A narrative review of reviews of nature exposure and human health and well-being in the UK

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Natural England Evidence Review NEER030

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NATURAL ENGLAND

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Report details

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Data access

Further information about the review of reviews can be obtained by contacting socialscience@naturalengland.org.uk

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Foreword

As Dasgupta highlights, ‘Our economies, livelihoods and well-being all depend on our most precious asset: Nature’ (Dasgupta Review, 2021). Nature is life. It underpins everything we do. It provides us with clean air, food, water and shelter. It regulates our climate and controls disease. Beyond this, it is central to recreational, cultural, social and spiritual aspects of human life. It is fundamental to our health and well-being.

As the Government’s statutory advisor on the natural environment, our vision is to create thriving nature for people and planet; helping nature to thrive, and connecting more people with the environment to improve health and wellbeing. By aligning nature recovery and health priorities we are opening up more diverse avenues to increase the quality and quantity of nature across England, creating better places to live, whilst also supporting better physical and mental health and reducing pressures across health and social care services.

The role that nature plays in supporting our health and wellbeing is increasingly well recognised across sectors and in the Government’s Environmental Improvement Plan (2023). Green social prescribing is embedded within the NHS Long Term Plan, and Public Health England (now the Office for Health Improvement and Disparities) recommend that Local Authorities should consider local green (and blue) space to be critical assets for maintaining and supporting health and wellbeing in local communities (in their 2020 publication ‘Improving access to greenspace’). The Department for Education’s ‘Sustainability and Climate Change Strategy’ (2022) draws on learning in the natural environment for physical and mental health, and the Government’s Levelling up Missions make reference to the importance of access to natural spaces.

This review will help provide policy-makers, funders and researchers with key evidence to better join up our aims at improving nature, increasing access to nature and improvements in public health and well-being. Given the wide-ranging links between our natural environments and human health and well-being, this review aims to make the breadth of research in this area more accessible, updating and building on earlier reviews to ensure that best practice is informed by current evidence. By understanding what current evidence tells us, but also identifying gaps in our knowledge base, this review can inform health systems and structures (such as Joint Strategic Needs Assessment and Integrated Care System plans) but also areas for research development.

Creating a robust, well-supported, collaborative approach for improving health and nature will bring significant benefits for people and nature as well as providing good value for money and use of resources.

Amanda Craig (Director, People and Nature) and Ruth Waters (Director of Evidence), Natural England

Executive summary

This 'review of reviews' identifies and provides a narrative summary of key evidence on both positive and negative changes in human health and well-being that are associated with exposure to and engagement with the natural environment in the United Kingdom.

Why is this review needed?

This evidence review was completed for the benefit of both the health and environment sectors. A clear understanding of existing evidence linking nature, health and well-being is needed to support evidence-led policies and programmes. This will add to understanding of the wider determinants of health (health sector) and inform our understanding of the human impacts of biodiversity loss (environment sector).

Given the wide-ranging links between our natural environment and human health and well-being, this review aimed to make the breadth of research in this area more accessible, updating and building on earlier reviews to ensure that best practice is informed by current evidence (Hartig et al., 2014; Lovell et al., 2018).

What do we mean by 'exposure to nature'?

The review does not look at the impact of nature's provision through material resources (e.g., food, fuel, medicine), but instead the impact of exposure to natural environments and active engagement with them. This includes both positive and negative outcomes, and considers the health and well-being changes associated with more passive (e.g., air quality impact on respiratory health), as well as active engagements (e.g., improved well-being through outdoor exercise groups).

What does the review tell us?

There is existing evidence that…

- Exposure to green space, particularly urban, is associated with improved psychological well-being, physical activity and linked health outcomes.
- Exposure to nature increases activity levels among children and young people.
- There is evidence for the psychological benefits of nature-based interventions, in particular reduced depression and improved mood.
- Growing evidence shows that blue space exposure is also beneficial for psychological well-being and physical activity.
- The flip side: Pathogens present during water-based recreation are associated with respiratory, gastrointestinal and other physical illness.
- Exposure to air pollution while outdoors from transport and industry has significant negative impacts on respiratory, cardiovascular and birth/early years outcomes.
- Strategy and intervention to improve air quality while outdoors could provide substantial improvements for quality and length of life.

More research is needed to understand…

- The impact of nature-based interventions for specific groups and specific activities.
- The risks that a changing climate within the UK poses to human health and well-being through exposure to changing nature.
- The health and well-being outcomes of nature improvement work.

The evidence base could be improved through…

- Consideration of both mapped natural spaces as well as qualities of spaces, levels of engagement and subjective experience.
- More consistent measurement of nature exposures and health and well-being outcomes.
- Seeking to identify what works, for whom and in what situations for nature-based interventions.
- Research cross-cutting sector, discipline and theoretical boundaries to better inform policy and programme efforts.

Contents

Glossary

25YEP: England's 25 Year Environment Plan 'indicators' of progress (Defra, 2022).

Engagement (with nature): Active engagement with nature is when someone spends time in nature or engaging with nature through remote means.

EIP: England's 'Environmental Improvement Plan' (Defra, 2023a)

Exposure (to natural environments): Referred to throughout as 'nature exposure', is the coming together of a person and the natural environment. Engagement with nature is an active form of this, but exposures may also be more passive (e.g., exposure to climate, extreme weather and ecological exposures).

Health: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." (World Health Organisation, 1946).

Narrative review: "Narrative reviews are typically used to describe a body of evidence relating to a particular topic and the results of such reviews are generally descriptive and are often used to identify needs for future research. Narrative reviews, whilst not fully systematic, are robust and rigorous; the review is carried out using systematic, documented and replicable methods." (Lovell et al., 2018)

Natural environment: the 'natural environment' relates to and encompasses all spaces or landscapes which feature natural elements. Natural environments could be public or private, urban or rural, and range from 'managed' and built places with natural elements (such as parks and gardens, urban woods, rivers and lakes or incidental spaces such as road verges, street trees and other forms of 'Green and Blue Infrastructure') to predominantly managed rural natural environments (such as farmland) and the more 'wild' spaces which are predominantly natural but which may or may not be managed, designed or affected by humans in some way (for instance urban nature reserves, native woodlands, marine areas and mountain landscapes; Natural England, 2016).

Well-being: Individual well-being is "a person's cognitive and affective evaluations of his or her life" (Diener et al., 2022, p. 63)

Background

The natural environment is described as those spaces and landscapes that contain natural elements:

> ‘Natural environments could be public or private, urban or rural, and range from ‘managed’ and built places with natural elements (such as parks and gardens, urban woods or incidental spaces such as road verges, street trees and other forms of ‘Green Infrastructure’) to predominantly managed rural natural environments (such as farmland) and the more ‘wild’ spaces which are predominantly natural but which may or may not be managed, designed or effected by humans in some way (for instance urban nature reserves, native woodlands, and mountain landscapes)’ (Natural England, 2016, p. 1).

A healthy natural environment forms the foundations for human life where ecosystem assets provide a wide range of benefits to people. These benefits include the provision of material resources (e.g., food, water, energy and medicines), the regulation and maintenance of the environment (e.g., regulating the impact of natural disasters and disease, and the purification of air and water), and the cultural, non-material contributions, such as recreational, social and spiritual benefits (The MA Board, 2005). However, there are several areas in which exposure to natural environments has negative impacts, such as allergens, diseases, animal attacks, poisonous organisms, and exposure to contaminated nature (von Döhren & Haase, 2015). Our natural environment needs to be in a good condition to provide these benefits to people, and therefore contribute to our health and wellbeing.

There has been a growth in recent years of research looking at benefits that exposure to and engagement with nature can provide for a range of physical and mental, health and well-being outcomes (Hartig et al., 2014; Lovell et al., 2018). This is reinforced by an increasing focus on how natural environments contribute to preventative health initiatives and reducing the burden of major conditions (Department for Health and Social Care, 2023). Increasing awareness of the impacts of climate change and biodiversity loss on our natural environments and the growing number of people living in urban areas (United Nations, 2019), magnify concerns around human access to and benefits from nature (Dasgupta, 2021).

The current narrative review of reviews therefore aims to bring together UK-relevant evidence on **both positive and negative changes in human health and well-being that are associated with exposure to and engagement with nature.**

This review does not look at the impact of nature’s provision through material resources, but instead the impact of being in and experiencing nature. The review is focused on the changes to health and well-being accrued through the recreational,

cultural, social and spiritual benefits that nature provides. However, the review also includes changes in health and well-being relating to time spent in nature, such as the impacts of air and water quality, heat and extreme weather events, and the mitigation against these that nature can provide. This aligns with the association between natural capital and well-being, with ecosystem assets providing the flow of benefits that underpin human well-being (Dasgupta et al. 2021)

Nature exposure and health and well-being: Current state of the evidence

A diverse range of nature exposures. Hartig et al. (2014) highlight the complexity of assessing the impact of exposure to nature on human outcomes because it is partly 'experienced subjectively' in a wide variety of contexts and ways. This is reflected in the multiple ways that nature exposures can be understood and defined in research, and then how it is measured.

Broadly there is support for a positive association between nature exposures and health and well-being. Key existing evidence reviews in this area have completed 'review of reviews' (Hartig et al., 2014; Lovell et al., 2018). This is due to the wide scope and the multitude of existing reviews that bring together primary research on specific nature exposures and specific health and well-being outcomes. Broadly speaking, these earlier umbrella reviews are unanimous in concluding that evidence supports nature's beneficial effects on human health and well-being. However, the many limitations to research in this area reduce the strength of this conclusion.

Limitations of this support. The conclusion that evidence supports a relationship between nature exposures and health and well-being is most often considered provisional based on the following limitations to the evidence base (Hartig et al., 2014; Lovell et al., 2018):

> **Inherent complexity in measuring human health and well-being outcomes.** Human health and well-being outcomes cover a huge array of factors, relate to change over a long period of time (i.e. the life-span), are often complex to quantify (e.g., articulating the 'value' of a particular 'dose' of nature for subjective 'well-being') and require data that is often hard/sensitive to access such as health records. Moreover, these outcomes are subject to a range of determinants beyond natural environments, such as other aspects of where we live, our income, genetics and social capital. These factors will moderate how nature impacts on different people. Sufficient modelling of this complexity is often not possible within limited research projects and so instead more immediate or proxy measures of health/well-being are often assessed (e.g., physiological response, physical activity, self-reported measures), and

these may not be considered alongside wider determinants of health. For this reason, we do not have clarity on longer-term health/well-being outcomes and nuance in terms of the size of these impacts, for whom and in what contexts.

Heterogeneity in measurement. This complexity in human outcomes is reflected in the wide variety of ways that health and well-being outcomes are defined and measured in this field of research. This heterogeneity prevents the pooling of results for use within meta-analyses and when pooling does occur, may lead to less informative findings relating to a general 'nature exposure', non-specific 'health and well-being' outcome and heterogeneous studies.

Lack of assessment of causality. The primary research within this field is too often correlational and unable to show causality through more rigorous research designs (such as experimental or longitudinal), using appropriate controls, large enough sample sizes and examining change over a sufficient length of time.

Mechanisms of impact. A range of explanations for the relationship between nature exposure and health and well-being have been theorised and tested. The relevance of different mechanisms will vary depending on the nature exposure measured. Five broad mechanisms are most often highlighted within existing literature:

Reduction of stress. Time spent in nature is suggested to have stress reducing restorative effects, shown through physiological and self-reported measures of stress (Ulrich et al., 1991).

Improving cognitive capacity. Theories like the 'Attention Restoration Theory' propose that people's attention can become fatigued through over stimulation and that exposure to nature has the potential to restore attentional capacity by demanding less directed attention (Kaplan & Kaplan, 1989). In this way nature is restorative.

Increased physical activity. Exposure to nature is said to relate to increased physical activity, and physical activity carried out in natural environments is viewed as more beneficial for health and enjoyment than similar activity in other spaces (Lovell et al., 2018).

Reduced exposure to environmental hazards. Particularly within urban environments and relating to the presence of trees/vegetation and blue space, nature has been investigated for its benefits in reducing the urban heat island effect and improving air quality (Bowler et al., 2010; Georgiou et al., 2021; Qiu et al., 2021).

Social contact. A range of literature discusses nature as a space in which both children and adults can come together for exercise and recreation. This benefits a range of social outcomes, sometimes referred to as social cohesion or contact, community and isolation/loneliness (Jennings & Bamkole, 2019).

Each of these proposed mechanisms is then linked to improvement in aspects of human health and well-being, whether that be the cardiovascular benefits of reductions in stress and increased physical activity, the respiratory benefits of reduced exposure to air pollutants, or the well-being benefits of increased social connection and restoration.

Nature exposure and health and well-being: Evidence need

There appears to be general agreement within policy and practice that exposure to nature is beneficial for health and well-being outcomes. In accordance with this, current policy outlines the need for a holistic approach, acknowledging the reciprocal relationship (sometimes termed ‘One Health’; Queenan et al., 2017) whereby human health and well-being is fundamentally linked to our interactions with natural environments, but also that the health of our natural environments is dependent on our care for it. This is demonstrated in recent policy documentation nationally, internationally, and in the health, environment, and wider fields, to name a few:

1. England’s Governmental ‘Environmental Improvement Plan’ (EIP) has ‘nature for well-being’ as part of its delivery plan, stating it will aim to “Incorporate the use of green and blue spaces into the healthcare system” (Defra, 2023b).This sits alongside indicators used to assess progress with the earlier 25 Year Environment Plan which explicitly state that human health and well-being advancements is part of this environmental progress (see indicator G7; Defra, 2022).
2. The United Nation’s ‘Sustainable Development Goals’ aim to establish a world-wide agreement for the sustainable use of nature, with human health at the heart of this aim. They acknowledge that “Building a healthier and greener world requires a multisectoral approach that recognizes the interconnection between people, animals, plants and their shared environment.” (World Health Organisation, 2019, 2022). This is demonstrated in Goal 11.7 which states that "By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities" (United Nations, 2023).
3. The United Kingdom’s (UK) Department for Health and Social Care consider the ‘built and natural environment’ as wider determinants of health, listing both

air quality and access to green spaces as core parts of this determinant (Public Health England, 2018).

4. The UK's Department for Education also articulate the reciprocal relationship between human and planetary health with a focus on young people: "A green, sustainable education estate that is resilient to the impacts of climate change will normalise and inspire young people to live sustainable lives, with impact felt widely in their families and communities. By improving the physical environment in and around education settings, we can impact positively on both the physical and mental well-being of children and young people." (Department for Education, 2022).
5. The Welsh Government's 'Well-being of Future Generations Act' describes its vision that 'Cymru is a better place to live and has a bright and optimistic future – thriving, inclusive and green', including climate and nature as central to its well-being objectives (Office of the Future Generations Commissioner for Wales, 2023).

Despite this clear acknowledgement, harnessing the benefits of nature may not yet be a priority for health organisations where funding for preventative health measures may be limited. Likewise, human health and well-being may not yet align with nature restoration efforts within environmental organisations. As suggested by Lovell et al., (2018), there is a lack of ownership within one department/body to ensure we coordinate initiatives that take a 'one health' perspective.

An evidence-led approach is more often requested to help prioritise policies, programmes and allocation of funds. This asks for confidence in findings and tangible outcomes often linked to economic benefit. This does not sit well with the current state of the evidence on what to do, which is still described as provisional. See Lovell et al. (2018) for greater detail on the opportunities around better using evidence to inform programmes and policies in this way. Relevant to the current umbrella review is the need to support the 'ongoing collation of robust, causal and explanatory evidence'. Understanding the existing evidence base, the gaps in this and the way this can be improved to inform programmes and policy effectively.

Aims

This review of reviews aimed to identify and summarise key research findings to-date and the strength of the evidence around the links between nature exposure and human health and well-being. This builds on the extensive work of Lovell et al. (2018) completed for the UK context by including new insights from the explosion of reviews in this area since 2016 (when the Lovell et al. search was completed); but also expands on this by more directly mapping evidenced links between specific nature exposures and health/well-being outcomes.

By bringing together evidence of the links between exposure to different aspects of nature and specific measures of health and well-being, this review aims to provide a detailed picture of this research area, where links are most established within the existing evidence base and where gaps in research still exist. This aims to provide clarity for organisations such as Natural England who the report was written by/for, and other nature-based and health organisations, so that future programmes, policy and research can be better targeted to meet organisational aims around nature and health/well-being.

Research question

This review addresses the research question: Among human subjects, is exposure to natural environments associated with health and well-being outcomes? Outlined through the PICO format as (Richardson et al., 1995):

- Population: any human subjects (e.g., animal or plant-based subjects excluded)
- Intervention: any nature exposure (defined in the glossary and expanded on below)
- Comparator: No nature exposure or no comparator
- Outcome: any health and well-being outcomes (defined in the glossary)

The intervention defined

The intervention — 'nature exposure' — is the coming together of a person and the natural environment. Engagement with nature is an active form of this, but exposures may also be more passive (e.g., exposure to climate, extreme weather and ecological exposures).

Based on a preliminary review of the existing evidence in this area, this review discusses nature exposures under the following main headings:

- **General nature exposure** describes the measurement of the physical presence of nature rather than actual individual engagement with natural environments. Most commonly this is measured as quantity/presence of green and blue spaces in the local area, their proximity, quality and/or type. Exposure to extreme weather events, climate, and specific bits of nature (e.g., pollen and wildlife) would also fit within this broad category of general nature exposure.
- **Active engagement with nature** may be measured as the frequency and/or length of an individual's time spent in natural environments or instead as organised activity (often termed 'nature-based interventions'), and sometimes

part of a health/well-being intervention or therapy (often termed ‘green social prescribing’).

- **Exposure to contaminated nature** is the measurement of contaminants that people may be exposed to during time in natural environments. These include pollutants, toxins, chemicals and foreign objects found within water, air and/or on the land.
- **Exposure to nature improvement** is the measurement of improvements to nature that people may experience during time in natural environments. This may be improvements in the quality or quantity of nature, whether land, air or water quality. Engagement with activity intended to achieve improvements is also included in this category.

The review therefore does not include literature pertaining to exposures that focus on indoor environments. For example, it does not include workplace biohazards; plants, animals and air quality inside the home and built environments; exposure to nature through electronic devices such as virtual reality or television; and consumption of nature, such as food, water and medicines.

Method

This summary took the approach of a narrative review of reviews (see similar Hartig et al., 2014; Lovell et al., 2018). A review of reviews was more appropriate than analysis of primary research due to the wide scope and the number of reviews of primary research already completed for specific nature exposures. A narrative synthesis of these reviews was used to provide a full description of the body of review evidence and allow for insights to be drawn from this large body of heterogeneous research.

The identification of articles for consideration was systematic through a documented and replicable search approach, including clearly outlined PICO, inclusion criteria, search strategy and sifting process. Once articles suitable for inclusions were identified using this systematic search approach, the selection of specific articles for inclusion in the narrative review of reviews was based on purpose-driven criteria and so cannot be considered fully systematic (See Appendix A for information on PRISMA and PRIOR adherence). Final articles selected for inclusion were those most relevant to the UK context (e.g., to avoid reporting on outdoor activities, pollutants or natural disasters not tested or common within the UK context), most recent and comprehensive in each area, as well as those more systematic reviews. However, in areas where older or less systematic reviews were the only available evidence, these are included/reported to provide a complete narrative review of the state of evidence in this area (more detail is given in the following method sections and Appendix A).

Search strategy

Relevant literature was obtained using a search string (Appendix B) applied to Web of Science and Scopus (at two points, first 19th April 2022), with the final search complete on 2nd March 2023 with no date limit.

Search terms were developed based on known reviews in this area (e.g., Gascon et al., 2017; Lovell et al., 2020), combining their terms relating to the article type, the nature exposure, health and well-being outcomes and population, using appropriate wildcards and Boolean operators.

Key words included (detailed search string in Appendix B):

Article type: Meta analysis, review, briefing, systematic.

Population: human, child, people, youth, women, men, female, male, adolescent, participant, teenage, adult, citizen.

Exposure: environment, nature, green, green space, natural environment, open space, land, terrestrial, tree, outdoor, outside, park, forest, wildlife, wilderness, wood, plant, garden, vegetation, landscape, playground, mountain, blue space, water, blue, river, lake, sea, coast, marine, ocean, ecosystem, biodiverse, air.

Outcome: well-being, health, quality of life, life satisfaction, psychological, symptom, mortality, physical activity.

In addition to the search of academic databases, the citations of several recent umbrella reviews in the area were backward searched to identify reviews referenced within the article (Hartig et al., 2014; Lovell et al., 2018, 2020; Yang et al., 2021). Additional relevant grey literature was identified through organisational contacts. The complete search is detailed in a flow diagram in Appendix C (Figure 1).

Inclusion criteria

For inclusion in the review of reviews database and therefore consideration as part of those chosen for reporting within the written overview, reviews must:

- Be written in English language
- Be a review of any kind (e.g., scoping review, systematic review, meta-analysis, narrative synthesis), providing an outline of review methodology
- Review primary research that provides evidence for the outlined PICO (Richardson et al., 1995)

Selection of articles meeting these inclusion criteria was completed through title screening and extraction/relevance assessment stages outlined below.

Title screening

Articles from the original searches were collated and duplicates removed, leaving 2280 titles for screening. The purpose of initial title screening was to exclude articles:

- Not in English language
- Not looking at human subjects (e.g., animal or plant-based subjects)
- Not using a nature exposure (defined in Glossary)
- Without a health/well-being outcome (defined in Glossary)
- That were not reviews of evidence

Two reviewers (CH and RL) each completed title screening for 50% of articles and then checked the title screening of the other 50%. Disagreements in inclusion/exclusion decisions were checked by a third coder (FK), leaving 874 reviews that were entered into the review of reviews database for extraction and relevance assessment.

Extraction to database

Basic information was then extracted by one reviewer only (RL or CH) from the 874 papers remaining after title screening and 50% of these checked by the other reviewer. This was done by first using the title and abstract, and then looking into the full text where necessary to extract:

- Reference detail (e.g., date of publication)
- Target group/s
- Nature exposure/s
- Health and well-being outcome/s
- Review specification (e.g., date range of search, review type, inclusion of UK data)
- Review findings for nature exposure relationship to health/well-being outcomes

During this extraction process, more detailed reading of articles led to the exclusion of a further 580 reviews that did not meet inclusion criteria (screening completed by one reviewer only) and a final 294 reviews were listed as eligible for inclusion in the review of reviews.

Relevance assessment

Following extraction of key information and categorisation based on nature exposure, outcome, date and review type, it was possible to order reviews in a way that allows for the assessment of key reviews in each area (i.e. covering specific exposure and outcome combinations).

As all papers identified were reviews, there was some overlap in their scope (i.e. the primary research they collate). The extracted information therefore was used to assess review relevance and choose a final selection of reviews for inclusion in the review of reviews with minimal overlap. These were selected with the aim of presenting a comprehensive overview of the current research looking at the evidence for links between exposure to nature and human health and well-being. Out of the 294 eligible reviews, 104 (35.4%) were chosen for inclusion in this review of reviews and are reported in the following narrative summary and tables.

No formal 'quality' assessment of reviews was completed due to time and resource limitations. Instead, the relevance assessment was based on the grouping of reviews that covered the same/similar population group, nature exposure and health/well-being outcome. Once grouped, representative reviews were chosen based on those that were:

- Most recent- using date of publication.
- Most rigorous- with a clear outline of methods and prioritising meta-analyses and systematic reviews. However, other review types where included where these were not available and no concerns were raised by reviewers in terms of broader quality of the publication.
- Most relevant to the UK setting- using extent of UK-based primary research and through pragmatic decisions around relevance of nature exposure within the UK setting.

Where recency and rigour were at odds (such as a meta-analysis completed in 2016 vs. a scoping review completed in 2023), the insights of both reviews were assessed in detail to decide which one contributed most to the review of review insights. In exceptional circumstance where two reviews met the above criteria equally, conclusions have been included from both reviews and they are discussed in relation to each other.

Scope and limitations of the review

This review of reviews highlights some of the most comprehensive and recent papers to review a wide range of different nature exposures and health and well-being outcomes. In this way it shows the current scope of the literature, highlighting areas covered and gaps still outstanding. Beyond this, it can be used to identify where evidence shows associations (or lack of association) between exposure to nature and human health and well-being.

Note, it cannot be used to draw conclusions around associations that have yet to be tested (i.e. where there is not enough primary evidence/interest to warrant a review). Results should be interpreted in light of this potential for missing insights.

The review should also be considered and used with awareness of its methodological limitations, including:

- Due to the inclusion of some, but not all the identified papers due to overlap in scope (criteria described under 'extraction and relevance assessment'), the review and final assessment of the evidence base cannot be considered fully systematic and may not be exhaustive.
- Formal quality checks were not completed on articles included.
- The evidence reviewed largely shows associations between nature exposure and health/well-being outcomes and cannot be considered to show causality (unless explicitly stated) or make comment on the size of the effect (aka. the relative impact of different nature exposures on health/well-being).

Presentation of results

As described, exposure to nature is experienced in a wide variety of contexts and ways. For the purposes of this review, it has been split broadly as: general exposure to nature, active engagement with nature, exposure to contaminated nature, and exposure to nature regeneration/improvement.

In most cases the descriptors used by authors for their exposure of interest have been used, but in some cases, descriptions were changed if an exposure showed substantial cross-over/similarity to those in other reviews. For example, papers stating their primary focus is 'green social prescribing' and those focusing on 'nature-based interventions' may be broken down into their common exposures/descriptors, like 'gardening' or 'education' or 'exercise'.

For ease of interpretation, evidence of relationships has been graded based on the *conclusions drawn by paper authors* and the criteria outlined in Table 1. This approach is based on advice from methodological papers on the reporting of overviews of reviews (Aromataris et al., 2015) and the usefulness of similar approaches can be seen in other overviews of reviews (e.g., Lee & Maheswaran, 2011; Lovell et al., 2018, 2020). Where outcomes of similar reviews are discrepant, these are discussed within the narrative, considering differences between the reviews and discussing how much confidence this provides in findings.

Results are presented in three ways for ease of interpretation:

1. **A narrative synthesis** (presented as the text under sub-headings below) of the key evidence for associations, bringing together insights from the detailed summary tables.
2. **Summary tables** (at the end of narrative syntheses, Tables 2-5) showing key associations found between nature exposures and health/well-being outcomes in current literature as a quick summary of the detailed tables.

Table 1. Outline of coding and definitions used for grading evidence reviews.

Colour code and label	Definition
Significant	A meta-analysis was conducted, and a *relationship found* between the nature exposure and health/well-being outcome.
Supported	It was not possible to conduct a meta-analysis, but based on alternative synthesis/review of the evidence, the paper cited concludes that evidence is *supportive* of a relationship between the nature exposure and health/well-being outcome.
Marginal	A meta-analysis was conducted but the relationship between the nature exposure and health/well-being outcome was described as *marginal*.
Mixed	It was not possible to conduct a meta-analysis and based on alternative synthesis/review of the evidence, the paper cited concludes that there is *mixed evidence* of a relationship between the nature exposure and health/well-being outcome.
Not supported	It was not possible to conduct a meta-analysis, but based on alternative synthesis/review of the evidence, the paper cited concludes that evidence is *not supportive* of a relationship between the nature exposure and health/well-being outcome
Not significant	A meta-analysis was conducted, but a significant *relationship was not found* between the nature exposure and health/well-being outcome.
Inferred	The paper provides evidence of the existence of potentially beneficial/harmful nature exposures but is not a review of literature that directly tests association with human health/well-being. This is instead *inferred* based on the nature of the exposure (e.g., 'pathogens' are by definition 'disease/illness causing'), and/or another field of evidence (e.g., linking air quality and respiratory health in controlled settings), and/or findings within laboratory experiments (e.g., necessary when looking at things like brain activity in response to nature). Inferred findings are crossed with other categories e.g., 'inferred/significant' but will never be coloured higher than amber irrespective of significant/supported findings.
Inconclusive	The paper reports results around the relationship between the nature exposure and health/well-being outcome as *inconclusive* due to lack of evidence. Where a review synthesises <3 studies, findings are marked as 'inconclusive' as default.

3. **Detailed tables** (in Appendices D-F) summarising associations between nature exposures and health/well-being outcomes tested in current literature, including all associations (e.g., significant, supported, inferred, mixed etc.).

General nature exposure

This section provides a narrative synthesis and summary table (Table 2) of reviews measuring the association between general exposure to natural environments and health/well-being outcomes. This includes exposures that fit under the headings:

- Non-specific green space (Table D1)
- Objectively measured green space (Table D2 and D3)
- Green space type and qualities (Table D4, D5 and D6)
- Group focus: Children and young people's green space exposure (Table D7)
- Blue space (Table D8)
- Climate and extreme weather events (Table D9)
- Ecological air exposures (Table D10)

Non-specific green space exposure

A range of measurements of exposure to green space were found within the reviews, including mapped green space, green space type, quality and green space interventions (described in more detail in later sections of this report). Some reviews do not discriminate between these different measures and indicators of exposure to green space, instead reflecting more broadly on the associations between cross-cutting green space exposure and health and well-being outcomes. This first section therefore starts broad, bringing together conclusions from several key reviews that have taken this cross-cutting approach to green space exposure (Table D1). Later sections break this down, looking at individual indicators of green space exposure to provide greater nuance.

In terms of physical health, non-specific green space exposure has shown significant positive associations with the following through meta-analysis (Twohig-Bennett & Jones, 2018): improved physiological response (such as reduced heart rate, diastolic blood pressure, and salivary cortisol), better self-reported health and reduced incidence of a range of type-2 diabetes, improved birth outcomes (reduced risk of preterm birth and being small for gestational age) and mortality (all-cause and cardiovascular). However, alongside this there were several physiological, health, birth and mortality outcomes that either had minimal research or a significant effect had not been found, including decreased systolic blood pressure, reduced incidence of stroke, asthma and coronary heart disease, and acceptable gestational age.

Another systematic review not using meta-analysis supports the link between non-specific green space exposure and reduced incidence of cardiovascular disease (Geneshka et al., 2021), but reported more mixed findings for links to reduced incidence of diabetes, obesity and cancer (Geneshka et al., 2021).

A range of psychological outcomes have also been linked to non-specific green space exposure, including increased positive affect, reduced anxiety/stress and restoration (Lackey et al., 2021). There are mixed findings when looking at mental health more broadly, and depression and general well-being (Lackey et al., 2021). One review aimed to understand how childhood and other life course nature exposure relates to mental health outcomes later in life (Li et al., 2021). Associations between early and life-course nature exposure and reduced incidence of mental health disorders (from medical records) was most consistent. Findings for self-reported outcomes like psychiatric symptoms, cognitive function, and well-being were more mixed and moderated by a range of factors when examined longitudinally (Li et al., 2021).

Finally, non-specific green space exposure has also been linked to improved sleep quality and quantity (Shin et al., 2020) and improved cognitive functioning (Besser, 2021; Li et al., 2021), but there are mixed findings for associations with cognitive impairment or dementia (Besser, 2021).

Evidence looking at non-specific exposures to green space supports conclusions that there are both positive physical and mental health outcomes associated with green space exposure. These cut across physiological, birth, disease, sleep, cognition, and a range of positive psychological outcomes, but are far from consistent across health and well-being outcomes.

Objectively measured green space

Measures that quantify the extent of green space within the local area are often described as ‘objective’ measures of green space or vegetation cover. They most commonly use Geographic Information Systems (GIS) which connect green space data to maps. The connected green space data that is included varies in its source and type, but most commonly used is the Normalized Difference Vegetation Index (NDVI) which uses satellite data to identify small-scale vegetation cover. ‘Buffer zones’ around an individual (e.g., residential or work postcode) or location (e.g., school grounds, city-level) then provide average exposure indices at different levels or distances from the chosen location (e.g., 50 metres; Zhang et al., 2021). Although NDVI is most commonly used, Zare Sakhvidi et al. (2022) describe how some tools within this space allow for the mapping of different ‘land cover types’ also, considering potential different health impacts of different types of vegetation.

Due to the greater standardisation of measurement in this area, meta-analyses are possible. A number of meta-analyses have shown mixed results in terms of associations between objectively measured green space and physical and mental health outcomes (Table D2; Hu et al., 2021; Yuan et al., 2021; Zare Sakhvidi et al., 2022; Zhang et al., 2021).

Meta-analyses examining various cancer incidence, prevalence, and mortality outcomes in relation to mapped green space were unable to show significant associations with prostate, lung and breast cancer and findings were inconclusive for colorectal and all-site cancer. Meta-analysis was not possible for skin cancer, but findings from three studies suggested higher mapped green space was associated with *increased* risk of skin cancer (Zare Sakhvidi et al., 2022). Although the three studies this accounts for were not UK-based, this shows the possible risks associated with green space as well as positive health outcomes. Another meta-analysis, including only cohort studies (those that follow the same people over time) showed significantly lower all-cause and stroke mortality (but not cardiovascular, respiratory or ischemic heart disease mortality) among older people living in an area with more objectively measured green space (Yuan et al., 2021). The Yuan et al. (2021) meta-analysis was unable to replicate the findings of an earlier meta-analysis by Gascon et al. (2016). It this earlier meta-analysis they found that when including ecological and cross-sectional data (not just cohort studies), there was a reduction in cardiovascular disease risk for those living in areas with higher levels of green space (Gascon et al., 2016).

One meta-analysis showed positive associations between mapped green space and higher birth weights for babies, but no lesser risk of pre-term birth or babies being small for gestational age (Hu et al., 2021).

Evidence based on limited primary research suggests that mapped green space is associated with greater perceived restorativeness, but findings are mixed for other social, psychological and well-being outcomes such as physical activity, perceived stress, social cohesion, mental illness and well-being (Zhang et al., 2021).

Findings suggest that associations between objectively mapped greenspace and health and well-being outcomes are not usually significant when subjected to meta-analysis, but that some evidence supports an association with reduced mortality and birth outcomes. No reviews found evidence for a strong link with mental health and well-being outcomes.

Mapped green space in comparison to other exposure measures

This section outlines several papers that have sought to compare objectively mapped green space exposure and (usually) other indicators of green space

exposure, in terms of their relationship to health and well-being outcomes (Table D3).

Browning & Lee (2017; Table D3 ‘comparison 1’) reviewed the relative associations between mapped green space and broad physical health, split by different GIS buffer zones. This showed that findings were mixed at all levels of buffer zone, but that a positive association between mapped green space and physical health outcomes was more likely to be found with bigger buffer zones (up to 2,000m).

Lou et al. (2020; Table D3 ‘comparison 2’) further compared the use of NDVI to map green space with other ‘objective measures’—residential proximity to green space, number of parks in the area, and proportion of green space—as predictors of overweight/obesity. Meta-analyses showed a significant relationship between just NDVI and reductions in overweight/obesity, suggesting it is a more sensitive objective measure for predicting weight-based health outcomes.

Objective mapping of green space is just one indicator of green space exposure and cannot account for individual experience, including access and engagement with the mapped green space. Here we highlight some reviews that have made comparisons between the use of these more objective and other relational indicators of green space exposure.

Zhang et al. (2022; Table D3 ‘comparison 3’) were interested to explore whether objective measures of green space exposure (described as ‘material’) more strongly predicted health and well-being outcomes, or if ‘relational green space measurement’ whereby people self-report on availability of green space nearby is a stronger predictor. They conclude that although both relational and material green space evidence is largely supportive of a positive association with general health and well-being, and mental health, that a larger proportion of relational green space evidence supports this. Relational green space evidence also shows a positive association with physical activity and physical health, whereas evidence of association to material green space is more mixed according to this review (Zhang et al., 2022).

Houldon et al.’s (2018; Table D3 ‘comparison 4’) review also looked at different ways of operationalising green space exposure and how these related to improved mental well-being. Once again, the self-reported and more ‘subjective’ measures of nature connection showed more consistent results as a predictor of mental health outcomes than other measures such as visits to green space, green space accessibility, quantity and type.

Measuring objectively mapped greenspace may be more predictive of health outcomes with larger buffer zone and when NDVI is used (as opposed to measures of proximity or parks). However, overall findings suggest that

measures of nature exposure that capture more of people's access and experience of nature may be more strongly associated with health and well-being outcomes.

Green space type and qualities

Green space is a general term used for a range of environments that carry very different characteristics and qualities. In recognition of this a range of reviews have examined how these 'qualities' assessed in different ways might be linked to health and well-being outcomes. Here we split these into the examination of, 1) green space types, and 2) green space 'qualities'.

Green space types

Some research has chosen to focus on a particular 'type' of green space to look at the role that different green spaces play in health and well-being (Tables D4 and D5). In particular, much research has focused on the importance of urban green space due to its proximity to greater masses of people (Gianfredi et al., 2021; Hunter et al., 2019). Other research has examined individual types of green space, such as parks, gardens, forests and grassland (World Health Organisation, 2021). There is overlap in some of these categorisations, such as urban green space including some parks, forests and grassland, but reviews have nonetheless tried to unpick individual contributions to health and well-being through these distinctions.

Urban green space

Urban green space is described by Gianfredi et al. (2021) as including urban parks, but also other green areas that are much smaller in size and used by people for recreation (i.e. general neighbourhood green spaces). These may be meadows, forest, agricultural, educational and even include bodies of water.

There is evidence (Table D4) that the presence of and engagement with urban green space is associated with increased physical activity (Gianfredi et al., 2021; Kondo et al., 2018), improved short-term cardiovascular markers (like heart rate; Kondo et al., 2018), reduced incidence of some mortality (including cardiometabolic and respiratory; Fernández Núñez et al., 2022; Kondo et al., 2018; Mueller et al., 2022), and improved lung function (Mueller et al., 2022).

Urban greenspace is associated with notable mental health outcomes too (Gianfredi et al., 2021), including improvements in mood and reduced self-reported stress (Kondo et al., 2018; World Health Organisation, 2021), better subjective well-being and restorativeness outcomes (World Health Organisation, 2021), and improvements in attention (Kondo et al., 2018).

Overall evidence supports the conclusion that green space within the urban environment is associated with increased physical activity, some improvements in linked physical health outcomes (e.g., lung function, cardiovascular and mortality outcomes) and a range of improved mental health and well-being outcomes for those living nearby.

Other green space types

A 2021 report by the World Health Organisation examined in more detail six green space types (Table D5)—urban green space, parks, gardens, forests and woodlands cover, grassland cover, and plants, shrubs or vegetation cover—and their association with a range of mental health outcomes. This systematic review found that there was most evidence (either mixed or supportive) for the association between all green space types and higher positive affect and reduced perceived stress, however, all green space types showed some positive associations with one or more mental health outcomes and the review concludes that overall findings do not indicate one green space type to be superior to another (World Health Organisation, 2021). Other cross-cutting qualities may be more relevant as examined in the next section and outcomes for physical health remain unclear.

There were no clear differences in mental health outcomes when looking at different green space types (e.g., parks, grassland, gardens, woodland). Instead, there was support across most green space types for an association with higher positive affect and reduced perceived stress, as well as several other mental health outcomes.

Green space ‘qualities’

Some research has examined qualities of green spaces that are largely cross-cutting (not specific to green space ‘type’) that are thought to improve people’s experience and engagement with these spaces, and therefore the health and well-being benefits that can be gained from them (Table D6). These range from natural qualities such as biodiversity and connectivity of green space (the placement of green spaces close to one another), to built qualities, such as cleanliness, infrastructure and amenities.

Biodiversity is one ‘quality’ of green space that is often discussed as important for health and well-being. Research in this area uses a wide range of measures of biodiversity and health/well-being, meaning that all reviews conclude that it is difficult to characterise this relationship based on the available evidence (e.g., Houlden et al., 2021; Marselle et al., 2019). Whereas in 2019, Marselle et al. stated that evidence was inconclusive for links between biodiversity and mental health and well-being, Houldon et al. in 2021 were comfortable concluding that there is some limited evidence for links between biodiversity and similar subjective well-being outcomes. Evidence for other health outcomes is inconclusive (Houlden et al., 2021).

Nguyen et al. (2021) provided the most comprehensive review of research, amalgamating the literature for a range of ‘qualities’, both natural and built. This provided general support for the importance of examining green space qualities alongside mapping proximity and density, but also specific aspects of quality that should be considered. Diversity or presence of specific types of green land cover predicted improved health outcomes, as did the overall ‘naturalness’ of the green space. These qualities speak to the importance of the mix of vegetation people experience in green spaces. The positive associations found between larger and more connected green spaces also speak to the need to consider location and form of green spaces. Mixed results were found for safety. Other built qualities were either not supported or inconclusive, including infrastructure and amenities, cleanliness and peacefulness.

However, measures that consider multiple components of green space qualities (both natural and built) were found to predict improved health outcomes (Nguyen et al., 2021). These measures either ask people to rate their perceptions of the quality of green spaces or use composite measures of quality through audits/assessors. Although allergic respiratory conditions, cardiovascular conditions and psychological well-being were noted as some of the key health/well-being outcomes for these quality exposures, it was hard to summarise this due to the wide heterogeneity in outcome measures used within this research. Therefore, while the authors could say that there were broadly positive associations with outcomes, these must be labelled broadly as ‘health’.

Reviews examining green space qualities show that there is evidence for associations between a range of green space qualities and health, particularly natural qualities. Evidence for associations between biodiversity and health/well-being outcomes are largely mixed due to the range of operationalisations of biodiversity. However, there is evidence that factors like form and connectivity of greenspaces, as well as people’s perceived quality of these spaces are predictors of health.

Group focus: Children and young people’s green space exposure

The benefits of green space exposure for children and young people (CYP) have been looked at separately within this review of reviews. This is due to the large quantity of reviews for this group (Table D7) and the sometimes distinct uses and outcomes of nature exposure within the educational context.

Fyfe-Johnson et al.’s (2021) comprehensive review of nature and children’s health looks at broad green space exposures (mapped green space at home and school and a range of interventions) and a range of health and well-being outcomes for

those under the age of 19. They found evidence to support that broad green space exposure is beneficial for physical activity, and improved cognitive, behavioural and mental health. Evidence showing the benefits of nature exposure for reductions in weight, improved learning, reduced asthma/allergy and cardiovascular/metabolic outcomes were mixed. Ye et al. (2022) also found mixed evidence to support the relationship between broad green space exposure and improved mental health among CYP.

A meta-analysis of objectively mapped green space around children's homes reported a significant relationship between NDVI and reduced obesity/overweight, but not for asthma and allergic rhinitis (Ye et al., 2022). Two further reviews looking at neighbourhood green space found positive outcomes for the outdoor play and physical activity of very young children (aged under 7; Christian et al., 2015) but mixed outcomes for emotional and behavioural functioning and academic achievement (Davis et al., 2021).

Van den Bogerd et al.'s (2020) review of campus greenspace within tertiary and secondary education (aged >12) found positive associations with indicators of restoration, as well as mixed findings for well-being and academic outcomes. School yard greening initiatives in earlier years (age 2 to 15) show mixed effects on physical activity and socioemotional health (Bikomeye et al., 2021).

Van Hecke et al. (2018) present one of the few studies to look more at young people's perceptions of qualities of public open spaces. They look at this in relation to how often these spaces are visited and their relationship with physical activity. Their review presents a range of insights from qualitative research around the features that young people like and dislike in public open spaces, such as age-appropriate facilities, greenness, beautiful landscape and good maintenance. However, findings from the quantitative research reported was much less conclusive due to the large amount of heterogeneity within each 'quality' and lack of quantitative research and controlled comparison of different qualities. For example, they discuss 'Features (facilities and amenities)' as one quality, but this covers both built (e.g., recreational facilities, lighting, bicycle racks) and natural features (e.g., foliage, ponds and trees).

Reviews in this area vary in age range, exposures and outcomes. However, there is evidence that green space around CYP is beneficial for physical activity and outdoor play, reduced weight and restoration. Findings relating to wider aspects of physical and mental health and social-cognitive outcomes are less clear.

Blue space

Blue space exposures are situations where humans encounter outdoor water environments, such as coasts, rivers, canals, ponds, fountains and lakes. Although many of the green space reviews already discussed will include blue space as part of the natural environments looked at, some reviews have more specifically focused on the contribution of blue spaces. The reviews identified (Table D8) measure 'exposure to blue space' in several ways, including quantity and proximity of blue space nearby, number of visits to blue space, water therapies and urban blue space regeneration nearby.

A systematic review that includes a range of these exposure types in analyses found mixed results for improvements in physical activity, mental health and well-being, obesity, general health and cardiovascular health (Gascon et al., 2017). The reviewers were unable to complete meta-analysis due to the heterogeneity of the studies. A later review (including some of the same primary research) focused on a smaller number of studies relating to urban blue space and through meta-analysis found significant but small positive effects of exposure on reduced obesity and mortality, and improved self-reported general health, mental health and well-being. Findings for depression and anxiety were mixed (Smith et al., 2021).

Other reviews looked at individual types of blue space exposure to try and overcome some of this heterogeneity from disparate measurement. Most notably, Georgiou et al. (2021) completed meta-analyses for 'amount of blue space in the local area', 'proximity to blue space', and 'contact with blue space' (visits). The authors found that amount of blue space is significantly associated with increased physical activity and markers of mental restoration, but not increased social interactions. The proximity of this blue space was only associated with increased physical activity out of the three outcomes. Finally, contact with blue space (visits) was significantly associated with restoration, but there was not enough research to look at its links to physical activity or social interaction (Georgiou et al., 2021).

In urban areas, artificial water spaces, such as ponds and fountains were associated with restorative effects, although findings for physical activity and social interaction were more mixed (Xie et al., 2021).

Reviews of the more limited research in this area suggest that exposure to blue space is associated with greater physical activity (linked to this also obesity, general health and mortality), and self-reported mental health and well-being, such as restoration.

Climate and extreme weather events

It is not only our green and blue spaces that may impact on health and well-being, but also the climate and weather we are exposed to in these places. Worldwide, our climate is changing and extreme weather events are becoming more common. Here we bring together evidence on the health and well-being impacts of climate and extreme weather events within the UK context (Table D9).

Exposure to extreme temperatures, including both heat and cold, has been linked to increased mortality, especially among older adults (Bunker et al., 2016; Zanobetti & O'Neill, 2018), In addition, the synergistic relationship between hot weather and air pollution is associated with increased morbidity and mortality, most often linked to respiratory illness (Grigorieva & Lukyanets, 2021; Hu et al., 2022). This is shown by looking at associations between health outcomes and increased concentration of air pollutants during high temperature episodes. These effects are found to be stronger for older people and young children (Grigorieva & Lukyanets, 2021) and vary depending on the pollutant examined (Hu et al., 2022). However, it is noteworthy that most research on this topic is set outside of the UK where greater extremes in temperature are experienced.

Research based within the UK has also looked at the impact of floods, showing that there is some (limited) evidence for the negative impact of floods on mental health, such as PTSD, depression and anxiety (Lee et al., 2020). Some research on increased risk for older people (Parker et al., 2016), increased risk to health due to contaminated water during floods (Cook et al., 2008) and higher rates of PTSD among survivors of landslide also exist (Kennedy et al., 2015) but are each presented in just one study and so not included in this review.

Together these reviews suggest that extreme temperatures (both hot and cold), and the synergistic impact of increases in temperature with air pollution increase morbidity and mortality, with greatest risk for older people and young children. There is limited research on the impacts of extreme weather events in the UK on health and well-being, such as the impacts of floods on mental health.

Ecological air exposures

There is limited evidence for the association between ecologically based exposures in the air and health outcomes (Table D10). One review looked at cyanobacterial algal bloom aerosols, where inhalation causes allergy, inflammation of the lungs, eyes and skin, and acute gastrointestinal illness (Wiśniewska et al., 2019).

Pollen exposure can produce an asthmatic response, most commonly affecting those who are younger or have pre-existing hay fever or asthma (Annesi-Maesano et al., 2023). The most comprehensive review to-date in this area reported significantly worse asthmatic outcomes from meta-analyses of data for the effects of grass pollen, but also showed support (from narrative review of studies) for worse outcomes for those under the age of 18 for tree pollen and total pollen in the air. More homogonous studies in this research area would enable further meta-analysis and stronger conclusions around pollen types and wider health outcomes (Annesi-Maesano et al., 2023). Another review investigated the synergistic interaction between air pollution and allergens, showing mixed findings as to whether allergens and air pollution in the air interact to worsen health outcomes (Lam et al., 2021).

The limited research on ecological air exposures shows a negative association with respiratory health outcomes, but it should be noted that this is limited to the largely localised exposure to algal blooms and seasonal exposure to pollens.

Table 2. Summary of positive and negative associations between general nature exposure and health and well-being outcomes, split by level of evidence.

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
Non-specific green space (Table D1)	**Positive** **Physical health/activity:** ↑ self-reported health [n≥10] ↓ physiological stress response e.g., diastolic blood pressure [n≥10], heart rate [n≥10] and salivary cortisol ↓ incidence of type 2 diabetes **Birth outcomes:** ↓ risk of preterm birth ↓ risk of small for gestational age **Mortality:** ↓ all-cause mortality	**Positive** **Mental health/well-being:** ↓ incidence of mental disorders [n≥10] ↓ anxiety/stress [n≥10] ↑ positive affect [n≥10] ↑ restoration **Physical health/activity:** ↑ sleep [n≥10] ↓ incidence of cardiovascular disease **Social/cognitive outcomes:** ↑ cognition [n≥10]	**Positive** **Mental health/well-being:** ↓ depression/ psychiatric symptoms ↑ well-being **Physical health/activity:** ↑ physical activity [n≥10] ↓ incidence of diabetes ↓ incidence of obesity ↓ incidence of cancer **Social/cognitive outcomes:** ↓ incidence of cognitive impairment/dementia	**Positive** **Physical health/activity:** ↓ systolic blood pressure [n≥10] ↓ incidence of hypertension ↓ incidence of stroke **Birth outcomes:** ↑ acceptable gestational age	Not applicable
Objectively measured green space (Table D2)	**Positive** **Birth outcomes:** ↑ improved birth weights [n≥20] **Mortality:** ↓ all-cause and stroke mortality- older people	**Negative** **Physical health/activity:** ↑ skin cancer incidence, prevalence and mortality (not UK-based research)	**Positive** **Mental health/well-being:** ↓ mental illness [n≥10] ↑ mental well-being [n≥10] ↓ stress **Physical health/activity:** ↑ physical activity [n≥10] **Social/cognitive outcomes:** ↑ social cohesion and support	**Positive** **Birth outcomes:** ↓ risk of pre-term birth [n≥20] ↓ incidence of small for gestational age [n≥20] **Physical health/activity:** ↓ lung, prostate and breast cancer incidence and prevalence. **Mortality:** ↓ lung, prostate and breast cancer mortality	Not applicable

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
				↓ respiratory, cardiovascular, and ischemic heart disease mortality	
Urban green space (Table D4)	Not applicable	**Positive** **Mental health/well-being:** ↑ mental health [n≥10] ↑ mood [n≥10] ↓ stress [n≥10] ↑ subjective well-being ↑ restoration **Physical health/activity:** ↑ physical activity [n≥10] ↑ lung function [n≥10] **Social/cognitive outcomes:** ↑ attention [n≥10] **Mortality:** ↓ respiratory [n≥10], cardiometabolic and all-cause mortality	**Positive** **Physical health/activity:** ↓ incidence of asthma [n≥30] ↓ respiratory hospital visits [n≥10] ↓ incidence of lung cancer [n≥10] ↓ incidence of rhinitis [n≥10] ↓ respiratory symptoms [n≥10] ↓ obesity [n≥10]	Not applicable	Not applicable
Group focus: Children and young people's green space exposure (Table D7)	**Positive** **Physical health/activity:** ↓ obesity	**Positive** **Mental health/well-being:** ↑ restoration **Physical health/activity:** ↑ outdoor play and physical activity [n≥40] **Social/cognitive outcomes:** ↑ cognitive, behavioural and mental health [n≥40]	**Positive** **Mental health/well-being:** ↑ mental health [n≥40] ↑ well-being **Physical health/activity:** ↓ asthma/allergy [n≥20] ↑ circulatory health [n≥10] ↑ cardiovascular and metabolic outcomes **Social/cognitive outcomes:**	**Negative** **Physical health/activity**: ↑ incidence of asthma [n≥10] ↑ incidence of allergic rhinitis	**Positive** **Social/cognitive outcomes:** ↓ prevalence of doctor diagnosed disorders- ADHD and Autism

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
			↑ learning [n≥20] ↑ socioemotional health ↑ academic outcomes		
Blue space (Table D8)	**Positive** **Mental health/well-being:** ↑ mental health and well-being ↑ markers of restoration **Physical health/activity:** ↑ physical activity [n≥10] ↑ general health ↓ obesity **Mortality:** ↓ mortality	Not applicable	**Positive** **Mental health/well-being:** ↓ depressive symptoms and anxiety **Physical health/activity:** ↑ cardiovascular health **Social/cognitive outcomes:** ↑ social interaction	Not applicable	Not applicable
Climate and extreme weather events (Table D9)	**Negative** **Physical health/activity:** ↑ respiratory illness [n≥20] ↑ genitourinary problems ↑ diabetes mellitus **Mortality:** ↑ cardiovascular [n≥40], respiratory [n≥30] and cerebrovascular [n≥10] mortality ↑ all-cause mortality [n≥20]	**Negative** **Physical health/activity:** ↑ morbidity (predominantly respiratory) [n≥10]	**Negative** **Physical health/activity:** ↑ cardiovascular illness [n≥20] ↑ infection-related morbidity	**Negative** **Physical health/activity:** ↑ cerebrovascular illness [n≥10]	Not applicable
Ecological air exposures (Table D10)	**Negative** **Physical health/activity:** ↑ in severe asthma exacerbations	**Negative** **Physical health/activity:** ↑ in emergency department visits and hospital admissions	Not applicable	**Negative** **Physical health/activity:** ↓ lung function	Not applicable

Note 1: This table is a summary of more extensive Tables in appendix D which includes references and further details of exposures.

Note 2: The ‘n’ next to outcomes denote the number of primary studies reported within the review that features the outcome. Only reviews with n>2 are included and those without an ‘n’ will have included <10 primary studies.

Note 3: Some Tables from appendix D are not summarised here due to complexity in exposures making this difficult, and so please refer to full tables for Table D3, D5 and D6.

Note 4: ‘Level of evidence’ refers to gradings in Table 1.

Active engagement with nature

This section provides a narrative synthesis and summary table (Table 3) of reviews that measured people's active engagement with natural environments alongside various health/well-being outcomes.

When trying to assess how people's active engagement with nature relates to health and well-being outcomes, nature exposures are often described as 'nature-based interventions' (NBIs). NBIs assume a range of activities and types of engagement, including gardening, exercise, sedentary activity and therapeutic activities. This section therefore looks at the exposures:

- Non-specific nature-based interventions (Table E1)
- Gardening and gardens (Table E2)
- Exercising outdoors (Table E3)
- Other therapeutic nature-based interventions (Table E4)
- Blue space interventions (Table E5)
- Group focus: Children and young people's active engagement with nature (Table E6)

Non-specific nature-based interventions

Some reviews do not discriminate between these different measures and indicators of engagement with nature, instead reflecting more broadly on the associations between cross-cutting NBIs and health and well-being outcomes (Table E1). This first section therefore starts broad once again, bringing together conclusions from several key reviews that have taken this approach. Later sections break this down, looking at individual types of NBI to provide more nuance.

A meta-analysis of NBIs has shown positive associations with reductions in depressive mood (Roberts et al., 2019), but wider systematic reviews show less consistent (mixed) associations with improved cardiovascular outcomes (Bikomeye et al., 2022), and broad mental, physical and well-being outcomes (Wilkie & Davinson, 2021). All studies note the heterogeneity in findings due to the large range of variability in both the exposure and outcomes. Therefore, these findings should be taken with caution.

Evidence for an association between NBIs and improved social and emotional outcomes for those with neurological disabilities (predominantly dementia) were noted in a review by Lakhani et al. (2019). One review relating to people with stress-related illness was also included due to its unique target group. The qualitative and

quantitative findings of the primary research it reviews highlights a broad range of mechanisms through which NBIs might support people with stress-related illness (e.g., through interactions with others, meaningful activity and increasing self-efficacy). In terms of health and well-being outcomes it largely supports the association between NBIs and improved health and well-being measured using a wide range of indicators, and shows more mixed findings for restoration and stress reduction (Johansson et al., 2022).

Findings for broad NBIs are largely mixed due to heterogeneity in the intervention and expected outcome types. However, there is evidence for reductions in depression and reviews focusing on particular clinical groups, including those with dementia and stress-related illness show promising indications that NBIs may benefit social and emotional outcomes.

Gardening and gardens

Some reviews looking at gardens/gardening (Table E2) include private gardening activity which is completed most often alone or with family and measured based on frequency of activity (Soga et al., 2017). However, more often reviews focus on community-based gardening or therapeutic gardening interventions (Kunpeuk et al., 2020; Tharrey & Darmon, 2022). Community gardening can take place in both private and public land, but involves the joint gardening of the space for non-commercial purposes (Kunpeuk et al., 2020). 'Urban collective gardening' examined by Tharrey and Damon (2022) is more inclusive in the sense that it refers to both community gardening and the use of separate allotments on a shared site, but is less inclusive due to its urban focus. Both reviews of community and urban collective gardening were included however as there was some, but not wide cross-over in primary research included. Gardening is often used as a well-being intervention due to its forecasted benefits for social, psychological and physical outcomes. This can be more formalised horticultural therapy (with a trained practitioner) or group-based activity, as well as being held within care institutions, the community and within education.

The meta-analyses included suggest there is a significant association between gardening activity and better broad health outcomes (e.g., mood, depression and body mass index; Soga et al., 2017), psychosocial well-being (e.g., loneliness, sense of community and trust; Spano et al., 2020) and reduce body mass index (Kunpeuk et al., 2020).

Evidence for community and collective gardening subject to systematic review show positive associations with improved mental health and nutrition through increased fruit and vegetable consumption, but less consistent associations with physical

health outcomes such as reduced body mass index, increased physical activity and improved physical health (Kunpeuk et al., 2020; Tharrey & Darmon, 2022).

Evidence shows that gardening interventions are associated with reduced depression and anxiety for people with mental health difficulties (Clatworthy et al., 2013). However, Briggs et al.'s (2023) meta-analysis of the impact of group-based gardening interventions for clinical (those with physical and/or mental health diagnoses) and non-clinical groups builds on this. Meta-analyses showed a significant association between group-based gardening interventions and improved well-being, but inconclusive evidence to support links with reduced depression, anxiety and stress, and improved quality of life. As with many of these reviews, varied study designs meant that there was large heterogeneity in the data and several studies were excluded from meta-analysis due to unsuitability.

Evidence for those living in care homes with dementia is largely inconclusive, possibly due to the lack of primary evidence or an available updated review of this evidence (Whear et al., 2014). Due to the challenges of outcome measurement (e.g., self-reported depression and anxiety) among those with communication difficulties, judgements of impact are often reliant on the reporting of care staff and family members. This reporting may be less sensitive to change in internal state and reliant on value judgements such as what level of sedentary behaviour or sleep patterns are 'better' (Whear et al., 2014).

Overall, there is promising evidence for the benefits of gardening activity for social, psychological and nutritional outcomes. However, more could be done to evidence the benefits for specific clinical groups based on their distinctive needs.

Exercising outdoors

The benefits of exercising outdoors as opposed to indoors have been examined in relation to a range of sports, most often walking, running and cycling (Table E3). Two of the most recent and comprehensive meat-analyses in this area (Brito et al., 2021; Li et al., 2022) found that exercising is typically associated with significant increases in positive psychological outcomes (e.g., higher positive affect and relaxation) and reductions in negative psychological outcomes (e.g., anger, depression, anxiety and stress). However, exercising outdoors showed mixed effects on indicators of performance efficiency, including significantly lower fatigue and higher levels of vigour, marginally lower cognitive performance, and no difference in cardiac output (Brito et al., 2021).

One meta-analysis reported that those taking part in outdoor walking groups have significantly better health outcomes, including cardiovascular, weight-related (body

fat, body mass index and cholesterol), and fitness related outcomes (VO2max and walking speed; Hanson & Jones, 2015). They also showed more positive self-reported physical functioning and reduced depression. However, these positive effects did not extend to wider self-reported mental health, blood profiles or waist circumference (Hanson & Jones, 2015). A review of the benefits of walking groups for those with mental health problems focused on mental health outcomes, reporting a positive association between group attendance and mood, but limited or inconclusive evidence for improved self-esteem and reduced depression (although likely due to limited primary research; Swinson et al., 2020).

Reviews of nature-based exercise sometimes also look at sedentary nature-based activity/seated relaxation in nature as a comparison (Table E3, 'comparison 1' and 'Comparison 2'). Comparisons of the same health and well-being outcomes between more active (e.g., walking) and more sedentary (e.g., seated relaxation) activity outdoors show very little difference in physiological (serum and salivary cortisol, heart rate variability) and mood outcomes (Mygind et al., 2021; Roberts et al., 2019).

Bolouki (2023) instead reviewed studies that compare real or virtual exposure to urban built and natural environments, finding favourable brain activity for more natural environments (showing more meditation, relaxation, and restoration, and less arousal and frustration). Due to the complex nature of measuring brain activity, this exposure was always sedentary, sometimes within the laboratory setting (exposure to virtual nature scenes) or in-situ.

Together this research shows the potential for outdoor exercise (with most examples looking at walking) to support positive outcomes, in particular improved cardiovascular health and improved psychological outcomes. When compared to exercise outdoors, sedentary activity has shown some similar beneficial outcomes (limited research).

Other therapeutic nature-based interventions

Sometimes engagement with the natural environment and these outdoor activities can take the form of a therapeutic intervention, whereby it is undertaken with the explicit intention of benefitting mental and/or physical health.

This is sometimes referred to as 'Green social prescribing' (GSP), 'nature-based social prescribing' or 'nature-based therapeutic interventions'. GSP is a sub-set of broader social prescribing practices which link people (through both clinical practitioners, community link workers and self-referral) to community-based resources and activities that aim to improve mental health and well-being (Garside et al., 2020). Many of the reviews already discussed will have included interventions that were therapeutic, and it has been outlined when the reviews relate to a

particular clinical group. These are more likely to involve some form of GSP. As GSP is a relatively new term used to describe the act of referring people to these interventions, evidence is more likely to show evidence for the links between the intervention activity and health and well-being outcomes, than links between the act of social prescribing and health and well-being outcomes. No reviews of GSP and health and well-being outcomes were identified for inclusion within this review of reviews.

In addition, some interventions such as care farming are more *explicitly designed* as therapeutic (Table E4). Care farming is the use of farm space and agricultural practices for the therapeutic benefit of groups like those with mental health problem, substance misuse, offenders and older people. The most recent review in this area found that the lack of primary research made drawing conclusions about the benefits of care farms difficult, and for the largest researched group (those with mental health problems and/or substance misuse) findings were largely mixed or not significant (Murray et al., 2019). Findings around care farm benefits for health and well-being are therefore inconclusive.

Overall, reviews provide very little conclusive evidence around the mental health and wider benefits of care farms for clinical groups. More primary research is needed in this area to allow for review.

Blue space interventions

Much less research has been completed looking at the relationship between nature-based interventions in blue space and health and well-being outcomes (Table E5). One review of the use of blue space accessed through water therapy for individuals with mental and/or physical health needs supports the conclusion that water-based therapy is associated with positive psychological and social outcomes, including indicators such as self-esteem, social confidence, and resilience (Britton et al., 2020). Evidence for similar effects on physical health outcomes was limited and long-term effects unclear (Britton et al., 2020).

One review highlights the positive psycho-social outcomes associated with a range of water-based therapies, but the lesser amount of research in this area compared to other nature-based interventions is notable.

Group focus: Children and young people’s active engagement with nature

Reviews focusing on children and young people (CYP) once again have been separated out (Table E6). A review by Gray et al. (2015) found consistent findings

that more time spent outdoors among children (aged 3 to 12 years old) is associated with reduced sedentary activity and increased physical activity. However, this review was unable to draw conclusions around the impact of this on cardiorespiratory and musculoskeletal outcomes due to lack of research (Gray et al., 2015). One review examined the benefits of green exercise more specifically but concluded that due to the heterogeneity in literature they were unable to draw conclusions regarding its benefits (Mnich et al., 2019).

Several reviews have looked at more specific green space interventions for children, particularly within the educational setting. One review (Qi et al., 2021) was able to look at school gardening activities and how these relate to fruit and vegetable consumption and weight-based health indicators (body mass index and waist circumference) using meta-analysis. It was found that the activity was related to increased fruit and vegetable consumption but not improved weight indices (Qi et al., 2021). Another review concerned with 'nature play' among 2 to 9 year olds found mixed results for improved physical activity, play and social outcomes (Dankiw et al., 2020). This lack of consistency with other reviews showing increased physical activity with exposure to nature among children is likely to be due to the comparison with other more traditional playground activity (often sports and games) rather than indoor/sedentary alternatives.

As with general green space exposure, getting outdoors more and green space interventions with CYP are associated with increased physical activity. Gardening-based activities have also shown benefits for fruit and vegetable intake, but more research is needed to understand any wider physical and mental health benefits for CYP beyond this.

Table 3. Summary of positive and negative associations between active engagement with nature and health and well-being outcomes, split by level of evidence.

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
Non-specific nature-based interventions (Table E1)	**Positive** **Mental health/well-being:** ↓ depressive mood [n≥30]	**Positive** **Mental health/well-being:** ↑ emotional health- people with dementia [n≥10] **Social/cognitive outcomes:** ↑ social health- people with dementia	**Positive** **Mental health/well-being:** ↑ mental health and well-being [n≥40] ↑ psychological health- people with dementia **Physical health/activity:** ↓ physiological stress response [n≥20] ↑ physical health [n≥30]	Not applicable	Not applicable
Gardening and gardens (Table E2)	**Positive** ↑ Better health (broad mental and physical) [n≥20] **Mental health/well-being:** ↑ psychosocial well-being **Physical health/activity:** ↓ body mass index	**Positive** **Mental health/well-being:** ↑ Improved mental health ↓ depression- people with mental health issues ↓ anxiety- people with mental health issues **Physical health/activity:** ↑ nutrition (fruit and vegetable consumption) [n≥10]	**Positive** **Mental health/well-being:** ↓ dementia-related behaviours (e.g., agitation, pacing and violence) **Physical health/activity:** ↑ self-reported physical activity ↑ physical health	Not applicable	**Positive** **Mental health/well-being:** ↑ health-related quality of life- including clinical groups **Physical health/activity**: ↑ physical outcomes- people with dementia (including improved sleep, physical exercise and reduced falls)

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
Exercising outdoors (Table E3)	**Positive** **Mental health/well-being:** ↓ anger [n≥10] ↓ confusion [n≥10] ↓ fatigue [n≥10] ↓ depression [n≥10] ↓ tension [n≥10] ↑ vigour [n≥10] ↑ feeling comfortable ↓ anxiety ↓ stress ↑ feeling relaxed ↑ feeling natural ↑ positive affect ↓ negative affect **Physical health/activity:** ↓ perceived fatigue [n≥10] ↑ health outcomes [n≥10] ↑ cardiovascular measures [n≥10] ↑ VO_{2max}	**Positive** **Mental health/well-being:** ↑ mood- people with mental health issues	**Positive** **Social/cognitive outcomes:** ↑ cognitive performance	**Positive** **Mental health/well-being:** ↑ restorativeness **Physical health/activity:** ↑ exercise performance efficacy ↑ cardiac output related to exercising ↑ blood profiles (lipids, HbA1c) [n≥10]	Not applicable
Blue space interventions (Table E5)	Not applicable	**Positive** ↑ psycho-social well-being- people with mental or physical health issues [n≥20]	**Positive** **Physical health/activity:** ↑ physical health- people with mental or physical health issues	Not applicable	Not applicable
Group focus: Children and young	**Positive** **Physical health/activity:**	**Positive** **Mental health/well-being:**	**Positive** **Mental health/well-being:** ↑ mental health [n≥10]	**Positive** **Physical health/activity:** ↓ waist circumference	Not applicable

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
people's active engagement with nature (Table E6)	↑ nutrition (fruit and vegetable intake)	**Physical health/activity:** ↑ physical activity [n≥10] ↓ sedentary behaviour	↑ self-esteem **Social/cognitive outcomes:** ↑ play (e.g., constructive, imaginative and associative) ↑ social outcomes (e.g., teacher and peer interactions and antisocial behaviour)	↓ body mass index	

Note 1: This table is a summary of more extensive Tables in appendix E which includes references and further details of exposures.

Note 2: The 'n' next to outcomes denote the number of primary studies reported within the review that features the outcome. Only reviews with n>2 are included and those without an 'n' will have included <10 primary studies.

Note 3: Table E4 is not summarised here due to lack of notable insights.

Note 4: 'Level of evidence' refers to gradings in Table 1.

Exposure to contaminated nature

This section provides a narrative synthesis and summary table (Table 4) of reviews that look at the health and well-being implications of people's exposure to nature that has been contaminated by human activity.

Exposure to 'contaminants' describes a range of pollutants, toxins, chemicals or foreign objects. The narrative summary below represents those for which research has been completed in the UK, while recognising that a range of other contaminants effect other countries due to wider industry and different levels of regulation against contaminants. Reviews that included UK data on both contaminants and health and well-being outcomes can be summarised under the two main headings:

- Contaminated water (Table F1)
- Air pollution (Table F2-F5)

Contaminated water

There is evidence for the health/well-being outcomes associated with pathogens in water used for recreation (Table F1). A meta-analysis determined contact with pathogens in blue space was linked to illnesses including gastrointestinal illness and respiratory illness, and that illness was more likely for swimming and sports-related contact with bathing waters (Russo et al., 2020). There were further significant findings for increased risk of infections of the skin, ears, eyes, nose, and throat, and cold/flu symptoms resulting from open water swimming (Russo et al., 2020).

Farrell et al. (2021) found evidence of a substantial number of pathogens—disease causing organisms—not included in the EU bathing water directive in designated bathing waters around Europe, including the UK. However, as this research did not include measurement of a health outcome, the evidence is classified as inferred. This tells us that the presence of waterborne organisms within bathing waters have the potential to cause illness or harm to humans.

It is clear from these reviews that those doing water-based recreation are more likely to be exposed to waterborne organisms that could cause harm/illness. Contaminated water used for recreation poses a risk to human health, in particular causing gastrointestinal and respiratory problems, but also skin, ear/nose/throat/eye problems, as well as cold/flu symptoms.

Air pollution

Once again starting broad, evidence for the effect of ambient air pollution on health is first discussed. Following this, evidence relating to particulate matter and several other key air pollutants is discussed. Finally, reviews looking at the impact of exercising in polluted air are summarised.

Ambient air pollution

Ambient air pollution is a broad term used to describe air pollution in outdoor environments. This includes pollutants from industry, transport, agriculture and other sources (Table F2).

There is conclusive evidence that ambient air pollution has a negative impact on general health as shown by Dominski et al.'s (2021) review of reviews. Reviews looking at primary research in this area show that there is extensive evidence for the links between ambient air pollution and worse health records (predominantly mortality), and incidence of respiratory and cardiovascular diseases (Sun & Zhu, 2019). These findings are reinforced by other similar reviews completed in this area but too similar for inclusion within this review of reviews (Bazyar et al., 2019). There is also growing evidence for links between ambient air pollution and increased incidence of chronic diseases, worse pre-natal, birth and early childhood outcomes, and increased incidence of cancer (lung and breast in particular; Sun & Zhu, 2019; Vrijheid et al., 2016). However, other reviews in this space have been more tentative about the conclusiveness of these links based on the lack of evidence for specific illnesses within these broader groups (such as specific cancers; Bazyar et al., 2019). Although evidence from the UK is limited, there is international research showing possible implications of air pollution for eye health (Alryalat et al., 2022).

In populations with coronary artery disease, evidence supports links between ambient air pollution with reduced cardiac function, showing the burden that air pollution may place on at-risk groups (Warburton et al., 2019).

Sun and Zhu (2019) report on many studies that find correlations between ambient air pollution and 'mental disorders', covering a wide range of neurological and mental health issues (e.g., cognitive function, depression/stress and Parkinson's disease). Once again however, Bazyar et al. (2019) are more tentative about conclusions for what they group as 'neurologic diseases' (including stroke and Parkinson's). Research looking at specific neurological or mental health outcomes (rather than grouping them as one outcome) may be able to draw clearer conclusions for the impact of air pollution on neurological and mental health outcomes. Linked to this, one review reports on a small number of studies that have shown greater inactivity

among those in more polluted areas, which may have wider implications for physical and mental health (An et al., 2018).

Exposure of to-be mothers to ambient air pollution has been linked to worse birth outcomes such as abnormal birth weight, increased risk of macrosomia and pre-term birth (Gheissari et al., 2022). Then in young children aged 0-5, ambient air pollution is linked to worse respiratory outcomes (particularly asthma) are evident (Spencer-Hwang et al., 2023), and a later review of research with children aged 0-10 found evidence for links to increased obesity and metabolic disorders (e.g., higher BMI, risk of diabetes and hypertension), worse respiratory and allergic outcomes (e.g., reduced lung function, increased respiratory tract infections and asthma) and adverse neurodevelopmental outcomes (e.g. impaired cognitive, motor, behavioural and language development; Gheissari et al., 2022).

Overall, worse health outcomes with clear links to ambient air pollution are all related to physical health, most notably: mortality, and increased respiratory and cardiovascular diseases. Child development and health is particularly vulnerable to the negative impacts of ambient air pollution. Evidence for links between ambient air pollution and mental health are less clear.

To better unpick relationships with health, air pollution research often considers pollutants individually, with most research looking at particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2) and carbon monoxide (CO). The findings of reviews for each of these, as well as other less common air pollutants are now summarised. The conclusions for these air pollutants are drawn from reviews including UK-based data, but broadly align with a comprehensive international meta-analysis in this area by Markozannes et al. (2022).

Particulate matter

Particulate matter (Table F3) refers to a heterogeneous mix of particles—both natural and man-made—that are released into the air from a range of sources, like vehicle and industrial emissions, dust and smoke. Particulate matter is often very small, and so categorised based on particle diameter. A 10 to 2.5 micrometre diameter is commonly denoted for larger particles, with particle smaller than this being called fine and ultrafine (<0.1 micrometer diameter).

A wide range of negative cardiovascular health impacts have been linked to exposure to particulate matter, including incidence of linked hospital admissions, disorders (cardiovascular disease, high blood pressure and coronary events) and mortality (all-cause, stroke, cardiovascular, and ischemic heart disease mortality; Niu et al., 2021; Pranata et al., 2020). Smaller bodies of research have linked exposure to PM_{10} with increased cancer mortality (Kim et al., 2018) and exposure to particulate

matter more broadly with increased respiratory hospital admissions and mortality (Anderson et al., 2012). For expectant mothers, exposure to particulate matter during pregnancy poses risks of pre-term birth (Klepac et al., 2018) and is associated with greater risk of infant mortality between the ages of 0 and 5 (Karimi & Shokrinezhad, 2020).

Reviews of the psychological impacts of particulate matter are largely inconclusive. Although Trushna et al. (2021) were able to meta-analyse a number of studies looking at psychological health, finding a significant association between increases in PM_{10} and psychological stress. Findings unexpectedly showed a slight decrease in anxiety disorders with increases in PM_{10} and $PM_{2.5}$. The authors however recommend that these findings be interpreted with caution due to their misalignment with existing knowledge in this area and the possibility that confounding factors that relate to living in more polluted areas (e.g., access to health care, education and recreation) may account for this finding.

Overall, existing reviews provide strongest evidence for an association between exposure to particulate matter and worse cardiovascular outcomes and mortality, as well as birth/early years and respiratory outcomes. It is less clear how exposure to particulate matter relates to psychological outcomes, although there is some evidence for links to increased psychological stress.

Other air pollutants

The most conclusive evidence for other sources of air pollution (Table F4) is for nitrogen dioxide which most commonly originates as nitrogen oxides (NO_x) from combustion. Nitrogen dioxide (similarly to particulate matter) is associated with worse cardiovascular (Niu et al., 2021; Pranata et al., 2020; Stieb et al., 2021), cancer (Kim et al., 2018; Stieb et al., 2021), birth and early years (Karimi & Shokrinezhad, 2020; Klepac et al., 2018; Li et al., 2012), and respiratory outcomes (Li et al., 2012; Stieb et al., 2021).

Carbon monoxide, sulphur dioxide, and ozone in the air have all been linked to stroke-related hospital admissions (Niu et al., 2021), carbon monoxide and sulphur dioxide have further links to infant mortality (Karimi & Shokrinezhad, 2020) and carbon monoxide shows links to worse pregnancy outcomes (Stieb et al., 2012). Many other potentially dangerous air pollutants exist, but may be less common in the UK (Stanek et al., 2011).

Beyond particulate matter, nitrogen oxides, carbon monoxide, sulphur dioxide, and ozone are the other air-based pollutants most likely to negatively impact human health in the UK. Once again, these are most likely to be linked to worse respiratory, cardiovascular, birth and mortality outcomes.

Exercise in polluted air

Exercise outdoors is of interest because it has the potential to both improve health through increased aerobic exercise, but also expose people to higher levels of air pollution which may attenuate these positive effects (as shown by reviews summarised in earlier sections). Several reviews have explored this interaction between exercise and air pollution on health outcomes (Table F5). It has already been noted that air pollution may reduce people's physical activity behaviours (An et al., 2018). Further reviews conclude that evidence using healthy subjects does not always show declines in lung function after exercise in polluted air and can even show some immediate increases. However, research with 'susceptible groups' (e.g., children, those with asthma or COPD) were more likely to provide evidence for the negative health impacts (both cardiovascular and respiratory) of exercising in polluted air (Madureira et al., 2019; Tainio et al., 2021).

Reviews of the health impacts of exercise in polluted air largely conclude that the benefits of increased physical activity on health outweigh the detrimental impacts of air pollution, but that research quality in this area is poor.

Table 4. Summary of positive and negative associations between contaminated nature and health and well-being outcomes, split by level of evidence.

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
Contaminated water- water-based recreation (Table F1)	**Negative** **Physical health/activity:** ↑ gastrointestinal illness [n≥40] ↑ respiratory illness [n≥10] ↑ skin symptoms [n≥10] ↑ ear/nose/throat symptoms [n≥10] ↑ eye symptoms [n≥10] ↑ cold/flu symptoms	**Healthy environment:** ↑ risk of exposure to waterborne organisms with potential to cause illness/harm	Not applicable	Not applicable	Not applicable
Ambient air pollution (Table F2)	Not applicable	**Negative** **Physical health/activity:** ↑ poor health records (mortality and hospital admissions) [n≥40] ↑ respiratory disease [n≥40] ↑ cardiovascular diseases [n≥40] ↑ other diseases [n≥40] ↑ respiratory and allergic outcomes- children [n≥40] ↑ cancer [n≥30] ↑ chronic diseases [n≥20] ↑ obesity and metabolic disorders- children [n≥20]	**Negative** **Physical health/activity:** ↑ poor vascular measures- people with coronary artery disease	Not applicable	**Negative** **Social/cognitive outcomes:** ↑ developmental disorders- children (e.g., autism and mental challenges) ↑ cancer- children

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
		↓ heart rate variability-people with coronary artery disease (indicative of reduced cardiac function) [n≥10] ↓ physical activity and increased leisure time physical inactivity **Birth outcomes:** ↑ adverse pre-natal and birth outcomes [n≥40] **Social/cognitive outcomes:** Adverse neurodevelopmental outcomes-children [n≥20]			
Particulate matter (Table F3)	**Negative** **Mental health/well-being:** ↑ psychological stress **Physical health/activity:** ↑ stroke incidence [n≥10] ↑ stroke hospital admissions [n≥10] ↑ high blood pressure [n≥10] ↑ acute coronary events ↑ cardiovascular disease ↑ heart failure **Birth outcomes:** ↑ preterm birth [n≥10]	**Negative** **Mortality:** ↑ respiratory mortality	**Negative** **Physical health/activity:** ↑ coronary heart disease	**Negative** **Physical health/activity**: ↑ atrial fibrillation	**Negative** **Mental health/well-being:** ↑ anxiety [n≥10]

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
	Mortality: ↑ cancer [n≥10], cardiovascular [n≥10] ischemic heart disease [n≥10] and stroke [n≥10] mortality ↑ all-cause mortality [n≥10] ↑ mortality- children				
Nitrogen dioxide (Table F4)	**Negative** **Physical health/activity:** ↑ acute coronary events [n≥10] ↑ stroke hospital admissions [n≥10] ↑ stroke incidence [n≥10] ↑ cardiovascular disease [n≥10] **Mortality:** ↑ Respiratory [n≥20] and heart [n≥10] disease mortality ↑ Cardiovascular [n≥20] and stroke [n≥10] mortality ↑ Lung [n≥20] and all cancer [n≥10] mortality ↑ all-cause mortality [n≥30]	**Negative** **Physical health/activity:** ↑ adverse respiratory symptoms [n≥20] ↓ lung function [n≥20]	Not applicable	**Negative** **Physical health/activity:** ↑ heart failure **Birth outcomes:** ↑ preterm birth **Mortality:** ↑ cerebrovascular [n≥10] and coronary heart disease mortality	**Negative** **Mental health/well-being:** ↑ anxiety
Ozone (Table F4)	**Negative** **Physical health/activity:** ↑ stroke hospital admissions [n≥10] **Birth outcomes:** ↑ preterm birth **Mortality:**	Not applicable	Not applicable	**Negative** **Physical health/activity:** ↑ stroke incidence [n≥10] **Mortality:** ↑ stroke mortality	Not applicable

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
	↑ mortality- children				
Sulphur dioxide (Table F4)	**Negative** **Physical health/activity:** ↑ stroke hospital admissions [n≥10] ↑ stroke incidence **Mortality:** ↑ mortality- children	Not applicable	**Negative** **Physical health/activity:** ↑ adverse respiratory symptoms- children ↓ lung function- children	Not applicable	Not applicable
Carbon monoxide (Table F4)	**Negative** **Physical health/activity:** ↑ stroke hospital admissions **Mortality:** ↑ mortality- children	Not applicable	**Negative** **Birth outcomes:** ↑ preterm birth	**Negative** **Physical health/activity:** ↑ stroke incidence **Mortality:** ↑ stroke mortality	Not applicable
Exercise in polluted air (Table F5)	Not applicable	**Negative** **Physical health/activity:** ↓ vascular function [n≥10] ↓ lung function- susceptible groups	**Negative** **Physical health/activity:** ↓ long-term health outcomes	**Negative** **Physical health/activity:** ↓ short-term health outcomes ↑ myocardial ischemia and angina ↓ lung function ↑ lung inflammation	Not applicable

Note 1: This table is a summary of more extensive Tables in appendix F which includes references and further details of exposures.

Note 2: The ‘n’ next to outcomes denote the number of primary studies reported within the review that features the outcome. Only reviews with n>2 are included and those without an ‘n’ will have included <10 primary studies.

Note 3: ‘Level of evidence’ refers to gradings in Table 1.

Exposure to nature improvement

This final narrative synthesis and summary table (Table 5) collates evidence looking at efforts to regenerate and improve the quality of natural environments and how exposure to and engagement with this kind of activity might relate to human health and well-being. This includes three very different areas of research, linked by their common target of improving the condition of our natural environments:

- Nature recovery work (Table G1)
- Air pollution mitigation strategies (Table G2)
- Pro-environmental behaviours (Table G3)

Nature recovery work

There are a range of initiatives that aim to increase or improve green and natural spaces in both urban and rural locations, depending on their purpose and form, sometimes known as ‘greening interventions’, but also ‘landscape restoration’, ‘rewilding’, ‘nature recovery’ ‘green infrastructure’ etc. (Table G1).

One review has looked at physical activity levels in relation to urban green space interventions, predominantly parks or greenways/trails in urban environments (Hunter et al., 2019). These can involve just physical changes to the space, but ‘dual’ approaches are when this is accompanied with promotion or signposting towards the change (Hunter et al., 2019). The review highlights the association between park-based interventions and greenways/trails for increased physical activity, but only in the context of physical change alongside promotion/signposting (Hunter et al., 2019). This dual approach was also associated with improved health and reduced stress for those local to vacant lots that had undergone greening. One review of those aged 14 to 24 also reported that urban green space interventions in streets, parks and forests were associated with better mental health among young people (Bray et al., 2022).

One review of urban blue space regeneration in deprived communities looked at water bodies such as rivers and water bodies connected to the sea, as well as inland water bodies like lakes and basins. The review concludes that the improved quality of blue spaces leads to healthier lifestyles, but this is inferred through signs of increased use of and physical activity within these spaces (Brückner et al., 2022).

This shows the potential for greening and blue space regeneration interventions to increase the physical activity and improve the mental health of those living close to them, but more so when change in the space is accompanied by engagement activity. Research on the health/well-being impacts of nature recovery work in the UK is however minimal.

Air pollution mitigation strategies

Evidence reviews focusing on the health impacts of removing or reducing air pollutants demonstrate positive health outcomes (Table G2; Burns et al., 2020; Gao et al., 2018; Georgiou et al., 2021; Qiu et al., 2021; Wang et al., 2016). Removing air pollution by increasing residential green spaces was found to have a significant association with reduced respiratory and cardiovascular disease, and reduced risk of low birth weight (Qiu et al., 2021). Georgiou et al. (2021) also report mixed findings for the benefits of blue space in the local area for reducing air temperature and improving air quality, inferring the health benefits that this might bring.

One review examined the association between land cover types and air temperature (Bowler et al., 2010). The potential for the introduction of vegetation within urban areas to was explored by Bowler et al. (2010) as a way of mitigating increases in temperature, particularly in urban areas. Using meta-analysis, they were able to offer support for reductions in air temperature in parks both during the day and night (e.g., compared to the surrounding area). Evidence (not meta-analysed) was also largely consistent for cooler temperatures under trees or in urban forests during the day, with some evidence of heat retention at night. Finally, evidence was more mixed for the role that ground or roof vegetation (e.g., compared to engineered surfaces) plays in cooling air temperatures above the ground. These findings are described as ‘inferred’ as no direct links to health are made, but the benefits of reduced air temperatures for human health are established (Chen et al., 2020).

Gao et al. (2018) explored the health links made with greenhouse gas mitigation/reduction strategies. They did this in relation to five highly impactful sectors: Energy generation, transportation, agriculture, household and industry. A range of research gathered within this review infers substantial health benefits of emissions reductions directly linked to improved air quality, in particular, reductions in premature deaths and improved ‘disability adjusted life years’ (DALYs) which represent improving quality of life (Gao et al., 2018). Representing some cross-over with Gao et al.’s (2018) areas of interest, Wang et al. (2016) instead looked at three types of ‘air quality strategies’ and their inferred benefits to human health. They report inferred benefits of ‘traffic emission control related interventions’ (e.g., low emission zones and congestion charges) for increased years of life gained. Additionally, inferred benefits of ‘general regulations on air quality control’ (e.g., directives on air quality), and ‘energy related strategies’ (e.g., ban of coal sales and introduction of energy efficiency interventions) for reductions in premature deaths.

Although research in this area is usually on as scale that requires health benefits to be inferred through modelling (rather than directly measured for individuals as a result of intervention), there is consensus that strategies and interventions to reduce air pollution will improve both quality and length of

life. A number of green space types were also shown to be beneficial in mitigation against rising air temperatures (parks and trees) and specific health outcomes such as respiratory and cardiovascular health.

Pro-environmental behaviours

A range of voluntary activities outdoors aim to benefit the environment, such environmental enhancement and conservation activity, but also lifestyle choices like choosing more environmentally friendly forms of transport (Table G3).

One review reported on active travel related to human health, but showed limited research in this area and mixed findings (Quam et al., 2017). Active forms of transport such as walking and cycling were presented as lifestyle choices that could mitigate against climate change. The studies included within the review broadly agreed that active transport was beneficial for levels of physical activity, but the impact of this mode of transport on exposure to air pollutants and traffic accidents was less clear (Quam et al., 2017).

The poor quality of research looking at the health and well-being benefits of environmental enhancement/conservation activity limits the conclusions that can be drawn around its benefits for people. Qualitative research reports benefits such as increased social contact, benefits for people's identity, knowledge and sense of achievement, as well as well-being. However, these findings have not been confirmed using quantitative methods (Husk et al., 2016).

The reviews discussed here provide very little summative evidence for the health and well-being benefits of human activity to protect the environment. This is an opportunity for future research to consider both the positive and negative health/well-being outcomes that can arise from people's efforts to benefit our natural environment.

Table 5. Summary of positive and negative associations between nature improvement and health and well-being outcomes, split by level of evidence.

Exposure	Significant	Supported	Marginal/mixed	Not supported/not significant	Inconclusive
Nature recovery work (Table G1)	Not applicable	**Positive** **Mental health/well-being:** ↑ mental health (e.g., anxiety, depression and self-esteem) [n≥10] ↓ stress **Physical health/activity:** ↑ physical activity ↑ health	Not applicable	Not applicable	**Positive** **Healthy environment:** ↑ healthier urban environments e.g. reduced air and noise pollution
Air pollution mitigation strategies (Table G2)	**Positive** **Physical health/activity:** ↓ respiratory diseases [n≥10] ↓ cardiovascular disease ↓ likelihood of other disease (e.g., obesity, mental health and blood pressure) **Birth outcomes:** ↓ likelihood of low birth weight **Healthy environment:** ↓ air temperature around parks and green spaces [n≥10]	**Positive** **Physical health/activity:** ↑ health [n≥40] ↓ premature death ↑ years of life gained ↑ DALYs **Healthy environment:** ↓ air temperature around beneath trees Improved air quality	**Positive** **Healthy environment:** ↓ air temperature ↑ air quality (lower PM2.5 concentrations) ↓ air temperature around on ground/roofs with vegetation*	**Positive** Physical health/activity: ↓ allergic reactions	Not applicable
Pro-environmental behaviours: Active transport and conservation (Table G3)	Not applicable	**Positive** **Physical health/activity:** ↑ physical activity	**Positive** **Physical health/activity:** ↑/↓ traffic injuries and fatality	Not applicable	**Positive** **Mental health/well-being:** ↑ quality of life ↑ mental and emotional health **Physical health/activity:** ↑ exposure to air pollution

Note 1: This table is a summary of more extensive Tables in appendix G which includes references and further details of exposures.

Note 2: The ‘n’ next to outcomes denote the number of primary studies reported within the review that features the outcome. Only reviews with n>2 are included and those without an ‘n’ will have included <10 primary studies.

Note 3: ‘Level of evidence’ refers to gradings in Table 1.

Conclusions

The narrative summary drawing together the evidence for each exposure is given above, each with an overarching summary statement. These conclusions bring together some overarching themes from these wide range of reviews:

Exposure to green space, particularly urban, is associated with improved psychological well-being, physical activity and linked health outcomes

Although the review of reviews found inconclusive results for whether objectively mapped green spaces predict health/well-being outcomes (e.g., Houlden et al., 2018; Zare Sakhvidi et al., 2022), wider research measured exposure to nature in a range of different ways (e.g., qualities of spaces and type of engagement). The broad conclusion of this research was that there is a correlation between exposure to green space and improved health and well-being outcomes, but that confidence in this trend is reduced by heterogeneity of both the exposures and outcomes measured (Lackey et al., 2021; Twohig-Bennett & Jones, 2018; Yuan et al., 2021; Zhang et al., 2022).

Reviews instead report greater confidence in the beneficial outcomes of green space in urban areas, which was associated with increased physical activity and linked health outcomes (cardiovascular and mortality), and a range of positive mental health and well-being outcomes (Fernández Núñez et al., 2022; Gianfredi et al., 2021; Kondo et al., 2018; Mueller et al., 2022; World Health Organisation, 2021). These findings suggest that accessibility/proximity of green space could be important in growing health and well-being benefits.

Exposure to nature increases activity levels among children and young people

Reviews focusing on children and young people varied not only in the age group, exposure type and outcomes looked at, but also their support for positive effects on health and well-being outcomes (e.g., Bray et al., 2022; Dankiw et al., 2020; Fyfe-Johnson et al., 2021; Qi et al., 2021). Results were largely mixed or inconclusive. However, physical activity (including play and reduced sedentary behaviour) was most consistently found to correlate with nature exposures (Christian et al., 2015; Fyfe-Johnson et al., 2021; Gray et al., 2015).

As might be expected, other health and well-being outcomes varied depending on the exposure type and age group. Reductions in obesity/overweight were associated with living near more green space for those age <19 (Ye et al., 2022). For those in

tertiary or secondary education (age 12+), greater school campus green space was associated with more positive indicators of restoration (van den Bogerd et al., 2020). School gardening activities were also associated with increased fruit and vegetable intake for children aged around 7 to 12 (Qi et al., 2021). Finally, urban green space interventions in streets, parks and forests were associated with better mental health of those aged 14 to 24 (Bray et al., 2022).

There is evidence for the psychological benefits of nature-based interventions, in particular reduced depression/improved mood

Reduced depression or depressive mood was the predominant outcome associated with nature-based interventions, most often gardening activity and outdoor exercise (focusing on walking; Clatworthy et al., 2013; Hanson & Jones, 2015; Li et al., 2022; Roberts et al., 2019). Similar decreases in negative affect and increases in positive affect and mood were reported (Brito et al., 2021; Li et al., 2022; Swinson et al., 2020).

Further beneficial psychological outcomes reported included: reduced anxiety, anger, confusion, fatigue, tension, stress, increased vigour, comfort and feeling relaxed and natural, and broader improved mental health, emotional health, and well-being (Briggs et al., 2023; Brito et al., 2021; Clatworthy et al., 2013; Johansson et al., 2022; Lakhani et al., 2019; Tharrey & Darmon, 2022). This shows the potential for nature-based interventions to positively impact on psychological health.

Growing evidence shows that blue space exposure is also beneficial for psychological well-being and physical activity

Exposure to blue space was broadly found to be positively correlated with improved health and well-being. Amount of blue space, closer proximity to blue space, general exposure to blue space, and water-based therapy all show significant and/or supported links to physical activity, markers of restoration and psychological well-being (Britton et al., 2020; Georgiou et al., 2021; Smith et al., 2021). The potential to use artificial blue space in improving health (Xie et al., 2021) is also encouraging, due to the large populations living in urban areas without as easy access to large bodies of water. However, the research base in this area is more limited in both the level of detail with which it looks at the exposure (blue space) and the diversity of health and well-being outcomes examined compared to green space research. In particular, multiple reviews noted the lack of research demonstrating the long-term impacts of exposure and engagement with blue space (Britton et al., 2020; Xie et al., 2021).

The flip side: Pathogens present during water-based recreation are associated with respiratory, gastrointestinal and other physical illness

Although human health and well-being is positively related to blue space exposure, the most well-established links between human health and water-based recreation are negative. Contact with pathogens during water-based recreation can result in gastrointestinal illness, respiratory irritation and a number of other negative health outcomes (Russo et al., 2020).

The UK Government's long-term EIP includes 'Goal 3: Clean and plentiful water' which sets out to improve the provision of clean drinking and bathing water (Defra, 2023b). The importance of these aims are reinforced through strong evidence for the negative implications of contaminated bathing waters for those engaging water-based in recreation (Russo et al., 2020) and also growing evidence of the presence of water contaminants in drinking water (e.g., Ozsvath, 2009; Sall et al., 2020; Ward et al., 2018).

The quality of 'bathing waters' have been monitored since 1995 and this data now feeds into a national indicator of 'Condition of bathing waters (B4)' for England (Defra, 2022). Alongside this, serious pollution incidents (indicator B2) are monitored, and an indicator of pollution loads entering waters (indicator B1) is being developed. The 2023 report concludes 'The number of designated bathing waters in England meeting at least the minimum standard ('sufficient', 'good' or 'excellent') has increased considerably from 45.7% in 1995 to 97% in 2022.' (Defra, 2022). This is expected to reduce physical illnesses such as gastrointestinal illness among bathers in these waters. However, at present less than 450 waters are designated for bathing and tested for quality across England, and the majority of these are marine waters (Defra, 2023a). Continued monitoring of water quality is important to demonstrate reductions in negative health outcomes such as gastrointestinal and respiratory illness.

In terms of drinking water, national indicators have tracked riverine inputs of the heavy metals, Cadmium, Copper, Lead, Mercury and Zinc, and nutrients Nitrogen and ortho-phosphate, since 2008 as part of the B1 indicator (Defra, 2022). Ratings of the overall state of the water environment are reported as part of the G3 indicator (Defra, 2022), and therefore account for other compounds identified in this review. Fluoride levels in drinking water are also monitored by the Office for Health Improvement & Disparities, due to the association with dental decay (OHID, 2022). In 2022, it was reported that water fluoridation, adding additional fluoride to drinking water where levels were too low, has been shown to improve inequalities in dental health.

Exposure to air pollution from transport and industry while outdoors has significant negative impacts on respiratory, cardiovascular and birth/early years outcomes

This review of reviews summarises unequivocal evidence that air pollution has substantial negative impacts on human health and well-being, particularly worse respiratory, cardiovascular and birth/early years outcomes (e.g., Gheissari et al., 2022; Spencer-Hwang et al., 2023; Sun & Zhu, 2019). Child development and health are particularly vulnerable to the negative impacts of air pollution (e.g., Gheissari et al., 2022; Spencer-Hwang et al., 2023). The impacts of air pollution on psychological outcomes are less clear, but living in polluted areas may reduce people's inclination to get outdoors and increase psychological stress (An et al., 2018; Bazyar et al., 2019; Trushna et al., 2021).

Strategy and intervention to improve air quality while outdoors could provide substantial improvements for quality and length of life

Reductions in air pollution can be achieved through nature-based solutions (e.g., increasing green space in built-up areas), and other intervention and regulation (e.g., low-emission zones, clean air directives). Reviews of such intervention provide evidence for substantial benefits in terms of reduced disease burden and longevity (e.g., Burns et al., 2020; Qiu et al., 2021). It is possible that improving air quality may not only have direct improvements for physical health but may also increase the likelihood of engagement with the outdoors (An et al., 2018) and ensure the benefits of outdoor activity outweigh the possible negative repercussions of polluted air (An et al., 2018; Madureira et al., 2019; Tainio et al., 2021).

Review limitations

Methodological limitations. Although systematic in its search approach and aiming to provide a broad overview of the research area, the review should not be considered fully systematic or exhaustive of evidence in this research area. This is due to the inclusion of some, but not all the identified papers. As with any review of reviews, it was not sensible to include all identified reviews due to overlap in scope and primary research included.

The evidence reviewed largely shows *associations* between nature exposure and health/well-being outcomes and cannot be considered to show causality (unless explicitly stated) or make comment on the size of the effect (aka. the relative impact of different nature exposures on health/well-being). In addition to this, formal quality checks were not completed on articles included and so we cannot be sure that all

reviews were of high quality. Future review of reviews might delve further into quality checks, including which reviews used comparison groups and longitudinal methodologies.

Limitations of the review scope. All reviews are bound by the body of primary research they seek to summarise. It should be acknowledged therefore that certain relationships may be underrepresented in this review due to limited primary research and subsequent reviews. Several reasons may account for this.

In some cases, research areas may be newer or less prevalent in the UK. An example of this might be the growing evidence around the positive effects of microbial exposure in natural environments on immune response. While this has been noted in earlier reviews (Aerts et al., 2018; Twohig-Bennett & Jones, 2018), often the research to-date was very limited and not UK based. Primary research like this therefore will not yet have trickled down into reviews and so will not have been summarised as part of this review of reviews. The bringing together of primary research is happening with greater pace however, as demonstrated by recent reviews of exposure to nature during the COVID-19 pandemic (Patwary et al., 2022).

Various biases in what primary research is delivered may also exist. For example, this may be based on the immediacy of an exposure, such as the dominance of terrestrial research over marine and other blue space research found within this review. Some research may also be more prevalent due to more obvious detrimental impacts for people (e.g., air quality and negative outcomes for respiratory health), or due to greater level of interest and/or funding in a particular area of research.

In other cases, primary research is underrepresented due to cultural or environmental differences and so the lack of UK-based research. For example, there is an abundance of reviews on forest bathing, but these very rarely include UK-based research. This is because it is a practice stemming from Japan, where it is known as ‘Shinrin-yoku’ (Kotera et al., 2022). Similarly, some reviews relating to contaminants and natural disasters were not included within this review of reviews due to their lack of UK-based primary research.

Finally, it should also be acknowledged that in some cases the scope of the review of reviews may have been limited by the search terms chosen. These had to be restrictive to allow for a manageable screening process. The lack of inclusion of UK-based ‘wildlife’ may be an example of this. Without first identifying key UK wildlife that may impact on health and well-being and using specific terms for each, this review was unlikely to capture more specific reviews on exposure to UK wildlife and specific disease outcomes (e.g., ticks and Lyme disease).

Recommendations

During the process of completing this review, a wide range of research gaps, as well as methodological limitations within the evidence base were identified. Here we outline a selection of these (not exhaustive) as recommendations for future research. These were chosen as research advancements that may help to inform programmes and policy reliant on this evidence base.

Remaining research questions

There remains a need for more research to understand:

The impact of nature-based interventions for specific groups and specific activities

As seen through this overview, larger bodies of research exist for a select few NBIs, including gardening and physical activity outdoors (focusing on walking). There is currently a lack of reviews—possible due to a lack of primary research—on NBIs such as retreats, creative activities, bird watching, conservation activity, other specific sports (e.g., running, climbing and cycling) and more sedentary activities like 'forest bathing' within the UK context (e.g., Buckley et al., 2020; Garside et al., 2020). There is increasing interest in the use of NBIs for therapeutic uses with different clinical groups as part of green social prescribing initiatives within the UK (NHS England, 2023). This shows clear gaps in our understanding of how NBIs of different kinds and used with different clinical groups might relate to health and well-being.

Many clinical groups have distinct disabilities or symptoms, impacting on their physical and mental health in different ways and requiring different levels of adjustment and support. Groups that were mentioned within the existing reviews include those with stress-related illness (Johansson et al., 2022), dementia (Lakhani et al., 2019; Whear et al., 2014), and mental health issues (Briggs et al., 2023; Clatworthy et al., 2013). One further review examined the psychological benefits of outdoor activity for those with type 2 diabetes (Fraser et al., 2020). However, only four studies were identified for review and presented heterogeneous outcome measures making it hard to draw conclusive findings. Among CYP, one review was found that examined nature-based interventions for young people who had experienced trauma (Boddy et al., 2021), showing encouraging results for mental health outcomes, but did not include UK data and noted the wider lack of research in this area. It is apparent from this review of reviews that for many clinical groups there is no appropriate synthesis of research insights for the use of nature-based interventions to support recovery and/or coping.

Building on this area, it might be appropriate to review evidence and identify research gaps relating to prevalent and long-term health conditions, such as those outlined by the UK government within their 'major conditions strategy' (Department for Health and Social Care, 2023), which includes conditions accounting for 60% of ill health and mortality in England. These include those living with cancer, cardiovascular diseases (including stroke and diabetes), chronic respiratory diseases, and musculoskeletal disorders, as well as building on existing reviews for those living with mental ill health and dementia.

The risks that a changing climate within the UK poses to human health and well-being through exposure to changing nature

This review of reviews highlights the need for a comprehensive review of research and potentially more UK-based research looking at the impacts of a changing climate on health and well-being in the UK. Global temperatures are rising including those in the UK, sea levels are rising and extreme weather events are becoming more frequent and impactful (IPCC, 2023; Met Office, 2023). However, there are human health and well-being risks beyond hot summers and flooding in the UK, such as the possible impacts of rising air and sea temperatures for the health of our ecosystems and our relationship with nature (Short et al., 2021).

We can learn from the health and well-being impacts already felt in other countries (Bunker et al., 2016; Lee et al., 2020; Zanobetti & O'Neill, 2018), as well as beginning to explore the impact already being seen within the UK, to inform how we mitigate against and adapt to minimise the impacts of climate change, especially for more vulnerable groups. This review of reviews highlights some opportunities here to use nature-based solutions to reduce urban heat islands (Bowler et al., 2010), as well as intervention and regulation to reduce carbon emissions while improving air quality (e.g., Burns et al., 2020; Qiu et al., 2021).

The health and well-being outcomes of nature improvement work

One notable gap in the review of reviews was research that informs our understanding of how nature improvement can produce the positive health and well-being impacts we are looking for. Reviews on air pollution mitigation strategies provide inferred evidence for substantial benefits in terms of reduced disease burden and longevity (e.g., Burns et al., 2020; Qiu et al., 2021), but other nature improvement activities are rarely evaluated for their benefits to human health and well-being. Adopting a One Health perspective (Queenan et al., 2017), it would be valuable to consider both beneficial outcomes for nature and humans when implementing nature improvement.

A good example of this would be research to show how nature recovery work in both urban and rural areas, large and small scale, relates to ecological improvements, as well as the health and well-being of those living close to renewed areas. One existing review identified and discussed in this area focused on small-scale urban interventions (Hunter et al., 2019) and indicated that greening interventions alongside appropriate promotion/signposting can increase physical activity in the short term. None of the identified reviews looked at nature recovery initiatives on a much larger scale, such as wide-spread landscape change and also the designation and implementation of protected areas in the UK. Existing international research suggests that there are both positive and negative effects of terrestrial protected areas used as part of conservation, but highlights the lack of evidence in this area and does not include marine protected areas or UK data (Pullin et al., 2013).

Additionally, as with land-based restoration and protection, evidence for the health and well-being benefits of blue space restoration and protection was lacking. The only review to look at the health and well-being impacts of Marine Protected Areas (MPA) or similar contained no European data (Rasheed, 2020) and the one review of urban blue space regeneration programmes does not contain enough health data to draw conclusions on the association between regeneration work and physical activity, air and noise pollution (Brückner et al., 2022). It is hugely beneficial to be able to evidence activities that both benefit nature and support human health and well-being, but at present rigorous research in this area is limited (Husk et al., 2016; Quam et al., 2017).

Improving the evidence base

Here, broader recommendations are made for possible ways to improve research design and focus in this field. These are broad reflections from the authors as a result of completing this review of reviews.

Consideration of both mapped natural spaces as well as qualities of spaces, levels of engagement and subjective experience

The review of reviews showed that mapped natural spaces could predict health/well-being outcomes, but also often did not (e.g., Houlden et al., 2018; Zare Sakhvidi et al., 2022). To properly capture the complex experience of people's exposure to nature and the benefits of this, mapped natural spaces should be looked at alongside the qualities of these spaces (e.g., connectivity, type of vegetation, blue as well as green space, contamination), peoples time spent in the spaces and their subjective appraisals of this time (Houlden et al., 2018; Nguyen et al., 2021). In addition, there was a lack of research considering the presence of wildlife as a contributing factor to health/well-being.

Qualities highlighted as correlated with health and well-being outcomes for adults through this review include connectedness and size of green spaces (Nguyen et al., 2021), as well as potential for temperature regulation (Bowler et al., 2010). Some reviews suggest that subjective measures of green space qualities can better predict health and well-being outcomes (Houlden et al., 2018; Zhang et al., 2022), showing the added value of considering green space quality, experience and quantity. A recent Natural England report (Satchwell et al., 2022) used creative methods to engage young people in this topic and help them share their thoughts on important qualities in green and natural spaces. Using qualitative insights like these, quantitative research could be designed to better examine the relationship between qualities and health and well-being outcomes for young people.

It is notable that none of the papers reviewed had looked at the quality or qualities of blue space in relation to health/well-being, instead focusing more on quantity, proximity and visits/engagement with blue space. Primary research has begun to look at blue space quality and human health and well-being (e.g., McDougall et al., 2022; Mishra et al., 2020), but Short et al. (2021) noted that there was still limited research on the impact of things like beach litter on health. Research might also look at those qualities relevant to terrestrial experience (e.g., biodiversity, form, connectivity), how poor water quality (contaminants) affects the accessibility and experience of being outdoors in local natural spaces, and how the relationship between blue and other natural spaces impacts on human health and well-being. Without these considerations, analyses may be less able to show how nature exposure relates to changes in health and well-being and through what mechanisms.

Methorst et al. (2020) was the only review identified that explicitly focused on ‘Wildlife’, operationalised as wild non-domestic living animal species in terrestrial and aquatic environments. This study has not been included within this review of reviews due to the small number of UK-based primary research included and the likely differences in the wildlife in other countries used to form the review’s conclusions. The review is worth noting however, showing interesting findings around both positive (increased inspiration, learning and connection to wildlife) and negative (reduced feelings of security and negative physical health) outcomes from the presence of wildlife (Methorst et al., 2020). The potential for a review better outlining the significance of UK wildlife for human health and well-being may be beneficial, this might pick-up findings around both seeing and interacting with wildlife, but also negative experiences with wildlife such as ticks and midges.

More consistent measurement of nature exposures and health and well-being outcomes

The review of reviews shows the wide variety of ways that exposure to nature can be defined and measured, but also the lack of co-ordination in how this is done for each

exposure type, such as quantity, quality, type and engagement. Echoing previous reviews in this area (e.g., Davis et al., 2021) we would suggest that considering different aspects of exposure to nature is important, but that greater co-ordination of 'best practice' when measuring each aspect would allow for the comparison and meta-analysis of studies looking at similar exposures and outcomes. This will provide more useful synthesis of evidence to inform what aspects of exposure to nature are linked to health and well-being outcomes, evidence which is needed to better guide policy and practice.

Similar to measures of exposure, the lack of consistency in the measurement of health and well-being outcomes is problematic (Cracknell et al., 2019). Wendelboe-Nelson et al. (2019) provide a clear demonstration of this, outlining more than 120 different instruments used for the measurement of mental health outcomes in relation to green space alone. Within this, there were 32 different measures used to capture 'well-being' and 25 measures of 'stress', showing that this is in part due to diversity in mental health outcomes but also due to lack of coordination of measures used for the same mental health outcomes. Where possible it would again be beneficial to have 'recommended' measures for key outcomes to provide comparability and to enable synthesis of research, acknowledging that certain measures may need to cater to or be modified for some participant groups (e.g., children or those with cognitive impairments).

Seeking to identify what works, for whom and in what situations for nature-based interventions

As suggested by the What Works initiatives across the UK, there is a need to conduct research that can identify 'what works, in what contexts and for whom' (Husk et al., 2020; Lovell et al., 2018). Recommendations have been made around the need for further primary research or collation of primary research to demonstrate the impact of interventions, whether nature recovery interventions or nature-based interventions. However, a scoping review of many of these existing interventions highlights the vast number of poor quality evaluations that do not allow for clear conclusions to be drawn. They recommend that evaluations should, 1) clearly describe the intervention setting and technique, 2) specify the theory that the intervention and its expected outcomes was based on, 3) use a design that can better inform public health guidance, such as larger samples and duration of measurement, as well as outcomes that inform dose-response relationships (Wilkie & Davinson, 2021). Improving research practices and reporting, alongside better co-ordination and consistency in measures used will better inform 'what works'.

This review of reviews has shown the breadth of impact that nature exposure can have on human health and well-being. While acknowledging this, we must also recognise that nature contact is not experienced in isolation from other social,

economic and environmental factors that shape health and well-being (Public Health England, 2018). It is important to ensure that nature is a key element of these models of 'wider determinants of health', as well as considering how wider determinants may interact with and effect the benefits that people accrue from nature. It was not within the scope of this review of reviews to unpick how exposure to nature might contribute to improved health equity, but Lovell et al.'s (2018) earlier review states that inequalities in access and engagement with natural environments can grow health inequalities. Other reviews such as Rigolon et al. (2021) argue that disadvantaged groups may benefit even more from nearby greenspace due to its protective effects as a health-promoting resource. Therefore, an equal effect of nature should not be assumed across groups and contexts. Instead, future research would benefit from also considering what works 'for whom and in what contexts'.

Research cross-cutting sector, discipline and theoretical boundaries to better inform policy and programme efforts

This review of reviews has demonstrated the cross-cutting nature of research on nature exposures and health and well-being, with relevance for the environment, health and social care, education, transport and many other sectors. This presents an opportunity for joined-up research which contributes to policies and programmes in multiple priority areas. Some early research around nature-based solutions has used co-design with stakeholders across different sectors. This research shows how cross-sector input can inform research questions and help identify evidence needs (Dick et al., 2020).

Research providing insights to inform policy and programmes also needs to operate outside of disciplinary silos (Dick et al., 2020). An example of this is the often highly focused research looking at NBIs. Research looking at the processes and outcomes of nature-based interventions often sits within limited disciplinary or theoretical silos. For example, it may focus on either the benefits of NBIs due to exposure to the natural environment (e.g., nature connection; McEwan et al., 2021), or physical activity (e.g., Van Hecke et al., 2018)), or the group context (e.g., social identity theory; Haslam et al., 2009). Instead, it would be valuable to bring these complementary disciplinary perspectives and theories together to understand the complexity of NBIs, in a way that informs policy and practice. Understanding the role that wider mechanisms—such as the social context and promotion of physical activity—play alongside the natural setting may increase understanding of what works and inform best practice.

As an example, despite the social context of many of the reviewed nature-based interventions, social well-being outcomes were rarely reported. Lakhini et al. (2019) found broadly that nature-based interventions were associated with better social health and Spano et al. (2020) found that gardening activity (often with others) was

associated with better psychosocial well-being (e.g., loneliness, sense of community and trust). Future research might better understand how outdoor activities with and without others, and with and without physical activity relate to social, health and well-being outcomes.

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Appendices

Appendix A: PRISM and PRIOR statements

While the current narrative review of reviews does not claim to be a fully systematic review for pragmatic reasons, it aligned where possible with PRISMA guidance on reporting of systematic reviews and meta-analyses (Moher et al., 2010), as well as the more recently developed PRIOR checklist. The 'preferred reporting items for overviews of reviews' (PRIOR) statements are used to demonstrate adherence to best practice for overviews of reviews (Gates et al., 2022). However, is better characterised as a 'narrative review of reviews' as it was pragmatic in not including two of the more restrictive and time-intensive aspects of the PRIOR checklist:

1) *No formal quality assessment of articles was completed.* As noted within the methods, during article data extraction any concerns with article quality were noted based on researcher experience and review methods were categorised. Based on this, meta-analyses and systematic reviews were prioritised, but other review types included where necessary.
2) *No systematic cross-checks of primary research within reviews*. This is a time-consuming activity which was not necessary for the purposes of this review. Cross-over was avoided by categorising exposures and outcomes and picking key articles that included each combination. Further, where reviews have some cross-over in articles it will have the affect of reaffirming conclusions already drawn which does not negatively impact upon the review conclusions on existing evidence and evidence gaps.

Appendix B: Search string

Search 2nd March 2023 (Scopus only)

TITLE(meta-analysis OR review OR briefing OR systematic) AND TITLE(environment* OR natur* OR green* OR “green space” OR “natural environment” OR “open space” OR land OR terrestrial OR tree* OR outdoor* OR outside OR park? OR forest* OR wildlife* OR wilderness OR wood* OR plant* OR garden* OR vegetation OR land* OR playground* OR mountain* OR "blue space" OR water* OR blue* OR river* OR lake* OR sea OR coast* OR marine OR ocean* OR ecosystem* OR biodiverse* OR air) AND TITLE(well-being OR well-being OR health OR “quality of life” OR “life satisfaction” OR psych* OR symptom* OR mortality* OR "physical activity") AND TITLE-ABS-KEY(human* OR child* OR people OR youth OR wom?n OR m?n OR female* OR male* OR adolescent OR participant* OR teenag* OR adult* OR citizen*)

Plus backwards reference checks of:

- Lovell R, and Depledge, Michael. (2018). Health and the natural environment: A review of evidence, policy, practice and opportunities for the future. European Centre for Environment and Human Health University of Exeter Medical School.
- Lovell, R., White, M.P., Wheeler, B., Taylor, T., Elliott, L. (2020) A rapid scoping review of health and well-being evidence for the Green Infrastructure Standards European Centre for Environment and Human Health, University of Exeter Medical School. For: Natural England, Department for the Environment, Food and Rural Affairs, Public Health England, and Ministry for Housing, Communities and Local Government, England
- Hartig, T., Mitchell, R., De Vries, S., & Frumkin, H. (2014). Nature and health. Annual review of public health, 35, 207-228.
- Yang, B. Y., Zhao, T., Hu, L. X., Browning, M. H., Heinrich, J., Dharmage, S. C., ... & Dong, G. H. (2021). Greenspace and human health: An umbrella review. The Innovation, 2(4), 100164.

Search 19th April 2022 (Scopus and Web of science)

TITLE(meta-analysis OR review OR briefing OR systematic) AND TITLE(environment* OR natur* OR green* OR “green space” OR “natural environment” OR “open space” OR land OR tree* OR outdoor* OR outside OR park? OR forest* OR wildlife* OR wilderness OR wood* OR plant* OR garden* OR vegetation OR land* OR playground* OR mountain* OR "blue space" OR water* OR blue* OR river* OR lake* OR sea OR coast* OR marine OR ocean* OR ecosystem* OR biodiverse* OR air) AND TITLE(well-being OR well-being OR health OR “quality of life” OR “life satisfaction”) AND TITLE-ABS-KEY(human* OR child* OR people OR youth OR wom?n OR m?n OR female* OR male* OR adolescent OR participant* OR teenag*)

Appendix C: Flow diagram of articles identified and selected

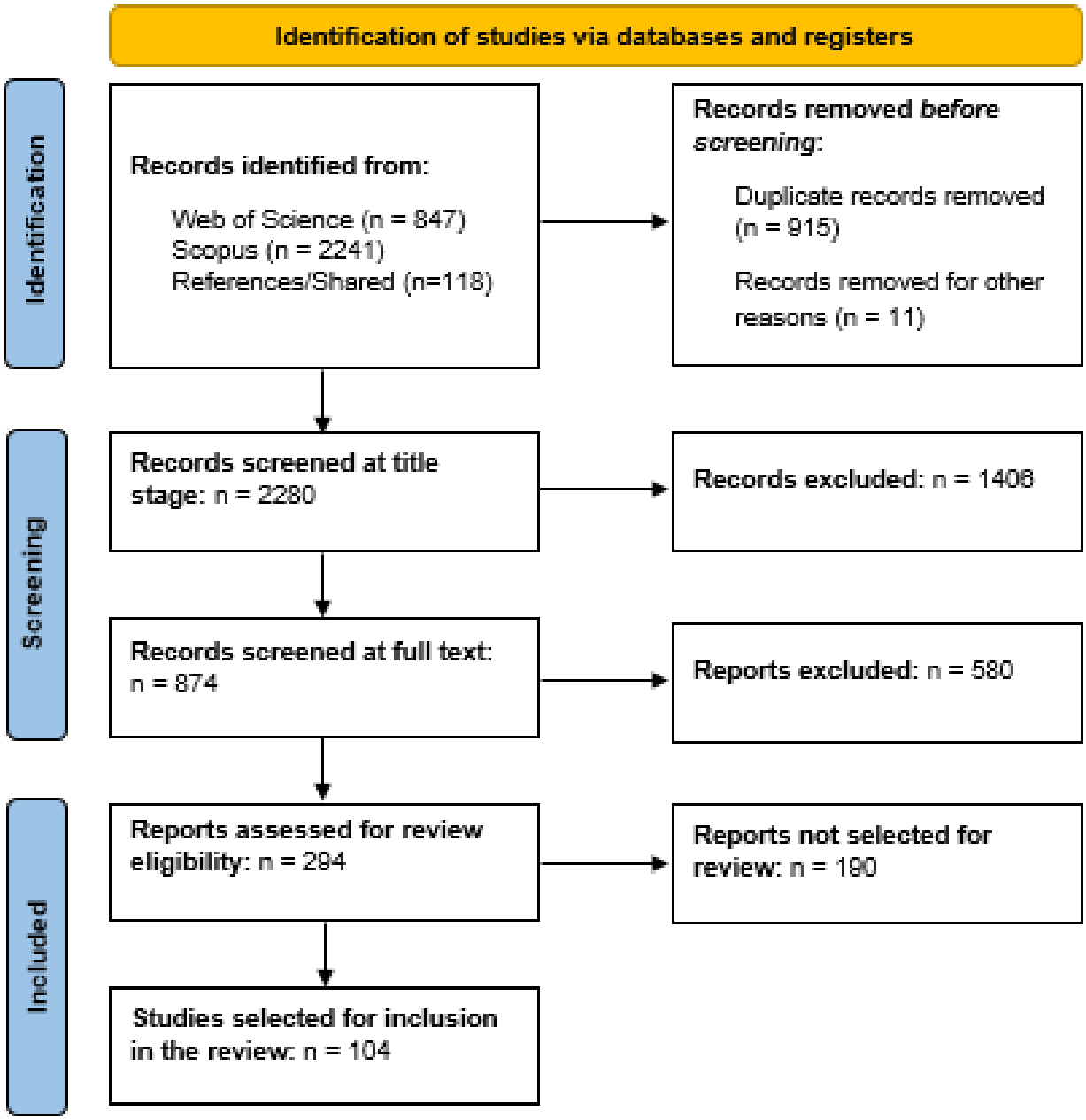

Figure 1. Flow diagram to show the process of article selection for the narrative review of reviews.

Note 1: This flow diagram follows previously used formats (Page et al., 2021)

Appendix D: General nature exposure

Table D1. Non-specific green space exposure and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Nature exposure (e.g., green space proximity, quantity, cover type, quality, availability of parks and engagements with green spaces, including interventions)	Positive	Decreased diastolic blood pressure (Twohig-Bennett & Jones, 2018)	12	Significant
	Positive	Better self-reported health (Twohig-Bennett & Jones, 2018)	10	Significant
	Positive	Decreased heart rate (Twohig-Bennett & Jones, 2018)	10	Significant
	Positive	Decreased salivary cortisol (Twohig-Bennett & Jones, 2018)	7	Significant
	Positive	Increased high frequency heart rate variability (Twohig-Bennett & Jones, 2018)	7	Significant
	Positive	Reduced incidence of type 2 diabetes (Twohig-Bennett & Jones, 2018)	6	Significant
	Positive	Decreased low frequency heart rate variability (Twohig-Bennett & Jones, 2018)	6	Significant
	Positive	Decreased risk of preterm birth (Twohig-Bennett & Jones, 2018)	6	Significant
	Positive	Reduced incidence of all-cause mortality (Twohig-Bennett & Jones, 2018)	4	Significant
	Positive	Reduced incidence of small for gestational age (Twohig-Bennett & Jones, 2018)	4	Significant
	Positive	HDL cholesterol (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Reduced incidence of cardiovascular mortality	2	Inconclusive

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
		(Twohig-Bennett & Jones, 2018)		
	Positive	Decreased systolic blood pressure (Twohig-Bennett & Jones, 2018)	13	Not significant
	Positive	Reduced incidence of hypertension (Twohig-Bennett & Jones, 2018)	4	Not significant
	Positive	Reduced incidence of stroke (Twohig-Bennett & Jones, 2018)	3	Not significant
	Positive	Acceptable gestational age (Twohig-Bennett & Jones, 2018)	3	Not significant
	Positive	Lower total cholesterol (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Lower LDL cholesterol (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Lower triglycerides (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Lower glycated haemoglobin (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Lower fasting blood glucose (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Reduced incidence of dyslipidaemia (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Reduced incidence of asthma (Twohig-Bennett & Jones, 2018)	2	Inconclusive
	Positive	Reduced incidence of coronary heart disease (Twohig-Bennett & Jones, 2018)	2	Inconclusive

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Nature exposure (e.g., green space proximity, quantity, cover type, quality, availability of parks and engagements with green spaces, including some bluespace)	Positive	Reduced incidence of cardiovascular disease (Geneshka et al., 2021)	3	Supported
	Positive	Increased physical activity (Geneshka et al., 2021)	13	Mixed
	Positive	Reduced depression (Geneshka et al., 2021)	9	Mixed
	Positive	Reduced incidence of diabetes (Geneshka et al., 2021)	7	Mixed
	Positive	Reduced incidence of obesity (Geneshka et al., 2021)	6	Mixed
	Positive	Reduced incidence of cancer (Geneshka et al., 2021)	3	Mixed
Nature exposure (e.g., green space proximity, quantity, cover type, quality, availability of parks and engagements with green spaces)	Positive	Improved sleep quality and quantity (Shin et al., 2020)	13	Supported
Nature exposure (e.g., green space proximity, quantity, cover type, quality, availability of parks and engagements with green spaces)	Positive	Better cognition (e.g., global cognition, working memory, attention, reasoning, verbal fluency and executive function)(Besser, 2021)	15	Supported
	Positive	Favourable MRI outcome (regional brain volumes, cortical thickness, amygdala integrity)(Besser, 2021)	3	Supported
	Positive	Reduced incidence of cognitive impairment/dementia (Besser, 2021)	5	Mixed
Nature exposure (e.g., outdoor recreation, natural green spaces, nature-based	Positive	Reduced anxiety/stress (Lackey et al., 2021)	16	Supported
	Positive	Increased positive affect (Lackey et al., 2021)	10	Supported

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
interventions and urban green space)	Positive	Improved cognition (Lackey et al., 2021)	4	Supported
	Positive	Restoration (Lackey et al., 2021)	3	Supported
	Positive	Reduced depression (Lackey et al., 2021)	8	Mixed
	Positive	Improved well-being (Lackey et al., 2021)	4	Mixed
	Positive	Improved mental health (Lackey et al., 2021)	3	Mixed
Childhood or life course exposure to nature (green space availability/density/ cover and quality, and visit frequency/duration)	Positive	Reduced incidence of mental disorders (e.g., ADHD, Schizophrenia, Dementia)(Li et al., 2021)	~19	Supported
	Positive	Increased cognitive function (Li et al., 2021)	~8	Mixed
	Positive	Reduced psychiatric symptoms and emotions (e.g., stress and depression)(Li et al., 2021)	7	Mixed
	Positive	Increased subjective well-being (Li et al., 2021)	5	Mixed

Note: '~' used where sample size is unclear.

Table D2. Objectively measured green space and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Objectively measured green space (satellite-based vegetation indices and GIS-derived measures)	Negative	Increased skin cancer incidence, prevalence and mortality (Zare Sakhvidi et al., 2022)	3	Supported
	Positive	Decreased lung cancer incidence, prevalence and	9	Not significant

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
		mortality (Zare Sakhvidi et al., 2022)		
	Positive	Decreased prostate cancer incidence, prevalence and mortality (Zare Sakhvidi et al., 2022)	4	Not significant
	Positive	Decreased breast cancer incidence, prevalence and mortality (Zare Sakhvidi et al., 2022)	4	Not significant
	Positive	Decreased colorectal cancer incidence, prevalence and mortality (Zare Sakhvidi et al., 2022)	2	Inconclusive
	Positive	Decreased all-site cancer incidence, prevalence and mortality (Zare Sakhvidi et al., 2022)	2	Inconclusive
Objectively measured green space (satellite-based vegetation indices and GIS-derived measures)	Positive	Reduced mental illness (Zhang et al., 2021)	16	Mixed
	Positive	Increased physical activity (Zhang et al., 2021)	~14	Mixed
	Positive	Improved mental well-being (Zhang et al., 2021)	10	Mixed
	Positive	Increased social cohesion (Zhang et al., 2021)	~8	Mixed
	Positive	Reduced perceived stress (Zhang et al., 2021)	~6	Mixed
	Positive	Increased social support (Zhang et al., 2021)	3	Mixed
	Positive	Increased perceived restorativeness (Zhang et al., 2021)	2	Inconclusive
Normalized difference	Positive	Improved (higher) birth weights (Hu et al., 2021)	~29	Significant

Exposure	Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
vegetation index (varied buffer zones)	Positive	Decreased risk of pre-term birth (Hu et al., 2021)		~29	Not significant
	Positive	Reduced incidence of small for gestational age (Hu et al., 2021)		~29	Not significant
Objectively measured green space (satellite-based vegetation indices and GIS-derived measures)	Positive	Older people	Reduced incidence of all-cause mortality (Yuan et al., 2021)	8	Significant
	Positive		Reduced incidence stroke mortality (Yuan et al., 2021)	4	Significant
	Positive		Reduced incidence respiratory disease mortality (Yuan et al., 2021)	5	Not significant
	Positive		Reduced incidence cardiovascular disease mortality (Yuan et al., 2021)	4	Not significant
	Positive		Reduced incidence ischemic heart disease mortality (Yuan et al., 2021)	3	Not significant

Note: '~' used where sample size is unclear.

Table D3. Mapped green space in comparison to other exposure measures and health/well-being outcomes

	Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Comparison 1	**GIS green space mapping, with buffer >2000**	Positive	Improved physical health (e.g., physical activity, birth and developmental outcomes, and	Unknown	Mixed
	GIS green space mapping, with	Positive		Unknown	Mixed

	Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
	buffer between 1000–1999		cardiovascular disease) (Browning & Lee, 2017)		
	GIS green space mapping, with buffer between 500-999m	Positive		Unknown	Mixed
	GIS green space mapping, with buffer between 250-499m	Positive		Unknown	Mixed
	GIS green space mapping, with buffer <250	Positive		Unknown	Mixed
Comparison 2	**Normalized difference vegetation index**	Positive	Reductions in overweight/obesity (Luo et al., 2020)	6	Significant
	Number of parks in the area	Positive		5	Not significant
	Residential proximity to green space	Positive		4	Not significant
	Proportion of green space	Positive		6	Inconclusive
Comparison 3	**Relational green space measurement (self-reported availability)**	Positive	Improved general health and well-being (Zhang et al., 2022)	19	Supported
		Positive	Improved mental health (Zhang et al., 2022)	18	Supported
		Positive	Increased physical activity (Zhang et al., 2022)	15	Supported
		Positive	Improved physical health (Zhang et al., 2022)	8	Supported
	Material green space	Positive	Improved mental health (Zhang et al., 2022)	56	Supported

	Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
	measurement (objectively mapped)	Positive	Improved general health and well-being (Zhang et al., 2022)	28	Supported
		Positive	Reduced mortality (Zhang et al., 2022)	19	Supported
		Positive	Increased physical activity (Zhang et al., 2022)	42	Mixed
		Positive	Improved physical health (Zhang et al., 2022)	41	Mixed
Comparison 4	**Subjective connection to nature**	Positive	Improved mental well-being (Houlden et al., 2018)	7	Supported
	Amount of local area green space	Positive		21	Mixed
	Visits to green space (interventions or visit patterns)	Positive		17	Mixed
	Green space types (e.g., land cover types)	Positive		10	Mixed
	Green space accessibility	Positive		8	Mixed
	Views of green space (e.g., from home or workplace)	Positive		3	Inconclusive

Table D4. Urban green space and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Urban greenness (mapped green	Positive	Reduced incidence of cardiometabolic mortality	~4	Supported

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
space around residence, and urban green spaces such as parks and sports fields)		(Fernández Núñez et al., 2022)		
	Positive	Reduced obesity (e.g., body mass index and waist circumference) (Fernández Núñez et al., 2022)	11	Mixed
Urban green space (e.g., mapped green space, land cover and tree cover)	Positive	Reduced incidence of respiratory mortality (Mueller et al., 2022)	20	Supported
	Positive	Improved lung function (Mueller et al., 2022)	14	Supported
	Positive	Reduced incidence of asthma (Mueller et al., 2022)	38	Mixed
	Positive	Fewer respiratory hospital visits (Mueller et al., 2022)	13	Mixed
	Positive	Reduced incidence of lung cancer (Mueller et al., 2022)	12	Mixed
	Positive	Reduced incidence of rhinitis (Mueller et al., 2022)	12	Mixed
	Positive	Reduced respiratory symptoms (Mueller et al., 2022)	12	Mixed
Urban green space (e.g., green space proximity, quantity, cover type, quality, availability of parks and engagements with green spaces)	Positive	Improved mental health (e.g., anxiety, stress, depression and well-being) (Gianfredi et al., 2021)	19	Supported
	Positive	Increased physical activity (Gianfredi et al., 2021)	15	Supported
Urban green space (e.g., mapped green space, greening interventions and interventions/engagements with green space)	Positive	Improved mood (Kondo et al., 2018)	~18	Supported
	Positive	Increased physical activity (Kondo et al., 2018)	~12	Supported
	Positive	Improved attention (Kondo et al., 2018)	~11	Supported

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
	Positive	Reduced mortality (Kondo et al., 2018)	~5	Supported
	Positive	Reduced self-reported stress (Kondo et al., 2018)	~3	Supported
	Positive	Improved short-term cardiovascular markers (e.g., heart rate) (Kondo et al., 2018)	Unclear	Supported
	Positive	Improved general health (Kondo et al., 2018)	~6	Mixed
	Positive	Reduced depression (Kondo et al., 2018)	~6	Mixed
	Positive	Decreased body mass index (Kondo et al., 2018)	~6	Mixed
	Positive	Reduced physiological stress response (Kondo et al., 2018)	~5	Mixed
Urban green space	Positive	Better subjective well-being (World Health Organisation, 2021)	~4	Supported
	Positive	Restorative outcomes (World Health Organisation, 2021)	~3	Supported
	Positive	Reduced perceived stress (World Health Organisation, 2021)	~3	Supported
	Positive	Increased positive affect (World Health Organisation, 2021)	~9	Mixed
	Positive	Better mental health (World Health Organisation, 2021)	~2	Inconclusive

Note: '~' used where sample size is unclear.

Table D5. Other green space types and health/well-being outcomes

Exposure		Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Green space type	Parks	Positive	Increased positive affect (World Health Organisation, 2021)	~17	Supported
		Positive	Better subjective well-being (World Health Organisation, 2021)	~9	Supported
		Positive	Reduced perceived stress (World Health Organisation, 2021)	~8	Supported
		Positive	Restorative outcomes (World Health Organisation, 2021)	~4	Supported
		Positive	Reduced severity of mental disorders (World Health Organisation, 2021)	~4	Supported
		Positive	Reduced physiological stress (World Health Organisation, 2021)	~19	Mixed
		Positive	Better mental health (World Health Organisation, 2021)	~8	Mixed
		Positive	Greater vitality (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Better quality of life (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Higher satisfaction with life (World Health Organisation, 2021)	~2	Inconclusive
	Gardens	Positive	Reduced severity of a mental disorder (World Health Organisation, 2021)	~7	Mixed
		Positive	Reduced physiological stress (World Health Organisation, 2021)	~6	Mixed
		Positive	Increased positive affect (World Health Organisation, 2021)	~4	Mixed
		Positive	Reduced perceived stress (World Health Organisation, 2021)	~2	Inconclusive

Exposure		Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
		Positive	Better subjective well-being (World Health Organisation, 2021)	~2	Inconclusive
	Forest and woodland cover	Positive	Reduced perceived stress (World Health Organisation, 2021)	~4	Supported
		Positive	Greater vitality (World Health Organisation, 2021)	~4	Supported
		Positive	Restorative outcomes (World Health Organisation, 2021)	~4	Supported
		Positive	Increased positive affect (World Health Organisation, 2021)	~31	Mixed
		Positive	Reduced physiological stress (World Health Organisation, 2021)	~26	Mixed
		Positive	Better mental health (World Health Organisation, 2021)	~5	Mixed
		Positive	Better subjective well-being (World Health Organisation, 2021)	~3	Mixed
		Positive	Reduced prevalence of a mental disorder (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Reduced severity of a mental disorder (World Health Organisation, 2021)	~2	Inconclusive
	Grassland cover	Positive	Increased positive affect (World Health Organisation, 2021)	~4	Supported
		Positive	Better mental health (World Health Organisation, 2021)	~3	Mixed
		Positive	Reduced perceived stress (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Reduced prevalence of a mental disorder (World Health Organisation, 2021)	~2	Inconclusive

Exposure		Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
		Positive	Better subjective well-being (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Reduced physiological stress (World Health Organisation, 2021)	~2	Inconclusive
	Trees and plants	Positive	Increased positive affect (World Health Organisation, 2021)	~4	Supported
		Positive	Reduced prevalence of a mental disorder (World Health Organisation, 2021)	~3	Supported
		Positive	Restorative outcomes (World Health Organisation, 2021)	~4	Mixed
		Positive	Better mental health (World Health Organisation, 2021)	~4	Mixed
		Positive	Reduced severity of a mental disorder (World Health Organisation, 2021)	~4	Mixed
		Positive	Reduced physiological stress (World Health Organisation, 2021)	~2	Inconclusive
	Biodiversity	Positive	Restorative outcomes (World Health Organisation, 2021)	~4	Mixed
		Positive	Increased positive affect (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Reduced physiological stress (World Health Organisation, 2021)	~2	Inconclusive
		Positive	Better subjective well-being (World Health Organisation, 2021)	~2	Inconclusive

Note: '~' used where sample size is unclear.

Table D6. Green space qualities and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Greater biodiversity (mixed measurement, including mapped vegetation, habitat surveys and perceived) of green space	Positive	Improved general well-being (Houlden et al., 2021)	6	Mixed
	Positive	Self-reported restoration (Houlden et al., 2021)	5	Mixed
	Positive	Improved mental well-being (Marselle et al., 2019)	19	Inconclusive
	Positive	Improved mental health (Marselle et al., 2019)	9	Inconclusive
	Positive	Reduced blood pressure (Houlden et al., 2021)	2	Inconclusive
Greater land cover diversity/specific land cover types of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	22	Supported
Greater naturalness of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	15	Supported
Better quality based on combined rating of different features of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	13	Supported
Larger size of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	11	Supported
Connectivity of green spaces	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	8	Supported
Better perceived quality of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	7	Supported
Better safety of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	6	Mixed

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
More infrastructure and amenities in green spaces	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	14	Not supported
Better cleanliness of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	4	Inconclusive
Peacefulness of green space	Positive	Improved health outcomes- varied (Nguyen et al., 2021)	3	Inconclusive

Table D7. Children and young people's green space exposure and health/well-being outcomes

Exposure		Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
Broad green space exposure	**Broad green space exposure (including residential/school green space, greening interventions, classroom interventions, wilderness experience, nature walks and general green space activity.**	Positive	Aged <19	Increased physical activity (Fyfe-Johnson et al., 2021)	108	Supported
		Positive		Improved cognitive, behavioural and mental health (Fyfe-Johnson et al., 2021)	85	Supported
		Positive		Reduced weight (Fyfe-Johnson et al., 2021)	45	Mixed
		Positive		Improved learning (Fyfe-Johnson et al., 2021)	27	Mixed
		Positive		Reduced asthma/allergy (Fyfe-Johnson et al., 2021)	26	Mixed

Exposure		Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
		Positive		Improved cardiovascular and metabolic outcomes (Fyfe-Johnson et al., 2021)	9	Mixed
	Broad green space exposure (mapped green space quantity and proximity, perceived green space and green space visits).	Positive	Aged <19	Improved mental health (Ye et al., 2022)	53	Mixed
		Positive		Improved circulatory health (Ye et al., 2022)	10	Inconclusive
Nature exposure at home	**Normalized Difference Vegetation Index in 500m buffer**	Positive	Aged <19	Reduced obesity/overweigh t (Ye et al., 2022)	5	Significant
		Positive		Increased incidence of asthma (Ye et al., 2022)	10	Not significant
		Positive		Increased incidence of allergic rhinitis (Ye et al., 2022)	7	Not significant
	Measured or self-reported neighbourhood greenness	Positive	Aged <12	Improved emotional and behavioural functioning (Davis et al., 2021)	22	Mixed
		Positive		Higher academic achievement (Davis et al., 2021)	9	Mixed
		Positive		Increased social functioning (Davis et al., 2021)	11	Inconclusive

Exposure		Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
		Positive		Improved well-being (Davis et al., 2021)	9	Inconclusive
		Positive		Improved cognitive skills (Davis et al., 2021)	5	Inconclusive
		Positive		Reduced prevalence of doctor diagnosed disorders- ADHD and Autism (Davis et al., 2021)	3	Inconclusive
	Home outdoor and neighbourhood green space	Positive	Aged <7	Increased outdoor play and physical activity (Christian et al., 2015)	22	Supported
Green space qualities	**Features (facilities and amenities)**	Positive	Mean age between 12 and 16	Physical activity (Van Hecke et al., 2018)	Unclear	Mixed
	Condition (maintenance, incivilities and upkeep)	Positive			Unclear	Mixed
	Aesthetics (attractiveness and appeal)	Positive			Unclear	Mixed
	Safety (personal security and fear)	Positive			Unclear	Mixed
	Policy (management, rules and restrictions)	Positive			Unclear	Mixed

Exposure		Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
Nature in the educational setting	Campus green space (in tertiary and secondary education)	Positive	Aged >12	Positive indicators of restoration (e.g., heart rate, anxiety and perceived restoration) (van den Bogerd et al., 2020)	~9	Supported
		Positive		Increased well-being (van den Bogerd et al., 2020)	8	Mixed
		Positive		Improved academic outcomes (van den Bogerd et al., 2020)	4	Mixed
	Nature views	Positive		Positive indicators of restoration (e.g., heart rate, anxiety and perceived restoration) (van den Bogerd et al., 2020)	3	Inconclusive
		Positive		Improved academic outcomes (van den Bogerd et al., 2020)	2	Inconclusive
	School yard greening	Positive	Aged >18	Improved socioemotional health (Bikomeye et al., 2021)	6	Mixed
		Positive		Increased physical activity (Bikomeye et al., 2021)	4	Mixed

Note: '~' used where sample size is unclear.

Table D8. Blue space and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
General exposure to blue space (e.g., distance, quantity, visits, visibility, quality)	Positive	Increased physical activity (Gascon et al., 2017)	13	Mixed
	Positive	Improved mental health and well-being (Gascon et al., 2017)	12	Mixed
	Positive	Reductions in obesity (Gascon et al., 2017)	8	Mixed
	Positive	Improved general health (Gascon et al., 2017)	6	Mixed
	Positive	Improved cardiovascular health (Gascon et al., 2017)	4	Mixed
General exposure to urban blue space (e.g., distance, quantity, visits, visibility, quality)	Positive	Improved self-reported mental health and well-being (Smith et al., 2021)	7	Significant
	Positive	Improved general health (Smith et al., 2021)	4	Significant
	Positive	Reduced obesity (Smith et al., 2021)	4	Significant
	Positive	Reduced mortality (Smith et al., 2021)	3	Significant
	Positive	Reduced depressive symptoms and anxiety (Smith et al., 2021)	4	Mixed
Contact with blue spaces (e.g., visits)	Positive	Improved markers of restoration (Georgiou et al., 2021)	5	Significant
Amount of blue space within local area	Positive	Increased physical activity (Georgiou et al., 2021)	9	Significant
	Positive	Improved markers of restoration (Georgiou et al., 2021)	6	Significant
	Positive	Higher level of social interaction (Georgiou et al., 2021)	3	Not significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
Artificial blue space e.g., artificial ponds, fountains and other man-made water features	Positive	Increased markers of restoration (Xie et al., 2021)		5	Supported
	Positive	Increased 'perception' (positive experiences of proximity to water feature) (Xie et al., 2021)		12	Mixed
	Positive	Increased physical activity (Xie et al., 2021)		8	Mixed
	Positive	Improved social interaction (Xie et al., 2021)		~4	Mixed
	Positive	Increased markers of physical health (Xie et al., 2021)		2	Inconclusive
	Positive	Increased markers of mental health (Xie et al., 2021)		2	Inconclusive
	Positive	Children and Young People	Increased water play (Xie et al., 2021)	5	Supported
Closer proximity to blue space	Positive	Increased physical activity (Georgiou et al., 2021)		11	Significant
	Positive	Improved markers of restoration (Georgiou et al., 2021)		5	Not significant
	Positive	Higher level of social interaction (Georgiou et al., 2021)		3	Not significant

Note: '~' used where sample size is unclear.

Table D9. Climate and extreme weather events, and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
High temperatures (e.g., mean ambient air temperature)	Negative	Older people (aged 65+)	Higher cardiovascular mortality (Bunker et al., 2016)	41	Significant
	Negative		Higher respiratory mortality (Bunker et al., 2016)	31	Significant
	Negative		Increased respiratory illness (Bunker et al., 2016)	23	Significant
	Negative		Increased genitourinary problems (Bunker et al., 2016)	4	Significant
	Negative		Higher cerebrovascular mortality (Bunker et al., 2016)	3	Significant
	Negative		Increased diabetes mellitus (Bunker et al., 2016)	3	Significant
	Negative		Increased dehydration (Bunker et al., 2016)	2	Inconclusive
	Negative		Increased cardiovascular illness (Bunker et al., 2016)	20	Marginal
	Negative		Increased infection-related morbidity (Bunker et al., 2016)	4	Marginal
	Negative		Increased cerebrovascular illness (Bunker et al., 2016)	12	Not significant
Low temperatures	Negative		Higher cardiovascular mortality (Bunker et al., 2016)	26	Significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
	Negative	Higher respiratory mortality (Bunker et al., 2016)	22	Significant
	Negative	Higher cerebrovascular mortality (Bunker et al., 2016)	14	Significant
	Negative	Increased respiratory illness (Bunker et al., 2016)	13	Significant
	Negative	Increased cardiovascular illness (Bunker et al., 2016)	19	Not significant
	Negative	Increased cerebrovascular illness (Bunker et al., 2016)	14	Not significant
Extreme temperatures (hot and cold)	Negative	Increased mortality (Zanobetti & O'Neill, 2018)	11	Supported
Synergistic impact of higher temperatures and ambient air pollution	Negative	Increased mortality (heat-related all-cause and non-accidental) (Hu et al., 2022)	22	Significant
	Negative	Increased mortality (predominantly respiratory) (Grigorieva & Lukyanets, 2021)	24	Supported
	Negative	Increased morbidity (predominantly respiratory) (Grigorieva & Lukyanets, 2021)	14	Supported
Flooding	Negative	Mental health issues (Lee et al., 2020)	2	Inconclusive

Table D10. Ecological-based air exposures and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
Inhalation of toxins from cyanobacteria algal bloom aerosols	Negative	Increased allergy, inflammation of lungs, eyes and skin (Wiśniewska et al., 2019)		Unclear	Mixed
	Negative	Acute gastrointestinal illness (Wiśniewska et al., 2019)		Unclear	Mixed
Air pollution and allergens interaction	Negative	Worse health outcomes (e.g., allergic symptoms, asthma hospital admissions) (Lam et al., 2021)		35	Mixed
Total pollen concentration	Negative	Increase in asthma-related emergency department visits and hospital admissions (Annesi-Maesano et al., 2023)		6	Supported
	Negative	Decreased lung function (Annesi-Maesano et al., 2023)		~4	Not supported
Increase in grass pollen, 0-2 day time lag	Negative	Those aged <18	Increase in asthma attacks and asthma-related emergency department visits and hospital admissions (Annesi-Maesano et al., 2023)	5	Significant
Increase in grass pollen, 2-4 day time lag	Negative	Increase in severe asthma exacerbations (Annesi-Maesano et al., 2023)		4	Significant
Increase in grass pollen, same day exposure	Negative	Those aged <18	Increase in asthma-related emergency department visits and hospital admissions (Annesi-Maesano et al., 2023)	3	Inconclusive
Increase in weed (ragweed) pollen	Negative	Those aged <60	Increase in severe asthma attacks (Annesi-Maesano et al., 2023)	4	Not significant
Increase in tree pollen, up to 7 day time lag	Negative	Those aged <18	Increase in asthma-related emergency department visits and hospital admissions (Annesi-Maesano et al., 2023)	Unclear	Supported

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
Increase in tree pollen, 0-2 day time lag	Negative	Those aged <18	Increase in severe asthma exacerbations (Annesi-Maesano et al., 2023)	3	Not significant

Appendix E: Active engagement with nature

Table E1. Non-specific nature-based interventions and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
Nature-based interventions (forest bathing, green exercise, gardening, and nature viewing)	Positive	Reduced physiological stress response (e.g., blood pressure, heart rate and nervous system measures) (Bikomeye et al., 2022)		26	Mixed
Nature-based interventions (green exercise, and nature viewing)	Positive	Improved mental health and well-being (Wilkie & Davinson, 2021)		41	Mixed
	Positive	Improved physical health (Wilkie & Davinson, 2021)		33	Mixed
Active (predominantly walking) and passive (seated relaxation) engagement interventions	Positive	Reduction in depressive mood (Roberts et al., 2019)		33	Significant
Nature-based interventions (forest bathing, gardening, nature-based rehabilitation/therapy)	Positive	People with stress-related illness	Improved health and well-being (Johansson et al., 2022)	Unclear	Supported
	Positive		Restoration and reduced stress (Johansson et al., 2022)	Unclear	Mixed
Nature-based interventions (e.g., forest therapy, green care farms, gardens and gardening, outdoor adventure programs)	Positive	People with neurological disability (predominantly dementia)	Improved emotional health (Lakhani et al., 2019)	13	Supported
	Positive		Improved social health (Lakhani et al., 2019)	8	Supported
	Positive		Improved psychological health (Lakhani et al., 2019)	5	Mixed

Table E2. Gardening/gardens and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Gardening broad (e.g., private gardening, community gardening, allotment gardening and horticultural therapy)	Positive	Better health (broad e.g., mood, depression and body mass index) (Soga et al., 2017)	22	Significant
	Positive	Improved psychosocial well-being (e.g., loneliness, sense of community and trust) (Spano et al., 2020)	3	Significant
Community gardening	Positive	Reduced body mass index (Kunpeuk et al., 2020)	6	Significant
	Positive	Improved nutrition (fruit and vegetable consumption) (Kunpeuk et al., 2020)	10	Supported
	Positive	Increased self-reported physical activity (Kunpeuk et al., 2020)	6	Mixed
Urban collective gardening	Positive	Improved mental health (e.g., stress, life satisfaction and well-being) (Tharrey & Darmon, 2022)	7	Supported
	Positive	Healthy dietary behaviours (Tharrey & Darmon, 2022)	5	Supported
	Positive	Improved physical health (e.g., self-reported, blood pressure and long function) (Tharrey & Darmon, 2022)	4	Mixed
	Positive	Reduced body mass index (Tharrey & Darmon, 2022)	5	Inconclusive
	Positive	Increased self-reported physical activity (Tharrey & Darmon, 2022)	3	Inconclusive
Group-based gardening interventions	Positive	Includes clinical groups e.g., physical: Improved well-being (Briggs et al., 2023)	4	Significant
	Positive	Includes clinical groups e.g., physical: Reduced depression (Briggs et al., 2023)	8	Inconclusive

Exposure	Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
	Positive	and mental health related	Improved health-related quality of life (Briggs et al., 2023)	7	Inconclusive
	Positive		Reduced anxiety (Briggs et al., 2023)	5	Inconclusive
	Positive		Reduced stress (Briggs et al., 2023)	3	Inconclusive
Care home gardens/horti cultural therapy	Positive	People living with dementia	Reductions in dementia-related behaviours (e.g., agitation, pacing and violence) (Whear et al., 2014)	7	Mixed
	Positive		Positive physical outcomes (including improved sleep, physical exercise and reduced falls) (Whear et al., 2014)	3	Inconclusive
	Positive		Increased positive affect (Whear et al., 2014)	2	Inconclusive
Gardening interventions	Positive	People with mental health issues	Reduced depression (Clatworthy et al., 2013)	6	Supported
	Positive		Reduced anxiety (Clatworthy et al., 2013)	4	Supported
	Positive		Increased attentional capacity (Clatworthy et al., 2013)	2	Inconclusive

Table E3. Exercising outdoors and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Outdoor exercise in both urban and rural green environments	Positive	Reduced anger (Li et al., 2022)	10	Significant
	Positive	Reduced confusion (Li et al., 2022)	10	Significant

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
(predominantly walking, but also running and cycling)	Positive	Reduced fatigue (Li et al., 2022)	10	Significant
	Positive	Reduced depression (Li et al., 2022)	10	Significant
	Positive	Reduced tension (Li et al., 2022)	10	Significant
	Positive	Increased vigour (Li et al., 2022)	10	Significant
	Positive	Feeling more comfortable (Li et al., 2022)	8	Significant
	Positive	Reduced anxiety (Li et al., 2022)	8	Significant
	Positive	Feeling more relaxed (Li et al., 2022)	6	Significant
	Positive	Feeling more natural (as opposed to artificial) (Li et al., 2022)	6	Significant
	Positive	Decreased negative affect (Li et al., 2022)	4	Significant
	Positive	Restorativeness (Li et al., 2022)	4	Not significant
	Positive	Increased positive affect (Li et al., 2022)	4	Not significant
Outdoor exercise in both urban and rural green environments (e.g., walking, running and cycling)	Positive	Lower perceived fatigue (Brito et al., 2021)	12	Significant
	Positive	Higher levels of vigour (Brito et al., 2021)	9	Significant
	Positive	Increased positive affect (Brito et al., 2021)	9	Significant
	Positive	Lower perceived stress (Brito et al., 2021)	7	Significant
	Positive	Improved cognitive performance (Brito et al., 2021)	7	Marginal

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
	Positive	Improved performance efficacy (Brito et al., 2021)	9	Not significant
	Positive	Reduced cardiac output related to exercising (Brito et al., 2021)	8	Not significant
Outdoor walking groups	Positive	Improved health outcomes (lower body fat, body mass index and total cholesterol) (Hanson & Jones, 2015)	~17	Significant
	Positive	Improved cardiovascular measures (systolic and diastolic blood pressure, and resting heart rate) (Hanson & Jones, 2015)	~15	Significant
	Positive	Improved VO_{2max} (or aerobic capacity) (Hanson & Jones, 2015)	7	Significant
	Positive	Reduced depression (Hanson & Jones, 2015)	5	Significant
	Positive	Greater distance for 6 minute walk time (Hanson & Jones, 2015)	2	Inconclusive
	Positive	Improved physical functioning (measured with SF-36 physical functioning index) (Hanson & Jones, 2015)	2	Inconclusive
	Positive	Improved blood profiles (lipids, HbA1c) (Hanson & Jones, 2015)	~10	Not significant
	Positive	Improved mental health (measured with SF-36 mental health constructs) (Hanson & Jones, 2015)	2	Inconclusive
	Positive	Smaller waist circumference (Hanson & Jones, 2015)	2	Inconclusive
Outdoor walking groups	Positive	People with mental: Improved mood (Swinson et al., 2020)	3	Supported

Exposure		Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
		Positive	health issues	Improved self-esteem (Swinson et al., 2020)	2	Inconclusive
		Positive		Reduced depression (Swinson et al., 2020)	2	Inconclusive
Time in green space (as opposed to urban space)		Positive	Favourable brain activity (showing more meditation, relaxation, and restoration, and less arousal and frustration) (Bolouki, 2023)		8	Supported
Comparison 1	**Walking in natural environments**	Positive	Improved heart rate variability (Mygind et al., 2021)		7	Significant
		Positive	Reduced stress response (serum and salivary cortisol) (Mygind et al., 2021)		4	Not significant
	Seated relaxation in natural environments	Positive	Reduced stress response (serum and salivary cortisol) (Mygind et al., 2021)		4	Mixed
		Positive	Improved heart rate variability (Mygind et al., 2021)		6	Mixed
Comparison 2	**Active engagement interventions (predominantly walking)**	Positive	Decreased depressive mood (Roberts et al., 2019)		20	Mixed
	Passive engagement interventions (seated relaxation)	Positive	Decreased depressive mood (Roberts et al., 2019)		8	Mixed

Note: '~' used where sample size is unclear.

Table E4. Other therapeutic nature-based interventions and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
Care farms	Positive	Mental health issues and substance misuse	Reduced depression (Murray et al., 2019)	4	Mixed
	Positive		Reduced anxiety (Murray et al., 2019)	3	Mixed
	Positive		Improved quality of life (Murray et al., 2019)	3	Not supported
	Positive		Self-efficacy (Murray et al., 2019)	2	Inconclusive
	Positive		Increased positive affect (Murray et al., 2019)	2	Inconclusive
	Positive		Improved social outcomes (Murray et al., 2019)	2	Inconclusive

Table E5. Blue space interventions and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
Water based therapy* (predominantly active e.g., surfing dragon boating and sailing)	Positive	Those with mental and/or physical health issues	Improved psycho-social well-being (Britton et al., 2020)	~27	Supported
	Positive		Improved physical health (Britton et al., 2020)	6	Mixed

Note: '~' used where sample size is unclear.

Table E6. Children and young people's active engagement with nature and health/well-being outcomes

Exposure		Association with Health/ Well-being		Health/well-being outcome	Number of studies included	Evidence of relationship
Outdoor activity	Duration of time spent outdoors	Positive	Aged 3 to 13	Increased physical activity (Gray et al., 2015)	~16	Supported
		Positive		Reduced sedentary behaviour (Gray et al., 2015)	~3	Supported
		Positive		Improved cardiorespiratory fitness (Gray et al., 2015)	2	Inconclusive
	Outdoor physical activity (e.g., general outdoor and playground activities/games, walking and cycling)	Positive	Aged 4 to 17	Increased self-esteem (Mnich et al., 2019)	4	Mixed
		Positive		Increased fatigue (Mnich et al., 2019)	2	Inconclusive
		Positive		Increased vigour (Mnich et al., 2019)	2	Inconclusive
		Positive		Reduced tension (Mnich et al., 2019)	2	Inconclusive
		Positive		Increased enjoyment of physical activity (Mnich et al., 2019)	2	Inconclusive
		Positive		Better self-reported health (Mnich et al., 2019)	2	Inconclusive
		Positive		Decreased blood pressure (Mnich et al., 2019)	2	Inconclusive
Nature in the [illegible]	School gardening activities	Positive	Aged ~7 to ~12	Increased fruit and vegetable intake (Qi et al., 2021)	5	Significant
		Positive		Reduced waist circumference (Qi et al., 2021)	6	Not significant

Exposure		Association with Health/ Well-being		Health/well-being outcome	Number of studies included	Evidence of relationship
		Positive		Lower body mass index (Qi et al., 2021)	5	Not significant
		Positive		Lower body mass index z-score (Qi et al., 2021)	5	Not significant
	Nature play (outdoor activity or intervention without structure, free play)	Positive	Aged 2 to 9	Physical activity (Dankiw et al., 2020)	7	Mixed
		Positive		Improved social outcomes (e.g., teacher and peer interactions and antisocial behaviour) (Dankiw et al., 2020)	4	Mixed
		Positive		Improved play (e.g., constructive, imaginative and associative) (Dankiw et al., 2020)	5	Mixed
Outdoor exercise e.g., walking, running, cycling and horse trekking		Positive	Aged 14 to 24	Improved mental health (e.g., anxiety, depression and self-esteem) (Bray et al., 2022)	8	Mixed
Outdoor adventure programs		Positive		Improved mental health (e.g., anxiety, depression and self-esteem) (Bray et al., 2022)	10	Mixed

Note: '~' used where sample size is unclear.

Appendix F: Exposure to contaminated nature

Table F1. Contaminated water and health/well-being outcomes

Exposure		Impact on Health/Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
Contact with pathogens during water recreation	Swimming contact	Negative	Increased gastrointestinal illness (Russo et al., 2020)	43	Significant
		Negative	Increased respiratory illness (Russo et al., 2020)	16	Significant
		Negative	Increased skin symptoms (Russo et al., 2020)	16	Significant
		Negative	Increased ear/nose/throat symptoms (Russo et al., 2020)	15	Significant
		Negative	Increased eye symptoms (Russo et al., 2020)	11	Significant
		Negative	Increased cold/flu symptoms (Russo et al., 2020)	9	Significant
	Sports-related contact	Negative	Increased gastrointestinal illness (Russo et al., 2020)	5	Significant
		Negative	Increased respiratory illness (Russo et al., 2020)	3	Significant
	Minimal contact (floating on or being near)	Negative	Increased gastrointestinal illness (Russo et al., 2020)	6	Not significant
		Negative	Increased respiratory illness (Russo et al., 2020)	2	Inconclusive

Exposure		Impact on Health/Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
	Sand contact	Negative	Increased gastrointestinal illness (Russo et al., 2020)	5	Not significant
Pathogens in EU bathing waters		Negative	Increased risk of exposure to waterborne organisms with potential to cause illness/harm (Farrell et al., 2021)	60	Inferred/Supported

Table F2. Ambient air pollution and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
Ambient Air Pollution	Negative	Worse health records (e.g., mortality and hospital admissions) (Sun & Zhu, 2019)	286	Supported
	Negative	Increased incidence of respiratory disease (e.g., Asthma, respiratory symptoms and lung diseases) (Sun & Zhu, 2019)	199	Supported
	Negative	Increased incidence of cardiovascular diseases (e.g., heart, blood and cardiovascular disease and stroke) (Sun & Zhu, 2019)	90	Supported
	Negative	Increased incidence of other diseases (Sun & Zhu, 2019)	82	Supported
	Negative	Increased incidence of cancer (e.g., lung and breast cancers) (Sun & Zhu, 2019)	38	Supported
	Negative	Increased incidence of chronic diseases (Sun & Zhu, 2019)	24	Supported

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
	Negative	Reduced physical activity and increased leisure time physical inactivity (An et al., 2018)		7	Supported
	Negative	Pre-natal and birth	Adverse pre-natal and birth outcomes (abnormal birth weight, risk of macrosomia and pre-term birth) (Gheissari et al., 2022)	~56	Supported
	Negative		Worse pre-natal, birth and child outcomes (e.g., fertility, birth weight and infant death) (Sun & Zhu, 2019)	52	Supported
	Negative	Children and young people aged 0-5	Increased respiratory diseases (e.g., asthma) (Spencer-Hwang et al., 2023)	28	Supported
	Negative		Increased incidence of ear infections (Spencer-Hwang et al., 2023)	9	Inconclusive
	Negative		Increased incidence of developmental disorders (e.g., autism and mental challenges) (Spencer-Hwang et al., 2023)	8	Inconclusive
	Negative		Increased allergies, eczema and rhinitis (Spencer-Hwang et al., 2023)	7	Inconclusive
	Negative		Increased incidence of cancer (Spencer-Hwang et al., 2023)	4	Inconclusive
	Negative		Increased incidence of cancer (Spencer-Hwang et al., 2023)	3	Inconclusive
	Negative	Children and young	Worse respiratory and allergic outcomes (e.g., reduced lung function, increased respiratory tract	57	Supported

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
		people aged 0-10	infections and asthma) (Gheissari et al., 2022)		
	Negative		Adverse neurodevelopmental outcomes (e.g. impaired cognitive, motor, behavioural and language development) (Gheissari et al., 2022)	26	Supported
	Negative		Increased obesity and metabolic disorders (e.g., higher BMI, risk of diabetes and hypertension) (Gheissari et al., 2022)	~22	Supported
	Negative	People with coronary artery disease	Reduced heart rate variability (indicative of reduced cardiac function) (Warburton et al., 2019)	13	Supported
	Negative		Worse vascular measures (e.g., blood pressure and heart rate) (Warburton et al., 2019)	5	Mixed

Table F3. Particulate matter and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
Particulate matter diameter 2.5 ($PM_{2.5}$)	Negative	Increased cancer mortality (Kim et al., 2018)	19	Significant
	Negative	Increased cardiovascular mortality (Pranata et al., 2020)	18	Significant
	Negative	Increased ischemic heart disease mortality (Pranata et al., 2020)	15	Significant
	Negative	Increased stroke incidence (Niu et al., 2021/Pranata et al., 2020)	7/15	Significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
	Negative	Increased all-cause mortality (Pranata et al., 2020)		14	Significant
	Negative	Higher stroke hospital admissions (Niu et al., 2021)		11	Significant
	Negative	Increased incidence of high blood pressure (hypertension) (Pranata et al., 2020)		10	Significant
	Negative	Higher stroke mortality (Niu et al., 2021)		10	Significant
	Negative	Increased incidence of acute coronary events (Pranata et al., 2020)		9	Significant
	Negative	Increased incidence of cardiovascular disease (Pranata et al., 2020)		8	Significant
	Negative	Increased incidence of coronary heart disease (Pranata et al., 2020)		8	Marginal
	Negative	Increased incidence of heart failure (Pranata et al., 2020)		4	Not significant
	Negative	Increased incidence of atrial fibrillation (Pranata et al., 2020)		4	Not significant
	Negative	Increased anxiety (Trushna et al., 2021)		11	Inconclusive
	Negative	Pre-natal and birth	Increased risk of preterm birth (Klepac et al., 2018)	13	Significant
	Negative	Children aged 0-5	Increased mortality (Karimi & Shokrinezhad, 2020)	7	Significant
Particulate matter diameter 10 (PM_{10})	Negative	Increased cancer mortality (Kim et al., 2018)		12	Significant
	Negative	Increased cardiovascular mortality (Pranata et al., 2020)		11	Significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
	Negative	Higher stroke hospital admissions (Niu et al., 2021)		11	Significant
	Negative	Higher stroke mortality (Niu et al., 2021)		10	Significant
	Negative	Increased all-cause mortality (Pranata et al., 2020)		9	Significant
	Negative	Increased ischemic heart disease mortality (Pranata et al., 2020)		5	Significant
	Negative	Increased incidence of heart failure (Pranata et al., 2020)		5	Significant
	Negative	Increased psychological stress (Trushna et al., 2021)		4	Significant
	Negative	Increased stroke incidence (Niu et al., 2021)		13	Not significant
	Negative	Increased incidence of coronary heart disease (Pranata et al., 2020)		9	Not significant
	Negative	Increased incidence of acute coronary events (Pranata et al., 2020)		8	Not significant
	Negative	Increased incidence of cardiovascular disease (Pranata et al., 2020)		7	Not significant
	Negative	Increased incidence of atrial fibrillation (Pranata et al., 2020)		4	Not significant
	Negative	Increased anxiety (Trushna et al., 2021)		10	Inconclusive
	Negative	Children aged 0-5	Increased mortality (Karimi & Shokrinezhad, 2020)	9	Significant
	Negative	Pre-natal and birth	Increased risk of preterm birth (Klepac et al., 2018)	6	Significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
Particulate matter (all size)	Negative	Increased respiratory hospital admissions (Anderson et al., 2012)		9	Supported
	Negative	Increased respiratory mortality (Anderson et al., 2012)		7	Supported
	Negative	Pre-natal and birth	Worse pregnancy outcomes (pre-term birth and low birth weight) (Stieb et al., 2012)	Unclear	Supported

Table F4. Other air pollutants and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
Nitrogen dioxide (NO_2)	Negative	Increased all-cause mortality (Pranata et al., 2020; Stieb et al., 2021)	9/39	Significant
	Negative	Increased mortality from respiratory disease (Stieb et al., 2021)	29	Significant
	Negative	Increased cardiovascular mortality (Pranata et al., 2020; Stieb et al., 2021)	13/29	Significant
	Negative	Increased mortality from lung cancer (Stieb et al., 2021)	28	Significant
	Negative	Increased (ischemic) heart disease mortality (Pranata et al., 2020; Stieb et al., 2021)	6/19	Significant
	Negative	Increased cancer mortality (Kim et al., 2018)	16	Significant
	Negative	Increased incidence of acute coronary events (Pranata et al., 2020)	13	Significant
	Negative	Higher stroke hospital admissions (Niu et al., 2021)	11	Significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
	Negative	Higher stroke mortality (Niu et al., 2021)		10	Significant
	Negative	Increased stroke incidence (Niu et al., 2021)		7	Significant
	Negative	Increased incidence of cardiovascular disease (Pranata et al., 2020)		7	Significant
	Negative	Increased incidence of atrial fibrillation (Pranata et al., 2020)		2	Inconclusive
	Negative	Increased incidence of stroke (Pranata et al., 2020)		11	Marginal
	Negative	Increased mortality from cerebrovascular disease (Stieb et al., 2021)		17	Not significant
	Negative	Increased incidence of coronary heart disease (Pranata et al., 2020)		6	Not significant
	Negative	Increased incidence of heart failure (Pranata et al., 2020)		3	Not significant
	Negative	Increased anxiety (Trushna et al., 2021)		11	Inconclusive
	Negative	Pre-natal and birth	Worse pregnancy outcomes (pre-term birth and low birth weight) (Stieb et al., 2021)	Unclear	Supported
	Negative		Increased risk of preterm birth (Klepac et al., 2018)	8	Not significant
	Negative	Children and young people	Increased mortality (Karimi & Shokrinezhad, 2020)	8	Significant
	Negative		Increased adverse respiratory symptoms (Li et al., 2012)	29	Supported

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
	Negative		Decreased lung function (Li et al., 2012)	28	Supported
Ozone (O_3)	Negative	Higher stroke hospital admissions (Niu et al., 2021)		10	Significant
	Negative	Increased stroke incidence (Niu et al., 2021)		18	Not significant
	Negative	Higher stroke mortality (Niu et al., 2021)		9	Not significant
	Negative	Pre-natal and birth	Increased risk of preterm birth (Klepac et al., 2018)	5	Significant
	Negative	Children aged 0-5	Increased mortality (Karimi & Shokrinezhad, 2020)	9	Significant
Sulphur dioxide (SO_2)	Negative	Higher stroke hospital admissions (Niu et al., 2021)		10	Significant
	Negative	Increased stroke incidence (Niu et al., 2021)		4	Significant
	Negative	Pre-natal and birth	Worse pregnancy outcomes (pre-term birth and low birth weight) (Stieb et al., 2021)	Unclear	Mixed
	Negative	Children aged 0-5	Increased mortality (Karimi & Shokrinezhad, 2020)	9	Significant
	Negative	Children and young people	Increased adverse respiratory symptoms (Li et al., 2012)	29	Mixed
	Negative		Worse lung function (Li et al., 2012)	28	Mixed
Carbon monoxide (CO)	Negative	Higher stroke hospital admissions (Niu et al., 2021)		6	Significant
	Negative	Increased stroke incidence (Niu et al., 2021)		4	Not significant

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
	Negative	Higher stroke mortality (Niu et al., 2021)		4	Not significant
	Negative	Pre-natal and birth	Worse pregnancy outcomes (pre-term birth and low birth weight) (Stieb et al., 2021)	Unclear	Supported
	Negative		Preterm birth (Klepac et al., 2018)	5	Marginal
	Negative	Children aged 0-5	Increased mortality (Karimi & Shokrinezhad, 2020)	8	Significant

Table F5. Exercise in polluted air and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
Outdoor exercise in polluted areas	Negative	Decrease in vascular function (Madureira et al., 2019)		~10	Supported
	Negative	Worse long-term health outcomes e.g., asthma, myocardial infarction and mortality (Tainio et al., 2021)		8	Mixed
	Negative	Worse short-term health outcomes e.g., cardiovascular and respiratory function (Tainio et al., 2021)		9	Not supported
	Negative	Increase in myocardial ischemia and angina (Madureira et al., 2019)		~7	Not supported
	Negative	Decrease in lung function (Madureira et al., 2019)		~5	Not supported
	Negative	Increase in lung inflammation (Madureira et al., 2019)		~4	Not supported
	Negative	Susceptible groups (e.g., children, people	Decrease in lung function	~3	Supported

Exposure	Association with Health/ Well-being	Health/Well-being Outcome		Number of studies included	Evidence of relationship
		with asthma or COPD)	(Madureira et al., 2019)		

Appendix G: Exposure to nature improvement

Table G1. Nature recovery work and health/well-being outcomes

	Exposure	Association with Health/ Well-being	Health/well-being outcome		Number of studies included	Evidence of relationship
Urban green space interventions	**Park-based interventions dual approach (physical change and promotion/sign-posting)**	Positive	Increased physical activity (Hunter et al., 2019)		7	Supported
	Greenways/trails dual approach (physical change and promotion/sign-posting)	Positive	Increased physical activity (Hunter et al., 2019)		2	Inconclusive
	Greening vacant lots dual approach (physical change and promotion/sign-posting)	Positive	Improved health (Hunter et al., 2019)		4	Supported
		Positive	Reduced stress (Hunter et al., 2019)		4	Supported
	Park-based interventions, physical change only	Positive	Increased physical activity (Hunter et al., 2019)		9	Mixed
	Greenways/trails, physical change only	Positive	Increased physical activity (Hunter et al., 2019)		3	Not supported
	Urban green space interventions (in streets, parks and forests)	Positive	Aged 14 to 24	Improved mental health (e.g., anxiety, depression and self-esteem) (Bray et al., 2022)	13	Supported

Exposure	Association with Health/ Well-being	Health/well-being outcome	Number of studies included	Evidence of relationship
Urban blue space regeneration in deprived communities	Positive	Behavioural changes toward healthier lifestyles e.g., increased user numbers and physical activity (Brückner et al., 2022)	~27	Inferred/Supported
	Positive	Healthier urban environments e.g. reduced air and noise pollution (Brückner et al., 2022)	Unclear	Inconclusive

Table G2. Air pollution mitigation strategies and health/well-being outcomes

Exposure		Association with Health/Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
Nature-based solutions	**Residential greenness air quality regulation**	Positive	Reduced respiratory diseases (e.g., asthma and rhinitis) (Qiu et al., 2021)	11	Significant
		Positive	Reduced cardiovascular disease (Qiu et al., 2021)	8	Significant
		Positive	Reduced likelihood of low birth weight (Qiu et al., 2021)	5	Significant
		Positive	Reduced likelihood of other disease (e.g., obesity, mental health and blood	3	Significant

Exposure		Association with Health/Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
			pressure) (Qiu et al., 2021)		
		Positive	Reduced allergic reactions (Qiu et al., 2021)	6	Not Significant
	Residential blue space	Positive	Improved (reduced) air temperature (Georgiou et al., 2021)	5	Inferred/Mixed
		Positive	Improved air quality (lower PM2.5 concentrations) (Georgiou et al., 2021)	4	Inferred/Mixed
	Parks and green spaces	Positive	Cooler air temperature during the day around parks and green spaces (Bowler et al., 2010)	16	Inferred/Significant
		Positive	Cooler air temperature during the night around parks and green spaces (Bowler et al., 2010)	7	Inferred/Significant
	Urban trees and forests	Positive	Cooler air temperature beneath trees (Bowler et al., 2010)	15	Inferred/Supported
	Ground and roof vegetation	Positive	Cooler air temperature on ground/roofs with vegetation	12	Inferred/Mixed

Exposure		Association with Health/Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
			(Bowler et al., 2010)		
Greenhouse gas mitigation measures	**In the energy sector (e.g., through less use, greater energy efficiency and use of renewables)**	Positive	Reduced premature death (Gao et al., 2018)	8	Inferred/Supported
	In the transport sector (e.g., through less use, greater energy efficiency and use of renewables)	Positive	Increased DALYs and reduced premature deaths (Gao et al., 2018)	9	Inferred/Supported
		Positive	Improved air quality (Gao et al., 2018)	6	Inferred/Supported
		Positive	Reduced premature death (Gao et al., 2018)	4	Inferred/Supported
	In the household sector (e.g., fuel switching, building materials and behavioural change)	Positive	Reduced DALYs and premature deaths (Gao et al., 2018)	2	Inferred/Inconclusive
Air quality strategies	**Traffic emission control related interventions (e.g., low emission zones and congestion charges)**	Positive	Increased years of life gained (Wang et al., 2016)	7	Inferred/Supported
	General regulations on air quality control (e.g.,	Positive	Reduced premature deaths (Wang et al., 2016)	4	Inferred/Supported

Exposure		Association with Health/Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
	directives on air quality)				
	Energy related strategies (e.g., ban of coal sales and energy efficiency interventions)	Positive	Reduced premature deaths (Wang et al., 2016)	3	Inferred/Supported
Interventions to reduce ambient air pollution		Positive	Improved health (Burns et al., 2020)	42	Inferred/Supported

Table G3. Pro-environmental behaviours and health/well-being outcomes

Exposure	Association with Health/ Well-being	Health/Well-being Outcome	Number of studies included	Evidence of relationship
Active transport (cycling or walking)	Positive	Increased physical activity (Quam et al., 2017)	9	Supported
	Negative/positive	Increased/reduced traffic injuries and fatality (Quam et al., 2017)	7	Mixed
	Negative	Increased exposure to air pollution (Quam et al., 2017)	9	Inferred/Inconclusive
Environmental enhancement and conservation activity	Positive	Improved quality of life (Husk et al., 2016)	8	Inconclusive
	Positive	Improved mental and emotional health (Husk et al., 2016)	5	Inconclusive
	Positive	Increased physical activity (Husk et al., 2016)	2	Inconclusive

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