Prevalence and effectiveness of nature-based interventions to impact adult health-related behaviours and outcomes: A scoping review

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Abstract

Evidence supports the positive influence of nature on population health, which has led to increased interest in nature-based interventions (NBIs). This scoping review explored how NBIs were currently being implemented to change adult health-related behaviours and outcomes linked with international public health indicators. Fifty-two of the 618 studies initially screened met the inclusion criteria. The review reinforced nature's potential to improve multiple health and wellbeing outcomes relevant to environment and public health disciplines. However, NBI effects were typically small, assessed short-term, and often based on comparisons between natural and highly urbanised settings. Vague NBI descriptions, an absence of theoretical frameworks guiding NBI design, and limited exploration of differences by socio-demographic or clinical group limited the conclusions. Based on the review findings, future NBIs should include clear, full descriptions of the settings and intervention techniques. The theoretical framework(s) utilised in the design and evaluation process should also be specified. NBIs duration should also be systematically investigated to establish if dose-response relationships differ by health outcomes to inform public health guidance on the "minimum duration for maximum benefit" for nature users. Another recommendation is for health behaviour change frameworks to be considered along with environment-health theories in NBI design and evaluation. This complementary approach could establish the full range of environment and health benefits associated with NBIs and better evidence the environmental, health and social impact.

1.0 Introduction

A growing evidence base indicates nature exposure is associated with positive health outcomes (WHO 2016; Hartig et al., 2014; Shanahan et al., 2015, Lachowyz & Jones, 2013). It enhances immune functioning (Kuo, 2015), reduces mortality (Kondo et al., 2018; Twohig-Bennett & Jones, 2018) and stress (Keniger et al., 2013; Twohig-Bennett & Jones, 2018), promotes physical activity (Kruize et al., 2019; van den Bosch & Ode Sang, 2017), improves subjective wellbeing and perceived quality of life (Houlden et al., 2018; McMahan & Estes, 2015; Twohig-Bennett & Jones, 2018; van den Bosch, et al., 2017; van den Berg, et al. 2015), and facilitates social connectedness (Jennings & Bamkole, 2019). This evidence has led to increased interest in the use of nature-based interventions (NBIs) to improve health (Roberts et al., 2016).

Many existing reviews of NBIs defined nature exposure using metrics such as the presence or amount of greenspace (Coon et al., 2011; Houlden, et al., 2018; Lachowyz & Jones, 2013; van den Bosch & Ode Sang, 2017). A limitation of these metrics was they implied exposure was simply about geographic proximity, without considering whether nearby nature was used, of good quality, or inaccessible (e.g., near busy road crossings) (Holland et al., 2021). Several authors concluded that researchers should broaden the definition of nature exposure to also examine different types of natural settings and their characteristics (Collins et al., 2020; Houlden, et al., 2018; Keniger, et al., 2013; van den Bosch & Ode Sang, 2017). To address this, the current review focused on NBIs where nature-based referred to "time spent outside in places defined as rich in natural beauty and/or biodiversity" (p. 82, Bloomfield, 2017). This included *both* biodiverse, unmanaged nature lacking human involvement (Bloomfield, 2017) and publicly accessible, managed urban greenspaces like parks and allotments/gardens (Hunter et al., 2015; Taylor & Hochuli, 2017). The objective was to determine the variety of nature settings currently used in NBIs.

To improve NBI design and potentially quantify its contribution to health outcomes, clearer understanding of intervention characteristics is also needed. In many environment disciplines (e.g., urban planning, ecological and landscape sciences, environmental social science), intervention has broadly referred to making physical change(s) to natural or built aspects of environments (Aldred, 2019; Hunter et al, 2015; Roberts et al, 2016; Blind Review, 2019), often with the intention to increase opportunities for nature exposure. Health-related disciplines have defined health behaviour interventions (HBIs) as a "coordinated set of activities designed to change specified behaviour patterns" (p. 1, Michie et al., 2011). HBIs focus on changing behaviour(s) by changing their underlying determinants (Kok et al., 2016); one determinant of interest is the intervention's environmental context (Cane et al., 2012; Michie et al., 2011). Shanahan and colleagues (2019) utilised a HBI lens to produce a behaviour-change focused definition of NBIs: "programmes, activities, or strategies that aim to engage people in nature-based experiences with the specific goal of achieving health and wellbeing" (p. 142). Despite the existence of definitions such as these, published reports of both NBIs and HBIs have been criticised for details that were either inconsistent or entirely lacking (Aldred, 2019; Prestwich et al., 2014; Prestwich et al., 2015; Roberts et al., 2016). As a result, there was a need in the current review to explore the terminology and methods used in interventions across disciplines to provide clarity for future NBIs and enhance their potential to contribute to public health.

This clarity also potentially addressed other barriers to the use of NBIs to enhance health and wellbeing. A recent review found two significant barriers were 1) a limited awareness by clinicians of the option for NBIs to be used in the prevention/management of health conditions and 2) a lack of clinically-relevant evidence of NBIs to impact health (Robinson et al., 2020). To address these barriers, this review focused on behaviours and health/wellbeing outcomes identified as national (PHE, 2016) and/or international (WHO,

2018) health indicators. The objective was to synthesize existing evidence for NBIs' influence on clinically-relevant health and wellbeing outcomes to potentially increase relevance for clinical practitioners.

Finally, we acknowledged that NBIs operate as part of complex system influenced by political, cultural, and community factors (Barton & Grant, 2006). The pathways between nature and health are inextricably linked to health inequalities (Kruize et al, 2019; Shanahan, et al., 2019; van den Bosch & Ode Sang, 2017; WHO, 2016). It is often the most deprived that can benefit from access to high quality nature (Twohig-Bennett & Jones, 2018; van den Berg, et al., 2015). Consequently, variations in the impact of NBIs on health and wellbeing outcomes by demographic group or health condition were also explored.

The aim of this scoping review was to determine how NBIs are currently being used to change adult health-related behaviours and outcomes. To achieve this aim and address limitations of prior reviews, we focused on four research questions:

1. What types of nature settings are used for NBIs?
2. What are the methodological characteristics of NBIs studies to impact adult health?
3. Which health outcomes and behaviours are targeted?
4. Does the impact of NBIs on health outcomes and behaviours vary based on demographics and health condition?

2.0 Method

There are varied methods to review literature. These differ in timeframe, extent of data sourcing, clinical focus, and summarisation method (Khangura et al., 2012). A scoping review was implemented because the aim was to broadly survey literature across disciplines/outcomes, identify narrative themes, and suggest areas for future research (Colquhoun et al., 2014). The current review focused on questions around clarification of key terms and methods used in NBIs and the targeted health outcomes or behaviours, in order

to improve the potential clinical relevance of future NBIs. A scoping methodology was appropriate for these objectives as opposed to a systematic review, which would have been suitable if the specific NBI methods that assessed clinical outcomes had already been established and our aim was to assess study quality and establish the size of any effects (Munn et al., 2018).

Five steps for scoping reviews were implemented (Arksey & O'Malley, 2005). Research question identification (step 1) was presented in the introduction. Identification of potential studies, inclusion/exclusion review and data charting (steps 2 – 4) are summarised in this section. Findings/recommendations (step 5) follow in the results and discussion.

Potential English-language studies with adult participants and published between January 2000-August 2019 were identified using PubMed, Science Direct and Web of Science searches conducted during July – August 2019 (step 2). Using iterative search procedures, authors discussed queries to ensure consistent search methodology. Each nature term (see Table 1) was combined with each intervention *and* health behaviour/outcome (e.g., greenspace AND intervention AND wellbeing). Nature search terms were identified from prior environment-health studies and included both naturally-occurring nature settings and urban vegetated spaces (Taylor & Hochuli, 2017). Agricultural settings were not included. Measurable behaviours/outcomes were selected from World Health Organization (WHO, 2018) and Public Health England's Health (2016) indicators[1]. As a result of the need for measurable outcomes, qualitative studies were excluded from the review. Intervention terms

[1] According to NICE (2019) outcomes are "The impact that a test, treatment, policy, programme or other intervention has on a person, group or population. Depending on the intervention, outcomes could include changes in knowledge and behaviour related to health or in people's health and wellbeing, the number of patients who fully recover from an illness or the number of hospital admissions, and an improvement or deterioration in someone's health, symptoms or situation." Indicators are "a statistic or marker that has been chosen to monitor health service activity."

were based on the National Institute for Clinical Excellence glossary of clinical and medical terms (NICE, 2019).

Insert Table 1 about here

After removing duplicates, 618 potential studies were identified using this search protocol. Both authors conducted independent abstract reviews based on inclusion/exclusion criteria (step 3, see Table 2). Studies were limited to adults over 18 years old. Studies with children and adolescents were excluded due to a concern their NBI participation may be confounded with or based on choices of adult caregivers. Additionally, the timeframe of activities within NBIs was limited to durations that were consistent with what individuals might consider practical for engaging with nature as part of their "normal" lifestyle; these included NBIs over two days (e.g., overnight stay for forest bathing) or where the intervention activities were brief within a longer intervention programme, such as undertaking an activity several times a week for a specified number of weeks. Examples of NBIs that were excluded based on duration include a long-term residential programme for young adults or a week-long forest bathing retreat for the elderly. We acknowledge a day trip or overnight stays to visit nature may not be possible for some people; for others, even access to a nearby greenspace may not be part of their normal life. These methodological decisions around duration were intended to set some boundaries for the scope of the review. NBIs that used virtual exposure to stimuli depicting physical nature settings were included if extensive technology was not required, based on the view people commonly use imagery or video to experience nature. Prior to the abstract review stage, one author used a random number generator to choose 10 titles. Inclusion/exclusion decisions were agreed for 100% of the abstracts. Both authors conducted an equal number of abstract reviews. At this stage, 139 articles were retained for full text review. Authors divided the full text reviews evenly and followed identical quality control procedures.

Insert Table 2 about here

Charting variables (step 4) included: author, date of publication, journal, study location, study design (e.g., between subjects, randomised control trial, within subjects), theoretical framework, activity type/duration, study aims, setting characteristics, sample, methods, wellbeing/health/other outcomes, and main findings (see Supplementary Table A for full charted data summary).

3.0 Results

The majority of studies excluded at the full text review (step 3) were based on inclusion/exclusion criteria (n = 75). However, further reading revealed some studies focused on therapeutic treatment programmes where nature exposure was not the primary intervention (n = 12) and were excluded on this basis. Fifty-two studies were included in the summary findings (see Figure 1).

Insert Figure 1 about here

Included studies were reported in 24 journals. Ten bridged environmental science and health, six were environmental science/social science journals, six were in psychology, and two were multi-disciplinary journals. Fifty percent (n = 26) were conducted in European countries and 40% (n = 21) in Asia. The remainder were in Australia (n = 1) or the United States (n = 4). Many studies (n = 30) were published between 2017-2019 (58%). The narrative findings (step 5) were organised by the four research questions guiding the review and generated from the charted data (see Supplementary Table A).

3.1 *What type of nature settings are used for NBIs?*

Approximately 29% of NBIs (n = 15) were set in urban nature contexts including forests, parks or greenspaces. A further 18 studies (35%) utilised forests or mountains. When details were provided, forests were described as boreal (Dolling et al., 2017), “old pine” (Kjellgren & Buhrkall, 2010), and wild or tended (Martens et al., 2011). Little description was given of

mountain settings. In this sense, urban nature included areas of vegetation adjoining or within urban conurbations and could be differentiated from forests or mountains distanced from the urban context (Taylor & Hochuli, 2017). Another 15 studies (29%) had more than one type of nature setting. These either included combinations of forests/urban forests, urban parks, rural countryside, blue spaces (e.g., coastal areas, rivers, lakes), tropical/subtropical locations, as well as what were described as "varied" nature scenes and nature settings chosen by the participant. Four studies (8%) used urban street settings with varying but limited degrees of tree cover or were streets of historic, cultural, or architectural interest. Nature settings were often compared in contrast with highly-urbanized, un-natural, city centre locations including intersections, a rail station, fitness centre/gym, and research laboratories.

Setting descriptions were vague; sample images gave some sense of the setting when provided. Four studies (8%) indicated setting size in hectares or kilometres. Others indicated city centre distance, either in kilometres and/or travel time ranging from 20 minutes – 1.5 hours. Although distance was not provided, one study was required an overnight stay with a 1-hour drive to each NBI setting from the accommodation location.

3.2 What are the methodological characteristics of NBI studies?

A variety of methodological characteristics were present in the included studies. Study designs were cross-referenced against the terminology in Table 1. Activities and intervention length were also described, as well as any included theoretical frameworks.

3.2.1 Sample: Sample sizes ranged from 12 to 364 participants. Most (56%) were with young adult or middle-aged populations (n = 29). Approximately 40% were student samples (n = 21) and two utilised elderly samples (4%). Of the 52 studies, 15% targeted clinical groups (n = 8, see section 3.4 for additional results). A small number of studies recruited by physical activity level. Three (6%) required participants to be engaged with sports and one (2%) involved the physically inactive. Five studies (10%) provided only age

and gender. Although 25 studies assessed activities by groups (48%), none systematically investigated the group's impact versus solitary participation.

3.2.2 Study Design: A between-subjects design was used in 21 studies (40%) including randomised control trials (*n* =3) as defined by NICE (2019). Within-subjects designs were used in 31 studies (60%). Of these, seven were crossover designs, a type of counterbalanced method included in the NICE glossary (2019). Nearly 70 percent of studies (*n* = 35) implemented random allocation to conditions and/or counter-balanced condition order. There were no instances of clinical trials, natural experiments, or observational studies as defined by NICE (2019). Additionally, 9 studies (17%) used the term *intervention* or *programme* to describe the activity. Five used the term consistent with the health behaviour change definition (Bang et al., 2017; Beute & de Kort, 2018; Calogiuri et al., 2016; Dolling et al., 2017; Plotinkoff et al., 2017).

3.2.3 Activity. Over 55% of studies used physical activity including strength training/cardiovascular exercise, cycling, with the majority walking/jogging/running (*n* = 29). Seven (13%) used forest bathing/therapy involving lengthy sessions of varied activities immersed in a forest. Eleven studies (21%) required participants to simply view the assigned environment. Viewing ranged from being sedentary in the environment, watching a slide show or a video of either images or a walk, and virtual 3D methods. There were five studies that gave participants options such as sitting or exercising, collecting nature elements, to vague descriptions of "15 minutes of activity" or "behaving as they normally would".

3.2.4 Duration. Time spent in NBIs varied from 1 minute to two days. Seven studies (12%) implemented exposure of less than 15 minutes. Eleven (21%) used a duration of 15 minutes. In thirteen studies (25%), exposure was between 31-60 minutes; six lasted 1-2 hours (12%). There were seven studies (13%) that required a participant time commitment from a half-day to a two-day intervention with overnight stay. A further eight studies (15%)

were conducted over a longer period. The shortest of these was a twice-daily, 3-minute intervention for six days (Beute & de Kort, 2018); the longest was a 20-week programme of 90-minute sessions that combined social support and physical activity (Plotnikoff et al., 2017).

3.2.5 Theoretical framework. In the current review, 23 studies (44%) lacked reference to a theoretical framework; the remaining studies integrated health behaviour change or nature-based theories. Three studies (6%) referred to behaviour change theories in their design or evaluation. A workplace intervention (Bang et al., 2017) compared outdoor to indoor exercise and utilised the Information-Motivation-Behavioural Skills model (IMB; Fisher et al.,2003). This intervention was supplemented with stress management lectures, information leaflets including the correct walking method, texts prompts, and activity tracking. Flowers and colleagues (2018) green exercise intervention included manipulating expectancy beliefs, consistent with the theory of planned behaviour (TPB; Ajzen, 1991) and green mind theory (Pretty et al., 2017). Plotnikoff and colleagues (2017) provided the most comprehensive application of theory and implemented aspects of Social Cognitive Theory (SCT; Bandura, 1997), Cognitive Behaviour Therapy strategies (Beck, 2011) and the Health Action Process Approach (HAPA; Schwarzer & Luszczynska, 2015) in an exercise intervention.

Nature-based theories were more prevalent. Twenty studies referred to attention restoration theory (ART, Kaplan, 1995; Kaplan & Kaplan, 1989), which describes the ability of nature contact to restore people's direct attention resources allowing for improved concentration on effortful tasks. Fifteen studies were contextualised with stress reduction theory (SRT, Ulrich, 1983; Ulrich et al., 1991), often in conjunction with ART. SRT proposes that nature provides emotional improvement and physiological recovery from stress.

3.3 Which health outcomes and behaviours are targeted?

Studies addressed a range of wellbeing and physical health outcomes. Wellbeing outcomes were broadly considered to represent subjective and psychological health as listed in Table 1. Physical health outcomes were more aligned with medical disciplines. With regards to the search terms used for health outcomes (Table 1), life satisfaction, loneliness, and social isolation were absent.

3.3.1 Mental health and wellbeing. Forty-one studies (79%) included outcomes such as mood, affect, stress, anxiety, self-esteem, depression, rumination, burnout, and self-reported health (e.g., general, health promoting behaviour). See Table 3 for details of studies mapped to each outcome. Across studies, evidence supported the efficacy of NBIs to improve positive mood and decrease negative mood and anxiety; however, findings were mixed for other mental health and wellbeing outcomes.

Insert Table 3 about here

Other studies considered the impact of NBI biodiversity. Walks in tended rather than wild nature produced greater improvement in positive mood and reduction in negative mood (Martens et al., 2011). Exposure to images of high-density vegetation showed the greatest improvements in positive mood, although participants preferred medium-density vegetation (Chiang et al., 2017). Gatersleben and Andrews (2013) found walks along routes with clear sightlines and little dense vegetation, which provided prospect when viewing the landscape, improved positive mood more than walks without these characteristics. These studies highlighted the importance of considering setting biodiversity and its impact on prospect in NBIs.

3.3.2 *Physical Health.* Physiological health outcomes were present in 33 studies (63%). Heart rate (HR), blood pressure (BP), and/or heart rate variability (HRV) measures were taken in 24 studies; BP was the most common (see Table 3). Nineteen studies (36%)

reported positive cardiovascular outcomes; however, no changes occurred in cholesterol and triglyceride levels. Some studies identified more specific effects in particular settings, with improved HRV in forest compared to urban environments, but not in park settings (Lanki et al., 2017) or in blue spaces when compared to urban environments (Triguero-Mas et al. 2017). Overall, the evidence was mixed; yet, on balance, supported the positive potential for NBIs to influence a range of cardiovascular outcomes.

Physiological stress effects were measured by skin conductance levels, cortisol or salivary amylase in eight studies (15%). Only one of seven (13%) studies measuring cortisol levels did not find an improvement. There were some differences due to interactions between nature type with individual differences. Cortisol was lower following forest bathing, but only for healthy weight women (Ochiai et al., 2015). Jiang and colleagues (2014) reported better cortisol and skin conductance levels as a function of tree density for men only.

Physical activity, a health-related behaviour, was the predominant activity in most NBIs. As a behavioural outcome, it was only assessed in five studies (10%). Four found positive, short-term effects of nature on physical activity including higher number of strides (i.e., cadence), increased moderate-to-vigorous activity, or perceived ease of exercise.

3.4 Does the impact of NBIs on health outcomes and behaviours vary based on demographics and health condition?

Out of 52 included studies, 23% were with clinical/sub-clinical samples diagnosed with depression, anxiety, stress/exhaustion/burnout, and poor mental health. Across studies, the evidence indicated benefits for positive mood and stress (Dolling, et al.,2017; Roe & Aspinall, 2011). However, several authors suggested this was a study effect instead of the result of nature exposure. There were equivalent improvements across exposure settings in mental wellbeing (Beute & de Kort, 2018), self-reported health, fatigue, stress, and burnout (Dolling, 2017), and mood and stress (Roe & Aspinall, 2011). There was also an indication

that individuals with poorer mental health outcomes at baseline improved more substantially than others (Berman et al, 2012; Roe & Aspinall, 2011).

Changes in physical health outcomes were investigated in men with hypertension (Song, et al., 2017b), people who were overweight (Rajoo et al., 2019), those at risk/diagnosed with Type 2 Diabetes (Plotnikoff et al., 2017), elderly women with a range of health conditions (Lee & Lee, 2014), and those who were physically inactive (Kinnafick & Thogerson-Ntoumani, 2014). Overall, findings suggested limited, short term benefits for cardiovascular markers (Lee & Lee, 2014; Rajoo, et al, 2019; Plotnikoff et al., 2017), parasympathetic nervous system activity (Song et al., 2017b), arterial stiffness, and pulmonary function (Lee & Lee, 2014). Physical activity increased in the diabetic sample (Plotnikoff et al., 2017) and the physically inactive (Kinnafick & Thogerson-Ntoumani, 2014). The findings suggested some potential for NBIs to facilitate changes in clinical groups, which may benefit a range of health conditions, even if only short term.

Generally, there was little investigation of demographic differences. Three studies (*n* = 6%) reported no gender differences in mood improvements (Bielinis et al., 2018a; Bielinis et al., 2018b; Elsadek et al., 2019). Ten studies conducted baseline analyses to explore whether differences existed. However, none explored if gender differences emerged after the NBI, assuming any reported effects were solely due to the intervention. Socio-economic influences were not investigated, but one study recruited participants from a government housing scheme as an indicator of deprivation (Legrand et al., 2018).

4.0 Discussion

This scoping review synthesized 52 studies investigating nature-based interventions (NBIs) targeting adult health-related behaviours and outcomes. Many studies compared highly urbanised areas lacking natural elements (e.g., near intersections, business districts) with either forests and mountains settings that were physically distant from urban locations or

296 greenspaces that adjoined urban areas. In this way, natural settings were positioned in
297 opposition to urban ones (Taylor & Hochuli, 2017), a stark comparison that has been
298 previously criticised (Andreucci et al., 2019; Karmanov & Hamel, 2008; Blind, 2015). The
299 evidence supported NBIs positive impact on several health-related behaviours and outcomes
300 linked to national and international health indicators. These positive effects were typically
301 small and assessed short term, with most NBI conditions lasting less than an hour (58%).
302 Therefore, it was not clear whether benefits were sustained over time or if participation
303 translated into changed behaviour. Future studies should determine how long effects
304 continue after an NBI because there is less evidence regarding their long-term efficacy
305 (Barton & Pretty, 2010; deBrito et al, 2020). Varying NBI durations should also be
306 investigated to establish whether different dose-response relationships exist for specific
307 health outcomes (Barton & Pretty, 2010; van den Bosch & Ode Song, 2017). This evidence
308 could inform recommendations of the "minimum duration for maximum benefit", given
309 people reported not using nature because of busy lifestyles (Boyd et al., 2018).
310 Detailed setting descriptions were mostly absent, which limits generalisability and
311 replication (Roberts et al., 2016). We reiterate the recommendation of others for better
312 reporting in this regard (e.g., Keniger et al., 2013; van den Bosch & Ode Sang, 2017;
313 Houlden, et al., 2018). Additionally, few included studies used clinical samples or explored
314 demographic differences; future studies should determine if there are differential effects
315 based on these factors.
316 *4.1 Strengths and limitations*
317 The primary strength of this review was its focus on the impact of NBIs from the perspective
318 of both environment and health disciplines. In this respect, it contributed to a growing body
319 of literature bridging these disciplines (Arnott et al. 2014, Roberts et al. 2016; Blind Review,
320 2019). Yet, this review was not without limitations. A scoping methodology meant the focus

was solely on peer-reviewed studies. Without canvassing grey literature, relevant NBIs may have been excluded. This review also only included studies reporting measurable health outcomes and behaviours, a decision based on the aim to link findings with international health indicators. We recognize NBIs impact other health-related outcomes outside the scope of this review. From a behaviour change perspective, it is important for future studies to explore barriers preventing NBI engagement and health behaviour change, as well as whether NBIs result in any unintended negative consequences. It would also be valuable to understand views of clinical practitioners regarding the use (or not) of NBIs. Understanding individual barriers and the views of practitioners would particularly suit qualitative enquiry. Finally, the included studies were primarily with healthy younger adults, who are the most reported group (Browning et al., 2020). There was little consideration of the sociodemographic influences impacting both nature exposure and health behaviours. Elderly participants were mostly absent from the included studies. As such, the generalizability of this review should be contextualised by these limitations.

4.2 Implications for future research

Perhaps the most important implications of this review are methodological recommendations for future research. The disciplinary diversity of included studies confirmed a need for common NBI terminology and detailed reporting standards to facilitate cross-disciplinary research (Blind Review, 2019; Roberts et al., 2016; Robinson, et al, 2020). Encouragingly, some studies implemented interventions or randomised control trials consistent with clinical definitions (NICE, 2019). This suggested there is potential to integrate these methods in NBI design, which may improve clinical and health care practitioner acceptance (Shanahan et al., 2019). Designers of future NBIs may also want to consider public health frameworks to guide the selection of outcomes, but as a complement to traditional environmental measures.

345 This would enhance the applicability of NBI findings for both environment and health
346 professionals.

347 We also recommend clear, explicit inclusion of theoretical underpinnings in the
348 design and reporting of NBIs. Several authors called for better theoretical understanding in
349 nature-based work by linking nature's pathways and mechanisms of impact to specific health
350 and wellbeing outcomes (Hartig et al., 2014; Joye & DeWitte, 2018; Shanahan et al. 2015).
351 Without this context, testing theoretical predictions and integrating findings will continue to
352 be hindered. One way to achieve this recommendation is to consider where theories and/or
353 frameworks from nature and health behaviour research potentially align.

354 In the review presented here, attention restoration theory (ART, 1995) and stress
355 recovery theory (SRT, Ulrich et al., 1991) were the most prevalent environment theories.
356 According to ART, natural environments have four qualities that facilitate recovery from
357 directed attention fatigue: evoking a sense of being away, visually (soft) fascinating qualities
358 that draw attention effortlessly, coherence that allows users to feel immersed, and
359 compatibility with internally-motivated activities (Kaplan & Kaplan, 1989; Kaplan, 1995).
360 Thus, according to ART, health and wellbeing is improved *via* the cognitive recovery
361 induced by nature exposure. SRT (Ulrich et al., 1991) also recognised the detrimental impact
362 of cognitive overload and nature's potential to reduce it. However, in SRT, nature's benefit
363 is achieved through positive, innate emotional responses to non-threatening nature which
364 result in sustained nature engagement and parasympathetic nervous system activation to
365 reduce physiological stress responses. Despite this difference in casual mechanisms, both
366 ART and SRT have potential synergies with two frameworks used in health behaviour
367 change interventions. We suggest interested readers consider the theoretical domains
368 framework (TDF, Cane et al., 2012) or the COM-B (capability, opportunity, motivation)
369 system of behaviour (Michie et al., 2011) as resources to help navigate behaviour change for

370 future NBI design. Both resources recognise the environment as an important mechanism
371 for facilitating sustained health behaviour change.
372 The cognitive processes central to ART correspond with the TDF core domain[2] of
373 memory/attention/decision making; and these processes are aligned with improving
374 capability, one of three key system components in the COM-B. As an outcome resulting
375 from nature exposure, improved cognition also positively impacts mood -- part of the TDF
376 *emotion* domain and a type of *automatic motivational process* in COM-B. Emotion, as one
377 central process in SRT, also links with both of these; therefore, in addition to the
378 parasympathetic benefits of nature according to SRT, emotion can also be considered as
379 important motivational influence on health behaviour. What is less clear is how to translate
380 these synergies into practical intervention design recommendations for NBIs.
381 NBIs are most effective when coupled with support programmes (Hunter et al 2015;
382 Blind Review, 2019) and health behaviour change models could be useful in this regard. For
383 example, existing NBIs could be coded using the Behaviour Change Technique Taxonomy
384 (BCTTv1, Michie et al., 2013), a tool which provides an overview of techniques utilised to
385 change health behaviours and their determinants. In the current review, two NBIs were good
386 examples of integration with health-behaviour change models. A workplace NBI
387 intervention (Bang et al., 2017) used stress management lectures, information leaflets about
388 correct walking methods, and activity tracking, which could be considered examples of
389 regulation, shaping knowledge, and feedback/monitoring techniques from BCTTv1. In a
390 randomised control trial of an outdoor exercise intervention (Plotnikoff, et al. 2017), twice-
391 weekly instructor-led training sessions, the use of smart phone technology, and social
392 activities corresponded with BCTTv1 techniques including shaping knowledge, regulation,

[2] A domain is defined as "a group of related theoretical constructs" that underly successful behaviour change (p. 2, Cane et al., 2012).

feedback/monitoring techniques, and social support. By using information about what has worked in previous NBIs (e.g., coding against BCTTv1), future NBIs could be developed by: 1) clearly specifying the environment theories and/or pathways for the intervention, 2) identifying relevant intervention components for behaviour change from the COM-B and TDF, and 3) specifying techniques to target the behaviours/their determinants to successfully enhance the targeted health and wellbeing outcomes. A useful approach for step 3 is the Intervention Mapping protocol (Kok et al. 2016), which provides an overview of the theories underlying the behaviour change techniques, their definitions, and pragmatic considerations for successful implementation.

5.0 Conclusion

This review investigated the potential for NBIs to contribute to population health and wellbeing by focusing on outcomes linked to national and international health indicators. Overall, the review supported the potential of NBIs in this regard. One recommendation going forward was to determine dose-response relationships for NBIs; another was to assess the longitudinal, clinically-relevant impact NBIs might have to prevent future ill health or manage existing conditions. There was also a clear need for better communication of the environment and health-behaviour theories underpinning NBIs and alignment with clinical methods where appropriate. We believe these recommendations would assist landscape and urban design professionals in determining the multi-faceted environment *and* health benefits of NBIs; and, in doing so, further highlight the essential role of built and natural environment research to population health.

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Table Captions

Table 1: Search terms

Nature Settings	Interventions	Health behaviours/outcomes	Source
Allotments	Behaviour change	Active transport*	WHO
Blue space	Clinical trial	Anxiety	PHOF
Forest	Experiment	Blood pressure	WHO
Garden*	Intervention	Cycling	WHO
private	Mixed treatment comparison	Depression	PHOF
Green	Natural experiment	Diabetes	WHO
Greenspace	Observational study	Exercise	Both
Greenway	Pre-post/before-after study	Excess weight	Both
Landscape	Randomised control trials	Happiness	PHOF
Nature/natural		Health/behaviour/related quality of life	Both
Outdoor		Life satisfaction	Both
Park/parkland		Loneliness	PHOF
Seaside		Mental health	Both
River*		Obesity	Both
side/front		Physical activity/inactivity	Both
Therapeutic landscapes		Social isolation	PHOF
Urban blue/green		Use of outdoors for exercise/health	PHOF
Water		Walking	WHO
Waterfront		Weight	Both
Wilderness		Wellbeing	Both

Note: Use of * indicates any combination of words e.g., garden, gardens, gardening. Source refers to links with international health indicators. WHO = WHO, 2018; PHOF = PHE Outcomes Framework, 2016; both = WHO and PHOF

Table 2: Inclusion and exclusion criteria

Inclusion	Exclusion
Adults	Children
English-language	Outdoor but not nature-based
Peer-reviewed	Qualitative
Primary research including	Conference proceedings/reviews/
Natural experiments	opinion or theory papers
Interventions	No specified health outcome or
Randomised Control Trials	behaviour
Quantitative	Duration reasonable for regular
Perceived or actual health outcome or	participation
behaviour	
Full-text	
Published 2000 to August 2019	

Table 3
Summary of health outcomes and behaviours targeted in included studies

Outcome	Direction	NBI Setting Comparison[a]	Studies
Mental Health/Wellbeing			
Affect/mood	Improved positive	Nature > Urban or Indoor	Bielinis et al (2018a; 2018b); Jang & So (2017); Song et al (2019); Takayama et al (2014)
		Varied nature > Urban or Indoor	Beute & de Kort (2018); Calogiuri et al (2016); Ojala et al (2019); Roe & Aspinall (2011); Sonntag-Ostrom et al (2014)
		Urban nature > Urban or Indoor	Berman et al (2012); Flowers et al (2018); Kinnafick & Thogersen-Ntoumani (2014); Neidermeier et al (2017b)
		Nature or Urban nature only	Martens et al (2011); Ochiai et al (2015); Sianoja et al (2017)
		Varied nature only	Pasanen et al (2018)
		Nature or Urban nature = Urban or Indoor[NBI]	Bodin & Hartig (2003); Dolling et al (2017); Kerr et al (2008); Legrand et al (2018)
		Urban street	Bornioli et al (2018); Elsadek et al (2019)
	Decreased negative	Nature > Urban or Indoor	Song, et al (2019); Stigsdotter et al (2017); Takayama et al (2014); Tsunetsugu et al (2013)
		Varied nature > Urban	Triguero-Mas et al (2017)
		Urban nature > Urban or Indoor	Bratman et al (2015); Kinnafick & Thogersen-Ntoumani (2014); Neidermeier et al (2017b); Song et al (2014)
		Nature only	Furuyashiki et al (2019)[*]; Martens et al (2011)
		Urban street	Elsadek et al (2019); Han (2017)
Anxiety	Decreased	Urban nature > Urban	Bratman et al (2015)
		Varied nature only	Zhou et al (2017)
		Urban nature = Indoor[NBI]	Neidermeier et al (2017b)
		Urban street	Elsadek et al (2019)
Burnout	Decreased	Nature = Indoor[NBI]	Dolling et al (2017)
Depression	Decreased	Urban nature > Urban	Bang et al (2017)
Rumination	Decreased	Urban nature > Urban	Bratman et al (2015)
Self-esteem	Mixed	Varied nature > Urban	Roe & Aspinall (2011)[†]
		Urban nature > Indoor	Flowers et al (2018)[†]
	No change		Dolling et al (2017)
Self-reported health	Improved general health	Nature = Indoor[NBI]	Dolling et al (2017)
	Improved health promoting behaviour	Urban nature > Urban	Bang et al (2017)
Psychosomatic complaints	No change		Beute & de Kort (2018)
Self-reported stress	Decreased	Varied nature > Urban	Roe & Aspinall (2011)
		Nature = Urban or Indoor[NBI]	Dolling et al (2017); Kjellgren & Buhrkall (2010)
	No change		Beute & de Kort (2018)

Physiological Cardiovascular			
Heart rate/heart rate variability/ pulse rate	Improved	Nature > Urban	Park et al (2009); Song et al (2017b); Song et al (2019); Tsunetsugu et al (2013)
		Varied nature > Urban	Beute & de Kort, (2018); Lanki et al (2017)
		Urban nature > Urban	Bang et al (2017); Song et al (2014)
		Nature or Urban nature only	Furuyashiki et al (2019)[‡]; Gatersleben & Andrews (2013); Kjellgren & Buhrkall (2010); Ochiai et al (2015)
	No change		Gidlow et al (2016); Neidermeier et al (2017a); Rajoo et al (2019); Stigsdotter, et al (2017)
Blood pressure	Improved	Nature > Urban	Lee & Lee (2014); Li et al (2011); Park et al (2009); Tsunetsugu et al (2013)
		Varied nature > Urban or Indoor or Control	Calogiuri et al (2016); Lanki et al (2017); Plotnikoff et al (2017); Sonntag-Ostrom et al (2014)
		Nature or Urban nature only	Furuyashiki et al (2019); Rajoo et al (2019); Song et al (2017a)
	No change		Ojala et al (2019); Neidermeier et al (2017a); Stigsdotter et al (2017); Song et al (2019); Triguero-Mas et al (2017)
Cholesterol	No change		Bang et al (2017); Li et al (2011)
Arterial stiffness	Improved	Nature > Urban	Lee & Lee (2014)
Triglycerides	No change		Li et al (2011)
Physiological Stress			
Adrenaline/ dopamine	Improved	Nature > Urban	Li et al (2011)
Cortisol	Improved	Varied nature > Urban or Indoor	Calogiuri et al (2016); Triguero-Mas et al (2017)
		Nature or Urban nature only	Hunter et al (2019); Ochiai et al (2015)[W]
		Urban nature = indoors[NBI]	Neidermeier et al (2017a)
		Urban street	Jiang et al (2014)[M]
	No change		Gidlow et al (2016)
EEG	Improved	Varied nature > Control	Chang et al (2008)
		Varied nature only	Chiang et al (2017)
Skin conductance level	Improved	Varied nature > Urban	Hedblom et al (2019)
Sleep	No change		Dolling et al (2017)
Physical Activity			
	Improved	Nature > Indoor	Jang & So (2017)
		Urban nature > Urban	Sellers et al (2012)
		Urban nature or varied nature only	Han & Wang (2018); Plotnikoff et al (2017)
	No change		Bang et al (2017)

[a] Categories based on Taylor & Hochuli (2017). Nature = natural space away from urban locations; Urban nature = natural space adjoining urban conurbations; Urban = highly built area; Urban street = streets with greenery, historic and/or cultural features; Varied nature = 2+ nature/urban nature settings or unspecified nature settings (e.g., participant's choice). NBI = Effect due to participation. Only = no comparator. No change = NBI had no effect.

[*]No change in positive mood. [†]Interaction effect: not all groups. [‡]Depressed participants only. [M]Males only. [W]Healthy weight women only.

Figures

List of Appendices