excessive noise from roads, air traffic and railways in urban

areas commonly resulting in stress (den Boer & Schroten 2007; Ozer *et al.* 2008). Habitats containing trees and shrub vegetation have been demonstrated to be particularly effective at providing barriers to noise in urban settings (Frumkin *et al.* 2004; Ozer *et al.* 2008; Ernstson *et al.* 2010; Fitter *et al.* 2010). Research has also demonstrated that the presence of vegetation can significantly reduce noise levels from urban motorways (Ozer *et al.* 2008). Furthermore, green belts have been suggested to be effective tools for the mitigation of traffic-generated noise (Pathak *et al.* 2011). However, the specific characteristics of the vegetation should be considered as the crown width, height and density of plants, and the position of their leaves against the direction of the noise, may influence their effectiveness (Ozer *et al.* 2008). The vegetation must also be tolerant to air pollutants from motorised transport (Pathak *et al.* 2011).

Vegetation is important for the interception of water in Urban habitats (Cornell University 2009). Large cities and towns are often covered with hard surfaces that do not allow for the absorption of water. During storms or times of high rainfall, this can result in high levels of surface water. This excess water often runs into sewer systems causing them to overflow into rivers and lakes, washing pollutants into them. The presence of trees and other vegetation can reduce this problem by lessening the surface water and enhancing water absorption via the soil. Vegetation can also transpire water from their leaves. The presence of vegetation in urban ecosystems is, therefore, of great importance as it can help to reduce flooding and prevent the pollution of rivers and lakes (Cornell University 2009).

23.5.3 Mitigation of the Heat Island Effect

The heat island effect is a well-established phenomenon of large urban settlements; the temperature difference between London and the surrounding suburbs, for example, can be as large as 9°C (Kolokotroni & Girdharan 2008). It is known that urban greenspace mitigates this effect (Gill *et al.* 2007). Trees also filter and take up air pollutants, including oxides of nitrogen and sulphur and particulates (Beckett *et al.* 1998; Tiwary *et al.* 2009). The current 7% tree cover in the West Midlands reduces air concentrations of PM₁₀ (particulates >10 micro-metres) by 4% (McDonald *et al.* 2007). Trees and other vegetation also intercept noise by absorbing reflected and laterally transmitted noise.

23.6 Direct Threats to Human Health

This section does not consider the toxicants, pollutants or contaminants introduced into the environment as a result of human activity or management. Those classes of compounds with known effects on human health include some pesticides, air pollutants, endocrine disruptors, PCBs, heavy metals, radionuclides, asbestos, aliphatics (e.g. vinyl chloride, formaldehyde), and oils (Conway & Pretty 1991; Frumkin 2005; Pretty 2005). The effects of some of these threats to health are dampened or mitigated by specific ecosystems.

Ecosystems themselves, however, can be a direct provider of threats to human health, and it is these threats that we are reviewing here. They include infectious agents (e.g. *Lyme borreliosis*, *Cryptosporidium* species, malaria, cholera, *cyclospora cayetanensis*, *campylobacter* species and *leptospiriosis* species); physical threats from wild animals (though not generally a factor in UK), domestic livestock and dogs; pollutants or contaminants from plants (e.g. bracken spores, VOCs, pollen); elemental threats through extremes of temperature or UV radiation; and accidents (Frumkin *et al.* 2004).

There are a wide variety of pathogens in water that comprise threats to health including *Escherichia coli* and *Salmonella*, *Campylobacter*, *Giardia* and *Cryptosporidium* species. Some of these come from natural sources, such as (waterbirds and wild animals, and some come from human sources. Vector-borne diseases involve the transmission of infectious agents (viruses, bacteria and parasites) by blood-sucking arthropods such as mosquitoes. A number of such diseases have emerged for the first time, or resurged, as significant public health threats during the past 25 years. These include Lyme Disease, Dengue Fever and the more serious Dengue Haemorrhagic Fever, Yellow Fever, Japanese Encephalitis, West Nile Virus, Alkhurma Virus, a subtype of Kyasanur Forest Disease, Venezuelan Equine Encephalitis, Epidemic Polyarthritis (Ross River Virus), Barmah Forest Virus, Rift Valley Fever, Oropouche Fever, California Encephalitis and Crimean-Congo Haemorrhagic Fever (Watson *et al.* 2005).

Lyme Disease, involving the infection of humans following a tick bite, has become a significant public health problem in the USA, and has recently increased within the UK. The Health Protection Agency now estimates that there are 1,000–2,000 cases of Lyme Disease in the UK each year. The ticks that cause Lyme Disease are commonly found in woodland and heathland areas because these types of habitats have a high number of tick-carrying animals such as deer and mice. Parts of the UK that are known to have a particularly high population of ticks include Exmoor, the New Forest, the South Downs, parts of Wiltshire and Berkshire, Thetford Forest in Norfolk, the Lake District, the Yorkshire Moors and the Scottish Highlands (NHS 2011b). The tick population is highest in late spring and early summer.

A further threat to human health arises from natural VOCs. These air pollutants originate from vegetation, such as oak and maple, but can also be anthropogenic in origin (Steinbrecher *et al.* 2008). The main natural VOCs are isoprene and terpene, and large forests can emit 50 kg/km² daily at the height of the growing season (Behr & Johnen 2008). Natural VOCs emitted by such habitats can contribute significantly to the formation of tropospheric ozone, which has negative health consequences (AQEG 2009).

Another threat to human health arises from noise intruding on ecosystems and consequently affecting well-being. The sources of noise pollution are mainly from transport. Van Pragg & Baarsma (2005) investigated aircraft noise around Amsterdam Schiphol airport and found that experienced noise nuisance was negatively related to well-being, although direct noise measures were not significant.

Climate also has an effect on human health. Redhanz & Maddison (2005) assessed climate parameters across 67 countries and found that greater well-being was associated with a higher mean temperature during cold months and a lower mean temperature during hot months. In addition, Brereton *et al.* (2006) found that higher well-being in Ireland was related to lower wind speeds, but higher rainfall.

In addition to the direct effects of climate on well-being, climate change is predicted to have a substantial future impact as altered conditions allow the spread and development of new vector-borne and waterborne diseases (Watson *et al.* 2005). It is not clear whether this will bring vectors that affect human health, but the livestock disease, Bluetongue Virus, has now become established in the UK since its arrival from the continent via migrating adult midges taking advantage of warmer conditions. Airborne allergens may also be significantly influenced by climate change. It has been shown that pollen counts rise with increasing temperatures (Tamura *et al.* 1997; Anhlholm *et al.* 1998). In addition, increased atmospheric carbon dioxide results in enhanced production of pollens from species such as ragwort (*Senecio jacobea*) (Ziska & Caulfield 2000). The recent comprehensive assessment by the Health Protection Agency (DH & HPA 2008) has concluded that outbreaks of malaria in the UK are likely to remain rare, but that there is still the possibility that more effective vectors (different species of mosquito) may arrive in the UK as the climate becomes more suitable for them. Tick-borne diseases are expected to become more common, but this is more likely to be due to changes in land use and leisure activities than to climate change. The likelihood that tick-borne encephalitis will become established in the UK is very low.

Finally, there are some natural sources of radiation in the UK (e.g. radon from granite rocks in south-west England and Scotland) that constitute significant natural threats to health.

23.7 Methods for Establishing Health Values

23.7.1 Questionnaire-based Measures for Mental Health

Table 23.4 summarises the main instruments in use for measuring mental health arising from exposure to nature. Many different methods are available, but **Table 23.4** comprises a list of the most commonly applied tools from key studies identified in earlier sections. This list is indicative rather than exhaustive.

23.7.1.1 Self-esteem

Self-esteem is commonly accepted as a key indicator of emotional stability and, therefore, is a contributor to mental well-being, quality of life and survival (Huppert & Whittington 2003). An individual's level of self-esteem has implications for health behaviours, motivations and lifestyle choices. High

levels of self-esteem are associated with healthy behaviours, such as healthy eating and physical activity, and also stress resilience and life satisfaction (Torres & Fernandez 1995; Fox 2000). Low self-esteem is closely linked to mental illness and the absence of psychological well-being, with symptoms including depression, trait anxiety, suicidal ideation and a sense of hopelessness (Fox 2000).

Rosenberg's Self Esteem Scale (RSE) is the most widely used and popular self-esteem measure (Rosenberg 1965). It is a standardised tool used in health psychology and is regarded as the standard against which other measures of self-esteem should be compared (Rosenberg 1965). The RSE scale consists of ten statements concerning how an individual views themselves, and requires a response of 'strongly agree', 'agree', 'disagree' or 'strongly disagree' for each (Rosenberg 1965). The scale's conservative measure, superior reliability and validity is widely acknowledged, and these qualities have been demonstrated with many different sample groups (Fox 2000): its use has been validated for adolescent, adult and elderly populations. The RSE has been used in a wide range of green exercise studies, predominantly in the UK (Pretty *et al.* 2005; Peacock *et al.* 2007; Pretty *et al.* 2007; Peacock *et al.* 2008; Barton *et al.* 2009; Barton & Pretty 2010; Barton *et al.* 2011).

23.7.1.2 Mood states and/or emotion

Mood is defined as "the subtle subjective state or feelings of a person at any given moment" (Hull 1991). It is an integral component of daily life and has a strong influence on feelings of happiness, being able to appreciate the moment, coping with stressful situations and general quality of life (Berger *et al.* 2002). Mood states are known to influence long-term health by both direct (immune system) and secondary (lifestyle choices) pathways.

The **Profile of Mood State (POMS)** standardised short form questionnaire is the primary instrument for measuring

mood due to its sensitivity to mood changes in many settings (McNair *et al.* 1971; Biddle 2000; Biddle *et al.* 2000). The POMS questionnaire comprises six subscale mood components: five negative and one positive. These are 'anger-hostility', 'confusion-bewilderment', 'depression-dejection', 'fatigue-inertia', 'tension-anxiety' and 'vigour-activity' (McNair *et al.* 1971). There are five words to represent each of the six subscales and respondents are requested to indicate the degree to which they are experiencing the particular mood state by selecting 'not at all', 'a little', 'moderately', 'quite a bit' or 'extremely' (McNair *et al.* 1971). The POMS questionnaire has been regularly used to assess short-term and acute mood changes in individuals after they have participated in nature-based activities in the UK (Pretty *et al.* 2005; Peacock *et al.* 2007; Pretty *et al.* 2007; Peacock *et al.* 2008; Barton *et al.* 2009; Barton & Pretty 2010; Barton *et al.* 2011).

The **Zuckerman Inventory of Personal Reactions (ZIPERS)** is a broad state affect test that assesses feelings on five factors: 'fear arousal', 'positive affect', 'anger/aggression', 'attentiveness' and 'sadness' (Zuckerman 1977; Ulrich 1981; Hartig 2003). The respondents indicate the extent to which the statements describe how they feel at that precise moment using a five-point scale (1=not at all to 5=very much) (Zuckerman 1977; Hartig 2003). The ZIPERS has been used in a large number of studies examining the effect of restorative environments, mainly in the USA (Ulrich 2002; Hartig 2003).

Anxiety is a mood or emotional state that includes feelings of apprehension, tension and nervousness (Spielberger 1970). The **Spielberger State-Trait Anxiety Inventory (S-STAI)** and the **S-STAI six item short version** are used to assess anxiety (Spielberger 1970; Diette *et al.* 2003). The S-STAI is a self-report questionnaire which requires participants to indicate whether they are feeling calm, tense, upset, relaxed, etc. Participants respond on a four-point scale using either

Table 23.4 Summary of mental health measures.

Questionnaire title	Mental health measure	Number of items/ Factors on questionnaire	Examples of ecosystem studies in which they have been utilised
1. Rosenberg's Self Esteem Scale	Self-esteem	10 items	Pretty <i>et al.</i> (2005), Peacock <i>et al.</i> (2007), Pretty <i>et al.</i> (2007), Barton <i>et al.</i> (2009), Barton & Pretty (2010), Barton <i>et al.</i> (2011)
2. Profile of Mood State Questionnaire	Mood	6 factors (30 items)	Van den Berg <i>et al.</i> (2003), Pretty <i>et al.</i> (2005), Peacock <i>et al.</i> (2007), Pretty <i>et al.</i> (2007), Peacock <i>et al.</i> (2008), Barton <i>et al.</i> (2009), Barton & Pretty (2010), Barton <i>et al.</i> (2011)
3. The Zuckerman Inventory of Personal Reactions	Emotion and mood	5 factors	Ulrich (1981), Ulrich <i>et al.</i> (1991), Honeyman (1992), Hartig <i>et al.</i> (1996), Ulrich (2002), Hartig <i>et al.</i> (2003)
4. Spielberger State-Trait Anxiety Inventory	Anxiety	20 items	Diette <i>et al.</i> (2003)
5. The Lewis Stressful Life Events Scale	Stress	20 item scale	Wells & Evans (2003)
6. The General Health Questionnaire	Mental well-being	28-item and 12-item questionnaires	Pretty <i>et al.</i> (2005)
7. The Rutter Child Behaviour Questionnaire	Psychological distress, behavioural problems, anxiety and depression	26 items	Wells & Evans (2003)
8. The Global Self-worth Scale	Perception of mental well-being	6 items	Wells & Evans (2003)

'not at all', 'somewhat', 'moderately' or 'very much so' (Spielberger 1970; Diette *et al.* 2003). The scores are summed and normalised to a scale with scores ranging from 20 to 80: 20 represents a low level of anxiety and 80 represents a high level (Diette *et al.* 2003).

The Lewis Stressful Life Events Scale is used to assess the frequency of stressful life events (Lewis *et al.* 1984) and was originally tested and developed on children in the USA (Wells & Evans 2003). The scale consists of 20 items each concerning a stressful life event. The respondent is asked to indicate the degree to which they experience this stressful life event using 'a lot', 'sometimes' or 'never' (Lewis *et al.* 1984; Wells & Evans 2003). Examples of items on the scale include "how often were you picked on or made fun of by other kids?" and "How often did you fight or argue with your parents?". The method has been used to explore relationships between access to nature and the ability to cope with stressful life events (Wells & Evans 2003).

23.7.1.3 Overall mental well-being

The **General Health Questionnaire (GHQ)** is the industry standard for measuring psychological health and provides an overall indication of psychological state (Chisholm *et al.* 1975; Goldberg 1978). There are several versions of the GHQ including a 28-item and 12-item version (Goldberg *et al.* 1997). Questions are scored using a three-point Likert scale, with variation in their meaning according to the question itself (Goldberg 1978; Goldberg *et al.* 1997). The 12-item version has been demonstrated to be robust and to work as well as the longer, 28-item version (Goldberg *et al.* 1997). On the 12-item version, the questionnaire scores range from a minimum of 0 to a maximum of 36. A score of 0 represents an excellent state of mental health, while a score of 36 represents a poor state of mental health (Pretty *et al.* 2005). Although this tool is commonly used in mental health research, it has only been used sparingly to assess the health values of contact with nature.

The **Rutter Child Behaviour Questionnaire** is used to assess psychological distress, including symptoms of behavioural disorders, anxiety and depression (Rutter *et al.* 1970; Boyle & Jones 1985; Wells & Evans 2003). The questionnaire is a standardised, widely used instrument that is commonly used in non-clinical populations. The questionnaire consists of 26 items that are responded to on a three-point scale by the child's mother (0=does not apply, 1=applies somewhat, 2=certainly applies) (Wells & Evans 2003). Items on the scale include phrases such as my child "often appears unhappy" and "bullies other children". This instrument has been used to explore relationships between access to nature and the ability to cope with stressful life events (Rutter *et al.* 1970; Boyle & Jones 1985; Wells & Evans 2003).

The **Global Self-Worth Scale** is used to assess children's perception of mental well-being (Harter 1982). The scale assesses three domains of self-competence, including social, cognitive and physical domains, and also assesses general self-worth (Harter 1982). The scale includes six items with statements such as "some kids like the kind of person that they are but other kids often wish they were someone else" (Wells & Evans 2003). The respondent responds to each

statement using either 'really true' or 'sort of true' (Wells & Evans 2003).

23.7.1.4 Mappiness methods

A custom iPhone application ('app') and accompanying back-end data server have been developed by (Mourato & MacKerron 2010). Recruitment of participants is opportunistic, relying mainly on media coverage and snowballing via Twitter. After downloading the app to their devices, participants provide basic demographic and health-related information, confirm settings, and give their informed consent in order to register. Participation is anonymous: no name, address, or other contact information is requested. Participants receive simple feedback, charting their happiness in different contexts, and can take part in the study for as long (or short) a period as they wish. Following registration, participants receive a notification (beep) on their device between one and five times a day, at their own choice. The notifications come at a random moment during hours agreed by the participant. The default frequency is twice a day, and the default hours are 8am–10pm. Each notification prompts the participant to open the app and to briefly report how they are feeling and, in broad terms, whom they are with, where they are and what they are doing. Respondents report the extent to which they feel 'Happy', 'Relaxed' and 'Awake' on a sliding visual analogue scale.

23.7.2 Physiological and Questionnaire-based Methods for Assessing Physical Health

The majority of the research assessing the health benefits of exposure to nature has predominantly used mental health measures. However, to establish an overall health value we also need to address the impact upon physical health indices such as heart rate, blood pressure, skin conductance and/or cortisol (stress hormone). Some authors have started exploring the impact on natural killer T cell activity and other key hormones to progress the research to a cellular level (Li *et al.* 2007).

23.7.2.1 Body Mass Index and Waist to Hip Ratio

Body Mass Index (BMI) is a simple index of weight:height that has been widely used to estimate body fat and to classify adults as underweight, overweight and obese for several decades (Keys *et al.* 1972; WHO 2011; NHS 2011a; NIH 2011). It is defined as the weight in kilograms divided by the square of the height in metres (kg/m^2). It has been used by the World Health Organization as the standard for recording obesity statistics since the early 1980s and is seen as a useful estimation of risk for diseases that can occur with more body fat. The higher the BMI calculation, the greater the risk for certain health issues such as Cardiovascular Disease, high blood pressure, Type 2 Diabetes, gallstones, breathing problems and certain cancers (NIH 2011). Although controversies over the use of BMI for medical diagnosis remain, it is generally accepted for individuals with an average body composition (WHO 1995). Classification of BMI scores are: <18.5 = underweight; 18.5–24.99 = normal; 25–29.99 = overweight and >30 = obese. Some studies have monitored changes in BMI over time as a result of participation in green exercise activities (Hine *et al.* 2011).

Others have explored the relationship between BMI and the mental health benefits experienced through nature-based activity (Pretty *et al.* 2005).

Waist to Hip Ratio (WHR) is a simple and useful measure of fat distribution and is a tool that helps determine overall health risk (NHS 2011a). People with more weight around their waist are at greater risk of lifestyle-related diseases, such as Cardiovascular Disease and diabetes, than those with weight around their hips. The classification of risk as defined by waist to hip ratios is as follows: for men: <0.95=low risk; 0.96–1.00=moderate risk; >1=high risk; and for women: <0.80=low risk; 0.81–0.85=moderate risk; >0.85=high risk. The norms for adults are 0.84 for males and 0.72 for females. Waist circumference is measured with a measuring tape around the narrowest circumference between pelvis and thorax (or two-finger width above navel) and hips are measured from the side at the level of the maximal protuberance of buttocks.

23.7.2.2 Blood pressure

Blood pressure is an important marker of cardiovascular health: particularly high levels are associated with Cardiovascular Disease and cerebrovascular events (HEW 2004). **Manual and digital sphygmomanometers** are most commonly utilised to assess blood pressure and are applicable in a variety of settings (O'Brien *et al.* 2001). They are simple to use and provide a quick assessment of blood pressure. However, the accuracy of the manual monitor is largely influenced by the assessor itself and should only be used by experienced individuals (O'Brien *et al.* 2001). Assessing blood pressure change pre and post nature-based interventions provides an indication of recovery, and many studies have used this approach to compare exposure to natural environments and urban areas lacking nature (Ulrich 1981; Ulrich *et al.* 1991; Parsons *et al.* 1998; Pretty *et al.* 2005). A **portapres** is used to measure blood pressure and can provide a beat-by-beat assessment for up to 24 hours (O'Brien *et al.* 2001). This would allow researchers to explore the longer-term impact of exposure to nature on blood pressure over a 24-hour period and introduce ambulatory monitoring rather than one-off measures. The portapres gives waveform measurements similar to intra-arterial recordings. However, this method can lead to various inaccuracies which may only be fixed by correction factors and digital monitors (O'Brien *et al.* 2001).

23.7.2.3 Heart rate and Heart Rate Variability (HRV)

Heart rate and heart rate variability (HRV) are important markers of autonomic nervous system activity and are contributors to cardiovascular health, especially as there is a significant relationship between the autonomic nervous system and cardiovascular mortality (Treiber *et al.* 1989; Task Force 1996). **Heart Rate monitors** are commonly utilised to assess heart rate as they are applicable in both laboratory and field settings (Treiber *et al.* 1989). Heart rate monitors consist of a chest strap and a wristwatch. The chest strap is fitted around the subject's chest to detect a heart rate reading; this reading is transmitted to the wristwatch which stores and monitors heart rate for a selected time period (Treiber *et al.* 1989). While heart rate

monitors are easy to use in both laboratory and field settings, there is some concern with regards to their accuracy (Treiber *et al.* 1989). Heart rate monitors have been used to assess experiences both in greenspaces and in urban areas lacking nature in a few studies (Ulrich *et al.* 1991; Parsons *et al.* 1998; Pretty *et al.* 2005).

Electrocardiograms (ECGs) are also used to assess heart rate and are considered to provide much more reliable results than heart rate monitors (Treiber *et al.* 1989). Not only do ECGs provide an overall measure of heart rate, but they also provide a measure of heart rate variability: beat-by-beat variation in heart rate (Task Force 1996; Martini 2006). Three electrodes are placed at different points on the body's surface and connected to a computer (Martini 2006). The computer generates a graph of each heart beat cycle, which is made up of several different features including a P-wave, QRS complex and T-wave. If a portion of the heart has been damaged, for example by a heart attack, the ECG will detect abnormalities in the normal heart beat cycle (Task Force 1996; Martini 2006). Although useful in laboratory studies using pictures of natural scenes and urban scenes lacking nature or greenspace (Ulrich *et al.* 1991), this method would have limited applicability in field settings.

23.7.2.4 Cortisol

Cortisol is a biomarker of psychosocial stress. Cortisol levels gradually increase within a few minutes of stress stimulation and reach peak concentrations 10–30 minutes after stress cessation (Foley & Kirschbaum 2010). Cortisol levels are commonly measured through saliva. A piece of absorbent cotton is placed in the mouth for approximately 1–2 minutes and placed in a test tube. The saliva sample can then be frozen and stored for later analysis of cortisol concentration (Foley & Kirschbaum 2010; Park *et al.* 2010). However, when cortisol is measured via samples of saliva, it is only possible to determine free cortisol levels (the concentration of those cortisol particles not bound to protein) (Foley & Kirschbaum 2010).

Blood samples can also be taken to measure cortisol levels. Unlike salivary samples, blood serum samples can provide both a measure of free cortisol levels and total cortisol (Foley & Kirschbaum 2010). However, blood-sampling is a more intrusive method. Exploring changes in cortisol profiles following participation in longer-term nature-based interventions is currently being considered for future research. Very few studies have analysed cortisol levels (Hartig *et al.* 1996) in relation to contact with nature, but investigating this stress hormone could potentially inform future calculated health values.

23.7.3 Questionnaire-based Methods for Establishing Connectedness to Nature

23.7.3.1 Connectedness to nature

Connectedness to nature is an important predictor of ecological behaviour and subjective well-being and has been demonstrated to be related to an increase in awareness of environmental issues and environmentally friendly behaviour (Hine *et al.* 2008b). The **Connectedness to Nature Scale (CNS)** is a standardised and validated questionnaire which is a 'new measure of individuals' trait feelings of being

- Berger, B.G.,** Pargman, D. & Weinberg, R.S. (2002) Foundations of exercise psychology. Fitness Information Technology, Morgantown.
- Berrigan, D.** & Troiano, R.P. (2002) The association between urban form and physical activity in US adults. *American Journal of Preventive Medicine*, **23**, 74–79.
- Bharucha, Z.** & Pretty, J. (2010) The roles and values of wild foods in agricultural systems. *Philosophical Transactions of the Royal Society*, **365**, 2913–2926.
- Biddle, S.,** Fox, K. & Boutcher, S. (2000) Physical activity and psychological well-being. Routledge, London.
- Biddle, S.J.H.** (2000) Emotion, mood and physical activity. Physical activity and psychological well-being. (eds S.J.H. Biddle, K.R. Fox, & S.H. Boutcher). Routledge, London. pp. 63–87.
- Biddle, S.J.H.,** Gorely, T. & Stensel, D.J. (2004) Health-enhancing physical activity and sedentary behaviour in children and adolescents. *Journal of sports sciences*, **22**, 679–701.
- Bigal, K.,** Ashmore, M. & Power, S. (2004) Ecological effects of diffuse air pollution from road transport. English Nature, Peterborough.
- Bird, W.** (2007) Natural Thinking. Investigating the links between the Natural Environment, Biodiversity and Mental Health. A report for the Royal Society for the Protection of Birds, Bedfordshire.
- Blair, S.N.** & Connelly, J.C. (1996) How much physical activity should we do? The case for moderate amounts and intensities of physical activity. *Research Quarterly for Exercise and Sport*, **67**, 193–205.
- Bokker, E.A.M.** (2006) Effects of interactions between humans and domesticated animals. In Hassink, J. and van Dijk, M. (eds.), *Farming for Health. Green-Care Farming Across Europe and the United States of America*, Wageningen: Springer Dordrecht.
- Bowler, D.E.,** Buyung-Ali, L.M., Knight, T.M. & Pullin, A.S. (2010) A systematic review of evidence for the added benefits to health of exposure to natural environments. *BMC Public Health*, **10**, 456–466.
- Boyle, M.** & Jones, S. (1985) Selecting measures of emotional and behavioural disorders of childhood for use in general populations. *Journal of Clinical Psychology and Psychiatry*, **26**, 137–159.
- Brereton, F.,** Clinch, J.P. & Ferreira, S. (2006) Environmental amenities and subjective well-being: testing the validity of hedonic pricing. School of Geography, University College, Dublin.
- Brugha, T.,** Morgan, Z., Bebbington, P., Jenkins, R., Lewis, G., Farrell, M. & Meltzer, H. (2003) Social support networks and type of neurotic symptom among adults in British households. *Psychological Medicine*, **33**, 307–318.
- Buccolieri, R.,** Gromke, C., Di Sabatino, S. & Ruck, B. (2009) Aerodynamic effects of trees on pollutant concentration in street canyons. *Science of the Total Environment*, **407**, 5247–5256.
- Burls, A.** (2008) Seeking nature: A contemporary therapeutic environment. *Therapeutic Communities* **29**.
- CABE (Commission for Architecture and the Built Environment)** (2010) Managing green spaces: seven ingredients for success. CABE, London.
- CDC (Centres for Disease Control)** (1996) Physical activity and health. A report of the Surgeon General. US Department of Health and Human Services, Centres for Disease Control and Prevention, National Centre for Chronic Disease Prevention and Health Promotion, Washington, D.C. [online] Available at: <<http://www.cdc.gov/nccdphp/sgr/contents.htm>> [Accessed 04.05.11].
- Chiesura, A.** (2004) The role of urban parks for the sustainable city. *Landscape and Urban Planning*, **68**, 129–138.
- Chisholm, D.M.,** Collis, M.L., Kulak, L.L., Davenport, W. & Gruber, N. (1975) Physical activity readiness. *British Columbia Medical Journal*, **17**, 375–378.
- Coley, R.L.,** Kuo, F.E. & Sullivan, W.C. (1997) Where does community grow? The social context created by nature in urban public housing. *Environment and Behaviour*, **29**, 468–494.
- Conner, M.** (2007) What is wilderness therapy and a wilderness program? [online] Available at: <<http://www.wilderness-therapy.org/Wilderness/WhatsWilderness.htm>> [Accessed 18.09.10].
- Conway, G.R.** & Pretty, J. (1991) Unwelcome harvest: agriculture and pollution. Earthscan, London. pp. 645.
- Cooper-Marcus, C.** & Barnes, M. (1995) Gardens in healthcare facilities: Uses, therapeutic benefits and design recommendations. The Centre for Health Design, Inc., California. [online] Available at: <<http://www.healthdesign.org/sites/default/files/Gardens%20in%20HC%20Facility%20Visits.pdf>> [Accessed 04.05.11].
- Cornell University** (2009) Urban silviculture research and education project: ecosystem services of urban trees. Cornell University, Cooperative Extension, New York City.
- Craig, C.L.,** Brownson, R.C., Cragg, S.E. & Dunn, A.L. (2002) Exploring the effect of the environment on physical activity: A study examining walking to work. *American Journal of Preventive Medicine*, **23**, 36–43.
- Davis-Berman, J.** & Berman, D.S. (1989) The wilderness therapy programme: An empirical study of its effects with adolescents in an outpatient setting. *Journal of Contemporary Psychotherapy*, **19**, 271–281.
- De Vries, S.,** Verheij, R.A., Groenewegen, P.P. & Spreeuwenberg, P. (2003) Natural environments – healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A*, **35**, 1717–1731.
- Defra (Department for Environment, Food and Rural Affairs)** (2007) Sustainable development indicators in your pocket 2007: An update of the UK Government Strategy Indicators Defra, London. [online] Available at: <http://collections.europarchive.org/tna/20080530153425/http://www.sustainable-development.gov.uk/progress/data-resources/documents/sdiyp2007_a6.pdf> [Accessed 04.05.11].
- den Boer, L.C.** & Schrotten, A. (2007) Traffic noise reduction in Europe: Health effects, social costs and technology and policy options to reduce road and rail traffic noise. CE Delft: Solutions for environment, ecology and technology, Delft, The Netherlands. [online] Available at: <<http://www.ce.nl>> [Accessed 04.05.11].
- DH (Department of Health)** (2004) Choosing Health? A consultation on action to improve people's health. National Health Service, London. pp. 1–12. [online] Available at: <<http://www.dh.gov.uk/assetRoot/04/07/57/54/04075754.pdf>> [Accessed 04.05.11].
- DH (Department of Health)** (2005a) Public Health White Paper. Choosing Health: Making healthy choices easier. Department of Health, London. [online] Available at: <<http://webarchive.nationalarchives.gov.uk/+www.dh.gov.uk/en/Publicationsandstatistics/Publications/>>

PublicationsPolicyAndGuidance/DH_4094550> [Accessed 04.05.11].

DH (Department of Health) (2005b) Choosing activity: A physical activity action plan. Department of Health, London.

DH & DCSF (Department of Health & Department for Children and Young People) (2009) Healthy Lives, Brighter Futures: The strategy for children and young people's health. Department of Health, Department for Children, Schools and Families, London. [online] Available at: <http://www.dh.gov.uk/prod_consum_dh/groups/dh_digitalassets/documents/digitalasset/dh_094397.pdf> [Accessed 04.05.11].

DH & HPA (Department of Health & Health Protection Agency) (2008) Health effects of climate change in the UK 2008: An update of the Department of Health report 2001/2002. Department of Health, London. pp. 124.

Diette, G.B., Lechtzin, N., Haponik, E., Devrotes, A. & Rubin, H.R. (2003) Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy. A complementary approach to routine analgesia. *Chest Journal*, **123**, 941–948.

DLTR (Department for Transport, Local Government and the Regions) (2002) Green Spaces Better Places: Final report of the Urban Green Spaces Taskforce. Department for Transport, Local Government and the Regions, London. [online] Available at: <<http://www.communities.gov.uk/documents/communities/pdf/131015.pdf>> [Accessed 04.05.11].

Dolan, P., Peasgood, T. & White, M. (2008) Do we really know what makes us happy? A review of economic literature on the factors associated with subjective well-being. *Journal of Economic Psychology*, **29**, 94–122.

Donovan, R.G., Stewart, H.E., Owen, S.M., MacKenzie, A.R. & Hewitt, C.N. (2005) Development and application of an urban tree air quality score for photochemical pollution episodes using the Birmingham, UK area as a case study. *Environmental Science & Technology*, **39**, 6730–6738.

Ernstson, H., Barthel, S., Andersson, E. & Borgstrom, S.T. (2010) Scale-crossing brakers and network governance of urban ecosystem services: the case of Stockholm. *Ecology and Society*, **15**, 28.

Escobedo, F.J. & Nowak, D.J. (2009) Spatial heterogeneity and air pollution removal by an urban forest. *Landscape and urban planning*, **90**, 102–110.

Escobedo, F.J., Kroeger, T. & Wagner, J.E. (2011) Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution*, In press.

Ferreira, S. & Moro, M. (2010) On the use of subjective well-being data for environmental valuation. *Environmental and Resource Economics*, **46**, 249–273.

Fine, A.H. (2006) Handbook on animal-assisted therapy. Academic Press, San Diego.

Fitter, A., Elmqvist, T., Haines-Young, R., Potschin, M., Rinaldo, A., Setälä, H., Stoll-Kleemann, S., Zobel, M. & Murlis, J. (2010) An assessment of ecosystem services and biodiversity in Europe. Ecosystem Services. (eds R.M. Harrison, & R.E. Hester). The Royal Society of Chemistry, London. pp. 1–28.

Foley, P. & Kirschbaum, C. (2010) Human hypothalamus-pituitary-adrenal axis responses to acute physiological stress in laboratory settings. *Neuroscience and Biobehavioural Reviews*, **35**, 91–96.

Foresight (2007) Tackling obesity: Future choices. Government Office of Science, London.

Foresight (2008) Mental health: Future challenges. Government Office of Science, London.

Fredrickson, B.L. & Branigan, C. (2005) Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition and Emotion*, **19**, 313–332.

Frey, B. (2008) Happiness: A revolution in economics. MIT Press, Cambridge, Massachusetts.

Frumkin, H., Frank, L. & Jackson, R. (2004) Urban sprawl and public health: Designing, planning and building for healthy communities. MIT Press, Cambridge, Massachusetts.

Frumkin, H. (2005) Environmental health: From global to local. Jossey Bass, San Francisco.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H. & Gaston, K.J. (2007) Psychological benefits of greenspace increase with biodiversity. *Biology Letters*, **3**, 390–394.

Fox, K. (2000) The effects of exercise on self-perceptions and self-esteem. Physical Activity and Psychological Well-Being. (eds S. Biddle, K. Fox, & S. Boutcher). Routledge, London. pp. 88–117.

Gill, S., Handley, J., Ennos, A. & Pauleit, S. (2007) Adapting cities for climate change: The role of the greenspace. *Built Environment*, **33**, 115–133.

Godfray, C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Nuij, J.F., J., P., Robinson, S., Thomas, S.M. & Toulmin, C. (2010) Food security: The challenge of feeding 9 billion people. *Science*, **327**, 812–818.

Goldberg, D.C. (1978) Manual of the General Health Questionnaire. NFER Publishing, Windsor.

Goldberg, D.P., Gater, R., Sartorius, N., Ustun, T.B., Piccinelli, M., Gureje, O. & Rutter, C. (1997) The validity of two versions of the GHQ in the WHO study of mental illness in general health care. *Psychological Medicine*, **27**, 191–197.

Grahn, P. & Stigsdotter, U.A. (2003) Landscape planning and stress. *Urban Forestry & Urban Greening*, **2**, 1–18.

Gray, M.C., Altman, J.C. & Halasz, N. (2005) The economic value of wild resources to the indigenous community of the Wallis Lakes Catchment. Blackie and Son, London.

Grove, J.M., O'Neil-Dunne, J., Pelletier, K., Nowak, D.J. & Walton, J. (2006) A report on New York cities present and possible urban tree canopy. University of Vermont, Burlington.

Handy, S.L., Boarnet, M.G., Ewing, R. & Killingsworth, R.E. (2002) How the built environment affects physical activity: Views from urban planning. *American Journal of Preventive Medicine*, **23**, 64–73.

Hans, T.A. (2000) A meta-analysis of the effects of adventure programming on locus of control. *Journal of Contemporary Psychotherapy*, **30**, 33–60.

Hansen-Ketchum, P., Marck, P. & Reutter, L. (2009) Engaging with nature to promote health: New directions for nursing research. *Journal of Advanced Nursing*, **65**, 1527–1538.

Harter, S. (1982) The perceived competence scale for children. *Child Development*, **53**, 87–97.

Hartig, T., Mang, M. & Evans, G.W. (1991) Restorative effects of natural environment experiences. *Environment and Behaviour*, **23**, 3–26.

Hartig, T., Book, A., Garvill, J., Olsson, T. & Garling, T. (1996) Environmental influences on psychological restoration. *Scandinavian Journal of Psychology*, **37**, 378–393.

- Hartig, T.** (2003) Guest Editor's Introduction: Restorative Environments. *Journal of Environmental Psychology*, **23**, 103–107.
- Hartig, T., Evans, G., Jamner, L.D., Davis, D.S. & Garling, T.** (2003) Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, **23**, 109–123.
- Hassink, J.** (2003) Combining agricultural production and care for persons with disabilities: a new role of agriculture and farm animals. Farming and Rural Systems Research and Extension. Local identities and Globalisation (eds A. Cirstovao, & L.O. Zorini). Fifth IFSA European Symposium, 8-11 April 2002. Florence, Wageningen University, Netherlands. pp. 332–341.
- Haubenhof, D.K., Elings, M., Hassink, J. & Hine, R.** (2010) The development of green care in Western European countries. *Explore*, **6**, 106–111.
- Heaton, A.** (2001) Duck Decoys. Shire Books, Buckinghamshire.
- HEW (US Department of Health Education and Welfare)** (2004) Role of blood pressure in cardiovascular morbidity and mortality. *Progress in Cardiovascular Diseases*, **17**, 5–24.
- Hine, R., Peacock, J. & Pretty, J.** (2007) Green spaces: Measuring the benefits, drawing on case studies from the East of England. Report for the National Trust. University of Essex, Colchester. [online] Available at: <http://www.nationaltrust.org.uk/main/w-green-_lungs.pdf> [Accessed 04.05.11].
- Hine, R., Peacock, J. & Pretty, J.** (2008a) Care Farming in the UK: evidence and opportunities. University of Essex, Colchester.
- Hine, R., Peacock, J. & Pretty, J.** (2008b) Evaluating the impact of environmental volunteering on behaviours and attitudes to the environment. Report for BTCV Cymru. University of Essex, Colchester.
- Hine, R., Pretty, J. & Barton, J.** (2009) Research project: Social, psychological and cultural benefits of large natural habitat and wilderness experience: A review of current literature. Report for the Wilderness Foundation. University of Essex, Colchester.
- Hine, R., Wood, C., Barton, J. & Pretty, J.** (2011) The mental health and well-being effects of a walking and outdoor based therapy project. A report for Discovery Quest. University of Essex, Colchester.
- Hollick, M.F.** (2004) Sunlight and vitamin D for bone health and prevention of autoimmune diseases, cancers and cardiovascular disease. *American Journal of Clinical Nutrition*, **80**, 1678S–1688S.
- Hollick, M.F.** (2005) Vitamin D: Important for prevention of osteoporosis, cardiovascular heart disease, type 1 diabetes, autoimmune diseases, and some cancers. *Southern Medical Association*, **98**, 1024–1027.
- Honeyman, M.C.** (1992) Vegetation and Stress: A comparison study of varying amounts of vegetation in countryside and urban scenes. The Role of Horticulture in Human Well-Being and Social Development: A National Symposium. (eds D. Relf). Timber Press, Portland. pp. 143–145.
- HSE (Health and Safety Executive)** (2008) Self-reported work-related stress and workplace injuries in 2006–07. National Statistics Publication, London.
- Hug, S.M., Hartig, T., Hansmann, R., Seeland, K. & Hornung, R.** (2009) Restorative qualities of indoor and outdoor exercise settings as predictors of exercise frequency. *Health and Place*, **15**, 971–980.
- Hull, R.B.** (1991) Mood as a product of leisure: Causes and consequences. Benefits of Leisure (eds B.L. Driver, P.J. Brown, & G.L. Peterson). Venture Publishing, Inc, State College, Pennsylvania. pp. 249–262.
- Huppert, F. & Whittington, J.** (2003) Evidence for the independence of positive and negative wellbeing: Implications for quality of life assessment. *British Journal of Health Psychology*, **8**, 107–122.
- Kahn, P.H. & Kellert, S.R.** (2002) Children and nature: Psychological, sociocultural and evolutionary investigations. MIT Press, Cambridge, Massachusetts.
- Kampman, M.T., Wilsgaard, T. & Mellgren, S.I.** (2007) Outdoor activities and diet in childhood and adolescence relate to MS risk above the Arctic Circle. *Journal Of Neurology*, **254**, 471–477.
- Kaplan, R. & Kaplan, S.** (1989) The experience of nature: A psychological perspective. Cambridge University Press, Cambridge.
- Kaplan, R.** (1992) The psychological benefits of nearby nature. The role of horticulture in human well-being and social development: A National Symposium. (eds D. Relf). Timber Press, Portland. pp. 125–133.
- Kaplan, R.** (2001) The nature of the view from home. *Journal of Environment and Behaviour*, **33**, 507–542.
- Kawachi, I., Kennedy, B., Lochner, K. & Prothrow-Smith, D.** (1997) Social capital, income inequality and mortality. *American Journal of Public Health*, **87**, 1491–1498.
- Keys, A., Aravanis, C., Blackburn, H., Van Buchem, F.S., Buzina, R., Djordjevic, B.S., Fidanza, F., Karvonen, M.J., Menotti, A., Puddu, V. & Taylor, H.L.** (1972) Coronary heart-disease: Overweight and obesity as risk factors. *Annals Internal Medicine*, **77**.
- Kolokotroni, M. & Giridharan, R.** (2008) Urban heat island intensity in London: An investigation of the impact of physical characteristics on changes in outdoor air temperature during the summer. *Solar Energy*, **82**, 986–998.
- Kruger, K.A. & Serpell, A.** (2006) Animal-assisted interventions in mental health. Academic Press, San Diego.
- Kuo, F.E. & Sullivan, W.C.** (2001a) Environment and crime in the inner city: Does vegetation reduce crime? *Journal of Environment and Behaviour*, **33**, 343–367.
- Kuo, F.E. & Sullivan, W.C.** (2001b) Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and Behaviour*, **33**, 543–571.
- Kuo, F.E., Sullivan, W.C., Coley, R.L. & Brunson, L.** (1998) Fertile ground for community: Inner-city neighbourhood common spaces. *American Journal of Community Psychology* **26**, 823–851.
- Laumann, K., Gärling, T. & Stormark, K.M.** (2003) Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology*, **23**, 125–134.
- Layard, R.** (2005) Happiness. Allen Lane, London.
- Leonti, M., Nebel, S., Rivera, D. & Heinrich, M.** (2006) Wild gathered food plants in the European Mediterranean. *Economic Botany*, **60**, 130–142.
- Lewis, C.E., Siegel, J.M. & Lewis, M.A.** (1984) Feeling bad: Exploring sources of distress among pre-adolescent children. *American Journal of Public Health*, **74**, 117–122.
- Li, Q., Morimoto, K., Nakadai, A. & al, e.** (2007) Forest bathing enhances human natural killer activity and expression of

anti-cancer proteins. *International Journal of Immunopathology and Pharmacology*, **20**, 3–8.

Lim, K. & Taylor, L. (2005) Factors associated with physical activity among older people: A population-based study. *Preventive Medicine*, **40**, 33–40.

Lohr, V.I., Pearson-Mims, C.H. & Goodwin, G.K. (1996) Interior plants may improve worker productivity and reduce stress in a windowless environment. *Journal of Environmental Horticulture*, **14**, 97–100.

Louv, R. (2005) Last child in the woods: Saving our children from nature-deficit disorder. Algonquin Books, North Carolina.

Maas, J., Verheij, R.A., Groenewegen, P.P., De Vries, S. & Spreeuwenberg, P. (2006) Green space, urbanity, and health: How strong is the relation? *Journal Epidemiology Community Health*, **60**, 587–592.

Mabey, R. (1996) *Flora Britannica*. Sinclair-Stevenson, London. pp. 480.

MacKerron, G. & Mourato, S. (2011) Mappiness: Quantifying wellbeing in relation to environment across space and time. European Association of Environmental and Resource Economists 18th Annual Conference, 29 June - 2 July, Rome.

Maller, C., Townsend, M., Brown, P. & St Leger, L. (2002) Healthy Parks Healthy People: The health benefits of contact with nature in a park context. Deakin University and Parks Victoria, Melbourne, Australia. [online] Available at: <<http://www.parkweb.vic.gov.au/resources/mhphp/pv1.pdf>> [Accessed 04.04.11].

Maller, C., Townsend, M., Pryor, A., Brown, P. & St Leger, L. (2006) Healthy Nature Healthy People: 'contact with nature' as an upstream health promotion intervention for populations. *Health Promotion International*, **21**, 45–54.

Martini, F.H. (2006) *Fundamentals of anatomy and physiology*. Pearson Education Inc.

Mayer, F.S. & McPherson Frantz, C. (2004) The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*, **24**, 503–515.

McDonald, A.G., Bealey, W.J., Fowler, D., Dragosits, U., Skiba, U., Smith, R.I., Donovan, R.G., Brett, H.E., Hewitt, C.N. & Nemitz, E. (2007) Quantifying the effect of urban tree planting on concentrations and deposition of PM₁₀ in two UK conurbations. *Atmospheric Environment*, **41**.

McNair, D.M., Lorr, M. & Droppleman, L.F. (1971) *EdITS manual for the Profile of Mood States*. Educational and Industrial Testing Service, San Diego, California.

McNicholas, J. & Collis, G.M. (2006) *Animals as social supports: Insights for understanding animal assisted therapy*. Elsevier, San Diego.

Mental Health Foundation (2009) *Moving on up*. Mental Health Foundation, London.

Mind (2007) *Ecotherapy: The green agenda for mental health*. Mind week report, May 2007. Mind, London.

Mitchell, R. & Popham, F. (2007) Greenspace, urbanity and health: Relationships in England. *Journal of Epidemiology and Community Health*, **61**, 681–683.

Mitchell, R. & Popham, F. (2008) Effect of exposure to natural environment on health inequalities: An observational population study. *The Lancet*, **372**, 1655–1660.

Morita, E., Fukuda, S., Nagano, J., Hamajima, N., Yamamoto, H., Iwai, Y., Nakashima, T., Ohira, H. & Shirakawa, T. (2006) Psychological effects of forest environments on healthy adults:

Shinrin-yoku (forest-air bathing, walking) as a possible method of stress reduction. *Public Health*, **121**, 54–63.

Moore, E.O. (1982) A prison environment's effect on health care service demands. *Journal of Environmental Systems*, **11**, 17–34.

Moote, G.T. & Wadarski, J.S. (1997) The acquisition of life skills through adventure-based activities and programmes: A review of the literature. *Adolescence*, **32**, 143–167.

Morecroft, M.D., Taylor, M.E. & Oliver, H.R. (1998) Air and soil microclimates of deciduous woodland compared to an open site. *Agricultural and Forest Meteorology*, **90**, 141–156.

Mourato, S. & MacKerron, G. (2010) *Cultural services and subjective wellbeing*. London School of Economics and Political Science, London.

NCFI (National Care Farming Initiative) (2011) National Care Farming Initiative (UK). [online] Available at: <<http://www.ncfi.org.uk>> [Accessed 18.09.10].

Newman, J. & Moller, H. (2005) Use of Matauranga (Maori traditional knowledge) and science to guide a seabird harvest: Getting the best of both worlds? *Senri Ethnological Studies*, **67**, 303–321.

NHS (National Health Service) (2011a) National Health Service choices. [online] Available at: <<http://www.nhs.uk/Tools/Pages/Healthyweightcalculator.aspx>> [Accessed 16.01.11].

NHS (National Health Service) (2011b) Lyme disease. [online] Available at: <<http://www.nhs.uk/conditions/Lyme-disease>> [Accessed 23.01.11].

NICE (National Institute for Health and Clinical Excellence) (2008) *Physical activity and the environment*. National Institute for Health and Clinical Excellence, London.

NICE (National Institute for Health and Clinical Excellence) (2009) *Promoting physical activity for children and young people*. National Institute for Health and Clinical Excellence, London.

NIH (National Institute of Health) (2011) National Institute of Health (US). [online] Available at: <http://www.nhlbi.nih.gov/health/public/heart/obesity/lose_wt/risk.htm> [Accessed 23.01.11].

Nisbet, E., Zelenski, J. & Murphy, S. (2009) The Nature Relatedness Scale: Linking individuals' connection with nature to environmental concern and behaviour. *Environment and Behavior*, **41**, 715–740.

Nisbet, E. (2011) *Nature Relatedness Research*. [online] Available at: <http://chat.carleton.ca/~enisbet/nature_relatedness_research.htm> [Accessed 15.02.11].

Nowak, D.J. (2006) Air pollution removal by urban trees and shrubs in the United States. *Urban Forestry & Urban Greening*, **4**, 115–123.

O'Brien, E., Waeber, B., Parati, G., Staessen, J. & Myers, M.G. (2001) Blood Pressure measuring devices: Recommendations of the European Society of Hypertension. *British Medical Journal*, **322**, 531–536.

Oldfield, T.E.E., Smith, R.J., Harrup, S.R. & Leader-Williams, N. (2003) Field and sports conservation in the UK. *Nature*, **423**, 531–533.

Ozer, S., Irmak, A. & Yilmaz, H. (2008) Determination of roadside noise reduction effectiveness of *Pinus Sylvestris L.* and *Populus Nigra L.* in Erzurum, Turkey. *Noise and Water Inception*, **144**, 191–197.

- Park, B.J.**, Yuko, T., Tamami, K., Takahide, K. & Yoshifumi, M. (2010) The physiological effects of Shinrin-yoku (taking in the forest atmosphere or forest bathing): Evidence from field experiments in 24 forests across Japan. *Environmental Health and Preventive Medicine*, **15**, 18–26.
- Parks, S.E.**, Housemann, R.A. & Brownson, R.C. (2003) Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *Journal of Epidemiology and Community Health*, **57**, 29–35.
- Parliamentary Office of Science and Technology** (2007) UK trees and forests. Postnote, London.
- Parsons, R.** (1991) The potential influences of environmental perception on human health. *Journal of Environmental Psychology*, **11**, 1–23.
- Parsons, R.**, Tassinary, L.G., Ulrich, R.S., Hebl, M.R. & Grossman-Alexander, M. (1998) The view from the road: Implications for stress recovery and immunization. *Journal of Environmental Psychology*, **18**, 113–139.
- Pathak, V.**, Tripathi, B.D. & Mishra, V.K. (2011) Evaluation of anticipated performance index of some tree species for green belt development to mitigate traffic generated noise. *Urban Forestry & Urban Greening*, **10**, 61–66.
- Peacock, J.**, Hine, R. & Pretty, J. (2007) Got the Blues, then find some Greenspace: The mental health benefits of green exercise activities and green care. Report for Mind. University of Essex, Chesterton.
- Peacock, J.**, Hine, R. & Pretty, J. (2008) The Turn Around 2007 Project. Report for the Wilderness Foundation. University of Essex, Colchester.
- Pieroni, A.** (1999) Gathered wild foods in the upper valley of the Serchio River (Garfagnana), Central Italy. *Economic Botany*, **53**, 327–341.
- Pilgrim, S.**, Smith, D. & Pretty, J. (2007) A cross-regional assessment of the factors affecting ecoliteracy: Implications for policy and practice. *Ecological Applications*, **17**, 1742–1751.
- Pilgrim, S.E.**, Cullen, L.C., Smith, D.J. & Pretty, J. (2008) Ecological knowledge is lost in wealthier communities and countries. *Environmental Science and Technology*, **42**, 1004–1009.
- Pitcairn, C.E.R.**, Leith, I.D., Sheppard, L.J., Sutton, M.A., Fowler, D., Munro, R.C., Tang, S. & Wilson, D. (1998) The relationship between nitrogen deposition, species composition and foliar nitrogen concentrations in woodland flora in the vicinity of livestock farms. *Environmental Pollution*, **102**, 41–48.
- Pretty, J.** & Ward, H. (2001) Social capital and the environment. *World Development*, **29**, 209–227.
- Pretty, J.**, Griffin, M., Sellens, M. & Pretty, C. (2003) Green Exercise: Complementary roles of nature, exercise and diet in physical and emotional well-being and implications for public health policy. CES Occasional Paper 2003-1, pp. 38.
- Pretty, J.** & Smith, D. (2004) Social capital in biodiversity conservation and management. *Conservation Biology*, **18**, 631–638.
- Pretty, J.** (2005) The pesticide detox. Earthscan, London.
- Pretty, J.**, Peacock, J., Sellens, M. & Griffin, M. (2005) The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research*, **15**, 319–337.
- Pretty, J.** (2006) From green exercise to green care: A new opportunity for farming in the UK? University of Essex, Colchester.
- Pretty, J.**, Hine, R. & Peacock, J. (2006) Green Exercise: The benefits of activities in green places. *The Biologist*, **53**, 143–148.
- Pretty, J.**, Peacock, J., Hine, R., Sellens, M., South, N. & Griffin, M. (2007) Green exercise in the UK countryside: Effects on health and psychological well-being and implications for policy and planning. *Journal of Environmental Planning and Management*, **50**, 211–231.
- Pretty, J.**, Angus, C., Bain, M., Barton, J., Gladwell, V., Hine, R., Pilgrim, S., Sandercock, G. & Sellens, M. (2009) Nature, childhood, health and life pathways. Interdisciplinary Centre for Environment and Society Occasional Paper 2009-02. University of Essex, Colchester, UK. pp. 1–30.
- Pretty, J.** (2011) This luminous coast. Full Circle Editions, Saxmundham.
- Rehdanz, K.** & Maddison, D. (2005) Climate and happiness. *Ecological Economics*, **52**, 111–125.
- Rehdanz, K.** & Maddison, D. (2008) Local environment quality and life-satisfaction in Germany. *Ecological Economics*, **64**, 787–797.
- Roland, G.** (2006) Atchafalaya Houseboat. Louisiana State University Press, Baton Rouge.
- Rosenberg, M.** (1965) Society and the adolescent self-image. Princeton University Press, Princeton, New Jersey.
- Ross, C.E.** (2000) Walking, exercising and smoking: Does neighbourhood matter? *Social Science and Medicine*, **51**, 265–274.
- Rowe, D.B.** (2010) Green roofs as a means of pollution abatement. *Environmental Pollution*, 1–11.
- Rubinstein, N.J.** (1997) The psychological value of open space. The Benefits of Open Space. (eds L.W. Hamilton). The Great Swamp Watershed Association, New Jersey.
- Russell, K.C.** & Phillips-Miller, D. (2002) Perspectives on the wilderness therapy process and its relation to outcome. *Child and Youth Care Forum*, **31**, 415–437.
- Russell, K.C.** (2006) Brat camp, boot camp, or...? Exploring wilderness therapy program theory. *Journal of Adventure Education and Outdoor Learning*, **6**, 51–68.
- Rutter, M.**, Tizard, J. & Whitmore, K. (1970) Education, health and behaviour. Longmans, London.
- Ryan, R.M.**, Weinstein, N., Bernstein, J., Warren Brown, K., Mistretta, L. & Gagne, M. (2010) Vitalizing effects of being outdoors and in nature. *Journal of Environmental Psychology*, **30**, 159–168.
- Samson, C.** & Pretty, J. (2005) Environmental and health benefits of hunting lifestyles and diets for the Innu of Labrador. *Food Policy*, **31**, 528–533.
- Sandercock, G.**, Voss, C., McConnell, D. & Rayner, P. (2010) The cardiorespiratory fitness of affluent English children are largely independent of changes in body mass index. *Archives of Disease in Childhood*, **95**, 46–47.
- Sempik, J.**, Aldridge, J. & Becker, S. (2003) Social and therapeutic horticulture: Evidence and messages from research. University of Loughborough. Centre for Child and Family Research, Reading, UK. pp. 60.
- Sempik, J.** (2007) Researching social and therapeutic horticulture for people with mental ill-health: A study of methodology. Thrive in association with the CCFR (Centre for Child and Family Research), Loughborough University, Leicestershire, UK.
- Sempik, J.**, Hine, R. & Wilcox, D. (2010) Green care: A conceptual framework. A report for the working group on the

health benefits of green care. COST Action. Loughborough University, Leicestershire, UK.

Spielberger, C.D. (1970) State-Trait Anxiety Inventory. John Wiley & Sons, Inc., New Jersey.

Sport England (2006) Active People Survey 2005/6. Sport England, London.

Steinbrecher, R., Smiatek, G., Koble, R., Seufert, G., Theloke, J., Hauff, K., Ciccioli, P., Vautard, R. & Curci, G. (2008) Intra- and inter-annual variability of VOC emissions from natural and semi-natural vegetation in Europe and Neighbouring countries. *Atmospheric Environment*, **43**, 1380–1391.

Stephenson, J. & Moller, H. (2009) Cross-cultural environmental research and management. *Journal of the Royal Society of New Zealand*, **39**, 139–149.

Sugiyama, T., Leslie, E., Giles-Corti, B. & Owen, N. (2008) Associations of neighbourhood greenness with physical and mental health: Do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology and Community Health*, **62**, e9.

Takano, T., Nakamura, K. & Watanabe, M. (2002) Urban residential environments and senior citizens' longevity in megacity areas: The importance of walkable green spaces. *Journal of Epidemiology and Community Health*, **56**, 913–918.

Tamura, Y., Kobayashi, Y., Watanabe, S. & Endou, K. (1997) Relationship of pollen counts of Japanese cedar to weather factors in Isehara City, Kanagawa. *Nippon Jibi Inkoka Gakkai Kaiho*, **100**, 326–331.

Tardio, J., Pascual, H. & Morales, R. (2003) Wild food plants traditionally used in the province of Madrid, Central Spain *Economic Botany*, **59**, 122–136.

Task Force (1996) Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. *Circulation*, **93**, 1043–1065.

Taylor, A.F., Kuo, F.E. & Sullivan, W.C. (2002) Views of nature and self-discipline: Evidence from inner city children. *Journal of Environmental Psychology*, **22**, 49–64.

Teas, J., Hurley, T., Ghumare, S. & Ogooussan, K. (2007) Walking outside improves mood for healthy postmenopausal women. *Clinical Medicine: Oncology*, **1**, 35–43.

Tennyson, J. (1949) Suffolk Scene. A book of description and adventure. Blackie and Son, London.

Thomas, G. & Thompson, G. (2004) A child's place: Why environment matters to children. Green Alliance / Demos Report, London.

Thompson Coon, J., Boddy, K., Stein, K., Whear, R., Barton, J. & Depledge, M.H. (2011) Does participating in physical activity in outdoor natural environments have a greater effect on physical and mental wellbeing than physical activity indoors? A systematic review. *Environmental Science & Technology*, **45**, 1761–1772.

Tiwary, A., Sinnett, D., Peachey, C., Chalabi, Z., Vardoulakis, S., Fletcher, T., Leonardi, G., Grundy, C., Azapagic, A. & Hutchings, T.R. (2009) An integrated tool to assess the role of new planting in PM₁₀ capture and the human health benefits: a case study in London. *Environmental Pollution*, **157**, 2645–2653.

Torres, R. & Fernandez, F. (1995) Self-esteem and the value of health as determinants of adolescent behaviour. *Journal of Adolescent Health Care*, **16**, 60–63.

Treiber, F.A., Musante, L., Hartdagan, S., Davis, H., Levy, M. & Strong, W.B. (1989) Validation of a heart rate monitor with children in laboratory and field settings. *Medicine and Science in Sports and Exercise*, **21**, 338–342.

Ulrich, R.S. (1981) Natural versus urban scenes: Some psychophysiological effects. *Journal of Environment and Behaviour*, **13**, 523–556.

Ulrich, R.S. (1984) View through a window may influence recovery from surgery. *Science*, **224**, 420–421.

Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. & Zelson, M. (1991) Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, **11**, 201–230.

Ulrich, R.S. (2002) Health benefits of gardens in hospitals. Conference for Plants for People – International Exhibition. Florida, United States of America.

van den Berg, A.E., Koole, S.L. & Van der Wulp, N.Y. (2003) Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology*, **23**, 135–146.

van den Berg, A.E., Hartig, T. & Staats, H. (2007) Preference for nature in urbanised societies: Stress, restoration and the pursuit of sustainability. *Journal of Social Issues*, **63**, 79–96.

van Praag, B.M.S. & Baarsma, B.E. (2005) Using happiness surveys to value intangibles: The case of airport noise. *The Economic Journal*, **115**, 224–226.

Wanless, D. (2002) Securing our future health: Taking a long-term view. HM Treasury, London. <http://www.hm-treasury.gov.uk/Consultations_and_Legislation/wanless/consult_wanless_final.cfm> [Accessed 04.04.11].

Wanless, D. (2004) Securing good health for the whole population. HM Treasury, London.

Ward Thompson, C. (2002) Urban open space in the 21st Century. *Landscape and Urban Planning*, **60**, 59–72.

Ward Thompson, C., Aspinall, P. & Montarzino, A. (2008) The childhood factor: Adult visits to green places and the significance of childhood experience. *Environment and Behaviour*, **40**, 111–143.

Watson, R.T., Patz, J., Gubler, D.J., Parson, E.A. & Vincent, J.H. (2005) Environmental health implications of global climate change. *Journal of Environmental Monitoring*, **7**, 834–843.

Wells, N.M. (2000) At home with nature: effects of “greenness” on children's cognitive functioning. *Environment and Behaviour*, **32**, 775–795.

Wells, N.M. & Evans, G.W. (2003) Nearby nature: A buffer of life stress among rural children. *Environment and Behaviour*, **35**, 311–330.

Wells, N.M. & Lekies, K.S. (2006) Nature and the life course: Pathways from adulthood nature experience to adult environmentalism. *Children Youth and Environments*, **16**, 1–24.

Wells, N.M., Ashdown, S., Davies, E.H.S., Cowett, F.D. & Yang, Y. (2007) Environment, design and obesity. Opportunities for interdisciplinary collaborative research. *Environment and Behaviour*, **39**, 6–33.

Welsch, H. (2006) Environment and happiness: Valuation of air pollution using life satisfaction data. *Ecological Economics*, **58**.

Wentworth Day, J. (1949) Coastal Adventure. Harrap, London.

Wentworth Day, J. (1950) Marshland Adventure. Harrap, London.

West, M.J. (1985) Landscape views and stress response in the prison environment. Department of Landscape, Architecture. University of Washington, Seattle.

Whitehouse, S., Varni, J.W., Seid, M., Cooper-Marcus, C., Ensberg, M.J., Jacobs, J.R. & Mehlenbeck, R.S. (2001) Evaluating a children's hospital garden environment: Utilisation and consumer satisfaction. *Journal of Environmental Psychology*, **21**, 301–314.

WHO (World Health Organization) (1948) Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference. 19–22 June 1946, New York, United States of America.

WHO (World Health Organization) (1995) Physical Status: The use and interpretation of Anthropometry. WHO, Geneva.

WHO (World Health Organisation) (2005) Ecosystems and human well-being. Health synthesis. WHO, Geneva.

WHO (World Health Organisation) (2011) BMI database website. [online] Available at: <http://apps.who.int/bmi/index.jsp?introPage=intro_3.html> [Accessed 16.02.11].

Wood, L. & Giles-Corti, B. (2008) Is there a place for social capital in the psychology of health and place? *Journal of Environmental Psychology*, **28**, 154–163.

Yang, J., McBride, J., Zhou, J. & Sun, Z. (2005) The urban forest in Beijing and its role in air pollution reduction. *Urban Forestry & Urban Greening*, **3**, 65–78.

Ziska, L.H. & Caulfield, F.A. (2000) Rising CO₂ and pollen production of common ragweed, a known allergy-inducing species: implications for public health. *Australian Journal of Plant Physiology*, **27**, 893–898.

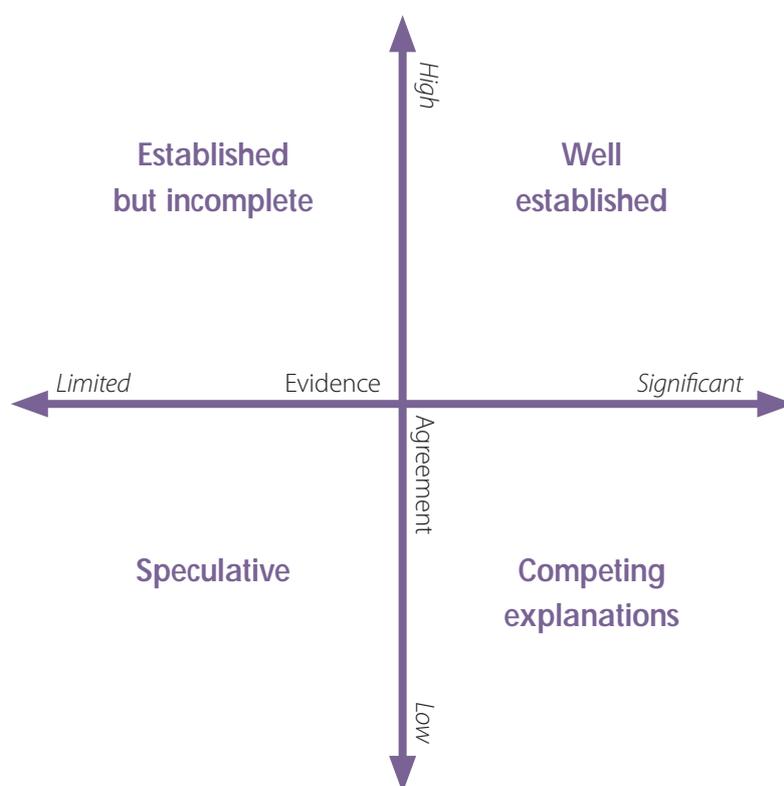
Zuckerman, M. (1977) The development of a situation-specific trait-state test for the prediction and measurement of affective responses. *Journal of Consulting and Clinical Psychology*, **45**, 513–523.

Appendix 23.1 Approach Used to Assign Certainty Terms to Chapter Key Findings

This chapter began with a set of Key Findings. Adopting the approach and terminology used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Assessment (MA), these Key Findings also include an indication of the level of scientific certainty. The ‘uncertainty approach’ of the UK NEA consists of a set of qualitative uncertainty terms derived from a 4-box model and complemented, where possible, with a likelihood scale (see below). Estimates of certainty are derived from the collective judgement of authors, observational evidence, modelling results and/or theory examined for this assessment.

Throughout the Key Findings presented at the start of this chapter, superscript numbers and letters indicate the estimated level of certainty for a particular key finding:

- | | |
|--|---|
| 1. <i>Well established:</i> | high agreement based on significant evidence |
| 2. <i>Established but incomplete evidence:</i> | high agreement based on limited evidence |
| 3. <i>Competing explanations:</i> | low agreement, albeit with significant evidence |
| 4. <i>Speculative:</i> | low agreement based on limited evidence |



- | | |
|-----------------------------------|--------------------------------|
| a. <i>Virtually certain:</i> | >99% probability of occurrence |
| b. <i>Very likely:</i> | >90% probability |
| c. <i>Likely:</i> | >66% probability |
| d. <i>About as likely as not:</i> | >33–66% probability |
| e. <i>Unlikely:</i> | <33% probability |
| f. <i>Very unlikely:</i> | <10% probability |
| g. <i>Exceptionally unlikely:</i> | <1% probability |

Certainty terms 1 to 4 constitute the 4-box model, while *a* to *g* constitute the likelihood scale.

