Green Blue Infrastructure Impacts on Health and Wellbeing; A Rapid Evidence Assessment

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Executive Summary

This rapid evidence assessment assesses current knowledge in the academic literature concerning the impacts of Green Blue Infrastructure on people's health and wellbeing in the UK, and the implications therein for policy and practice and its use in Parliamentary work. Health and wellbeing include physical health, mental health, and wellbeing whilst "Green Blue Infrastructure" is a strategically planned multifunctional network of natural and semi-natural areas and features designed and managed to deliver multiple benefits to people. Many green spaces have not been designed and managed to deliberately maximise multiple benefits, and so, strictly speaking, do not fit this definition. Nevertheless, they are likely to provide benefits to climate, health, and biodiversity. This makes Green Blue Infrastructure of cross-cutting interest for environmental, health and planning policy covering multiple government departments.

Key findings:

- More studies show the positive impacts of Green Blue Infrastructure (GBI) on general wellbeing than on specific physical and mental health conditions, particularly: -
  - Most evidence exists to show improved wellbeing from using and interacting with GBI, often through self-reported methods.
  - Evidence shows that living near GBI can increase rate of physical activity including during the COVID-19 pandemic.
  - Some evidence shows that increased physical activity from GBI can reduce childhood obesity and slow health declines in the elderly.
  - Evidence also shows improved cooling and air quality from urban GBI can reduce morbidity.
  - Evidence supports GBI positively impacting mental health, but evidence only exists to show this is from multiple direct pathways and there is an evidence gap relating to indirect pathways. Of this evidence, social prescribing of GBI, notably in wetlands, shows positive impacts on anxiety and depression.
  - Limited evidence shows GBI can reduce premature mortality, through increased exposure and use, and improved air quality.
- The positive impacts reported are the result of direct pathways (such as increased physical activity, increased exposure) and indirect pathways (such as improved air quality and reduced urban heating)
- There is very little evidence that GBI negatively impacts health and wellbeing. Evidence that does exist, shows that poor design and management of GBI can increase the number of pest species. It can also increase pollen exposure from urban trees.
- Areas with more GBI may reduce mental health inequalities in socio-economic deprived communities.
- Very few studies research direct and indirect pathways together with a cumulative impact deficit.
- Research attention to date has studied certain type of GBI pathways and impacts more than others, meaning the evidence of health and wellbeing impacts of GBI is not yet fully understood, hindering its wider adoption in health and environmental practice.
- Rural and Peri-Urban GBI is the least explicitly studied form of GBI in relation to health and wellbeing.

Implications for parliament & policy

- Health benefits of GBI may be best realised holistically working across disciplines, government departments and sectors including, health, planning and environmental practitioners working together.
- The lack of research on the impacts of different type of GBI (for example SuDS, Green Walls; Green Roofs) limits the ability to develop specific evidence-based policy for these interventions, in relation to health and wellbeing.

- GBI helps contribute to government objectives of reducing health inequalities.
- Knowledge gaps may benefit from greater alignment between academic research, policy and practice to support evidence-led health policy.
- GBI health benefits may be increased by identifying and factoring in the diverse needs of users and the most appropriate GBI interventions in the design stages. Especially, to those who currently have the least access to greenspace and GBI.
- There is a lag-time between the design and implementation of GBI, and their ability to deliver health and wellbeing benefits, due to the time for some features of GBI to mature and current perceptions of high maintenance costs.

The implications described above, as well as a lack of definitional and operational clarity regarding health and well-being impacts from GBI highlight key potential questions for select committee scrutiny and wider policy investigation. Specifically:

- How can we get the most out of GBI with health to improve multifunctionality?
- To what extent can GBI reduce burdens on the NHS and local authorities across the UK?
- Is there sufficient evidence from different GBI interventions (i.e. living walls, green roofs, SuDS) to understand their individual and collective health and wellbeing impacts?
- How effectively is inequality addressed in GBI and wellbeing policy responses? In particular, how is planning policy addressing this in policies, plans, projects and programmes?
- How is GBI and health and wellbeing delivery affected by different time and spatial scales?
- What lessons can be learnt from experiences in Scotland, Wales and Northern Ireland through different systems of governance in tackling health and wellbeing benefits from GBI?
- How can joint working between health and environment practitioners and researchers be improved? And what can be learnt from examples of good practice relating to GBI and health and wellbeing?

1. Review Context & Scope

This rapid evidence assessment provides policymakers and analysts working in the UK parliament with a summary of current knowledge in the academic literature, relating to the impacts of Green Blue Infrastructure (GBI) on people's health and wellbeing in the UK, and the resulting implications for policy and practice interventions. GBI is of cross-cutting importance for environmental, health and planning sectors covering work priorities of multiple government departments (DEFRA, DLUHC, DHSC, DCMS, DESNZ, DOT, DSIT). In order for GBI benefits to be optimised there is a need for much better joint working and understanding across government departments with GBI seen as critical infrastructure to help solve key challenges rather than the traditional reliance[1] on engineered grey infrastructure solutions[2]. Equity is also an important consideration given that a third of the population in England do not live within a 15 minute walk to greenspace[3]. There is also a considerable time lag between designing and delivering GBI and realising its full benefits in the long term which can be compromised due to perceived maintenance costs. Collectively, these factors create the need for this evidence assessment.

First, the scope and context of the assessment is outlined, including the difference between greenspace and green infrastructure alongside the pathways to different health and wellbeing impacts. Second, the academic evidence, to date, is summarised showing how different types of GBI impact on different health and wellbeing outcomes through both direct and indirect impact pathways. Finally, the implications of these findings for policy and parliamentary work are discussed. This rapid evidence assessment forms part of a pilot for the Parliamentary Office of Science and Technology (POST) in collaboration with International Public Policy Observatory (IPPO) and Capabilities in Academic Policy Engagement (CAPE) to evaluate the different approaches for rapid evidence assessment design and delivery to better support the work of Parliament.

1.1 Not all Green and Blue Spaces are Green Blue Infrastructure

Green Infrastructure (GI) is a contested concept, with no standard definition that is widely accepted or used consistently in research and practice[4]. This is further complicated when academics integrate alternative terminology in discussions of what GI/GBI is and compartmentalise these considerations in their presentation of "GBI" as a concept. This includes the use of: Nature-Based Solutions (NBS), Ecosystem Services (ES), greenspace planning, urban greening, Water-Sensitive Urban Design (WSUD), Low Impact Development (LID) and biophilic design amongst others[4], all of which have overlap.

The relationship between greenspace and GI is important to understand in the context of this assessment. Greenspace only becomes GI/GBI (Figure 1) when it has been designed and managed to provide multiple benefits. For example, the Queen Elizabeth Olympic Park (Box 1) provides an exemplar of multifunctional GBI. GBI can also take a range of forms[4], as shown in Figure 2. Green infrastructure is defined in this assessment as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services, such as water purification, air quality, space for recreation, and climate mitigation and adaptation". This network of green (land) and blue (water) spaces can improve environmental conditions and therefore citizens' health and quality of life. It also supports a green economy, and creates job opportunities[5].

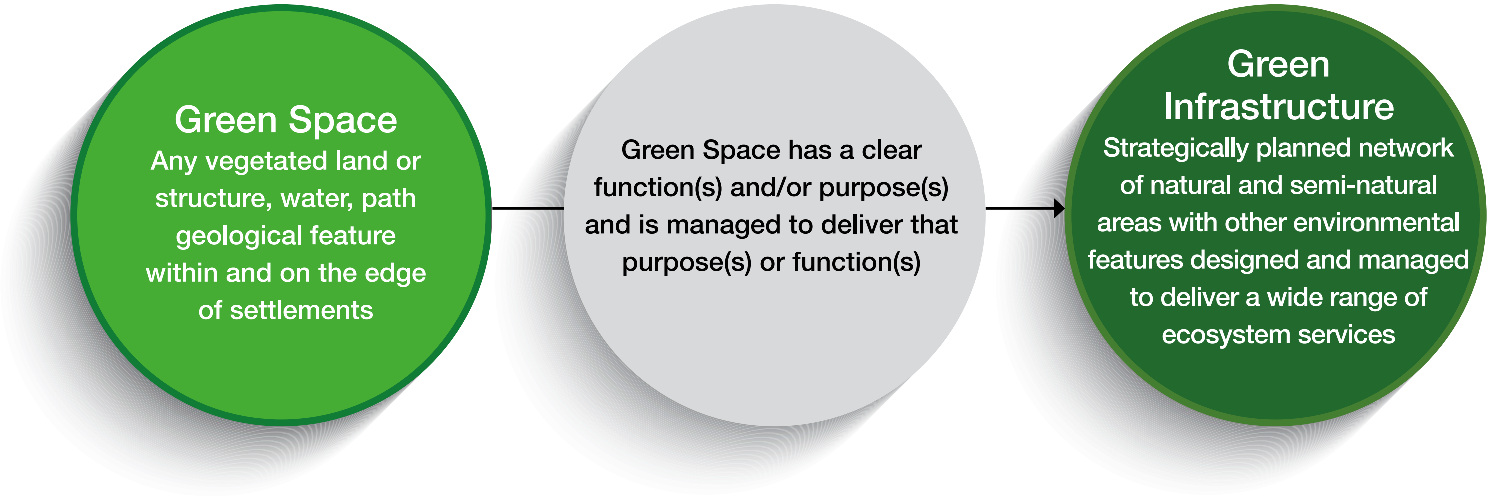

Figure 1: Distinction between green space and green infrastructure (source: authors)

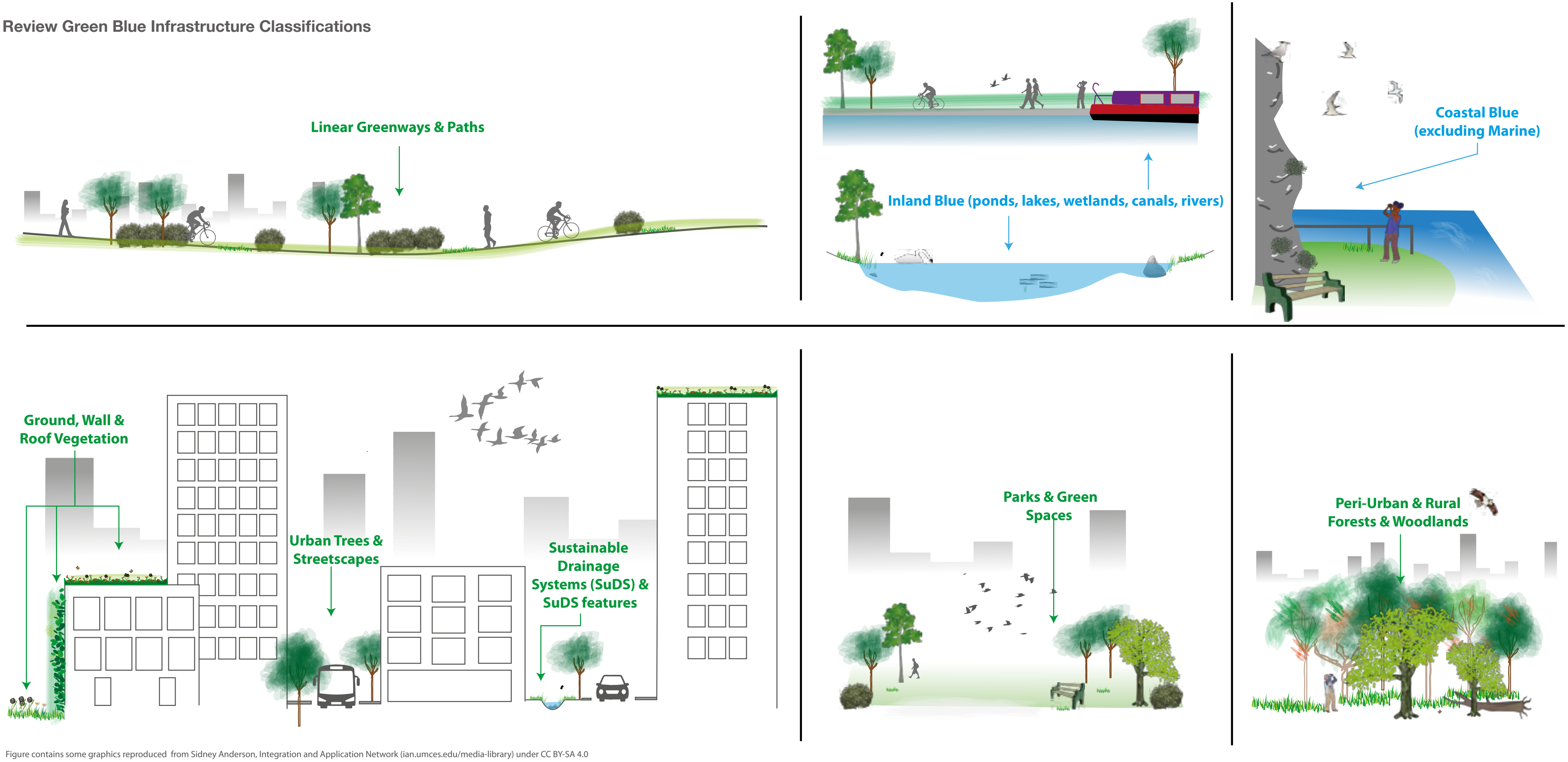

Figure 2: Typology of green blue infrastructure developed for this assessment (source: authors)

Box 1: Queen Elizabeth Olympic Park – multifunctional green blue infrastructure

Designed and built for the 2012 London Olympic and Paralympic Games, the Queen Elizabeth Olympic Park is an exemplar of Green Blue Infrastructure[4]. Designed and managed to provide multiple beneficial functions to its users and the surrounding area, including sustainable flood management, biodiversity and greater connection with nature. Shown in image (a) the Lea Waterworks and City Mill Rivers flow through the centre of the park. The waterway has been improved with vegetation to improve it's habitat for wildlife, as well as opportunities for access to angling, and flood management for the area. Image (b) shows a dry vegetation bed providing important habitat for pollinator and insects. Image (c) shows a sustainable drainage swale to retain and slow the flow of stormwater, as well as providing a habitat. Images (d) and (e) show how people physically use the space, though formal and improvised paths to engage with the sites. In all images, the functional assets also make an aesthetically pleasing and varied landscapes to provide different recreational experiences. Since the site's development, the GBI has continued to develop with age and management to provide multifunctionality.

This definition excludes some greenspace research on health and wellbeing from the assessment. This distinguishes this assessment from previous evidence assessments which include broader greenspace research (see:[6,7]). Unlike green space, blue space is a term less associated with green infrastructure, even though many definitions of green infrastructure include, blue spaces implicitly. As many relevant studies use the term blue spaces[8] we included "blue spaces" in the scope of this assessment as long as they were being used in accordance with our definition of GBI. We use the term "green blue infrastructure (GBI)" to describe the subject of this assessment to avoid any ambiguity. Like green space, some blue spaces are not being used as blue infrastructure and were therefore excluded in the scoping phases. To establish if and how different types of GBI have different impacts on health and wellbeing, a typology of GBI intervention types was developed from those commonly used in the literature (Figure 2).

1.2 Different pathways to Health and Wellbeing Impacts

The evidence for positive impacts of green space on health and wellbeing is extensive (POSTnote 538) but, still not fully accepted and translated into policy and decision-making across government[9–11]. It is less clear what impacts GBI have on different aspects of health and wellbeing, and whether different types of GBI themselves have different impacts. Wellbeing is also contested as a term, with no consensus on how to apply this subjective concept across populations and in policy[12,13] especially in terms of economic measures such as GDP (POSTnote 421). In this assessment health and wellbeing is defined as: "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"[14].

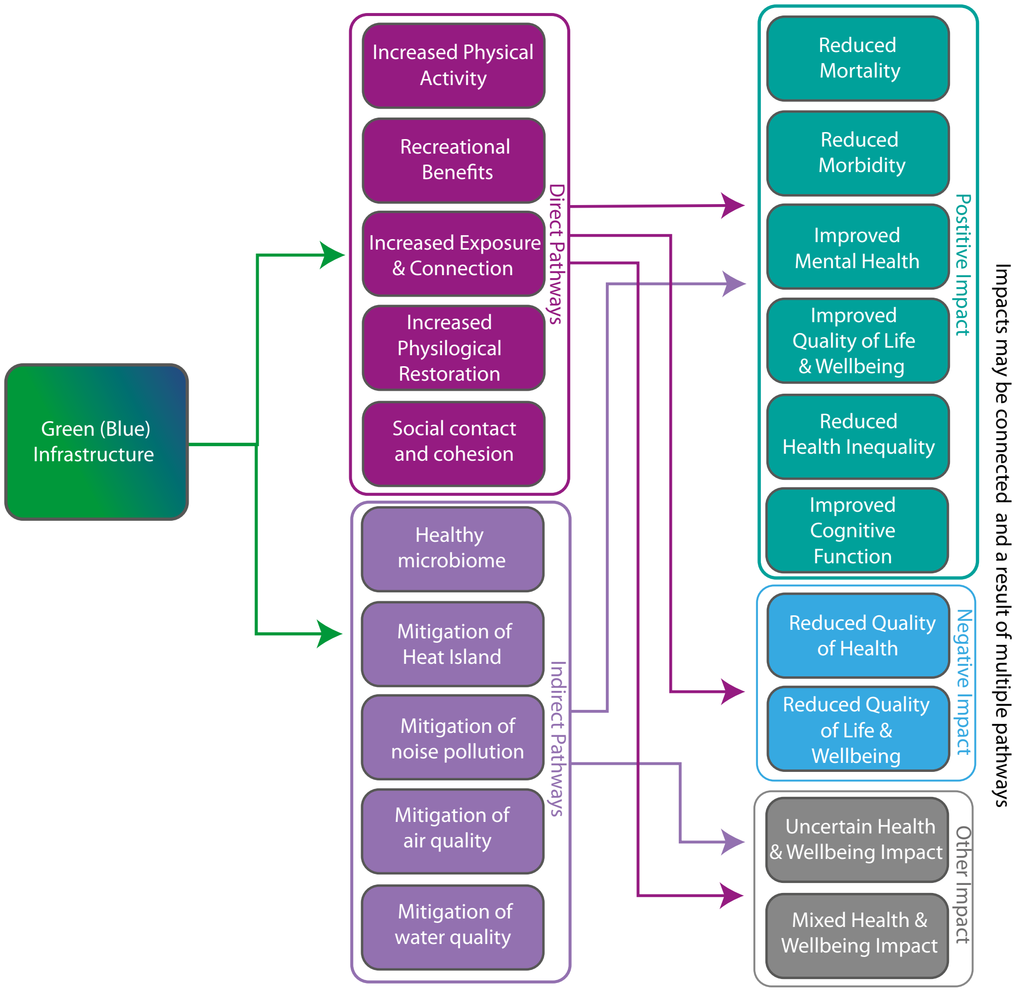

Figure 3: Green Infrastructure pathways to different health and wellbeing impacts (source: authors) Pathways and impacts adapted and developed from Lovell et al., 2020[6]

Health and wellbeing impacts can be positive or negative, and impacts can be the result of several direct and indirect pathways (Figure 3). Building from previous assessments on health and green space,[6,15] different health and wellbeing impacts were categorised, as well as the direct and indirect pathways from GBI. These classifications are shown in Figure 3. Pathways and health outcomes can be measured quantitatively, but wellbeing outcomes are often measured qualitatively due to their subjective characteristics[13] and self-reported metrics. As reflected in Figure 3, health and wellbeing outcomes and their pathways are interrelated, and complex to fully quantify.

1.3 Relevance for UK Parliament

There is contestation across the built and natural environment reflecting the differing demands of stakeholders as to how land should be used[16]. Land in the UK is used for housing, food, recreation and wellbeing, conservation and development. In the UK the land resource is constrained, magnifying conflict. Intervention in the form of planning policy is needed to manage land for societal benefit and it is here that GBI multifunctionality becomes important for UK policy reflecting the ideal that multiple land uses can coexist together. In the UK, environment, planning and health are devolved matters to the governments of Scottish, Welsh and Northern Ireland, therefore, the policy relevance for the UK parliament mainly relates to English plans, policies, and programmes.

The policy context for GBI and heath crosses built and natural environment policy contexts. The National Planning Policy Framework[17] (NPPF) in England sets out the policy framework local planning authorities must follow in their plans and decisions across England. It sees GBI supporting the delivery of the planning system in various ways. Key highlights include:

- Paragraph 20 states that strategic policies should make 'sufficient provision' for green infrastructure
- Paragraph 91 looks to Green Infrastructure to support local health and wellbeing needs.
- Paragraph 150 states that Green Infrastructure can help in adapting to climate change.
- Paragraph 171 states "Plans should…take a strategic approach to maintaining and enhancing networks of habitats and Green Infrastructure: and plan for the enhancement of natural capital at a catchment or landscape scale".

More detailed National Planning Practice Guidance[18] (PPG) helps translate the NPPF into practice and is more regularly updated. Here Green Infrastructure is described as a "natural capital" that can provide a range of benefits which notably include enhanced wellbeing, outdoor recreation and access, urban cooling, and the management of flood risk, amongst others. In planning terms, the PPG states that Green Infrastructure can help to achieve five planning goals thus enhancing multifunctionality:

- Building a strong, competitive economy;
- Achieving well-designed places;
- Promoting healthy and safe communities;
- Mitigating climate change, flooding and coastal change; and
- Conserving and enhancing the natural environment.

PPG states that cross boundary collaboration and liaison with stakeholders such as Local Nature Partnerships, Health and Wellbeing Boards and Local Enterprise Partnerships are important elements when developing GI strategies. In relation to decision making, the PPG emphasises that GI opportunities and requirements need to be considered at the earliest stages, and as an integral part, of development proposals. Delivery and funding of GI can use planning conditions, obligations, or the Community Infrastructure Levy, as well as greenspace budgets[18].

The other key policy context for GBI is set out in the government's 25 Year Environment Plan[19], which aims to improve the policy and delivery for the natural environment. The provisions of the plan were signed up to and agreed by all government departments. Relevant key actions were to:

- Produce stronger standards for GI. For example, Natural England were to develop a GI standards framework, which has now been launched as a GI standards framework in 2023.
- Supporting community forests to bring GI to towns and cities and their surroundings, here a set of Defra pilots have been launched (2022).
- Launched the development of Local Nature Recovery Networks and their associated strategies.
- Key role for improving health and wellbeing with a quantity target of planting 1 million trees.

Whereas not as prominent as in planning and environmental policy, the health sector in the UK recognises the importance of investing in GI for health and wellbeing. The NHS health and wellbeing framework20 states that "Investing in green infrastructure would reduce costs to the NHS alone by £2.1 billion" (pg 51) if everyone had access to good GI.

We have identified several operational select committees across both houses for which the results of this rapid evidence assessment may have relevance. Table 1 maps the interests of these select committees to elements within our rapid evidence assessment.

Table 1: Relevant Select Committees and interest to the assessment

Select Committee	Interest in Topic
Environment, Food and Rural Affairs Committee (Commons)	Relevance to rural mental health enquires, and broader interest how benefits of green infrastructure is promoted by Defra (biodiversity, forestry, tree strategy, rural economies)
Health and Social Care Committee (Commons)	Interest in green social prescribing and how green infrastructure can improve physical and mental health and reduce costs to healthcare. Also, NHS grounds include large areas of green space that could be adapted to provide multiple health and wellbeing benefits to hospital staff and patients.
Levelling Up, Housing and Communities Committee (Commons)	Interest in how green infrastructure can be used in the planning system to create heather places and contribute to climate change mitigation and adaptation. The Department of DLUHC is also the policy lead for urban parks.

Environmental Audit Committee (Commons)	How health benefits of green infrastructure can contribute to sustainable and environmental protection targets, and how and a number of enquires namely: Greening the post-Covid recovery, Sustainability of the built environment. How GI can adapt and mitigate places to effects of climate change – the effects (flooding, urban overheating) have significant physical and mental health impacts.
Public Accounts Committee (Commons)	How health benefits of green infrastructure can provide value from any and reduce health budgets.
Built Environment Committee (Lords)	How planning and urban design can better promote health benefits from green blue infrastructure. There may also be links to the inquiry on public transport in towns and cities due to unequal access to greenspace, climate change.
Land Use in England Committee (Lords)	How green infrastructure can provide multifunctionality in land-use, especially in more urban and peri-urban areas. Relevant for their inquiry on Land Use in England
COVID-19 Committee (Lords)	Importance and impact of the pandemic on use of green infrastructure
National Plan for Sport and Recreation Committee (Lords)	The use of green infrastructure to reduce inactivity and improve health and wellbeing
Environment and Climate Change Committee (Lords)	Using green blue infrastructure to address climate and biodiversity emergencies. How GI can adapt and mitigate places to effects of climate change – the effects (flooding, urban overheating) have significant physical and mental health impacts.
Digital, Culture, Media and Sport Committee (Commons)	There is interest in how green infrastructure can improve health and wellbeing in the context of their current inquiry on *Reimagining where we live: cultural placemaking and the levelling up agenda.* Also, DCMS is the policy lead for historic gardens and landscapes; and playing fields.

2. Approach to evidence assessment

This assessment should be seen within the context of other evidence assessments[6,7] on greenspace, bluespace, GBI and health; each of which have used different methods and approaches to identify relevant literature reflecting the lack of any standardised or universally accepted method for rapid evidence assessments[21,22]. Therefore, this assessment contributes to the literature at the GBI-health interface, with a sole focus on academic peer-assessment literature. An objective of this pilot was to inform a robust but pragmatic and replicable methodology for further POST rapid evidence assessments. A streamlined systematic assessment approach was favoured and adapted for this rapid evidence assessment making pragmatic trade-offs compared to a conventional systematic assessment process. This was informed with ongoing discussions with colleagues at POST and EPPI centre as well as our own iterative reflections. The software EPPI Reviewer was used to assess the literature with staff support.

Key word searches of academic databases were used to identify possible relevant academic literature. Key words included “green infrastructure”, “blue infrastructure”, “green blue infrastructure”, “blue space”, “health”, “wellbeing” and “quality of life” with variations AND/OR, order and formats of terms. The databases “Web of Science”, “Scopus” and “PubMed” were searched and complemented with automatic searches of OpenAlex based on the literature sample (See Appendix 2 Table A2.2).

Following the removal of duplicate (5150), 5025 documents were identified for initial screening. The documents title and abstracts were screened and included if they were (1) primary empirical studies or assessments, (2) studying the UK context, (3) the intervention studied was explicitly GBI as defined previously, and (4) studied health and wellbeing impacts or pathways. Screening used EPPI assessmenters priority screening algorithm to prioritise articles. This resulted in 178 documents included for full text assessment, where the same inclusion criteria were applied to the full text, resulting in 74 documents (37 assessments & 37 primary studies) for full inclusion in this assessment.

Full texts were then coded in EPPI Reviewer for key study characteristics including type of GBI, impacts found, pathway to impact, sub-factors researched, study group, study type, and location studied. Evidence maps were created from these characteristics to identify gaps in research. Full texts were coded line-by-line in EPPI Reviewer to capture the studies’ research questions, key headline findings, implications for policy and practice and research gaps. A full and detailed description of the method is found in Appendix 2. It is important to note that whereas a substantial grey literature around greenspace and health exists, it was not included in the pilot due to resource limitations and the need to focus more on academic research which was a recognised deficiency in parliamentary work[11].

2.1 Key limitations of the Rapid Evidence Assessment process

Compared to established systematic assessment approaches[23], trade-offs were necessary in this rapid evidence ssessment due to time and resource constraints. This involved the omission of a formal quality assurance step and the sole use of peer review academic literature at the expense of grey literature. There was no weighting of evidence and comparative analyses between evidence derived from primary research studies and evidence from review articles.

The strict use of the GBI definition (involving a network managed for multifunctional benefits) necessarily excludes some greenspace research on health and wellbeing from the assessment, which may explain why there is less evidence on mental health benefits compared to greenspace research (POSTnote 538), as well as different elements of GBI, such as SuDS and green walls. Reflecting the rapid nature of this assessment, our search terms did not contain specific types of GBI intervention or health conditions, but instead used umbrella terms relating to GBI and health. Terminology relating to both GBI, and health are contested; for example, the World Health Organisation includes wellbeing as part of health, whereas in other sectors, such as economics, it does not. GBI is often used interchangeably and uncritically to describe greenspace, which is not purposively designed or managed for multifunctionality. Consequently, within this assessment, some greenspace literature which may have met the definition of GBI may have therefore been excluded as part of our eligibility criteria (Appendix 2).

3. Knowledge Overview

Seventy-four academic articles on the GBI pathways and impacts on health and wellbeing were identified after scoping. Research attention to date has studied certain types of GBI pathways and impacts more than others, meaning the evidence of health and wellbeing impacts of GBI is not yet fully understood, hindering its wider adoption in health, environment and planning practice. Overall, there is compelling evidence that GBI broadly has a positive impact on health and wellbeing, albeit with insufficient evidence on how different GBI types[1], positively impact on health and wellbeing. There also seems to be a deficit of more quantitative based studies that provide evidence of positive impacts when compared to more qualitative based or user-led studies, which were used to measure the effects of GBI on wellbeing.

As shown in Figure 4, most studies researched GBI in its broadest sense (31), not looking at specific types of GBI with even fewer articles comparing different type of GBI from a health and wellbeing perspective, signifying a key research gap. After general GBI, inland blue spaces, urban trees & streetscapes, coastal blue and parks & greenspaces respectively were the most studied types with peri-urban and rural forestry and woodland and sustainable drainage systems being the most underrepresented types in the assessment. The lack of SuDS research is surprising given the extensive research that has been done[24]. One reason for this may be the lack of explicit links to health and wellbeing in those studies, which meant they were out of our scope. This also highlights a wider problem in the use of different terminology[4].

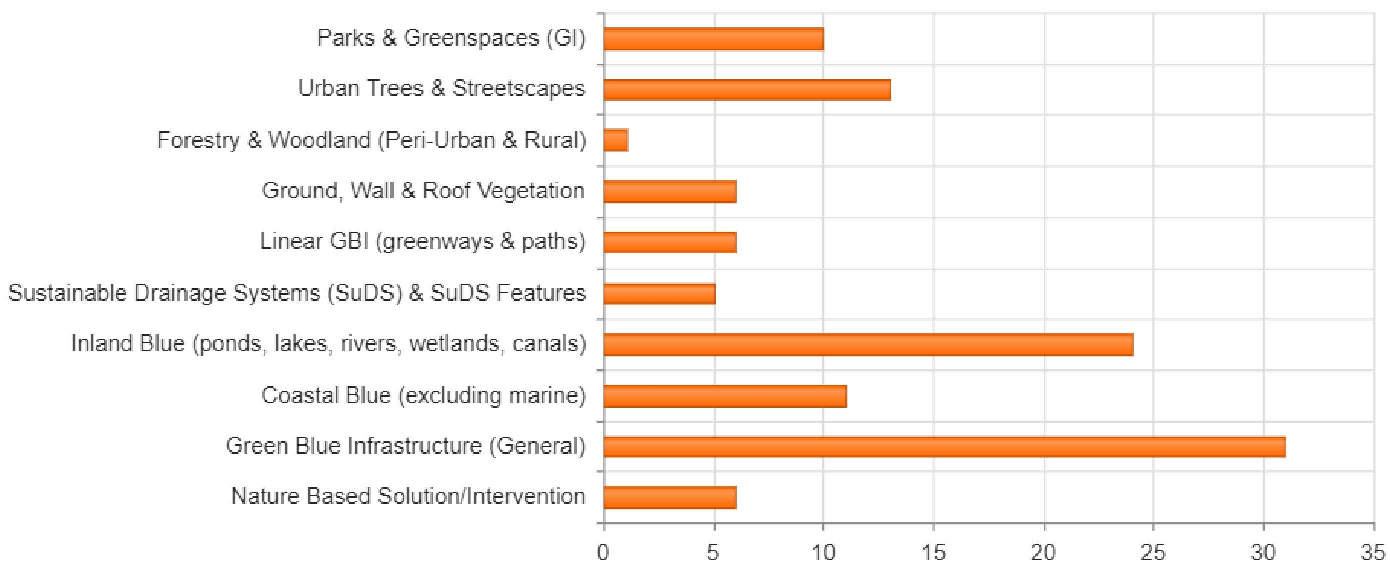

Figure 4: Included studies by GBI type(s) studied (N)

[1]See Figure 2 GBI typology

The evidence surrounding the types of impacts and impact pathways are also unevenly studied as shown in Figures 5 & 6. When looking at different types of health, there is nearly double the amount of evidence showing the positive impact GBI has on quality of life and wellbeing than on improved mental health and reduced morbidity. Many of those studies which identified improved mental health and reduced morbidity also found improved wellbeing. This may be due to the qualitative and often self-reported way wellbeing is measured, which is less research intensive, compared to the more quantitative clinical methods often used to measure physical health impacts. Notably, less evidence exists for reduced mortality, reduced health inequality and reduced cognitive function from GBI, again constituting a research gap. A small number of studies (16) found mixed or uncertain impacts on health and wellbeing, highlighting the complexity of the pathways involved, again, constituting a research gap.

This complexity of pathways is due in part to contextual factors, inter and intra population differences, or study design, which can unintentionally bias studies[25]. For example, researching exposure to GBI takes place in a real-world setting, with many environmental factors outside the direct control of the research design, meaning that GBI is not the only exposure or influence. Other non-measured pathways may contribute to the health and wellbeing outcomes; not just those created by the GBI[25]. For example, increased social interaction is a pathway which may occur in a GBI site, but this pathway and positive impact may not be so reliant on the GBI element of a site. Finally, two studies showed evidence that some GBI can reduce health and wellbeing introducing the concept of disservices. Disservices refers to nuisances and losses which ecosystems (including GBI) can create; for example habitats for pest species or unpleasant noises and smells or allergies[26].

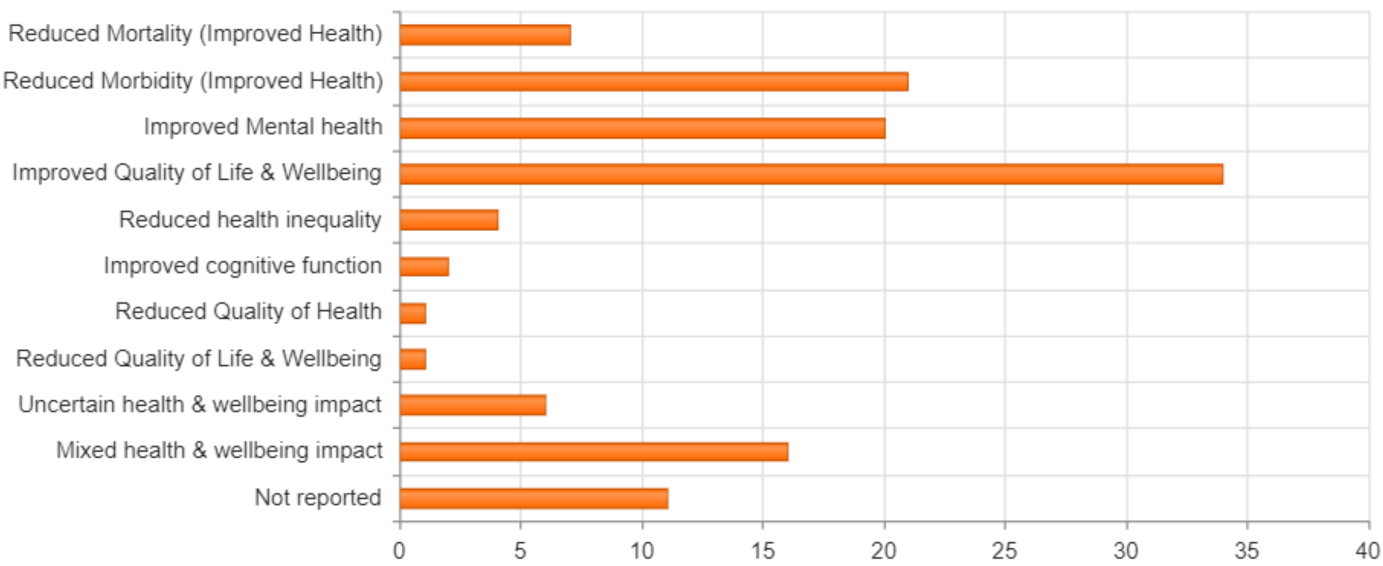

Figure 5: Included studies by health and wellbeing impact identified (N)

More evidence exists detailing the impact of direct pathways than indirect pathways[2], with increased connection/exposure to GBI, increased physical activity and recreation benefits respectively, the most studied pathways leading to increased health and wellbeing. In terms of indirect pathways, most evidence relates to the mitigation of heat island and mitigation of air quality. Very few studies (n=3) investigate the combination of both direct and indirect pathways for health and wellbeing.

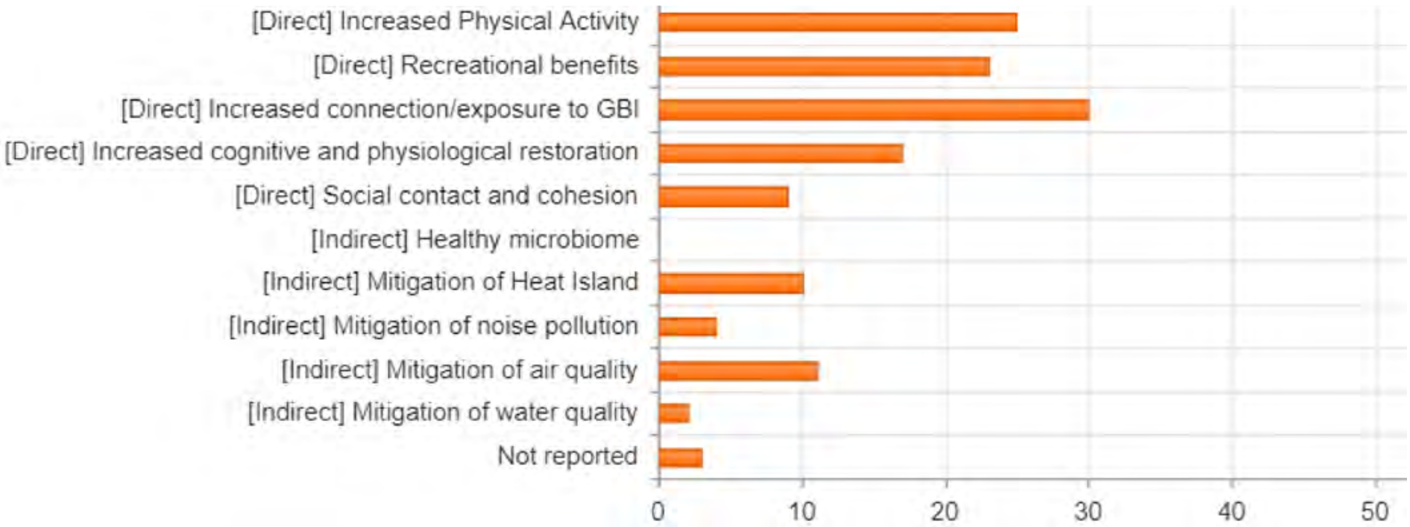

Figure 6: Included studies by pathways to health and wellbeing impact identified/studied (N)

As well as the uneven distribution of studies relating to different types of GBI, pathways and impacts, the locations and groups studied also varied, as shown in Figures 7 & 8. Notably, the majority of the evidence came from primary studies in England (n=22) and international assessment (n=28), which included UK literature. No primary studies which met the eligibility criteria were found specific to Wales or Northern Ireland. In terms of groups studies, the majority of studies looked at representative population samples (n=21) or adults (n=25). However, a number of studies looked at more specific populations, including the elderly, early years and deprived communities. No research which met the eligibility criteria looks specifically at the effects of BAME groups or refugees.

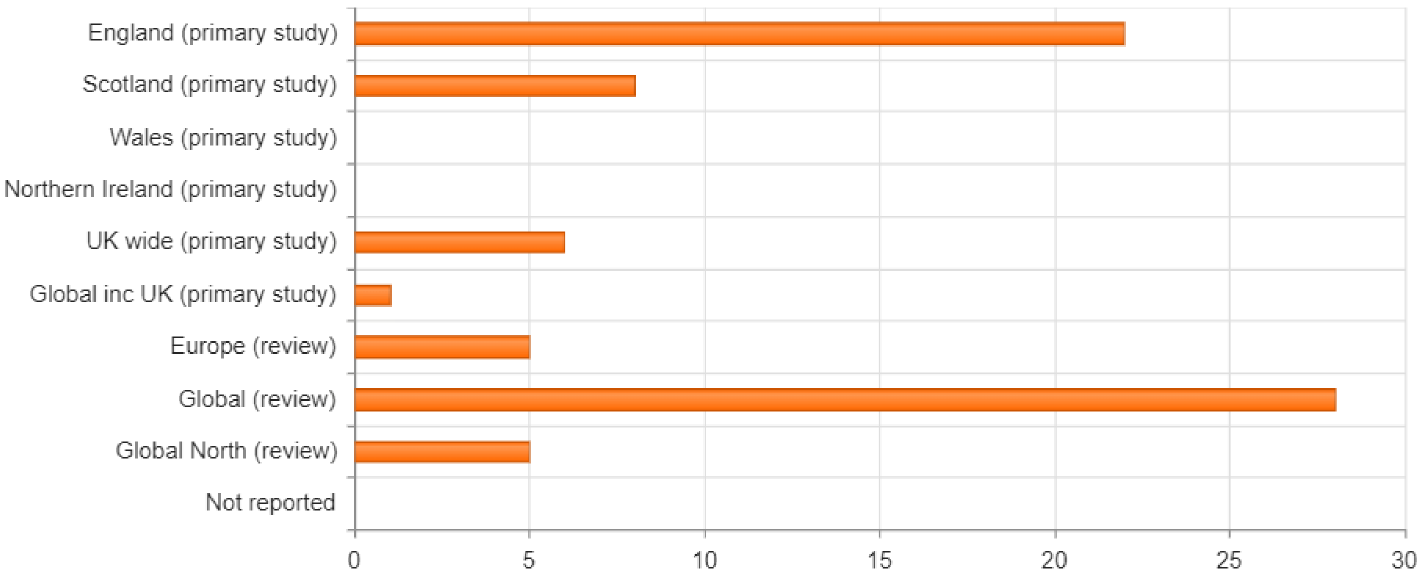

Figure 7: Location of studies included in the rapid evidence assessment (N)

[2]See figure 3 for outline of impact pathways to health and wellbeing from GBI

Interactive Evidence (Gap) Maps are available here: with prebuilt key evidence maps shown in Appendix 1. The reviewed and classified literature is stored as a database and can be accessed and analysed. This has been coded according to a range of categories included GBI type, health and wellbeing impact, pathway studied, geographical locations and study group amongst others.

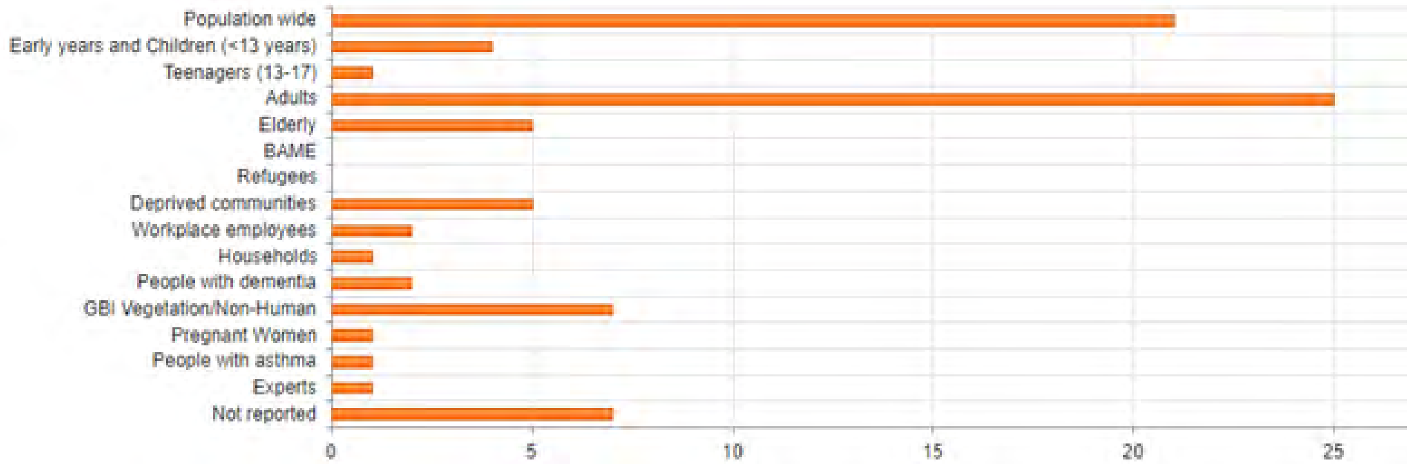

Figure 8: Study groups included in the Rapid Evidence Review (N)

4. Topic-by-Topic Narratives – what does the evidence show?

In the following sub sections, the evidence for GBI impacts on different health and wellbeing categories from Figure 5 is unpacked further, as well as the GBI studied and associated impact pathways (Figure 6).

4.1 Positive Impact: Reduced Mortality

Compared to other health impacts, there is comparatively less evidence on the impacts of GBI on mortality. A small body of evidence (n=7) suggests that direct pathways in the form of increased exposure and use of GBI can contribute to reduce aspects of mortality in people, including birth outcomes[27] and premature deaths (by as much as 10 years)[28]. Increased cognitive and physiological restoration gained from physically using GBI was also found to contribute to positive birth outcomes[27]. Recreational use of regenerated inland blue space was found to decrease mortality in one study by 3%[29] as well as reducing in incidents of strokes by 15%[30]. Additionally, some evidence suggests that indirect pathways from GBI may reduce overall mortality rates through mitigation of air quality (reduced particulate matter)[31], and urban heat island mitigation[32].

Most of these studies linking GBI and mortality, study GBI in broad terms, with very few assessing the impacts of specific types of GBI. One notable exception was with street trees which were shown to be important through an indirect pathway to mortality reduction[31,32]. Additionally, these studies mainly considered the green in GBI compared to the blue. However, one study which looked at both showed greenness of GBI to be more important than blueness for impact on birth outcomes[27]. Conversely, as already stated, regenerated inland blue spaces have been shown to reduce mortality[29,30].

Overall links between GBI and mortality are uncertain, which may be due to limited number of studies investigating mortality and GBI, as well as the unknown contributions of other non-GBI factors to the health outcomes.

4.2 Positive Impact: Reduced Morbidity

Morbidity refers to illness, disease, or ongoing medical conditions. We identified more than double the amount of studies (n=21) showing GBI impacts on morbidity than mortality. Several studies which found positive impacts on mortality also found positive impacts on morbidity[27,28,31–33]. More than half of the studies which present evidence of reduced morbidity studied impacts of GBI broadly. The remaining studies focused on specific GBI types including evidence of reduced morbidity from street trees and streetscapes [32,34,35], blue spaces [36–40] and parks and greenspaces [41]. No evidence was found linking SuDS, ground, roof or wall UGI to reduced morbidity, but it is likely some evidence exists which has not been captured in this rapid evidence assessment, especially for SuDS, as explained in section 3. The limited research on streetscapes and linear GBI (Figure 1) highlighted their importance as spaces for physical activity during the COVID-19 pandemic which contributed to sustained physical health[34]. This was especially important given the restrictions on other facilities for physical activities. These findings were mirrored in GBI more generally with less physical inactivity with increased exposure to GBI[40,42].

Most of the evidence suggests that GBI may reduce morbidity through direct pathways rather than indirect pathways. This may simply reflect a shortage of research studies with research studying direct and indirect pathways together; a notable evidence gap. Direct pathways to increased exposure to GBI, increased physical activity and increased recreational benefits were the most reported pathways respectively. Many of these direct pathways were found with respect to specific population sub-groups. For example, notable morbidity improvements include reductions in child obesity through increased physical activity in close proximity to GBI (parks and greenspaces)[41]; slower decline in health in the elderly with living in areas with higher densities of GBI[43] and outdoor swimming in blue spaces which may reduce musculoskeletal injury in older people. However, these impacts from outdoor swimming were self-reported[38]. Intervention of GBI with people with dementia resulted in improved apathy and engagement[44].

There is only a limited number of studies (n=3) which show evidence of indirect pathways to morbidity impacts. These include mitigation of air quality through street trees which reduced respiratory conductions[31,45] and mitigation of urban heat island reducing overheating[45]. Similarly, increasing the tree cover in urban areas considerably decreases levels of heat-related morbidity[32]. Whilst the evidence suggests that GBI can reduce morbidity to some degree, this is complicated by differences in study design and potential impacts of other contextual factors. Additionally, from the evidence it is not clear how different types of GBI may affect morbidity. No studies were found to show the impact on morbidity from GBI through microbiomes, even though research has shown links with broader greenspaces[46] and is an accepted pathway[6], suggesting a research gap between greenspace and GBI research.

4.3 Positive Impact: Improved Mental Health

Mental health refers to conditions such as depression, generalised anxiety disorder, panic disorder, social anxiety disorder, obsessive-compulsive disorder and post-traumatic stress disorder, as well as severe mental health disorders such as bipolar, psychosis and schizophrenia[47]. Mental health was the third most identified impact from GBI in the identified research. The evidence supports the notion that GBI positively impacts mental health. Nearly all the evidence relates to GBI generally and notably blue spaces (inland and coastal), with no evidence showing the impact of more specific types of GBI, involving SuDS, green walls & roofs, linear greenways and urban trees/streetscape. Evidence was only found to suggest that beneficial mental health impacts result from direct pathways from GBI with no evidence of any indirect pathways impacting mental health positively. Improved mental health was shown to be the result of increased physical activity (n=12), increased exposure to GBI (n=11), recreational benefits (9 studies), increased cognitive and physiological restoration (10 studies), and social contact (n=5). Nearly all impacts on positive mental health impact were found to result from multiple direct pathways, and those which only reported one pathway were limited by the scope of the study design.

In terms of notable evidence, from three studies, social prescribing programmes in England resulted in reduced use of medicines in treating mental health conditions[55] and positive treatments for anxiety and depression and in wetland GBI[49] . In one study social contact was identified as a key pathway, but it is uncertain if the GBI setting was of primary importance[48], highlighting the complexity in the interconnected nature of pathways to health and wellbeing impacts. Research on young people showed evidence that a 15-minute walk in GBI such as parks or forests can reduce levels of anxiety but did not find evidence of sustained impacts which reduced mental health diagnoses[52,55]. Mental health benefits may also be achieved more from direct visits to GBI rather than just living in proximity, supporting the importance of direct pathways[36]. Contextually, evidence suggests that visiting GBI during the COVID-19 pandemic had positive supporting function on depression and anxiety[42].

Evidence from blue spaces suggest that the recreational or physical activities conducted in blue spaces may be more important than the setting itself in mental health rehabilitation[38,40,56,57]. Conversely, one study found water-based recreation was not responsible for mental health improvements but living in proximity was[53]. Social inequality featured in access to blue spaces with excluded groups at great risk from mental health disorders[58,59]. Living closer to blue spaces may reduce the risk of developing a mental health condition by as much as 6% in socioeconomically deprived communities[37]. Similarly, to GBI broadly, living closer to large blue spaces was shown to reduce antidepressant medication prevalence in adults[39]. The evidence suggests that direct pathways from GBI can positively impact mental health conditions more broadly, but evidence is still scarce on the impacts of GBI on specific mental health conditions, especially from standardised clinical research where findings can be compared[36]. This may be a key factor to explain observed contradictions between different study findings.

4.4 Positive Impact: Improved Wellbeing & Quality of life

Wellbeing is an overall evaluation that an individual makes of his or her life in all its important aspects[60]. Most evidence identified supports GBI improving wellbeing and quality of life positively (n=34). As mentioned previously, this may be in part be due to the fact wellbeing is often measured through self-reported methods compared to more intensive clinical methods required to measure and validate other health impacts. Nearly all the studies that found evidence of positive mental health impacts, also reported positive wellbeing impacts. As with the other impacts the majority of research on wellbeing looks at GBI broadly, followed by inland blue spaces and coastal blue spaces respectively, with very little evidence of the other GBI types benefiting wellbeing. This is attributed to a lack of studies and likely impacts from these GBI types, representing a knowledge gap.

Unlike impacts on mental health, more general positive wellbeing impacts were found to result from both direct and indirect pathways. Much more evidence exists to support the role of direct pathways. The limited evidence from indirect pathways shows that a reduction in urban heat island led to reduced morbidity and mortality, with also a positive impact on wellbeing and livability through cooler temperatures[45], as well as improving air quality and improved self-reported health and well being[45]. Research on indirect pathways from GBI should be a research priority, given the focus to date on direct pathways.

Direct pathways to improved wellbeing mirror those identified in mental health, namely: increased connection/exposure to GBI (15 studies), increased physical activity (18 studies), recreational benefits (17 studies), increased cognitive and physiological restoration (13 studies) and social contact and cohesion (18 studies). Again, like mental health, the evidence shows wellbeing benefits are the result of multiple direct pathways. In terms of findings, studies (n=11) found self-reported wellbeing improvements from GBI in a range of study populations including: momentary wellbeing in young people[55], outdoor swimmers[38,40,61], employees[62,63] and people with dementia[44]. Another study on dementia sufferers found that perceived levels of GBI was more important than actual GBI[64]. Specific groups were also shown to benefit from social prescribing[48,49,54] some of which lasted up to 3 months[54].

Other contextual factors which were important in GBI impacts on wellbeing included; viewing a favoured blue space[56], targeted GBI regeneration projects[30,65–67], naturalness of GBI[68], proximity to protected high nature value GBI[69], frequency of visiting an inland blue space[70], and proximity to coastal GBI[53]. The COVID-19 pandemic streetscape provided an important setting for supporting wellbeing[34] as well as more general GBI during the pandemic[42,71]. Wetland was shown to be an influential GBI setting for wellbeing[49,54,62] perhaps due to the combination of green and blue elements and recreational activities they support. But this also may be due to their higher frequency of use as study locations. Several studies looked at larger and more general populations finding causal impacts of GBI to wellbeing[33,36,50–52,72–74]. There were some important site context factors including conflict between user groups and other nuisances in GBI sites which limited overall wellbeing gains[75]. Wellbeing benefits to blue spaces were disproportionately distributed among participants especially if they have access to a car[58]. In terms of perception of benefits when asked, people appear willing to pay for GBI due to the benefits they feel it provides[76].

Overall, the evidence supporting the positive impacts of GBI on human wellbeing and quality of life is the strongest in this assessment in terms of quantity, however key research gaps, as identified, remain.

4.5 Positive Impact: Reduced Health Inequality

Research on reduced health inequality focused more on inland blue spaces [29,30,37] than any other type of GBI. For example, health benefits of blue spaces may be greatest among more socioeconomically deprived regions with greater reductions in morbidity and mortality in deprived communities[30]. Increased exposure and recreational use were also shown to reduce the negative effects of socioeconomic deprivation on mental health with a 6% risk reduction and may also reduce medication intake[37]. All three of these studies looked at the same city and project: Glasgow[29,30] meaning the transferability to other inland blue spaces is uncertain, especially given the contextual nature of the socioeconomically deprived communities.

In GBI more broadly, reduced premature mortality was shown to be more pronounced Socio-economically deprived populations[28], and regeneration of GBI may close the gap between mortality rates between deprived and non-deprived neighbourhoods[29]. Only one study looked at several types of GBI (parks, streetscapes, peri-urban forest and linear GBI) in the context of inequality in elderly populations, finding that older people in low income urban areas appear to be disproportionately healthier (less chronic morbidity) if their locality has accessible GBI[77]. This suggests that socio-demographic contexts may be important in determining the degree of GBI benefits. They also found that in terms of type of GBI, size and diversity of GBI type may be influential in generating these beneficial impacts[77]. Overall, evidence on GBI and reduced health inequality is still very limited with a lack of research into the impacts of other GBI types and a sufficient range of case studies in the UK. A knowledge gap relates to how findings on broader greenspace and inequality translate to more purposeful GBI.

4.6 Positive Impact: Improved cognitive function

Only two studies were identified which present evidence of GBI contributing to improved cognitive function[42,55] meaning it is one of the least studied impacts. Results suggest that young adults who spend time in an urban park or forest can result in increased momentary cognitive function compared to urban streets. However, evidence of longer lasting outcomes were not found[55]. However, GBI may have been important during the COVID-19 pandemic in providing improved cognitive function alongside improved wellbeing[42]. A knowledge gap exists to understand GBI impact on cognitive function to draw substantive conclusions on the impacts, as well as how momentary impacts can be increased over longer terms.

4.7 Negative Impact: Reduced Quality of Health & Wellbeing

Only two studies were identified which present evidence that GBI actively reduces human health and wellbeing [78,79]. In Sustainable Drainage Systems (SuDS) and wetlands examples, this related to colonisation of mosquitos and increased exposure to GBI[79] having the potential to transmit vector-borne and zoonotic diseases, associated with climate change[78]. Results were inconsistent across sites studied, showing that these negative effects are not found everywhere in England, but are more likely to be from the result of (poor) management interventions[79]. An additional reduction of health and wellbeing was found from street trees and parks where certain tree species emit high level of pollen, which can have allergenic effect[78]. Species selection for urban tree planning should consider these potential negative effects[78].

4.8 Uncertainties in Health and Wellbeing Impacts

Whereas the majority of studies provide evidence of the positive health and wellbeing impact of GBI, a number of studies (n=16) reported mixed or uncertainties in these results, especially in relation to different aspects of health and wellbeing. This is in addition to the differences identified in the previous sections between studies. Some of these were due to a lack of papers on specific focuses such as the impact of sex and gender on health benefits from GBI[80]. Others found conflicting evidence; for example among office workers, such as increased wellbeing in some categories and decreases in other, which the authors attributed to problems with study design[63]. One assessment article highlighted that due to the bias to certain types of GBI, comparative impacts were hard to establish[81]. Some of the most mixed results came from indirect studies on street trees, with air quality mitigation of particulates only in certain streetscapes and local conditions[82], a finding mirrored by UHI mitigation[83]. The data and scale studied can also impact the findings, especially resolution of data[84].

5. Implications for policy & research

The key findings above have implications for policy and research which are summarised below.

5.1. Tensions between specific and holistic GBI considerations

Most research identified at the health-GBI interface is generic, lacking quantification and detailed insight into the different health impacts/outcomes from different types of GBI, meaning a knowledge gap exists for policy to be more specific (SuDS, Green Walls, Green Roofs etc). There was concern in some papers that a siloed approach to policy was unduly restrictive, needing more holistic policy responses that champion a systems approach. For example, a nationwide survey of contact with nature highlighted the risk that the cumulative impact of GBI may go undetected in studies that only examine one contact type[76]. This challenge calls for more research on specific types of GBI impacts in isolation in favour of cumulative impact[33]. A similar finding was apparent with respect to contributions of GBI to urban cooling. When considered separately, greenspace was better for mitigation but when considered together, they offer additional benefits and cooling synergies, together with other ecosystem service benefits[83]. This argument was evident, highlighting the danger of using cultural ecosystem services in isolation reflecting their overall complexity and interrelationships as well as trade offs[72]. Consequently, by employing a more holistic approach this may also help layering of interventions to ensure more active engagement with local communities and stakeholders extending beyond simply health and planning professionals, as shown in studies where planners and health professionals were involved in the design[56,67]. The key take home message here is that you need both generic and specific aspects to unpack the complex GBI health picture.

5.2. Mind the GBI knowledge gaps

Some clear knowledge gaps were evident in this assessment. First, there was the contradictory evidence from work on bluespace. The lack of studies and the differing methods therein signify caution in the results presented due to the knowledge gaps caused by inconsistent methods, and general lack of number of studies. Uncertainty becomes important when there is a lack of studies as identified with impacts on cognition, disservices and mortality.

Second, as mentioned previously there does seem to be a literature on the different aspects of GBI (not covered in this assessment) but this becomes very sparse when looking at the intersection with health and wellbeing. The multifunctional aspects of GBI which formed the focus of the assessment as opposed to many other assessments which use green and blue space is clearly underrepresented at this interface. Lack of definitional clarity over GBI is a source of potential confusion and dilution.

Third, there is a lack of studies looking at both direct and indirect pathways collectively; currently they are looked at separately, which again dilutes the power of GBI, therefore limiting the full potential positive impacts GBI may have on health and wellbeing.

Finally, there were a lack of quantitative clinical studies as opposed to the qualitative, self-reported studies which dominated.

5.3. Greater research alignment with policy and practice

The relationship between academic research on GBI and its use in practice has not been unpacked in this rapid evidence assessment as the grey literature was out of scope. But some of the papers assessed included policy and practice participants in the research design[67], which is important for policy. This is a knowledge gap reflecting the lack of policy-led research and the lack of longitudinal studies, which may help address future research agendas such as those managed by UK Research and Innovation.

5.4. GBI designed and planned as a multifunctional resource going beyond health and wellbeing concerns alone

A lot of the policy implications highlight the need for GBI to be designed and planned to deliver multifunctional benefits to diverse groups of publics[34]. This means identifying and factoring in the diverse needs of users and the most appropriate GBI interventions in the design stages[39,51], bringing into focus issues of equity and inclusion together with other ecosystem service benefits that GBI can deliver. This more integrated cross sector phenomena can become problematic for policy which is often siloed, particularly within government departments[16]. There is also the way that funding packages are also siloed towards particular benefits.

One unexpected finding[49,70] was the importance and value of blue space for delivering positive health outcomes; particularly health and well-being and improved mental health outcomes and how this finding could be used more actively as a tool for urban planning interventions particularly to address equity and deprivation issues[29,30,37,86]. There was a need to ensure that health equity was embedded in both research and policy responses with accessibility and inclusivity being seen as key priorities at the design stage[39,74]. Research did reveal that different groups (e.g. younger and older age groups; urban and rural populations) benefitted differently from blue space interactions, meaning a one size fits all approach would not necessarily work. Policy implications suggest the need to target bespoke interventions between different groups according to need with areas of high crime and deprivation being commonly identified[58,87]. One paper did, however, suggest a degree of caution needed before using the positive health impacts associated with blue space to inform health policy interventions suggesting that there was not yet sufficient research to do this confidently[40].

Whilst the positive impacts of blue space dominated, there were a minority of papers that included their disservices in particular, emanating from algae blooms and water related fatalities suggesting the need for policy makers to undertake more (pro)active management responses[70]. Other work on disservices associated with blue space such as colonisation of mosquitos and associated vector borne diseases in GBI, such as SuDS, highlighted disservices, but they could be mitigated by appropriate management which need to be considered much earlier in the design and management process[79]. There may be trade-offs for human health risks when designing blue spaces, between limiting mosquitoes and algae blooms by creating deeper spaces and the risks from this from people swimming or falling in[78]. There is a generic issue that disservices and their resultant trade-offs are a notable knowledge gap in GBI research and policy[56,61].

5.5 GBI produces positive health outcomes

In general, GBI produced positive health outcomes with only a few papers looking specifically at disservices. Here, one study highlighted the need to better capture potential risks and trade-offs in different GBI interventions and their impact on vulnerable groups to avoid unforeseen consequences. This highlights the need for improved prioritisation of GBI interventions according to need. For example, where outdoor blue spaces can be better used as an urban planning tool for regeneration to target specific socio-economic groups[36,58].

Another implication is the general tendency for positive impacts on health outcomes to be claimed for GBI interventions but without the active involvement of the health sector involved in the research design and process. Specifically, there was an opportunity space for health professionals to work more closely with urban planners and environmental groups to address physical and mental health disorders and reduce inequalities[37,50,77]. This collectively signals the benefits of more transdisciplinary research at the health-GBI interface with more co-design and co-production of methods and stakeholders[56,74]. Here the concept of nature based interventions and/or solutions were increasingly advocated, notwithstanding the identified need for improved evaluation of their impacts to be built in from the outset[42,45,50,54].

There are limited quantitative findings apparent from our research that could inform policy evaluation. For example, GBI provision has been shown to have made substantial health care savings “£136 million in 2015, resulting from 900 fewer respiratory hospital admissions, 220 fewer cardiovascular hospital admissions, 240 fewer deaths and 3600 fewer Life Years Lost” through improved air quality from GBI in the UK[31]. A particularly novel study explored edible green infrastructure and found that when plants were cultivated near (10 m) to a pollution source such as a main road or factory the risk of contamination increased 1.5 times as opposed to them being grown 60 m away, highlighting the importance of site specific context information and appropriate tools for local authority planners to use[35]. Research on the value of social prescribing revealed that the most effective interventions were typically offered for between 8 and 12 weeks, with the optimal dose ranging from 20 to 90 min[54]. This has implications for practice given that in the UK nature-based interventions that are offered through social prescribing are most commonly delivered for 12 weeks.

Finally, whereas this assessment shows the general health and wellbeing benefits of GBI, there is a time lag between a) understanding these benefits, b) developing policy, c) implementing policy, d) developing and planting GBI and e) releasing the benefits. For example, given the importance of street tree GBI for positive health and wellbeing outcomes, it may take as much as 20-30 year period to mature[82] and therefore fully realise these benefits[32,35]. The example of the Queen Elizabeth Olympic Park as an exemplar GBI project, shows how the sites has both matured ecologically and developed its own character over the last 10 years.

5.6 Potential scrutiny questions

Drawing from the findings outlined and discussed across this assessment, we have responded proactively to the key knowledge gaps by suggesting relevant questions which may merit further parliamentary scrutiny, for example through future select committee inquiries and future more focused rapid evidence assessments.

- How can we get the most out of GBI with health to improve multifunctionality?
- To what extent can GBI reduce burdens on the NHS and local authorities across the UK?
- Is there sufficient evidence from different GBI interventions (i.e. living walls, green roofs, SuDS) to understand their individual and collective health and wellbeing impacts?
- How effectively is inequality addressed in GBI and wellbeing policy responses? In particular, how is planning policy addressing this in policies, plans, projects and programmes?
- How is GBI and health and wellbeing delivery affected by different time and spatial scales?
- What lessons can be learnt from experiences in Scotland, Wales and Northern Ireland through different systems of governance in tackling health and wellbeing benefits from GBI?
- How can joint working between health and environment practitioners and researchers be improved? And what can be learnt from examples of good practice relating to GBI and health and wellbeing?

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Appendix 1: Rapid Evidence Maps

Interactive versions and database available here


Map 2: GBI Intervention & Health/ Wellbeing pathway
GBI Intervention
Parks & Greenspaces (GI)
Urban Trees & Streetscapes
Forestry & Woodland (Peri-Urban & Rural)
Ground, Wall & Roof Vegetation
Linear GBI (greenways & paths)
Sustainable Drainage Systems (SuDS) & SuDS Features
Inland Blue (ponds, lakes, rivers, wetlands, canals)
Coastal Blue (excluding marine)
Green Blue Infrastructure (General)
Nature Based Solution/Intervention
Pathway to Health & Wellbeing impact
Direct Pathway
Indirect Pathway
[Direct] Increased Physical Activity
[Direct] Recreational benefits
[Direct] Increased connection/exposure to GBI
[Direct] Increased cognitive and physiological restoration
[Direct] Social contact and cohesion
[Indirect] Healthy microbiome
[Indirect] Mitigation of Heat island
[Indirect] Mitigation of noise pollution
[Indirect] Mitigation of air quality
[Indirect] Mitigation of water quality
Not reported
Legend
Primary Study
All Reviews


Map 3: Health/Wellbeing Impact & Health & Wellbeing pathway
Health & Wellbeing Impacts
Reduced Mortality (Improved Health)
Reduced Morbidity (Improved Health)
Improved Mental health
Improved Quality of Life & Wellbeing
Reduced health inequality
Improved cognitive function
Reduced Quality of Health
Reduced Quality of Life & Wellbeing
Uncertain health & wellbeing impact
Mixed health & wellbeing impact
Not reported
Pathway to Health & Wellbeing impact
Direct Pathway
Indirect Pathway
[Direct] Increased Physical Activity
[Direct] Recreational benefits
[Direct] Increased connection/exposure to GBI
[Direct] Increased cognitive and physiological restoration
[Direct] Social contact and cohesion
[Indirect] Healthy microbiome
[Indirect] Mitigation of Heat Island
[Indirect] Mitigation of noise pollution
[Indirect] Mitigation of air quality
[Indirect] Mitigation of water quality
Not reported
Legend
Primary Study
All Reviews

Appendix 2: Methodological Approach

The assessment was managed and conducted using the EPPI-Reviewer software, and undertaken by two researchers, with technical support from a third researcher with expertise in EPPI-Reviewer and systematic assessments.

Eligibility Criteria

Identified research studies, reported in academic publications which met the eligibility criteria outlined in Table A2.1, were included in the rapid evidence assessment. The following sections outline the methods and iterative procedures used to search for, select and code/extract data from included studies.

Table A2.1: Study eligibility criteria

Eligibility Criteria	
Geographical Extent	**Include:** • Primary studies of the UK. • Reviews from all geographical regions if they include (at least 10%) of UK. • International assessment of core significance to the project's scope.
	Exclude: • Primary studies not of the UK. • Reviews clearly excluding the UK.
Intervention	**Include:** • Green Infrastructure, Blue Infrastructure, Green-Blue Infrastructure and Blue space as defined.
	Exclude: • Primary studies not of the UK. • Studies of greenspace and blue space more broadly.
Impact	**Include:** • Physical health (individual- and/or population level, direct & indirect). • Mental health and wellbeing (individual- and/or population level). • People's perceptions and/or lived experiences of green and/or blue infrastructure and its impacts on health and wellbeing.
	Exclude: • Studies which do not study a health and wellbeing impact or pathways to impact.

Eligibility Criteria	
Study Type:	**Include:** • Reviews [broadly defined] of empirical primary studies. • Recent empirical primary studies (quantitative, Qualitative & mixed) (see 'Publication Year' below). • Any linked corrections or errata. • Studies of applied tools and frameworks.
	Exclude: • Opinion pieces. • Guidance or consensus statements. • Correspondences. • Protocols for studies or assessments which do not report findings data. • Methods studies/papers (including validation of data collection methods). • Evaluation frameworks without applied results.
Publication Type	**Include:** • Journal articles will be included.
	Exclude: • Conference abstracts, working papers, book chapters and pre-print articles. • Retracted articles (studies), responses or replies which do not report substantive new data or analysis • Editorials.
Language	**Include:** • English language studies.
	Exclude: • All other languages.

Searches

First, electronic searches of three selected literature databases (Web of Science, Scopus and PubMed) were conducted up to 11th August 2022, using the key word search strategies shown in Table A2.2 ('Original Database Searches'). These databases were selected for their multidisciplinary nature (Web of Science and Scopus) or their specific focus on health (PubMed). These key word searches were developed based on the assessment questions and eligibility criteria, in consultation with our Northumbria University librarian and colleagues at UCL's EPPI Centre and POST. Next, the sensitivity of the original key word searches was tested using an initial corpus of 52 records (articles) reporting potentially eligible (including borderline eligible or ineligible) studies that had been separately assembled by one of the researchers, using preliminary scoping searches (also managed in EPPI-Reviewer). Key word search strategies were then refined based on results; culminating in the revised, expanded search strategies, also shown in Table A2.2 ('Expanded Database Searches'), which were used to update electronic searches of the same three databases, up to 22nd August 2022. All database search results were imported into EPPI-Reviewer as bibliographic (title-abstract) records via .ris files.

In addition to the database searches described above, a supplementary, automated 'network graph search' of the OpenAlex dataset was performed on 16th August 2022, using OpenAlex Browser tools in EPPI-Reviewer. OpenAlex is a continuously updated, open access dataset, which currently comprises >250 million bibliographic (title-abstract) records of research articles from across science, connected in a large network graph. The 'network graph' search conducted for this assessment retrieved all records that were connected, in the OpenAlex network graph up to 1st May 2022, to a 'seed' set of matched, known eligible records (i.e. those matched from the initial corpus of 52 eligible articles), either via a 'one-step' forwards ('cited by') or backwards ('cites') citation network relationship, and/or via a 'one-step' forwards ('recommended by') or backwards ('recommends') 'related publications' relationship. This 'network graph' search retrieved 2,572 OpenAlex records, which were directly imported into EPPI-Reviewer.

Next, EPPI-Reviewer's 'manage duplicates' tools were used to semi-automatically identify duplicate articles (records) within and between the four sources that had been searched. First, the 'advanced mark automatically' tool was used to automatically identify and mark duplicates with a similarity score above 0.80. Second, items in the remaining potential duplicate groups (that is, items with a similarity score threshold of between 0.70 and 0.79) were manually checked and resolved by a single researcher. All identified duplicate records were set aside. In total, 5,150 duplicates were identified within and between the four sources searched (with the majority of these due to the updated electronic database searches conducted on 22nd August, which both replicated and expanded on the 11th August searches). The remaining 5,012 de-duplicated records were assigned for title abstract screening.

Tables A2.2 – Electronic Database Searches

Original Databases Searches
Web of Science (all databases): TS=((“Green Infrastructure*” OR “Blue Space*” OR “Blue Infrastructure*”) AND (“Health*” OR “Wellbeing” OR “Well being”)) **Records retuned: 1926 on 11th August 2022** **Web of Science** by Thomson-Reuters (All collections): A multidisciplinary database of peer-assessmented scientific literature, books, book chapters and conference proceedings
Scopus: TITLE-ABS-KEY ((“Green Infrastructure*” OR “Blue Space*” OR “Blue Infrastructure*”) AND (“Health*” OR “Wellbeing” OR “Well being”)) **Records retuned: 1333 on 11th August 2022** **Scopus** by Elsevier: A multidisciplinary database of peer-assessmented scientific literature, books, book chapters and conference proceedings
PubMed: All Fields = ((“Green Infrastructure*” OR “Blue Space*” OR “Blue Infrastructure*”) AND (“Health*” OR “Wellbeing” OR “Well being”)) **Records retuned: 393 on 11th August 2022** **PubMed** by US National Library of Medicine: A database of biomedical literature from MEDLINE, life science journals, and online books.
Expanded Database Searches
Web of Science (all databases): TS= ((“Green Infrastructure*” OR “Green-Infrastructure*” OR “Blue Space*” OR “Blue Infrastructure*” OR “Blue-Infrastructure*” OR “green-blue Infrastructure*” OR “blue-green Infrastructure*” OR “living infrastructure*”) AND (“Health*” OR “Wellbeing” OR “Well being” OR “well-being” OR “quality of life”)) – **Records retuned: 2049 on 22nd August 2022**
Scopus: TITLE-ABS-KEY ((“Green Infrastructure*” OR “Green-Infrastructure*” OR “Blue Space*” OR “Blue Infrastructure*” OR “Blue-Infrastructure*” OR “green-blue Infrastructure*” OR “blue-green Infrastructure*” OR “living infrastructure*”) AND (“Health*” OR “Wellbeing” OR “Well being” OR “well-being” OR “quality of life”)) **Records retuned: 1476 on 22nd August 2022**
PubMed: All Fields = ((“Green Infrastructure*” OR “Green-Infrastructure*” OR “Blue Space*” OR “Blue Infrastructure*” OR “Blue-Infrastructure*” OR “green-blue Infrastructure*” OR “blue-green Infrastructure*” OR “living infrastructure*”) AND (“Health*” OR “Wellbeing” OR “Well being” OR “well-being” OR “quality of life”)) **Records retuned: 410 on 22nd August 2022**

Selection

The 5012 articles "title-abstract" were first screened in EPPI-Reviewer. Include-Exclude codes were developed, based on the eligibility criteria, and are shown in Table A2.3. Screening was done by two reviewers with split allocations so documents were not double screened. However, a second opinion code allowed for consultation between reviewers on any papers they were uncertain about. The Records were screened in 'priority screening' mode in EPPI-Reviewer. 'Priority screening' mode uses 'active learning', whereby a binary machine learning algorithm progressively 'learns' to distinguish between 'included on title-abstract' (positive class) and 'excluded on title-abstract' (negative class) records based on the growing corpus of eligibility decisions made by either of the two researchers; and is then applied to regularly reprioritise the ranked list of records yet to be screened, so that those most likely to be 'included on title-abstract' are most likely to be screened next. Initially, records from the initial corpus of 52 potentially eligible studies were screened, to ensure early coding of some 'includes' for the positive class (in addition to 'excludes' for the negative class), to help train the active learning algorithm; followed by the remaining, main tranche of records assigned from database or OpenAlex searches. A screening progress graph was monitored to visually track the number of 'included on title-abstract' records identified compared with the number of records screened in 'priority screening' mode, and the title-abstract screening stage was truncated at the point when this graph had 'flatlined', and we judged that very few further potentially eligible records would have been likely to be identified from any further screening. This procedure resulted in 2,468 prioritised records being screened on title-abstract, while the other 2,544 unscreened records were set aside.

Following truncation of priority screening, but before commencing full-text screening – and due to the large number of articles provisionally 'included on title-abstract' – the researchers collectively reassessed the records (articles) and made some key changes to further refine the assessment eligibility criteria, namely: checking that study interventions fully met the definition of Green Blue Infrastructure.

Table A2.3 Title-Abstract Include/Exclude codes

Excluded on Title-Abstract - Not a UK study (primary studies only)
Excluded on Title-Abstract - Clearly no included UK studies (assessments only)
Excluded on Title-Abstract - Not an eligible intervention
Excluded on Title-Abstract - Not a health or well-being impact
Excluded on Title-Abstract - Not an eligible study design
Excluded on Title-Abstract - Not an eligible publication type
Excluded on Title-Abstract - Not English language
Duplicate
Included on Title-Abstract Second Opinion

Based on the iterative title-abstract screening process described above, 180 articles were selected for full text screening, of which 178 corresponding full text articles could be retrieved. Full text articles were uploaded to their respective records in EPPI-Reviewer. Full text screening was conducted by the same two researchers, now working independently, with two researchers screening each record. The latest, refined eligibility criteria were applied at the full text screening stage, with some slight changes to the code set, which are shown in Table A2.4. Notably, the inclusion codes were expanded to enable coding of the broad type of research reported in each eligible study. The 'info' box function for codes in EPPI-Reviewer was utilised to record reasons for the include/exclude decision, and this aided the reviewers when resolving conflicts via discussion and consensus. A comparison report was generated from EPPI-Reviewer to compare the two researchers' respective coding decisions. The same coding decision was made by both reviewers for 85 of 178 (53%) of the articles included. Following resolution of the disagreements, 74 studies, reported in 74 articles, were selected for inclusion in this rapid evidence assessment.

Table A2.4 – Additions/changes to full text assessment codes

Excluded on Full Text - Less than 10% UK studies (assessments only)
Included on Full Text - Review Included on Full Text - Primary Study (primary, secondary or mixed data study) Include on Full Text - Relevant International Review

Data Extraction & Coding

The 74 studies (74 articles) included in the rapid evidence assessment were next coded in EPPI-Reviewer. First the coding scheme shown in Table A2.5 was developed to categorise and classify selected key characteristics of included studies, needed to build a series of evidence and gap maps. EPPI-Visualiser tools were then used to create these maps within an open access web database. Second, the code set shown in Table A2.5 was developed for line-by-line coding, to extract key information and findings needed to support the narrative synthesis. Both code sets were developed in collaboration with UCL's EPPI-Centre and POST, with the aim of capturing information at the appropriate level for the scope of the rapid evidence assessment. Each of the two reviewers separately coded half of the 74 included studies ('single data extraction').

No formal assessments of risk of bias, or appraisals of methodological quality, were conducted on included studies. Along with use of 'priority screening' mode with 'single screening' for title-abstract screening, and 'single data extraction', this supported the 'rapid' element of the assessment.

Table A2.5 – Rapid Evidence Map Code Set

Parent Code		Child Code
GBI Intervention		Parks & Greenspaces (GI)
		Urban Trees & Streetscapes (urban)
		Forestry & Woodland (Peri-Urban & Rural)
		Ground, Wall & Roof Vegetation
		Linear GBI (greenways & paths)
		Sustainable Drainage Systems (SuDS) & SuDS Features
		Inland Blue (ponds, lakes, rivers, wetlands, canals)
		Coastal Blue (excluding marine)
		Green Blue Infrastructure (General)
		Nature Based Solution/Intervention
Health & Wellbeing Impacts		Reduced Mortality (Improved Health)
		Reduced Morbidity (Improved Health)
		Improved Mental health
		Improved Quality of Life & Wellbeing
		Reduced health inequality
		Improved cognitive function
		Reduced Quality of Health
		Reduced Quality of Life & Wellbeing
		Uncertain health & wellbeing impact
		Mixed health & wellbeing impact
		Not reported
Pathway to Health and Wellbeing Impact	*Direct Pathway*	Increased Physical Activity
		Recreational Benefits
		Increased connection/exposure to GBI
		Increased Cognitive and physiological restoration
		Social contact and cohesion
		Healthy microbiome
	Indirect Pathway	Mitigation of Heat Island
		Mitigation of noise pollution
		Mitigation of air quality
		Mitigation of water quality
	Not Reported	Not reported

Study Group	Population wide
	Early years and Children (<13)
	Teenagers (13-17)
	Adults (All)
	Elderly
	BAME
	Refugees
	Deprived communities
	Workplace employees
	Households
	People with Dementia
	GBI Vegetation/Non-human
	Pregnant Women
	People with asthma
	Experts
	Not reported
Study Type	Qualitative (primary study)
	Quantitative (primary study)
	Mixed (primary study)
	Systematic Review
	Other assessment
	Grey Literature
	Systematic Map
	Meta Analysis
Location Studied	England (primary study)
	Scotland (primary study)
	Wales (primary study)
	Northern Ireland (primary study)
	UK wide (primary study)
	Global inc UK (Primary study)
	Europe (assessment)
	Global (assessment)
	Global North (assessment)
	Not reported

Table A2.6 – Line-by-Line coding

Line-by-line coding: Research questions
Line-by-line coding: Key “headline” findings
Line-by-line coding: Policy/practice implication
Line-by-line coding: Gaps

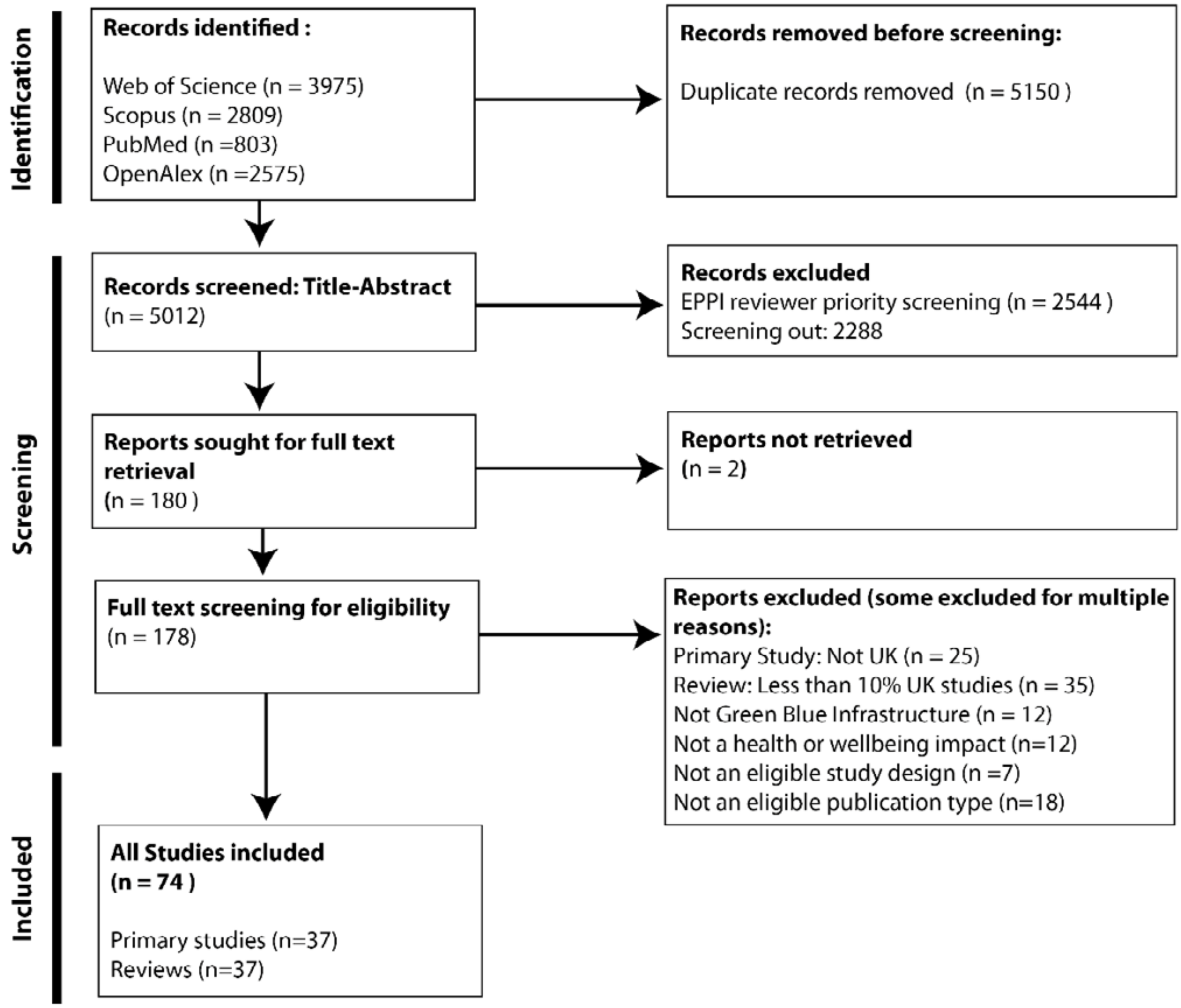

Figure A2: PRISMA diagram for the GBI and Health Rapid Evidence Assessment