Evidence Statement on the links between natural environments and human health

March 2017

Introduction and scope

This evidence statement provides a broad overview of evidence on the links between natural environments and human health. It summarises global, landscape scale and other indirect links between natural environments and human health before considering direct benefits in more detail. The review focuses predominantly on direct benefits to health and wellbeing at the individual and population level which result from use of or exposure to natural environments. It acknowledges but does not focus on environmental threats and stressors such as poor air quality or diseases that can be passed from wildlife to humans.

The evidence statement makes use of higher order evidence such as peer-reviewed systematic reviews and other robust forms of evidence where possible, but is not itself systematic. A summary of the nature of the evidence used for each section is shown in the technical appendix. Evidence is used which is relevant to the environment and population of the United Kingdom.

Findings

Global ecosystem services, landscape scale and other indirect links between natural environments and human health

- **Global ecosystem services, biodiversity and health:** Human health and wellbeing depends on air, food, shelter and water, all partly or fully derived from the natural environment. Evidence indicates that biodiversity is critical to underpin ecosystem functioning and the delivery of goods and services that are essential to human health and wellbeing.

- **Landscape, ecosystem and city scale linkages:** At an intermediary level there is a growing body of evidence which demonstrates the interlinkages between landscape scale processes and human health outcomes. At catchment level, new analyses are showing how upstream processes, such as water retention in upland peat, can have significant implications for the health of downstream communities, for instance through the avoidance of flooding and improved water quality. Bunch et al. (2014; 240) state that health and wellbeing are products of inter-related social and biophysical processes and that effective watershed management therefore needs to move beyond ‘typical reductionist approaches toward more holistic methods’. Green infrastructure within urban areas offers a range of health related services including reductions to noise, ozone levels, personal exposure to particulates, and mitigation of some of the harmful effects of air pollution, as well as opportunities for direct exposure to nature (Pretty et al. 2011; James et al. 2015).
Direct links between natural environments and human health at the individual and population level

- An extensive and robust body of evidence suggests that living in greener environments (e.g. greater percentage of natural features around the residence) is associated with **reduced mortality**. Reduced rates of mortality have been found for specific population groups including men, infants and lower socio-economic groups. There is evidence to suggest that **health inequalities** in mortality may be reduced by greener living environments.

- Several studies have shown positive associations between **self-rated health** and natural environments. Self-rated health has also been shown to be higher in those living in places with a greater proportion of good quality natural environments (indicators included bird species richness and percentage of protected and designated landcover).

- There is relatively strong and consistent evidence for **mental health** and wellbeing benefits arising from exposure to natural environments, including reductions in stress, fatigue, anxiety and depression, together with evidence that these benefits may be most significant for marginalised groups. Socioeconomic inequality in **mental wellbeing** has been shown to be 40% narrower among those who report good access to green/recreational areas, compared with those with poorer access. Although many studies assessed short term outcomes, the use of longitudinal data and stronger study designs have resulted in more robust evidence and indications of a causal relationship.

- There is consistent evidence from birth cohort studies which shows exposure to green space during pregnancy is associated with **fetal growth** and **higher birth weight**.

- Some of the strongest evidence concerns the importance of direct contact with nature to the development of a **healthy microbiome**. The human microbiome, the consortium of microorganisms that cohabit the human body, typically consists of around 10,000 species with eight million protein-coding genes (Bernstein 2014). Human babies are born essentially sterile (Hough 2014) and studies have determined that exposure to diverse natural habitats is critical for development of a healthy microbiome. Following this, evidence suggests an unambiguous causal relationship between exposure to natural environments and the maintenance of a healthy **immune system** and reduction of **inflammatory-based diseases** such as asthma (Sandifer et al. 2015). This is a major beneficial effect of green space and neglected ecosystem service.

- There is evidence to suggest that rates of **obesity** tend to be lower in populations living in greener environments. Across eight European cities, people were 40% less likely to be obese in the greenest areas, after controlling for a range of relevant factors.

- Exposure to natural environments has been linked with more favourable: **heart rate**; **blood pressure**; **vitamin D levels**; **recovery rates**; and **cortisol levels**. Greenspace may also help to reduce the prevalence of **type 2 diabetes**.

Pathways and influencing factors

- Natural environments are associated with and may support higher levels of **physical activity** and therefore physical health. Studies have found that specific natural environments such as woodlands, gardens, parks, grassland and farmland, are supportive of vigorous activity.

- Positive relationships have been found between **social contact and community cohesion** and natural environments.
• The impacts of exposure to natural environments and direct use of green space often differ between social and demographic groups. Variation has been found in health outcomes associated with exposure, between physical and psychological perceptions of accessibility, and in motivations for use of natural environments. Although lower socio-economic groups are thought to disproportionately benefit from natural environments they often face the greatest barriers to use.

• The quality of the environment may influence health outcomes; biodiverse natural environments and those that are well maintained (e.g. free from litter and in which people feel safe) are associated with good health and wellbeing.

• Although much of the evidence relates to urban greenspace there is evidence to suggest that exposure to other types of natural environment (broadleaf woodland, arable and horticulture, improved grassland, saltwater and coastal) result in greater health gain.

• There is a significant volume of evidence showing that a greater quantity and proximity of the natural environment (mainly in relation to living environment) is consistently positively associated with health outcomes. Understanding of a potential dose-response relationship is limited but growing.

The monetary value of benefits

A range of figures have been calculated to illustrate the value of health and wellbeing benefits derived from the natural environment.

Natural England (2009) estimate that £2.1 billion would be saved annually through averted health costs if everyone in England had equal good perceived and/or actual access to green space. A view of green space from home is estimated to have a health value of £135-452 per person per year, and the health benefits of having your own garden are estimated to have a value of £171-575 per person per year (Mourato et al. 2010 cited in Bateman et al. 2011). White et al. (2016) found that the annual physically active visits to the natural environment were associated with an estimated 109,164 Quality Adjusted Life Years (QALYs) with an annual value of approximately £2.18 billion. However it is important to note that this is a developing area and reliable values are limited.

Further valuation evidence is needed, including work to understand health values associated with the natural environment and the benefits and cost effectiveness of different policy and intervention options.

Policy and delivery

There is growing recognition of the links between natural environments and health and wellbeing. However, the evidence highlights a need for more integrated policy and delivery across the health and natural environment sectors at a wide range of spatial scales (Convention on Biological Diversity and World Health Organization 2015).

Integrated policy and delivery is also required to help recognise and take account of multiple benefits. Even if the health benefits of a particular form of contact with nature are small, public investment may still be justified if there are benefits across a wide range of other policy domains (Hartig et al. 2014).

There is a need to learn lessons from other sectors and wider evidence on influencing behaviours and securing transitions across systems. Policy and delivery should aim to
encourage and enable people and organisations to behave differently to improve health outcomes and benefit the natural environment.

The evidence supports the following priority actions (Allen and Balfour 2014):

- Improving coordination and integration of policy and delivery;
- Ensuring interventions are user-led;
- Increasing the quality, quantity and use of natural environment assets that equitably benefit people’s health and help prevent ill health;
- Ensuring sustainable delivery of services that use the natural environment.

**Key evidence gaps**

There is a need to improve understanding of causal links between the natural environment and human health (Hartig et al. 2014; Hough 2014) using robust study designs, and to develop interdisciplinary evidence across the natural and social sciences. There is a lack of evidence specifically designed to inform the development of policy and interventions, including evaluation demonstrating which interventions work, for whom, in what circumstances, and why. There are also significant opportunities to take advantage of technological developments and make greater use of existing data.

Some evidence suggests that the key requirement for further research on the natural environment and health may not be to improve understanding of the health benefits which can be derived from increased contact with nature, but how to increase the number of people who choose to engage with nature.

**Conclusions**

In summary:

- Particularly strong links are found in relation to: mental health and wellbeing; development and maintenance of a healthy immune system and reduction of inflammatory-based diseases; and in relation to variation between social and demographic groups;
- Generally positive associations are found concerning: landscape, ecosystem and city scale linkages; perceived health status; mortality; maternal health, pregnancy outcomes and children’s cognitive development; other physiological outcomes; physical activity (in selected groups); and social contact and community cohesion;
- The evidence is mixed or unclear in relation to: global ecosystem services, biodiversity and health; obesity; physical activity (at population level); environmental quality; the type of natural environment; exposure mode, duration and a dose-response relationship; the monetary value of benefits; and the effectiveness of policy and interventions.

This review assesses the nature of evidence used in relation to each of these topics. It highlights the following four areas where there is high quality evidence of strong links or generally positive associations, which may provide a useful focus for future policy and delivery:

- Mental health and wellbeing;
- Development and maintenance of a healthy immune system and reduction of inflammatory-based diseases;
- Landscape, ecosystem and city scale linkages;
- Physical activity (in selected groups).

Overall, evidence indicates that exposure to, contact with, and use of the natural world can bring a range of health and wellbeing benefits. Further benefits should be gained through more integrated policy and delivery across the health, natural environment and other sectors at a range of spatial scales. It may be helpful to focus future efforts in a small number of pilot areas, because of the potential for integrating across a range of policy areas as part of place based approaches at local and regional scales.
Evidence Statement on the links between natural environments and human health - Technical Appendix

1 Introduction and background

The evidence statement and this technical appendix provide an overview of the evidence on the ways in which the natural environment supports human health and wellbeing.

The environment, whether social, built or natural, is recognised as a determinant of health (World Health Organisation 2014). The natural environment influences our health through a number of direct and indirect pathways operating at a range of scales as shown in the Millennium Ecosystem Assessment conceptual framework (MEA 2005) (Figure 1).

In the last 20 years there has been a significant shift in environmental policy and related evidence agendas towards an Ecosystem Approach and in particular towards greater understanding of ecosystem services, the benefits human society receives from the natural world. Human health and wellbeing is in many respects the ultimate or cumulative ecosystem service (Sandifer et al. 2015). Despite this, the links between health and environments have received relatively little explicit attention.

We are experiencing major losses of biodiversity, climate change and shifts in the use of natural resources yet we have limited understanding of the consequences for future human health and wellbeing. At the same time, there is major demographic change with, for example, aging populations as well as increasing urbanisation. The key health challenges in developed societies are shifting, and now include non-communicable diseases and other conditions linked to urban and more sedentary lifestyles, including obesity, depression and inflammatory diseases such as allergies and asthma (Beaglehole et al. 2011). As a result health systems are facing increasing demands on finite resources. There is, therefore, a need to consider the multiple, inter-related and often upstream determinants of health, to think creatively about alternative cost-effective approaches to health promotion, and to ensure that all environmental decision making with the potential to influence health recognises these links in order to contribute to reduced demand on primary health care systems.
The interlinkages between these factors are complex, and there are still major gaps in understanding. However, the evidence base has developed significantly in the last ten years and suggests that the environment should be recognised as both a potential stressor and, importantly, a resource for the maintenance and promotion of good health. This review outlines some of the key insights as well as some of the issues requiring further research.

The structure of the technical appendix is:

- Section 2 outlines the scope and provides a brief overview of methods;
- Section 3 presents findings in relation to global ecosystem services, landscape scale and other indirect links between natural environments and human health, direct links between natural environments and human health at the individual and population level, and pathways and influencing factors. This section also outlines the monetary value of benefits, presents findings in relation to policy and delivery, and identifies key evidence gaps;
- Section 4 provides conclusions.

2 Scope and brief overview of methods

This review provides a broad overview of evidence on the links between natural environments and human health. The ‘natural environment’ is taken to be the whole of our physical and biological world, excluding spaces where the key components are non-living built structures created by humans but including urban green space, parks and gardens. It is recognised that most, if not all, ‘natural environments’ in the UK are to some extent ‘man-made’. The review adopts a similarly broad definition of human health, which is ‘a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity’ (WHO 1946). This definition of health was adopted by WHO in 1946, entered into force in 1948 and has not been amended since.

The review summarises global, landscape scale and other indirect links between natural environments and human health before considering direct benefits in more detail. It focuses predominantly on direct benefits to health and wellbeing at the individual and population level which result from use of or exposure to natural environments. It is recognised that these linkages interact and that to some degree an arbitrary distinction has been drawn. The review acknowledges but does not focus on environmental threats and stressors such as poor air quality or zoonotic diseases that can be passed from wildlife to humans, e.g., Lyme disease.

The evidence statement and technical appendix make use of higher order evidence such as peer-reviewed systematic reviews and other robust forms of evidence where possible, but are not themselves systematic. Recent evidence is used which is relevant to the environment, population, health and wellbeing of the United Kingdom. However, no specific geographic or date limits were set.

Assessment of evidence quality

All individual pieces of evidence used have been categorised using the descriptions in Table 1. The approach is intended to provide an indication of the nature and to some extent the reliability of the evidence used. The categories are not intended to be strictly hierarchical; however they do reflect the overall importance attached to a systematic approach and to the established peer review process. The code for each individual journal article, report or other
piece of evidence is shown in square brackets throughout the text in the core ‘Findings’ section of the technical appendix and also in the list of references.

The overall nature of the body of evidence used for each ‘Findings’ section is outlined using a narrative summary and an evidence quality code at the beginning of each section using the descriptions in Table 2. Our assessment reflects the amount of evidence we identified and the types of studies (e.g. considering factors such as peer review and whether a review was systematic or not). As above, the categories are descriptive and not necessarily hierarchical.

The approach draws on methods used in restatements of natural science evidence (Godfray et al. 2013; 2014). However, since the evidence statement and technical appendix are neither systematic nor exhaustive, the assessment of the evidence used for each section should be interpreted cautiously.

Table 1 Descriptions of evidence quality used for individual journal articles, reports and other pieces of evidence

<table>
<thead>
<tr>
<th>Description</th>
<th>Evidence quality code</th>
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<tbody>
<tr>
<td>Peer reviewed systematic review or meta-analysis¹</td>
<td>[1]</td>
</tr>
<tr>
<td>Peer reviewed non-systematic review or meta-analysis</td>
<td>[2]</td>
</tr>
<tr>
<td>Other peer reviewed journal article or peer reviewed report</td>
<td>[3]</td>
</tr>
<tr>
<td>Other (including non-peer reviewed reports etc.)</td>
<td>[4]</td>
</tr>
<tr>
<td>Not applicable</td>
<td>[5]</td>
</tr>
</tbody>
</table>

Table 2 Descriptions of the overall quality of the body of evidence used for each section

<table>
<thead>
<tr>
<th>Description</th>
<th>Evidence quality code</th>
</tr>
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<tbody>
<tr>
<td>Evidence drawn from a range of peer-reviewed systematic reviews or meta-analyses, together with other supporting evidence</td>
<td>[A]</td>
</tr>
<tr>
<td>Evidence drawn largely from peer-reviewed non-systematic reviews or meta-analyses, together with other supporting evidence</td>
<td>[B]</td>
</tr>
<tr>
<td>Mixed evidence sources, including systematic and/or other reviews, individual journal articles or peer reviewed reports, and/or sources that have not been peer reviewed</td>
<td>[C]</td>
</tr>
<tr>
<td>Evidence drawn largely from individual peer-reviewed journal articles or peer reviewed reports, or sources that have not been peer reviewed</td>
<td>[D]</td>
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The evidence statement uses a plurality of terms for different types, features and locations of natural environments, and concepts such as ‘exposure’ and ‘access’ to these environments. This reflects the diversity of terms within the existing literature and that there are often no common definitions. The language used to report findings in relation to environment types, features and locations and terms such as ‘exposure’ and ‘access’ follows the original studies.

¹ Where the methods used to identify, select and quality appraise evidence are systematic and transparent, thereby reducing potential for multiple forms of bias.
3 Findings

3.1 Global ecosystem services, landscape scale and other indirect links between natural environments and human health

This section considers the indirect linkages between natural environments and human health; first in relation to global ecosystem services, biodiversity and health, and second at landscape, ecosystem and city scales.

Global ecosystem services, biodiversity and health

The evidence discussed in this section is largely from peer-reviewed reviews or meta-analyses which are not systematic. The section uses some evidence from peer-reviewed systematic reviews or meta-analyses, and some evidence from reports and other sources which have not been peer-reviewed [B]

At a global level, humans clearly depend on the natural environment for air, food, shelter and water. Bernstein (2014) [2] states that functioning ecosystems and biodiversity underlie much of what keeps people healthy. In a comprehensive review, the Convention on Biological Diversity and World Health Organization (CBD and WHO 2015 [2]) outline a range of key linkages between the natural environment and human health in relation to water; air quality; biodiversity, food and nutrition; infectious diseases; medicines, including pharmaceuticals and traditional medicine; spiritual and cultural values; climate change and disaster risk reduction; and sustainable consumption and production.

It is also clear that human health and wellbeing is often increased as a result of anthropogenic activity that depletes the natural environment, for example economic development might simultaneously threaten species and increase human life expectancy (Hough 2014 [1]). Hough notes that while human wellbeing has steadily increased at global scale, approximately 60% of ecosystem services have been degraded over the past 50 years (MEA 2005 [2]). However, Hough states that many of the ecosystem services in decline were regulating and supporting services, while most of those enhanced were provisioning services such as crops, livestock and aquaculture. A wide range of specific activities may increase human health and wellbeing, at least in the short term, while decreasing the diversity of natural resources.

Although ecosystems that are reduced or degraded may continue to function at some level, they may reach a threshold or tipping point beyond which the services which support human health cannot be maintained and from which it may be difficult to recover. In many contexts, there is significant uncertainty in relation to when these thresholds may be reached and the ability of ecosystems to recover. There is therefore considerable uncertainty regarding the impact of global level ecosystem damage and biodiversity loss to health outcomes.

Although many of the linkages are complex, overall the evidence indicates that biodiversity is critical to underpin ecosystem functioning and the delivery of goods and services that are essential to human health and wellbeing. Consequently, loss of biodiversity is likely to lead to decreases in some aspects of human health and wellbeing (CBD and WHO 2015 [2]; Sandifer et al. 2015 [2]).

The relevance of biodiversity and ecosystems to health policy, delivery of health services and health sciences has been articulated through the OpenNESS project (Kretsch and Keune 2015 [4]). In a review of current understanding the authors noted that biodiversity and ecosystems are ‘relevant to health risk prevention, health promotion, and the three core
areas of public health intervention: trauma (relating to injury and violence, including effects of natural disasters), infectious disease (caused by pathogens such as bacteria, viruses and parasites), and non-communicable disease (including physical and mental health, systemic illnesses, and toxicity) (Kretsch and Keune 2015 [4]).

Landscape, ecosystem and city scale linkages

The evidence discussed in this section is largely from peer-reviewed systematic reviews or meta-analyses, with some evidence from peer-reviewed reviews or meta-analyses which are not systematic. All evidence used in this section has been peer-reviewed [A].

There is a growing body of evidence using approaches such as complex systems thinking that is beginning to inform our understanding of intermediate landscape and catchment scale interlinkages between natural environments (including the state, diversity, composition and distribution of land cover type, ecosystem function, and biodiversity) and health.

In the case of the catchment level, new analyses are showing how upstream processes, such as water retention in upland peat, may have significant implications for the health of downstream communities, for instance through the avoidance of flooding and improved water quality (Figure 2). However, as the review conducted by Bunch et al. (2014) [1] highlighted, despite the clear implications for human health, our understanding of these complex and non-linear processes is currently limited. They state that health and wellbeing are products of inter-related social and biophysical processes and that there is a need to move beyond ‘typical reductionist approaches toward more holistic methods’ (Bunch et al. 2014; 240 [1]).

At a city scale there is a growing body of evidence which links natural environments (e.g. Green Infrastructure) with multiple indirect health outcomes. Studies have suggested that urban greenery can reduce noise, ozone levels, personal exposure to particulates, and mitigate some of the additional harmful effects of air pollution matter, in addition to the direct benefits discussed in the next section (Pretty et al. 2011 [2]; James et al. 2015 [2]).

Hartig et al. (2014) [1] discuss multiple ways in which vegetation in urban areas may impact on air quality; certain tree species and other vegetation may reduce pollution from gases and particulate matter, but they also release hydrocarbons. Some trees and other plants release pollen, exacerbating allergies, but they also cool urban environments and reduce energy demand. Brack (2002, cited in Hartig et al. 2014 [1]) found that monetary savings related to reduced building energy use may be greater than those of pollutant removal.
Bowler et al.'s (2010b) [1] review and meta-analysis of the role of greener environments on mitigating high air temperature in urban areas found, on average, a park was 0.94°C cooler in the day than the surrounding built environment. They also noted that larger parks and those with trees were cooler during the day than smaller areas with less tree cover.

3.2 Direct links between natural environments and human health at the individual and population level

This section draws upon recent systematic syntheses which have identified multiple direct links between human health and wellbeing and exposure to natural environments. A range of possible benefits are discussed, including enhanced mental health and wellbeing, reduced mortality and obesity, and the development and maintenance of a healthy internal biome.

Mental health and wellbeing

The evidence discussed in this section is from a range of peer-reviewed systematic reviews or meta-analyses, with some evidence from peer-reviewed reviews or meta-analyses which are not systematic. The section also presents evidence from other peer-reviewed journal articles or peer-reviewed reports. All evidence used in this section has been peer-reviewed [A]

There is relatively robust evidence of a relationship between mental health and wellbeing outcomes, including lower rates of stress, fatigue, anxiety and depression, and exposure to natural environments. There is some evidence that these benefits may be most significant for marginalised groups. However, the evidence is mixed with some systematic reviews finding only weak evidence of the relationship between green space exposure and mental health and wellbeing.

There are now several syntheses which have reviewed the strength and nature of the associations between natural environments and mental health:

- Bowler et al. (2010a) [1] conclude that there is reliable evidence of the benefits of contact with nature in relation to emotional state, self-reported anger, fatigue, anxiety, sadness, and an increase in feelings of energy;
- A meta-analysis undertaken by Barton and Pretty (2010) [2] found that compared to those undertaking other forms of outdoor exercise participants undertaking exercise in green places reported improved self-esteem and mood;
- Hartig et al. (2014) [1] state there is considerable evidence of potential benefits of contact with nature for reducing stress and attentional fatigue, although they note the majority of this evidence relates to short-term benefits;
- In a systematic review examining the relationship between long term exposure to natural environments and mental health, Gascon et al. (2015) [1] found some evidence of a causal relationship between surrounding greenness and mental health in adults, but the evidence for children was not yet adequate to draw reliable conclusions.

Recent efforts have been made to use more robust research designs (e.g. analysis of longitudinal data) to explore mental health outcomes. Alcock et al. (2014) [3] found that individuals who moved to greener areas (n=594) had significantly better mental health in all three postmove years (P=0.015; P=0.016; P=0.008) compared to their premove mental health scores. Further analysis of longitudinal data found that compared with when they lived in areas with less green space, people had significantly lower mental distress (as indexed by General Health Questionnaire score and significantly higher wellbeing (as indexed by life-
satisfaction ratings) when living in greener environments (White et al. 2013 [3]). Both studies controlled for income, employment status, marital status, health, housing type, and local-area-level variables (e.g. crime rates). A twin study found greater access to green space was associated with less depression (models were adjusted for income, physical activity, neighbourhood deprivation, and population density) (Cohen-Cline et al. 2015 [3]).

In relation to deprived and marginalised groups, socioeconomic inequality in mental wellbeing has been shown to be 40% narrower among those who report good access to green/recreational areas, compared with those with poorer access (Mitchell et al. 2015 [3]). This analysis used models adjusted for factors such as sex, age, illness limiting daily activities, education level, employment status, environmental quality, and median household income. Plane and Klodawsky (2013) [3] examined the relationship between neighbourhood amenities and health, and found that a local park was subjectively identified as the most meaningful place influencing health and quality of life for marginal women. In a longitudinal study, Weimann et al. (2015) [3] found that while the overall effect of living in a greener area on general and mental health was weak (after controlling for confounders), more beneficial effects were indicated for a vulnerable subgroup with a poorer prognosis for good general health. Weimann et al. also note that it is likely that the perceived quality of the greenness in a neighbourhood is most important for wellbeing, rather than the absolute amount, possibly particularly for these vulnerable subgroups.

**Perceived health status**

*The evidence discussed in this section is largely from peer-reviewed journal articles or peer-reviewed reports, with some evidence from a peer-reviewed systematic review. All evidence used in this section has been peer-reviewed [C]*

Perceived health status correlates well with more objective measures of health status and is a robust indicator. A review undertaken by van den Berg et al. (2015) [1] of epidemiological studies linking exposure to natural environments and a variety of health outcomes found moderate evidence of a positive link with self-perceived health. The review indicated that the majority of studies to have considered perceived health status are cross-sectional and are therefore unable to indicate causality.

There are several primary studies which have considered the spatial distribution of the self-rated health question from the UK census in relation to proximity to natural environments in the living environment. Mitchell and Popham’s (2007) [3] analysis, for example, found that after controlling for selection effects and area population characteristics, a higher proportion of greenspace in an area was generally associated with better perceived health. Significant associations have also been found between self-rated health status and higher quality landscapes (bird species richness and percentage of protected and designated spaces), after adjusting for socio-economic deprivation and rurality (Wheeler et al. 2015 [3]).

**Mortality**

*The evidence discussed in this section is largely from peer-reviewed journal articles or peer-reviewed reports. The section also uses some evidence from peer-reviewed systematic reviews or meta-analyses and evidence from peer-reviewed reviews or meta-analyses which are not systematic. All evidence used in this section has been peer-reviewed [C]*

A systematic review found evidence of a positive association between residential greenness and mortality, with effects greatest for cardio-vascular mortality (Gascon et al. 2016 [1]).
A Canadian cohort study (Villeneuve et al. 2012 [3]) of approximately 575,000 adults found that an increase in the interquartile range of green space (using a 500 m buffer) was associated with reduced non-accidental mortality (RR=0.95, 95% CI=0.94-0.96). Reductions in mortality with increased residential green space were observed for each underlying cause of death; the strongest association was found for respiratory disease mortality (RR=0.91, 95% CI=0.89-0.93). Rate ratios were adjusted for a range of socio-economic and other variables, including income, marital status, ambient air pollution and contextual neighbourhood characteristics. However, the authors indicate that results should be interpreted with caution as there may be residual confounding of socio-demographic and lifestyle factors.

Mitchell and Popham (2008) [3] found associations between income deprivation and mortality (assessed using individual mortality records) which differed significantly according to exposure to green space for mortality from all causes (p<0.0001) and circulatory disease (p=0.0212), after controlling for potential confounding factors. They identified a lower incident rate ratio for all-cause mortality for groups with higher exposure to green space (Figure 3). However, no association was found for lung cancer or intentional self-harm, causes of death less likely to be affected by green space.

Specific outcomes included:

- Health inequalities related to income deprivation in all-cause mortality and mortality from circulatory diseases were lower in populations living in the greenest areas;
- The incidence rate ratio (IRR) for all-cause mortality for the most income deprived quartile compared with the least deprived was 1.93 (95% CI 1.86-2.01) in the least green areas, whereas it was 1.43 (1.34-1.53) in the most green;
- For circulatory diseases, the IRR was 2.19 (2.04-2.34) in the least green areas and 1.54 (1.38-1.73) in the most green.

Richardson and Mitchell (2010) [3] showed that after controlling for relevant confounders cardiovascular disease and respiratory disease mortality rates decreased with increasing green space amongst men, but no significant associations were found for women. A French study (Kihal-Talantikite et al. 2013 [3]) of neonatal mortality found that the greenness of the living environment (within the city of Lyon) partially explained the spatial distribution of infant mortality, after adjusting for deprivation.

Following a review of the literature, James et al. (2015) [2] conclude that there are positive associations between increased greenness in the living environment and reduced mortality. However, they highlight the limitations of cross-sectional or ecological designs in most studies on these issues.
Obesity

The evidence discussed in this section is from peer-reviewed systematic reviews or meta-analyses and other peer-reviewed journal articles or peer-reviewed reports. All evidence used in this section has been peer-reviewed [C]

A systematic review conducted by Lachowycz and Jones (2011) [1] found a positive association between exposure to natural spaces and obesity (i.e. reduced BMI). Specific findings included:

• Increased vegetation associated with reduced weight among young people living in high population densities;
• Increased greenspace associated with less weight gain over 2 years;
• Across eight European cities, people were 40% less likely to be obese in the greenest areas.

The majority (68%) of the papers reviewed by Lachowycz and Jones found a positive (though typically weak) association between greenspace and obesity-related health indicators; however findings were inconsistent and mixed across studies. For instance, several studies found the relationship varied by factors such as age, socioeconomic status and type of greenspace measure.

Physical activity is likely to be an important mediating factor (see below). In a study of the residents of Bristol (n=6821), Coombes et al. (2010) [3] found that respondents living closest to the type of green space classified as a ‘formal park’ were more likely to achieve the physical activity recommendation and less likely to be overweight or obese. The authors adjusted for respondent characteristics, area deprivation, and a range of characteristics of the neighbourhood environment.

Development and maintenance of a healthy immune system and reduction of inflammatory-based diseases

The evidence discussed in this section is largely from peer-reviewed reviews or meta-analyses which are not systematic. The section uses some evidence from peer-reviewed systematic reviews or meta-analyses. All evidence used in this section has been peer-reviewed [B]

Some of the strongest evidence concerns the importance of direct contact with nature to the development of a healthy microbiome. The human microbiome, the consortium of microorganisms that cohabit the human body, typically consists of around 10,000 species with eight million protein-coding genes (360 times the number of protein-coding genes in the ‘human’ genome) (Bernstein 2014 [2]). Human babies are born essentially sterile (Hough 2014 [1]) and studies have determined that exposure to diverse natural habitats is critical for development of a healthy microbiome. Lack of contact with nature may therefore be contributing to another megatrend in human health and wellbeing, the increasing prevalence of allergies, asthma, and other chronic inflammatory diseases especially among urban populations (Sandifer et al. 2015 [2]).

Sandifer et al. (2015;10) [2] state that ‘the only unambiguous causal relationship between biodiversity and human health concerns the maintenance of a healthy immune system and reduction of inflammatory-based diseases’. The authors cite a seminal paper by Rook (2013) [2] which concluded that the requirement for microbial input from the environment to drive immunoregulation is a major component of the beneficial effect of green space, and a
neglected ecosystem service that is essential for wellbeing (also see CBD and WHO 2015 [2]).

Bernstein (2014) [2] states that overweight people tend to have less diverse intestinal microbial ecosystems than people of normal weight. He suggests that tackling obesity will require greater attention to the intestinal microbiome, as well as diet and exercise.

**Maternal health, pregnancy outcomes and children's cognitive development**

*The evidence used in this section is from a range of sources. Some is from peer-reviewed systematic reviews or meta-analyses. Some evidence is from peer-reviewed reviews or meta-analyses which are not systematic, and some is from other peer-reviewed journal articles or peer-reviewed reports [C]*

James et al.’s (2015) [2] synthesis found consistent evidence from birth cohort studies which shows exposure to green space during pregnancy is associated with a range of maternal, foetal and cognitive outcomes.

A Spanish study (Dadvand et al. 2012 [3]) found a beneficial impact of surrounding greenness on measures of foetal growth. Higher density of greenness was associated with increases in birth weight and head circumference (adjusted regression coefficients with 95% confidence intervals of 44.2 g (20.2 g, 68.2 g) and 1.7 mm (0.5 mm, 2.9 mm) for an interquartile range increase in average satellite-based Normalized Difference Vegetation Index within a 500m buffer). This study adjusted for potential confounders such as maternal age, education, smoking and alcohol consumption. An American study found that, after adjusting for variables including education and race, a 10% increase in tree-canopy cover within 50m of a house reduced the number of small for gestational age births by 1.42 per 1000 births (95% CI=0.11-2.72, n=5696) (Donovan et al. 2011 [3]).

A German cohort study (Markevych 2014 [3]) also found positive associations between residential greenness and birth weight outcomes. The authors reported that an increase of surrounding greenness (around the residence) was associated with an average birth weight increase of 17.6 g (95% CI=0.5 to 34.6, n=3203) with the effect strengthening after adjustment for factors such as air pollution rates, distance to major road, and population density. The authors also found enhanced impacts for marginalised populations with the strongest association in mothers with less than 10 years of school education.

A small body of research suggests that childhood contact with nature can provide cumulative benefits with far reaching developmental significance (Hartig et al. 2014 [1]). For example, contact with nature may improve attentional function in children with attention deficit disorder and improve self-discipline in children without a diagnosis (Taylor et al. 2002; 2009, cited in Hartig et al. 2014 [1]). Bratman et al.’s (2012) [2] review of the cognitive impacts of exposure to natural environments found positive impacts to memory, attention, concentration, impulse inhibition, and mood across a range of socio-demographic populations. Recent research has suggested that natural spaces in and around the school environment are also associated with cognitive development in children. Dadvand et al.’s (2015) [3] comparative study of the impact of greenery around 36 schools in Barcelona found that a high level of exposure to green spaces was associated with a 5% improvement in working memory, 6% increase in superior working memory, and a 1% reduction in inattentiveness.
Researchers have considered the impacts of exposure to or use of natural environments on a range of further physiological outcomes.

In a recent review Pretty et al. (2011) [2] state that contact with nature has been shown to have a significant positive impact on heart rate and blood pressure. For instance, an early study by Hartig et al. (2003) [3] found a significant and positive impact of exposure to natural environments on diastolic blood pressure. This finding has been replicated in a number of experimental and cohort studies (e.g. Juyoung et al. 2009 [3]). Positive associations between ‘green activities’ or living in greener urban environments and cardiovascular health have been identified in a number of studies (e.g. Ekblom-Bak et al. 2014 [3]).

Pretty et al. (2011) [2] also note that humans depend on the sun for 90% of our vitamin D requirement. Increased time spent in natural environments is associated with increased likelihood of meeting this requirement, thus helping to avoid poor bone health and the development of Rickets in children which is associated with vitamin D deficiency.

Type 2 diabetes, a chronic long-term condition, is an increasing healthcare priority. Positive associations between the percentage of greenspace in the living environment and type 2 diabetes prevalence have been demonstrated in a large cross-sectional study from England (Bodicoat et al. 2014 [2]). The odds ratio (95% CI) for screen-detected type 2 diabetes was 0.67 (0.49 to 0.93) in the greenest locations compared with the least green (models were adjusted for ethnicity, age, sex, area social deprivation score and urban/rural status) (P=0.01, n=10,476). The authors suggest that greenspace may be protective for type 2 diabetes.

Hough (2014) [1] discusses a well-known study (Ulrich 1984) which found that patients with a view of green space from hospital required fewer painkillers and were discharged more quickly. However, Hough is sceptical of the health measures used in this study and considers that at best it demonstrates an association between improved patient outcomes and looking at trees.

Several small scale studies have used cortisol levels to investigate the impacts of natural environments on stress. Typically these studies find a positive association between residential greenness and use of natural environments for recreation and significantly lower cortisol levels, after controlling for other factors which may influence stress such as employment, exercising and smoking (Honold et al. 2015 [3]; Ward Thompson et al. 2012 [3]).

3.3 Pathways and influencing factors

This section considers the impacts of the natural environment on a small number of recognised pathways to good health (physical activity and social contact and cohesion), which may also be considered as desirable outcomes in and of themselves. The section also addresses the role of influencing factors such as the differential exposure of different social groups to natural environments and barriers to engagement.
Physical activity

The evidence discussed in this section is largely from peer-reviewed systematic reviews or meta-analyses, with some evidence from other peer-reviewed journal articles or peer-reviewed reports. All evidence used in this section has been peer-reviewed [A].

Numerous studies show a relationship between greenness and physical activity, though the evidence is mixed. It has been hypothesised that the availability of natural environments (particularly in urban areas) is associated with physical activity behaviours and that physical activity in natural spaces is of greater benefit (compared to exercise taken in indoor or non-green environments). It is well established that physical activity independently promotes mental and physical health (Woodcock et al. 2011 [1]).

In a systematic review of links between green space and obesity, Lachowycz and Jones (2011) [1] found 20 studies (40% of the total included in the review) which reported an unambiguous positive relationship between green space and levels of physical activity (for example living within 1 mile of a park was positively associated with park use and frequency of leisure exercise) and a further 13 (26%) which reported weak or mixed results. Only two studies (4%) found a negative relationship, and 15 (30%) found no evidence of a relationship.

In the UK context a significant association has been demonstrated between residential proximity to coastal environments and the likelihood of achieving the recommended rate of physical activity (controlling for factors such as area green space, deprivation and individual age, gender, SES, marital status, employment status, children, ethnicity, disability, car ownership, dog ownership, year and season) (White et al. 2013 [3]) (Figure 4). Other studies have found that specific natural environments such as woodlands, gardens, parks, grassland and farmland are supportive of vigorous activity (see, for example, Coombes et al. 2013 [3]).

Figure 4. Coastal proximity and physical activity rates (White et al. 2013 [3])

Mitchell (2013) [3] used data from the Scottish Health Survey to examine the impact of physical activity in natural environments on mental health. The results indicated that regular exercise in a natural environment may cut the risk of suffering from poor mental health by half. There was an independent association between regular use of natural environments and a lower risk of poor mental health, however this was not found for physical activity in other types of environments. The odds of poor mental health (assessed using the General Health Questionnaire) for those who made regular use of woods or forests for physical activity were 0.557 (95% CI 0.323-0.962), compared to non-users. All models were adjusted for age group, sex, equivalised household income, average hours of physical activity per week, urban/rural status and green space in a respondent's neighbourhood.
A review by Thompson Coon et al. (2011) [1] found that exercising in natural environments was associated with greater feelings of revitalization and positive engagement, decreases in tension, confusion, anger, and depression, and increased energy compared with indoor exercise. There were also more positive perceptions of the activity including greater enjoyment and satisfaction and participants expressed a greater intent to repeat the activity at a later date.

Hartig et al. (2014) [1] provide a useful breakdown of the types of activity where the physical environment may affect levels of physical activity - work, active transport, and leisure. They state that in the work domain, green space is unlikely to be significant in determining levels of activity. There may be a stronger relationship for the other two domains, but overall the evidence is mixed. In the case of active travel, they suggest that the negative associations that are sometimes observed may be due to greater distances travelled and higher levels of car ownership in greener areas.

Hartig et al. (2014) [1] discuss the relationship between green space and physical activity for selected population subgroups. For children, they identify one review (Ding et al. 2011) in which approximately 40% of studies showed a relationship between park access or vegetation and physical activity; but in the other 60% of studies no relationship was found. Similarly, out of two recent systematic reviews for older people, one (Van Cauwenberg et al. 2011) found no clear relationship while the other (Broekhuizen et al. 2013), which focused specifically on green space, found a positive relationship in seven out of eight studies.

Lachowycz and Jones (2011) [1] highlight the methodological limitations of many studies examining links between green space, physical activity and health. In particular, it is not possible to determine if relationships are causal. For example, they note that more active people may choose to live in greener environments. They also highlight that since a wide range of different variables were used to adjust for socio-economic factors in the studies they reviewed, some positive results could have been caused by residual confounding.

**Variation between social and demographic groups**

*The evidence discussed in this section is largely from peer-reviewed journal articles or peer-reviewed reports. The section uses some evidence from peer-reviewed systematic reviews or meta-analyses, as well as some evidence that has not been peer-reviewed [D]*

As has been noted above the impacts of exposure to or use of natural environments often differ between social and demographic groups, examples include:

- After controlling for relevant confounders male cardiovascular disease and respiratory disease mortality rates decreased with increasing green space in the living environment, but no significant associations were found for women (Richardson and Mitchell 2010 [3]);
- Although a general association between greener living environments and perceived health status was found by Mitchell and Popham (2007) [3], the relationship was not significant in higher income suburban and higher income rural areas, whereas in suburban lower income areas, a higher proportion of greenspace was associated with worse health. The authors suggest the latter findings may be due to the poorer quality of greenspace in poorer communities (all models were adjusted for indicators of socio-economic deprivation and rurality);
- Astell-Burt et al.’s (2014) [3] longitudinal analysis of the British Household Panel Survey (1996-2004) found variation in the association between green space and mental health according to life stage and by gender. Their results showed that for men, the benefit of more green space emerged in early to mid-adulthood. Among older women, a curvilinear association materialised where those with a moderate availability of green space had
better mental health. The regression models included age, gender, employment status, household tenure, marital status, education, smoking status and household income.

There are several theories which attempt to account for the observed variations in impacts, these include:

- Communities with lower socio-economic status often have poorer access to good quality natural environments;
- Different socio-demographic groups use the natural environment for different reasons and in different ways (e.g. a local park may have more impact on men’s health via physical activity, such as playing football, than for women);
- Specific socio-cultural norms influence how (and indeed whether) different groups engage with or benefit from the natural environment.

In relation to the availability (where, typically, no assumptions are made about actual access or use of such spaces) of natural environments the evidence is mixed, with outcomes likely to be partly influenced by the indicators used and by analytic approach. However the trend of the evidence is consistent with that found by Jones et al. (2009) [3], who concluded that there were strong disparities in access with respect to deprivation whereby the most income-deprived groups were also the most deprived with regard to access to public parks (models were adjusted for respondent age, sex and self-rated health).

There are significant differences between different groups of people in the extent to which they visit the natural environment and have direct experience with nature, and therefore the extent to which they may benefit. The latest MENE annual report (Natural England 2015a [4]) indicates that only 34% of those aged 65 or over visit the natural environment at least once a week, 31% of those in social grades DE (semi-skilled manual workers to unemployed with state benefits only), 28% of those in Black, Asian and minority ethnic groups, and 33% of those with an illness or disability, compared to an average of 42% in the population as a whole. In response to a more general question where respondents were asked to estimate the average frequency of their outside leisure activity over the previous 12 months, 58% of the population as a whole claimed to visit once a week or more, 35% once or twice a month or less, and 8% said they never visit.

In relation to motivations for visiting the natural environment, around two-fifths of visits by 16-44 year old were for health and/or exercise, compared to half of visits taken by those aged 45 or over (Natural England 2015a [4]). Health and/or exercise is also a significantly greater motivation for those in social grades ABC1 (higher to junior managerial, administrative and professional) compared to C2DE (skilled manual workers to unemployed with state benefits only).

There may be significant barriers to greater engagement with the natural environment for many different groups. For example, Hitchings (2013) [3] examines reasons why city professionals rarely visit the various parks and gardens around their offices. The study reveals a range of factors suggesting green space may be forgotten or deliberately avoided because the opportunities for relaxation and restoration may be subtly inconsistent with the personal and cultural expectations of professional working life.

Hartig et al. (2014) [1] note that variations between different groups of people remain consistently underexplored, in terms of access to, use of and responses to nature. Hitchings (2013) [3] suggests that the key requirement for further research on the natural environment and health may not be to improve understanding of the health benefits which can be derived from increased contact with nature, but how to increase the number of people who choose to engage with nature.
Social contact and community cohesion

The majority of evidence used in this section is from peer-reviewed journal articles or peer-reviewed reports. The section uses some evidence from peer-reviewed systematic reviews or meta-analyses. All evidence used in this section has been peer-reviewed [D]

The potential for greenspaces to facilitate social contact and enhance social cohesion and quality of life has been proposed as an important mediating factor in the observed relationships between natural environments and health outcomes.

The systematic review by Hartig et al. (2014) [1] concluded that there are positive relationships between social cohesion and natural environments with, for example, residents living in areas with more trees and grass tending to display less aggressive behaviour and experiencing lower crime levels. Others have shown that green spaces (particularly in urban areas) offer places to meet which help reduce the likelihood of loneliness and provide opportunities to build social support systems (van Dillen et al. 2011 [3]). Links have also been made with feelings of social safety (Groenewegen et al. 2006 [3]; Maas et al. 2009 [3]) and motivations for community activity (van Dillen et al. 2011 [3]). Each of the studies mentioned above controlled for socio-economic and demographic characteristics.

Environmental quality

The evidence discussed in this section is from a range of peer-reviewed systematic reviews or meta-analyses, with some evidence from peer-reviewed reviews or meta-analyses which are not systematic. The section also presents evidence from other peer-reviewed journal articles or peer-reviewed reports. All evidence used in this section has been peer-reviewed [C]

There is limited evidence regarding links between the ecological quality of the natural environment and health and wellbeing benefits, with inconsistent associations between ecological quality and mainly mental health and wellbeing outcomes. Sandifer et al. (2015) [2], whilst noting that they found strong evidence linking biodiversity with production of ecosystem services and between general nature exposure and human health, found less that supported the argument that biodiversity and ecological state is an important factor in the nature exposure pathway. This is potentially due to the relatively recent scientific interest in the role of biodiversity in supporting good health rather than lack of a relationship.

Evidence from the UK is currently limited to a small number of observational studies of urban green/blue space and a range of quality of life and psychological indicators (Lovell et al. 2014 [1]). The review conducted by Lovell et al. (2014) [1] concluded that there is some evidence to suggest that biodiverse natural environments may be associated with good health and wellbeing. Benefits were manifest in a number of ways, from better mental health outcomes following exposure, to associations with increased health promoting behaviours. The relationships are most evident at a local level and following immediate encounters or through presumed repeated exposures (e.g. via proximity to residence). Wheeler et al.’s (2015) [3] analysis of large scale datasets also found evidence of an association between ecological state and health, with an association between the density of protected/designated areas and bird species richness (an indicator of local biodiversity) and prevalence of good health. Models were adjusted for indicators of socio-economic deprivation and rurality. There is also a small quantity of evidence, mainly qualitative, finding largely positive associations between experience of wildlife and psychological and quality of life outcomes (for example Curtin 2009 [3]).
There is growing evidence that health is negatively affected by degraded environments. For instance, a series of studies in the US have demonstrated that after controlling for confounders, women living in counties infested with emerald ash borer (which resulted in the loss of significant numbers of trees) had a 25% higher risk of cardiovascular disease (Donovan et al. 2015 [3]).

There is an established body of evidence (predominantly observational and qualitative) which has shown that the state or maintenance of natural environments (in terms of litter and other incivilities) is related to wellbeing, and in some cases health. Mitchell and Popham (2007) [3] hypothesised that their finding that a greater proportion of greenspace in the living environment for lower socio-economic groups was related to worse health was likely to be due to the poor state of those spaces. The models in this study adjusted for indicators of socio-economic deprivation and rurality. McCormack et al.'s (2010) [1] review supported this hypothesis and suggested that attributes including safety, aesthetics, amenities, and maintenance of urban parks are important determinants of use. The authors note that perceptions of the social environment are inextricable from perceptions of the physical environment, suggesting that interventions to promote use of natural environments would need to consider both the physical resource and social context.

The type of natural environment

The evidence used in this section is from a range of sources. Some is from peer-reviewed systematic reviews or meta-analyses. Some evidence is from peer-reviewed reviews or meta-analyses which are not systematic, and some is from other peer-reviewed journal articles or peer-reviewed reports. The section also uses limited evidence that has not been peer-reviewed [C]

It is also important to consider the different health and wellbeing benefits provided by different types of natural environment. Church et al. (2011) [2] distinguish between cultural ecosystem services provided by different types of environmental settings, including domestic gardens, formal and informal green and blue spaces, nearby and wider countryside and national landscapes, suggesting that these offer quantitatively and qualitatively different experiences and health and wellbeing benefits. As noted previously, local environmental settings provide opportunities for frequent contact with nature. In contrast, Church et al. note that more remote ‘special’ environments may offer opportunities to see particular fauna and flora, or climb particular crags. There is qualitative evidence that visits to National Parks and other similar environments can provide long-term restorative effects (see Wilson 2015 [4] and Curtin 2009 [3]).

This issue can also be approached by assessing benefits associated with specific land uses and land covers. The review by O'Brien and Morris (2013) [2], for example, provides a typology of health and wellbeing benefits from engagement with woodlands and forests, including physical wellbeing, mental restoration, escape and freedom, and enjoyment and fun. They discuss evidence that indicates the importance of trees and woodlands to people from different social groups and illustrate how carefully designed and targeted interventions can encourage people to visit woodlands and possibly get involved in new activities, and therefore realise health and wellbeing benefits.

In relation to direct health outcomes, there is a small quantity of evidence, drawn from a range of study types including experimental, epidemiological, and qualitative which has specifically explored or considered different types of land cover.

There is evidence of some positive associations between certain types of natural environment, including urban green spaces (Hartig et al. 2014 [1]), blue spaces (Völker and
Kistemann 2011 [1]), woodlands and forests (O’Brien and Morris 2013 [2]), and arable/horticultural (Wheeler et al. 2015 [3]), and predominantly general health status or mental health and wellbeing outcomes.

Wheeler et al. (2015) [3], after adjusting for potential confounders, found positive associations between good health prevalence and the density of different greenspace types, including broadleaf woodland, arable and horticulture, improved grassland, saltwater and coastal. White et al. (2013) [3] used repeated waves of Natural England’s Monitoring Engagement with the Natural Environment survey (2009-2011), to show that visits to coastal, woodlands and forests, and hills, moorland, and mountains resulted in the greatest psychological benefits and visits to town and urban parks with the least. This study controlled for demographic and visit characteristics. MacKerron and Mourato (2013) [3] also showed that the greatest feelings of happiness were found during time spent in marine and coastal margins, but that all other green or natural environment types they considered - mountains, moors, and heathlands; freshwater, wetlands and flood plains; woodland, grasslands, and farmland - resulted in happier people than continuous urban environments. The authors controlled for weather, daylight, activity, companionship, location type, time, day, and response trend.

In the urban setting it appears that both accessible and usable natural environments (whether public or private), such as gardens and parks as well as ‘incidental’ greenspaces including verges, roundabouts and other forms of green infrastructure are related to health. Van Dillen et al. (2011) [3] found that streetscape greenery is at least as strongly related to self-reported health as ‘useable’ green areas, after controlling for socio-demographic and socioeconomic characteristics. Kardan et al. (2015) [3] linked high-resolution satellite imagery and individual tree data with self-reported general health perception, cardio-metabolic conditions and mental illnesses from the Ontario Health Study. After controlling for socio-economic and demographic factors including income, age and education, they found that:

- Having 10 more trees on a city block, on average, improves health perception in ways comparable to an increase in annual personal income of $10,000 and moving to a neighbourhood with $10,000 higher median income or being 7 years younger;
- Eleven more trees on a city block, on average, decreases cardio-metabolic conditions in ways comparable to an increase in annual personal income of $20,000 and moving to a neighbourhood with $20,000 higher median income or being 1.4 years younger.

However, the authors state that they used cross-sectional data and that longitudinal data would improve inferences of causality. They also highlight their assumption that controlling for area median income accounts for many other neighbourhood variables that could affect mental and physical health in indirect ways, and note that this may not always hold true.

**Exposure mode, duration and a dose-response relationship**

The evidence used in this section is from a range of sources. Some is from peer-reviewed systematic reviews or meta-analyses. Some evidence is from peer-reviewed reviews or meta-analyses which are not systematic, and some is from other peer-reviewed journal articles or peer-reviewed reports. All evidence used in this section has been peer-reviewed [C]

Bratman et al. (2012) [2] considered the extent to which the nature, duration and type of exposure to the natural environment and the impact on health outcomes had been investigated. They found that the majority of existing studies rely either on cross-sectional designs with assumed repeated exposure over an un-known period of time, or short term
experimental approaches where people are exposed to different conditions (e.g. more/less green, built/green) in a controlled setting. More recently researchers have begun to make use of repeated cross-sectional and longitudinal survey datasets to investigate dose-response relationships (for example see Kardan et al. 2015 [3] in previous section).

As noted previously there is strong and relatively extensive epidemiological evidence that suggests that repeated exposure to natural environments through everyday living is associated with better health outcomes. There is a significant volume of evidence showing that the *quantity* and *proximity* of the natural environment in the living environment is consistently positively associated with mental and physical health and wellbeing outcomes (van den Berg et al. 2015 [1]). The evidence is mainly drawn from epidemiological studies which focus on associations between the greenness of the environment around the home and health outcomes or status in a population. Few epidemiological studies have investigated the role of natural environments around the work or educational setting.

White et al. (2013) [3] used Natural England’s Monitor of Engagement with the Natural Environment dataset to investigate psychological benefits of visits to a range of different natural environments. Their results showed that, after controlling for demographic and visit characteristics, feelings of restoration were positively associated with visit duration (which they argued is an indication of a potential dose-response effect), and visits with children were associated with less restoration than visits alone. They did not find evidence that activity type (e.g. walking, exercising) was associated with restoration.

Shanahan et al.’s (2015) [2] review considered the evidence for dose-responses relationships and, despite noting that few studies have addressed this dimension, they presented four examples relating to different exposures and health outcomes (Figure 5).

**Figure 5. Dose-response relationships (Shanahan et al. 2015 [2])**

Examples of the dose-response relationship between nature and measures of health or wellbeing from previous studies; (a) psychological wellbeing ("reflection") in response to exposure to different numbers of habitat types in Sheffield, United Kingdom (Fuller et al. 2007); (b) the relationship between green space cover (in a 3-kilometer radius around the home) and the percentage of respondents stating their health is “good” or better (adapted from Maas et al. 2006 to show the inverse of the data originally presented); (c) the change in stress levels in response to different landscape types (adapted from Beil and Hanes 2013 to show the inverse of the stress measure originally presented); (d) the change
in mean arterial diastolic blood pressure over time during exposure to urban and natural settings in California (adapted from Hartig et al. 2003 to show only the first section of the experiment where participants were not exercising) (from Shanahan et al. 2015 [2]).

Our understanding of the influence of the type and duration of exposure and of a dose-response relationship is limited by the nature of data available. There are few datasets which allow us robustly to investigate relationships between exposure mode (e.g. passive, such as viewing through a window, or more active exposure such as physical activity in a park) or duration and health outcomes at a population level.

3.4 The monetary value of benefits

The evidence discussed in this section is largely from sources that have not been peer-reviewed. The section uses some evidence from peer-reviewed reviews or meta-analyses which are not systematic, as well as some from other peer-reviewed journal articles or peer-reviewed reports. This section does not use evidence from peer-reviewed systematic reviews or meta-analyses [D]

A wide range of benefits to health linked to the natural environment have been valued, including general health and wellbeing benefits to individuals and society and avoided costs to the NHS. There is an overlap with other valuation evidence, e.g., recreational benefit values are high in part reflecting health values.

However, it is important to note that this is a developing area and reliable values are limited. A useful discussion of the difficulties is provided by Natural England’s (2014) [4] ‘Microeconomic Evidence for the Benefits of Investment in the Environment 2’ report. Further, economic valuations should take into consideration potential environmental dis-benefits, for example the potential synergistic effect between environmental pollutants and pollen (Salmond et al. 2016) [3].

Natural England (2009; 1) [4] estimate that £2.1 billion would be saved annually through averted health costs if everyone in England had equal ‘good perceived and/or actual access to green space’. This figure is derived from research which showed that where people have good access to green space they are 24% more likely to be physically active (Hillsdon et al. 2011, cited in Natural England 2009; 3 [4]). White et al. (2016) [3] found that the annual physically active visits to the natural environment were associated with an estimated 109,164 Quality Adjusted Life Years (QALYs) with an annual value of approximately £2.18 billion. Pretty et al. (2011) [2] note that if only 1% of the sedentary population adopted a more healthy pattern of activity, 1,063 lives and £1.44 billion would be saved each year.

The estimated values of a proposed expansion of the Walking the Way to Health Initiative (typically the walks make use of natural environments such as urban parks) were found to be 2,817 Quality Adjusted Life Years (QALYs) delivered at a cost of £4,009 per QALY. This was estimated to be a potential saving to the health service of £81 million (based on life-cost averted) at a cost-benefit ratio of 1:7.18 (Natural England 2009 [4]).

However, many of these figures have significant caveats. The reference above to ‘good perceived and/or actual access to green space’ (Natural England 2009; 1 [4]) highlights that provision of green space is only one factor in determining use and that many people face significant barriers to use (whether economic, social, psychological or cultural). Pretty et al. (2011) [2] state clearly that there is no guarantee people will make use of available green space, but highlight that existing evidence indicates significant benefits and savings from modest improvements in access to green space and/or behaviour change. Analysis carried out in 2005 supports this assertion and highlights that greenspace interventions are likely to
be cost-effective because they avoid the capital expenditure associated with others forms of physical activity infrastructure such as gyms (Willis and Osman 2005 [4]).

Bateman et al. (2011) [2] report tentative values for a range of health benefits derived from ecosystems. For example, they cite a study undertaken by Mourato et al (2010) which used a geo-referenced survey to estimate the physical and mental health effects associated with UK ecosystem types. The health benefits associated with having a view of green space from home were estimated to have a value of £135-452 per person per year. Similarly, the health benefits of having your own garden were estimated to have a value of £171-575 per person per year.

Nef Consulting (2013) [4] estimated the value of the Ecominds programme (nature based health interventions for mental health) finding that for five Ecominds participants, savings of £35,413 in one year (an average of £7,082 each; see example for a single participant in Figure 6) were achieved through reduced NHS costs, benefits reductions and increased tax contributions (Mind 2013 [4]). Using a formula of cost savings developed by Nef, Mind estimated that, for just one year, the programme would result in savings of £1.46m for the 246 people who found full-time work.

**Figure 6. Annual economic benefits for an individual participant of an Ecominds project (Mind 2013 [4])**

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Value (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoided prescription costs</td>
<td>258.27</td>
</tr>
<tr>
<td>Avoided medical consultation costs</td>
<td>408.92</td>
</tr>
<tr>
<td>Avoided community psychiatric nurse costs</td>
<td>6,968.00</td>
</tr>
<tr>
<td>Avoided Jobseeker’s Allowance</td>
<td>2,953.60</td>
</tr>
<tr>
<td>Avoided Disability Living Allowance</td>
<td>1,092.00</td>
</tr>
<tr>
<td>Increased tax contribution</td>
<td>572.90</td>
</tr>
<tr>
<td>Increased NI contribution</td>
<td>545.94</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12,799.63</strong></td>
</tr>
</tbody>
</table>

The Scottish ‘Branching Out’ programme (patients with mental health issues are prescribed a series of formal led woodland activities) found that based on 335 service users per year, the cost per QALY was £8,600 (Willis et al. 2015 [3]). The authors note that in comparison to the NICE threshold of £30,000 per QALY, the Branching Out programme is cost-effective.

Buck and Gregory (2013) [4] cite research which assessed the economic values of Birmingham’s city-wide Be Active programme. They suggest that approximately £23 was recouped for every £1 spent. These values related to higher quality of life, reduced NHS use, increased productivity, as well as other gains to local authorities. The authors suggest that such interventions, which aim to improve health through physical activity, are more cost-effective than most medical interventions.

Social return on investment assessments undertaken by Greenspace Scotland (undated) [4] in conjunction with public and 3rd sector organisations found a range of favourable cost-benefit ratios of health related natural environment interventions, including:

- **Bums Off Seats** found that every £1 invested in a single health walk would generate around £5 of benefit;
- **Edinburgh and Lothian Greenspace Trust** found that every £1 invested in a summer bike club at Hailes Quarry Park would generate around £6 of benefit;
- **Friends of Sunnybank Park** found that every £1 invested in delivering a programme of regular community events in the park would generate around £8 of benefit;
- **North Ayrshire Council** found that every £1 invested in supporting volunteers to reinstate the Coronation Gardens at Spier’s Old School Ground would generate around £20 of benefit;
• Woods for Health Steering Group found that every £1 invested in structured outdoor activities on Kinnoull Hill for individuals with mental health problems would generate around £9 of benefits;
• Scottish Wildlife Trust found that every £1 invested in the Glen Mile Mountain Bike Trail would generate around £3 of benefits.

Overall, the monetary value of benefits associated with increased access to and use of green space is difficult to assess precisely, but is potentially large. Pretty et al. (2015) [3] estimate the annual health costs of seven lifestyle-related conditions in the UK, all of which are influenced by links to natural places. The seven conditions are mental ill-health, dementia, obesity, physical inactivity, diabetes, loneliness and cardiovascular disease. Individualised annual health costs amount to £62 billion for the National Health Service and £184 billion to society as a whole.

3.5 Policy and delivery

This section reviews evidence concerning the effectiveness of existing interventions for harnessing the value of the natural environment for health and discusses options for future policy and practice.

The effectiveness of existing policy and interventions

This section makes use of evidence from a wide range of peer-reviewed systematic reviews or meta-analyses, as well as some peer-reviewed reviews or meta-analyses which are not systematic. Evidence is also included from other peer-reviewed journal articles or peer-reviewed reports. The section makes use of limited evidence that has not been peer reviewed [A]

There is growing practical experience of using or managing the natural environment to provide a context or resource for health related interventions. This can take many forms, from ensuring adequate access to greenspaces in the living environment (whether through planning for new spaces or improving physical access to existing spaces) to specific practitioner led therapeutic interventions in woodlands. The evidence for the effectiveness of these interventions is, as of yet, limited; this is likely due to the high cost and complexity of intervention evaluation and the relatively recent interest in such activities. There are, however, numerous small scale programme and project evaluations which are beginning to be brought together to synthesise reported outcomes across related projects (see, for example, Lovell et al. 2015 [1] and Nef Consulting 2013 [4]).

Pretty et al. (2011) [2] discuss a broad range of ‘green care’ interventions which seek to improve the health and wellbeing of vulnerable groups, such as psychiatric patients and people with learning disabilities. Interventions include horticulture, green exercise therapies, animal-assisted therapy, care farming, ecotherapy and wilderness therapy. These activities can be informal and self-led (recuperative and restorative) or part of formal programmes which one can elect to join or be referred to by a health professional. Such interventions are led by a diverse range of organisations from public bodies such as Natural England and the National Parks to environment or health focused non-governmental organisations (e.g. Wildlife Trusts or Mind). In some cases they are supported by or developed in collaboration with the health sector (e.g. with funding from Health and Wellbeing Boards or commissioned through Clinical Commissioning Groups).

Whilst overall the use of natural environment based health interventions is in its infancy there appears to be significant (if un-coordinated) activity. A survey undertaken in 2010 (Jepson et
al. [4]) in Scotland of ‘Green Interventions’ found over 170 formal programmes where patients were referred to schemes which used the natural environment as a context for supported physical activity. Pretty et al. (2011) [2] highlight that these approaches have not been widely evaluated. However the existing evidence is suggestive of multiple benefit pathways.

Lovell et al. (2015) [1] undertook a systematic review of health and wellbeing benefits associated with environmental conservation activities (the review was partly conducted through the Cochrane Collaboration). Such activities are a common form of green intervention, aiming to protect and enhance the natural environment and improve health and wellbeing. A number of NGOs lead such programmes, the most common and well known of which is TCV’s (The Conservation Volunteers) Green Gyms (which recently won the highest award from the Royal Society for Public Health for the promotion of health and wellbeing through policies that empower communities and individuals). Although much of the quantitative evidence was inconclusive, some positive psychological and quality of life outcomes were identified. The qualitative evidence indicated that activities were perceived to be beneficial to health and wellbeing, through providing exposure to natural environments and enjoyment, as well as a sense of achievement and social contact.

A review of nature based therapeutic interventions (Annerstedt and Wahrborg 2011; 371 [1]) found a ‘small but reliable evidence base supports the effectiveness and appropriateness of NAT [nature-assisted therapy] as a relevant resource for public health’. A meta-analysis of outdoor walking groups (Hanson and Jones 2015 [1]) showed a range of impacts to health including statistically significant reductions in mean difference for systolic blood pressure of \(-3.72\) mm Hg \((-5.28\) to \(-2.17\)) and diastolic blood pressure of \(-3.14\) mm Hg \((-4.15\) to \(-2.13\)); resting heart rate \(-2.88\) bpm \((-4.13\) to \(-1.64\)); body fat \(-1.31\%\) \((-2.10\) to \(-0.52\)), body mass index \(-0.71\) kg/m² \((-1.19\) to \(-0.23\)), total cholesterol \(-0.11\) mmol/L \((-0.22\) to \(-0.01\)) and statistically significant mean increases in VO²_{max} of 2.66 mL/kg/min (1.67-3.65), the SF-36 (physical functioning) score 6.02 (0.51 to 11.53) and a 6 min walk time of 79.6 m (53.37-105.84). The evaluation of the Lottery funded ‘Ecominds’ project led by the charity Mind (2013) [4] reported a range of beneficial impacts including 7 out of 10 participants experienced significant increases in mental wellbeing (before-after assessed using the Warwick-Edinburgh Mental Wellbeing Scale). The evaluation found that 56% of participants were men, while recent IAPT statistics show that men account for only 36% of those attending psychological therapies.

Longitudinal studies of people moving between areas with differing amounts of greenspace suggest that increasing the quantity and proximity of greenspaces may have a beneficial impact on health, after controlling for selected area and individual level effects (Alcock et al. 2014 [3]). Direct studies of environmental change have mixed outcomes. Initial results from the Woods In and Around Towns programme are positive. Using a controlled design the evaluation found significant increases in indicators of quality of life, frequency of woodland use, in attitudes to woodlands as places for physical activity, and in perceptions of safety at the intervention site over time, compared with no significant changes in the control sites (Ward Thompson et al. 2013 [3]). Using a controlled repeated cross-sectional design a Dutch study of urban greening in deprived neighbourhoods found no effect on physical activity rates or general good health status (n 48,132) (Droomers et al. 2015 [3]).

A systematic review of interventions to promote physical activity found some evidence that changes to the built environment encouraged use and resulted in increased physical activity in urban green space (Hunter et al. 2015 [1]). McCormack et al. (2010) [1] reviewed research to understand the factors that lead to increased park use. They found safety, aesthetics, amenities, maintenance and proximity are all important factors.
Green health care settings have been shown to have positive impacts. For instance, a formal systematic review found that the use of dementia gardens was associated with decreased agitation (Whear et al. 2014 [1]).

Although currently limited, our understanding of the extent, process and outcomes, and cost-effectiveness of environmental health interventions is growing. The Wildlife Trusts are currently undertaking a review of their health intervention activity and a number of academic studies, focusing on specific mechanisms (such as the commissioning and referral process) and outcomes, are underway. TCV are currently embarking on an assessment of the impacts and cost-effectiveness of the Green Gym programme and the National Institute for Health Research released a funding call in spring 2016 for evaluations of the health impacts of nature based interventions².

Future policy and delivery options

The evidence discussed in this section is from a range of peer-reviewed systematic reviews or meta-analyses and other peer-reviewed reviews or meta-analyses which are not systematic. The section also presents a range of evidence which has not been peer-reviewed [C]

The evidence indicates a need for more integrated policy and delivery across health, natural environment and other sectors at a wide range of spatial scales (see, for example, Hartig et al. 2014 [1]; Sandifer et al. 2015 [2]). The Convention on Biological Diversity and World Health Organization (CBD and WHO 2015 [2]) highlight the need to create coherent cross-sectoral strategies to ensure that biodiversity and health linkages are widely recognised, valued, and reflected in national public health and biodiversity conservation policies, and suggest joint responsibility for implementation. Recommendations based on this State of Knowledge Review were taken forward at the meeting of the CBD’s Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) in Montreal on 2-5th November 2015 (CBD 2015 [5]).

Integrated policy and delivery is required to help recognise and take account of multiple benefits. Hartig et al. (2014) [1] note that even if the health benefits of a particular form of contact with nature are small, public investment may still be justified if there are benefits across wider policy domains such as better storm water management, species preservation and carbon sequestration. Place-based approaches may enable benefits to be considered more effectively across policy areas including economic development, education, environment, health and social care, planning and transport.

There is a need to learn lessons from other sectors and wider evidence on influencing behaviours and securing transitions across systems. Policy and delivery should aim to encourage and enable people and organisations to behave differently to improve health outcomes and benefit the natural environment (see for example Dolan et al. 2010 [4]; Fell and Giorgi 2016 [4]; Spurling et al. 2013 [4]).

Policy should also recognise population level effects. Evidence indicates that benefits to human health and wellbeing may sometimes be small at individual level relative to socio-demographic or genetic factors, and some may be long term, but aggregate health benefits may still be significant (Hartig et al. 2014 [1]). Buck and Gregory (2013) [4] and Willis and

Osman (2005) [4] also argue that the infrastructure costs of natural environments managed and/or used for health interventions are likely to be low relative to other comparative options such as indoor gyms.

There is a wide range of guidance in relation to developing more effective interventions targeted at individuals and communities. For example, in a useful report targeted at local authorities, Buck and Gregory (2013) [4] identify a series of priority actions including:

- Working with local communities to develop strategic plans for green space. They also suggest access to green space could be prioritised in planning developments;
- Investment to ensure parks are maintained and anti-social behaviour does not become a disincentive for people to use parks;
- Active involvement of community groups and volunteers in the management of green spaces through programmes such as the Green Gym;
- Development of new funding models;
- Commission and work with GPs to implement activities in green spaces, consistent with Department of Health’s Let’s Get Moving toolkit (DH 2012).

Buck and Gregory also highlight that interventions need to be specifically targeted and designed with a clear purpose, with detailed knowledge of local needs, attitudes and cultural contexts.

Bragg and Atkins (2016) [4] reviewed nature-based interventions aiming to improve the mental health of vulnerable groups. In order to scale up commissioning of these kinds of services, they recommend pilots to test and evaluate new approaches to larger scale delivery, as well as greater coordination between green care providers to provide a more appealing offer to health and social care commissioners.

The ‘Natural Solutions’ report from the UCL Institute of Health Equity considered how the natural environment could contribute to reducing health inequality. It concluded that ‘There is some research showing that interventions using the natural environment to improve health can deliver costs savings for health and related services and improve physical and mental health outcomes. So, increasing the amount and quality of green space can be part of a low cost package to address health inequalities, improve health outcomes and deliver other benefits’ (Allen and Balfour 2014; 5 [4]). The authors identified four key priorities:

- Improving coordination and integration of delivery and ensuring interventions are user-led;
- Building a stronger evidence base to ensure programmes are evidence-led;
- Ensuring sustainable delivery of services that use the natural environment (i.e. breaking out of the ‘pilot’ stage);
- Increasing the quality, quantity and use of natural environment assets that equitably benefit people’s health and help prevent ill health.

Often the barriers to effective interventions are related to misunderstandings of the value of natural environments to health. A small scale pilot programme evaluation of two ‘Communities First’ areas of South Wales suggested that gaining the support and buy in of professional key support workers was fundamental to the success of encouraging hard-to-reach communities to use their local natural environments. However it was noted that community development workers, youth workers and health workers do not necessarily understand or recognise that the availability of accessible local greenspace is a resource that could contribute to achieving targets on health, wellbeing and employability (Natural Resources Wales 2015 [4]).
3.6 Key evidence gaps

The evidence discussed in this section is largely from peer-reviewed systematic reviews or meta-analyses and other peer-reviewed reviews or meta-analyses. The section includes limited evidence from other peer-reviewed journal articles or peer-reviewed reports and from sources which have not been peer-reviewed [A]

This final section identifies gaps in the evidence base concerning our understanding of the benefits of natural environments to health and in relation to future policy and delivery.

The linkages between natural environments and human health are many, complex and variable and whilst there is a substantial (and growing) evidence base there are a number of key evidence gaps and needs which are discussed in more detail below:

- Methodologically, more robust evidence which seeks to identify causal pathways is crucial.
- There is a need for more extensive and reliable evidence in relation to specific policy interventions and to understand the factors which promote and facilitate inter-sectoral working at different spatial scales.
- Existing evidence needs to be transformed, synthesised and disseminated more effectively for different audiences.

There is a need to improve understanding of causal links between the natural environment and human health (Hartig et al. 2014 [1]; Hough 2014 [1]). At present, many studies identify associations but are unable to demonstrate causality, although in some cases this may be largely due to the limited number of studies (e.g., Gascon et al. 2015 [1]). Partly to address this issue, Church et al. (2011) [2] note that further evidence is required from longitudinal studies. Natural experimental designs should also be used to take advantage of changes in policy and practice or in the use or design of the environment (for instance the creation or expansion of National Parks could be explored as an interesting natural experiment).

There is also a more widespread need to improve the robustness of study designs. Sandifer et al. (2015) [2] note that many studies lack adequate controls, sample sizes and duration, and often rely on self-reported information rather than objective data. However, despite these weaknesses, they state that it is ‘exceptionally important’ to note that the overwhelming evidence in this area finds a wide range of positive health responses to natural environments (Sandifer et al. 2015; 3 [2]).

A review of key intersections in policy, both national and local, might help identify future policy and delivery opportunities. Across Europe a number of regions have adopted progressive and integrated approaches to decision making where environmental concerns are considered alongside those of health. An example is the Welsh Well-being of Future Generations Act 2015 which aims to facilitate inter-sectoral decision making. There is a need to learn from these examples and to understand the transferability of such approaches.

There is a lack of evidence specifically designed to inform the development of policy and interventions, including evaluation demonstrating which interventions work, for whom, in what circumstances, and why. Both Shanahan et al. (2015) [2] and Hartig et al. (2014) [1] highlight the need to support environmental policy and delivery more effectively by improving assessments of what nature can and cannot do for human health and wellbeing. They state that, arguably, this requires knowledge about the ‘doses’ of nature needed to generate particular benefits. However, Hartig et al. (2014) [1] recommend caution with this approach, since the long term consequences of particularly powerful forms of contact with nature might be difficult to assess and therefore neglected.
There is a large volume of evaluative activity which could enhance our understanding of the ways in which the environment is or could be used to benefit health. However evaluations are often not of a quality suitable to inform policy or practice and are rarely disseminated and shared effectively. There is a need to develop practical ways in which to support cost-effective but robust evaluations, and to gather and synthesise this evidence (Allen and Balfour 2014 [4]).

Additional valuation evidence is needed, including work to understand health values associated with the natural environment and the benefits and cost effectiveness of different policy and intervention options.

Mirroring the discussion of more integrated policy and delivery, further cross-sectoral and interdisciplinary evidence is also required. For example, Sandifer et al. (2015; 1) [2] highlight the need for ‘a new coalition of ecologists, health and social scientists and planners to conduct research and develop policies that promote human interaction with nature and biodiversity’. Alongside quantitative data, qualitative evidence can provide valuable information to help understand and inform the design of interventions for particular target groups (Hitchings 2013 [3]; McCormack et al. 2010 [1]). Environmental interventions are often complex and likely to impact on a number of health, social, cultural and educational outcomes. Despite this, current research and evaluation approaches often fail to effectively identify the breadth of impact. A better understanding of the complexity of outcomes may help support integrated policy and delivery.

There are significant opportunities to take advantage of technological developments and make greater use of existing data. Sandifer et al. (2015) [2] highlight the potential for using data from mobile and wearable sensors to collect a variety of health-relevant data for many different kinds of environmental exposures. They also note that very little biodiversity monitoring data is integrated and made accessible in ways that make it useful for public health purposes.

Natural England (2015b) [4] provides a summary of the evidence on access and engagement, including discussion of what is known, live research questions, and what is not known on key topics. This covers patterns of use of the natural environment, evidence about places where people interact with nature, and issues that arise from engagement. Evidence gaps are identified in relation to health and wellbeing, including understanding of complex, long-term pathways and the effectiveness of interventions.

Further gaps around our understanding of impacts and in realising the benefits of exposure to the natural environment include:

- What factors or interventions are effective in encouraging health related use of the natural environment?
- What are the necessary conditions for natural environments to be effective in promoting health?
- What can be learnt from international contexts and cultures?
- How can interventions be scaled up to have substantial effects at national level?
- How can settlements be redesigned to increase social interaction and engagement with green spaces?
- At what life stages are interventions to promote the health benefits of natural environments most effective?
- How can benefits to population health be achieved through environmental interventions without exacerbating health inequalities?
- What role does the natural environment have in promoting individual or community health related resilience (particularly in relation to multiple deprivation)?
4 Conclusions

This review has summarised the links between natural environments and human health and wellbeing. It has considered global ecosystem services, landscape scale and other indirect links before focusing in more detail on direct benefits associated with use of green space and exposure to the natural world. It has used robust and reliable evidence relevant to the environment, health and wellbeing in the United Kingdom.

At global level, human health and wellbeing depends on air, food, shelter and water, all part of or derived from the natural environment. If global or local thresholds are exceeded, human health and wellbeing may be threatened. At an intermediate level natural environments are crucial for healthy functioning landscapes that support health through a variety of pathways including flood avoidance or mitigation, and reduced air pollution.

At a more local level, there is relatively strong evidence that direct contact with the natural world can bring a range of physical and mental health and wellbeing benefits. Particularly strong evidence is seen in for mental health and wellbeing and a healthy internal biome and immunological system. The extent and ways in which different socio-demographic groups benefit is variable and is influenced by a range of factors. Although lower socio-economic and other marginalised groups often have poorer access to good quality natural environments they appear to enjoy the greatest benefit. There is evidence that suggests greenness may have a role in supporting the physical activity, and therefore the physical and mental health, of specific groups. Factors such as the type and quality of the environment and exposure mode moderate the potential benefit of exposure to or use of natural environments. There is some evidence that suggests specific interventions which make use of the natural environment as a setting are effective in promoting health and are cost-effective.

Overall, whilst the evidence for many of the links between the natural environment and human health is tentative, this is a complex area and the evidence has developed rapidly in the last ten years. Key research gaps and needs exist in relation to causality, intervention effectiveness, outcome complexity, and pragmatic policy and delivery strategies. Despite this, multiple robust syntheses of the evidence suggest that there are several plausible impact pathways and mechanisms linking natural environments to health and wellbeing.

In summary, particularly strong links are found in relation to: mental health and wellbeing; development and maintenance of a healthy immune system and reduction of inflammatory-based diseases; and in relation to variation between social and demographic groups. Generally positive links are found concerning: landscape, ecosystem and city scale linkages; perceived health status; mortality; maternal health, pregnancy outcomes and children’s cognitive development; other physiological outcomes; physical activity (in selected groups); and social contact and community cohesion. The evidence is mixed or unclear in relation to: global ecosystem services, biodiversity and health; obesity; physical activity (at population level); environmental quality; the type of natural environment; exposure mode, duration and a dose-response relationship; the monetary value of benefits; and the effectiveness of policy and interventions.

The review has also summarised the quality of evidence used in each section, categorising this from A-D. Table 3 shows the strength of links between the natural environment and human health by quality of evidence. This highlights the following four areas where there is high quality evidence of strong links or generally positive associations, which may provide a useful focus for future policy and delivery:

- Mental health and wellbeing;
• Development and maintenance of a healthy immune system and reduction of inflammatory-based diseases;
• Landscape, ecosystem and city scale linkages;
• Physical activity (in selected groups).

Rather than waiting until the evidence base is significantly more extensive, there appears to be a strong case for developing more integrated policy and practice across the health and natural environment spheres, with a strong emphasis on learning and evaluation to improve understanding of the most effective approaches and assess impacts. Such policies have the potential to deliver health and wellbeing benefits, and strengthen the case for protecting and enhancing the natural environment. It may be helpful to focus future efforts in a small number of pilot areas, because of the potential for integrating across a range of policy areas as part of place based approaches at local and regional scales. At the same time, continued effort is required to improve the evidence base to address key issues identified in this evidence statement and technical appendix, and careful design, implementation and evaluation of integrated policy and delivery in pilot areas will offer opportunities in this regard.

Table 3 Strength and quality of evidence by section

<table>
<thead>
<tr>
<th>Quality of evidence</th>
<th>Evidence largely from peer-reviewed systematic or non-systematic reviews or meta-analyses [A] [B]</th>
<th>Evidence largely from mixed evidence sources, individual journal articles and reports, or sources that have not been peer reviewed [C] [D]</th>
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<td>Strength of links between natural environments and human health</td>
<td>Strong evidence 3.2.1 Mental health and wellbeing 3.2.5 Development and maintenance of a healthy immune system and reduction of inflammatory-based diseases</td>
<td>3.3.2 Variation between social and demographic groups</td>
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<tr>
<td>Generally positive links</td>
<td>3.1.2 Landscape, ecosystem and city scale linkages 3.3.1 Physical activity (in selected groups)</td>
<td>3.2.2 Perceived health status 3.2.3 Mortality 3.2.6 Maternal health, pregnancy outcomes and children’s cognitive development 3.2.7 Other physiological outcomes 3.3.3 Social contact and community cohesion</td>
</tr>
<tr>
<td>Evidence is mixed or unclear</td>
<td>3.1.1 Global ecosystem services, biodiversity and health 3.3.1 Physical activity (at population level) 3.5.1 The effectiveness of existing policy and interventions</td>
<td>3.2.4 Obesity 3.3.4 Environmental quality 3.3.5 The type of natural environment 3.3.6 Exposure mode, duration and a dose-response relationship 3.4 The monetary value of benefits 3.5.2 Future policy and delivery options</td>
</tr>
</tbody>
</table>
References

As indicated in Section 2, all evidence included is categorised using the following descriptions, which are not intended to be strictly hierarchical. The code for each individual journal article, report or other piece of evidence is shown in square brackets throughout the text in the ‘Findings’ section of the technical appendix and at the end of each reference in the list below.

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<th>Description</th>
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<tr>
<td>Peer reviewed non-systematic review or meta-analysis</td>
<td>[2]</td>
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<tr>
<td>Other peer reviewed journal article or peer reviewed report</td>
<td>[3]</td>
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<tr>
<td>Other (including non-peer reviewed reports etc.)</td>
<td>[4]</td>
</tr>
<tr>
<td>Not applicable</td>
<td>[5]</td>
</tr>
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</table>


http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2811%2960393-0/abstract [2]


http://bmjopen.bmj.com/content/4/12/e006076.full [2]

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http://jech.bmj.com/content/61/8/681.full [3]

http://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2808%2961689-X/abstract [3]


About this Evidence Statement

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The European Centre for Environment and Human Health is an interdisciplinary centre, based in the University of Exeter Medical School, which focuses on understanding the emerging threats to health and wellbeing posed by the environment, and the health and wellbeing benefits the natural environment can provide.

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