Environmental Research 191 (2020) 110169

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Review article

Blue space, health and well-being: A narrative overview and synthesis of potential benefits

Mathew P. White [a,b,*], Lewis R. Elliott [a], Mireia Gascon [c,d], Bethany Roberts [a], Lora E. Fleming [a]

[a] European Centre for Environment & Human Health, University of Exeter, UK
[b] Urban & Environmental Psychology Group, University of Vienna, Austria
[c] Universitat Pompeu Fabra (UPF), Barcelona, Spain
[d] CIBER Epidemiología y Salud Pública (CIBERESP), Madrid, Spain

ARTICLE INFO

Keywords:
Blue spaces
Aquatic environments
Health
Well-being
Narrative review

ABSTRACT

Research into the potential health and well-being benefits from exposure to green spaces such as parks and woodlands has led to the development of several frameworks linking the different strands of evidence. The current paper builds on these to provide a model of how exposure to aquatic environments, or blue spaces such as rivers, lakes and the coast, in particular, may benefit health and well-being. Although green and blue spaces share many commonalities, there are also important differences. Given the breadth of the research, spanning multiple disciplines and research methodologies, a narrative review approach was adopted which aimed to highlight key issues and processes rather than provide a definitive balance of evidence summary. Novel aspects of our framework included the inclusion of outcomes that are only indirectly good for health through being good for the environment, the addition of nature connectedness as both a trait and state, and feedback loops where actions/interventions to increase exposure are implemented. Limitations of the review and areas for future work, including the need to integrate potential benefits with potential risks, are discussed.

1. Introduction

Aquatic environments pose a wide range of threats to human health and well-being. There are an estimated 370,000 drownings globally per year (World Health Organisation (WHO), 2014), and water-borne diseases such as cholera (Ali, 2015; Nelson et al., 2015), account for nearly 2 million deaths annually, mostly among children under 5 years (WHO, 2019). Storms and floods exacerbate both issues, especially if drinking water supplies and sanitation facilities are contaminated with polluted floodwaters, events that are expected to increase in many parts of the world under climate change and sea level rise (Neumann et al., 2015). Recreational bathing waters are associated with large numbers of gastroenteric infections when contaminated with human or animal sewage, with the loss of some 66,000 disability-adjusted life years (DALYs) annually (Shuval, 2003). Chemical pollution from mining, agriculture and industry (Landrigan et al., 2018), harmful algal blooms (Fleming et al., 2015), and emerging threats such as pharmaceuticals (Webb et al., 2003), and micro-plastics (Science Advice for Policy by European Academies (SAPEA), 2019), all have the potential to undermine human health and well-being though contact with aquatic environments (Borja et al., 2020; Fleming et al., 2014, 2019; Depledge et al., 2017, 2019).

But we also need freshwater to live, not only for drinking but for irrigating crops and for livestock, as well as in healthcare, sanitation, industry and commerce (Aylward et al., 2005). Coastal and marine waters also have considerable value in terms of their “ecosystem services”, i.e. the beneficial effects they have on human well-being via ‘provisioning’ services (e.g. fish, shellfish, seaweeds, aggregates, etc.) and ‘regulatory’ services (e.g. water quality and climate regulation) (Millennium Ecosystem Assessment (MEA), 2005). It is no surprise, therefore, that most large towns and cities are sited on the coast or near large inland water bodies in order to exploit the potential benefits to human well-being they provide (Solomon, 2010; Martinez et al., 2007). Yet despite general recognition of these benefits, research exploring them in detail has been relatively scarce compared to ‘green spaces’ such as urban parks, woods and forests, and even private gardens (Twohig-Bennett and Jones, 2018; Markevych et al., 2017; van den Bosch and Sang, 2017; van den Berg et al., 2015).

* Corresponding author. European Centre for Environment and Human Health, University of Exeter Medical School, c/o Knowledge Spa, Royal Cornwall Hospital, Truro, Cornwall, TR1 3HD, United Kingdom.
E-mail address: mathew.white@exeter.ac.uk (M.P. White).

https://doi.org/10.1016/j.envres.2020.110169
Received 21 August 2020; Received in revised form 28 August 2020; Accepted 3 September 2020
Available online 22 September 2020
0013-9351/

1.1. Aims and scope

The aim of current paper, therefore, was to bridge this gap in the literature and to attempt to provide a narrative overview and synthesis of the potential benefits of aquatic environments, or 'blue spaces', for health and well-being (Depledge and Bird, 2009; Grellier et al., 2017; White et al., 2016). The aim was not to provide a risk-benefit analysis. It is too early to attempt such an endeavour, not least because the risks are generally far better articulated and documented than the benefits (Borja, 2020; Fleming et al., 2019). Rather, the focus was on integrating the emerging research on the potential benefits to health and well-being, and in particular research that suggests improved access to, and safe use of blue spaces, could play a role in tackling some of the major public health challenges of middle to high-income countries in the 21st Century. These include common mental health disorders such as anxiety and depression (Bloom et al., 2011; WHO, 2013), and a lack of physical activity (Guthold et al., 2018), that in the long-term can increase the risk of cardiovascular disease, dementia and some cancers (WHO, 2018). It also explores evidence suggesting that blue spaces can be used not just to prevent disease, but to promote good psychological health and help individuals with chronic health conditions manage their rehabilitation, recovery or ongoing health states.

The overview and synthesis draws on a range of research methodologies including large epidemiological studies, visitor surveys, field and laboratory experiments as well as in-depth qualitative research. Because of its breadth, it should be considered a narrative rather than systematic review. Although every attempt was made to be inclusive, it would be impossible in a single article of this nature to derive a single manageable review question of the type required of systematic reviews. Rather, the aim was to provide a broad introduction to some of the key themes across the field, and to signpost areas for further exploration.

1.2. Structure

To help structure the evidence, we build on several earlier models of green space and health/well-being, to create a bespoke blue space and health/well-being model (Fig. 1). First, we deconstruct blue space exposure/contact into four types: a) home/work proximity; then building on Keniger et al. (2013), b) indirect exposure (e.g. window views or TV programmes); c) incidental exposure (i.e. exposure that occurs even though the main activity was for a different purpose e.g. commuting); and d) intentional exposure (deliberately spending time in aquatic settings e.g. for work or recreation). We then extend Markevych et al.'s (2017) three pathways linking green spaces and health, to blue spaces and health. Each pathway incorporates several sub-processes: a) Mitigation (i.e. reduction of harm, e.g. urban heat island effect); b) Instoration (e.g. promotion of positive outcomes such as improved mood or greater physical activity); and c) Restoration (e.g. recovery from depleted attentional capacity or stress). We also adopt the two sets of effect modifiers proposed (although not named) by Hartig et al. (2014): a) Situational (e.g. access, quality, weather, culture, etc.); and b) Individual (e.g. personal characteristics such as age, gender, SES, etc.).

As well as extending previous models to blue spaces in particular, we make three additional contributions. First, we included 'Planetary health and well-being' as an outcome variable. Given the well-established links between planetary health and human health (Whitmee et al., 2015), evidence that blue space exposure might improve pro-environmental behaviours (Alcock et al., 2020) suggests that this can also have positive effects on human health and well-being. Second, we introduce feedback loops from health outcomes to exposure and intermediate pathways reflecting interventions that may result from the outcomes and which ultimately feedback to changes in exposure. Here, we propose three broad types of intervention/action: a) Societal; b) Local; and c) Personal. Finally, we include the psychological concept of

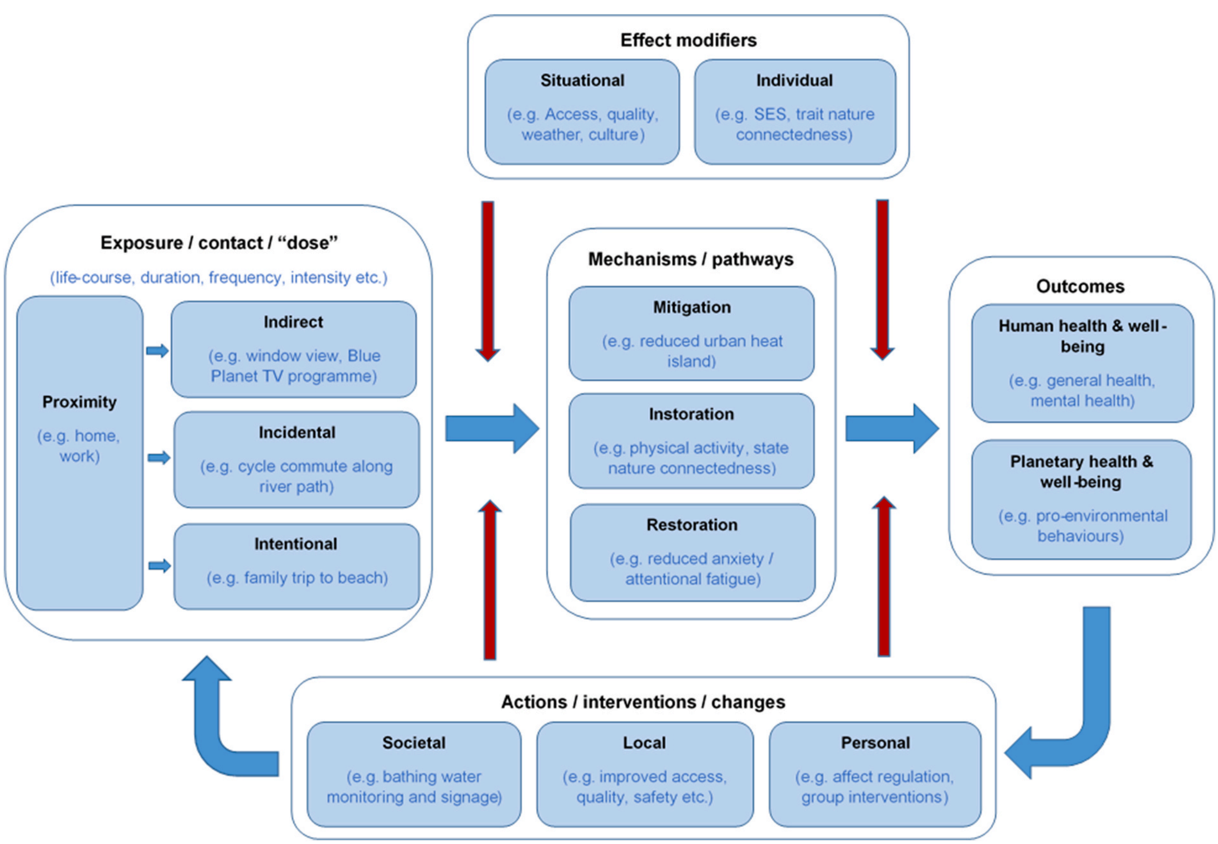

Fig. 1. A conceptual diagram of the relationships between blue spaces and health and well-being. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

nature connectedness in two different ways. First, we include it as a dispositional *trait* (e.g. Mayer and Frantz, 2004) that might moderate linkages between exposure and pathways/outcomes. Second, we include it as a *state*, reflecting short-term changes in attitudes/feelings towards the natural world that might result in immediate benefits (Martin et al., 2020; Pritchard et al., 2019). The remainder of the paper goes through each section in turn.

2. Exposure, health and well-being

We begin by exploring issues of exposure (the left of Fig. 1), including evidence of exposure-outcomes that did not consider intermediate pathways.

2.1. Proximity & other exposures

Most people live relatively close to a water body of some kind. In Germany, for instance, the average home distance to a significant piece of water is < 1.5 km (Wüstemann et al., 2017). Unsurprisingly, people who live closer to blue spaces tend to have greater indirect, intentional and incidental exposure. Having a view of water from home (indirect exposure) is directly associated with proximity, although as Nutsford et al. (2016) point out, elevation (e.g. living on a hill or in a block of flats) can increase blue space views while not living particularly close. With respect to intentional exposure (deliberately visiting e.g. for recreation), studies in Denmark (Schipperijn et al., 2010), England (White et al., 2014; Boyd et al., 2018), and across 18 different countries (Elliott et al., 2020) all demonstrate that the closer one lives to blue spaces, the more frequently one visits, with most studies showing an exponential decay function. Of note, visit frequencies may be moderated by socio-economic and/or ethnic status. In one study, although lower SES/Hispanic individuals often lived nearer to urban waterways than higher income/white individuals, the latter tended to visit them for recreation more (Haeffner et al., 2017). Finally, a study in Hong Kong (Garrett et al., 2019a), a city dominated by the coast, shows that home proximity to the coast is associated with the likelihood of blue space on one's commute (an incidental exposure).

2.2. Proximity and health and well-being outcomes

One of the first studies to show a relationship between living near blue spaces and health and well-being outcomes was Brereton et al. (2008) which found that people who lived within 2 km of the coast in Ireland (but not 2–5 km) were significantly more satisfied with their life than people living >5 km away. Subsequent research has found that living near the coast or inland water bodies is associated with better mental health, e.g. in Canada (Pearson et al., 2019), China (Helbich et al., 2019), England (Alcock et al., 2015; Garrett et al., 2019b), and the Netherlands (de Vries, 2016). Several studies have also shown a positive relationship with home proximity to water bodies and self-reported general health, e.g. in Belgium (Hooyberg, 2020), England (Wheeler et al., 2012, 2015), and Spain (Ballesteros-Olza et al., 2020). A longitudinal study in England found that over time the same people report better mental and general health in the years when they live close to the coast (<5 km) versus inland (White et al., 2013b).

A systematic review of 35 different studies around the world by Gascon et al. (2017) rated 22 of the studies to be of 'good quality' and concluded that the balance of evidence suggested "*a positive association between greater exposure to outdoor blue spaces and both benefits to mental health and well-being (N = 12 studies) and levels of physical activity (N = 13 studies). The evidence of an association between outdoor blue space exposure and general health (N = 6 studies), obesity (N = 8 studies) and cardiovascular (N = 4 studies) and related outcomes was less consistent*" (p.1207). Further, not all subsequent research has demonstrated a positive effect for mental health (Gascon et al., 2018; Helbich et al., 2018), especially for more serious conditions such as schizophrenia (Boers et al., 2018).

The lack of effects seen in some recent studies may be due to evidence suggesting that the effects of living near blue space on health and well-being tend to be significantly stronger for people living in poorer regions (Wheeler et al., 2012) or lower income households (Garrett et al., 2019b). Studies that have not explored the modifying effect of income may therefore be failing to reveal differences at different levels of income. If these studies are replicated more generally in the future, it would suggest that access to blue spaces may help mitigate chronic socio-economic related inequalities in health (WHO, 2019).

In many developed countries, homes close to inland and coastal waters, especially those with blue space views, tend to be more expensive including in Hong Kong (Jim and Chen, 2009), the Netherlands (Luttik, 2000), and the UK (Gibbons et al., 2014). The same applies to hotel rooms (Lange and Schaefer, 2001), something which extends to hospitality globally with waterfront hotels and sea views commanding higher prices. Economists assume that people are willing to spend more on accommodation close to blue spaces because buyers derive extra benefit or 'utility'. To the extent this is true, then this 'hedonic pricing' approach would also suggest that well-being is gained from living or staying near water. This is consistent with a range of studies which show that stated preferences for landscapes are higher for those containing water (Völker and Kistemann, 2011; White et al., 2010, 2018).

2.3. Indirect & incidental exposure and health and well-being outcomes

Several recent studies have found evidence that having a water view (over and above proximity) may play a role. In New Zealand, Nutsford et al. (2016) showed lower rates of poor mental health among those with a sea view, controlling for proximity (and other factors). In Hong Kong, Garrett et al. (2019b) found general health was significantly higher with a sea view, but there was no association with mental health. Finally, in Ireland, Dempsey et al. (2018) found a lower risk of depression among those with the highest level of sea views, although no effect of coastal proximity. Both of the latter studies were conducted with older aged samples; and it has been argued that blue space views from home may be particularly important to older adults with poorer mobility (Coleman and Kearns, 2015). We expect more research in this area as innovations in "viewshed" analysis develop that take into account both elevation and obstruction (Nutsford et al., 2016; Qiang et al., 2019), as well as street view breakdown (Helbich et al., 2019) and even body cameras that film local neighbourhoods from the wearer's perspective (Pearson et al., 2017).

In terms of assessing incidental blue space exposure, we know of only one study, the Hong Kong study with older adults by Garrett et al. (2019b). Although having to travel through, or by, blue space on one's commute to work was associated with a higher probability of spending time in and around blue spaces, there was no significant additional effect on this form of incidental exposure on either general health or mental health once indirect (view) and intentional (recreational) visits were taken into account. This lack of effect is in contrast to a study that suggested that daily commuting through natural environments in general (including green and blue spaces) was associated with better mental health than commutes without natural features (Zijlema et al., 2018). However, this study did not control for indirect and intentional exposure; and without such controls commuting through blue space in the Garrett et al. (2019b) paper was also associated with significantly better mental and physical health.

As with viewsheds, we suspect that innovations in analyzing street views will enable further work exploring incidental contact. For instance, in a study by Helbich et al. (2019), older adults in Beijing were less likely to show signs of depression if their local neighbourhood had both green and blue views at the street level. Crucially, there were no significant effects for satellite estimates, suggesting that the on the ground views may be more important than basic amount of land covered.

2.4. Intentional exposure and health and well-being outcomes

Although there are now several studies which look at the relationships between intentional blue space visits, most of these focus on the short-term immediate stress reduction potential of specific visits rather than more global mental health. As such, these studies are reviewed below in section 3.3 on 'restoration'. In terms of the potential longer-term benefits discussed here, Garrett et al. (2019b) did include a measure of blue space visit frequency and measures of general and mental health in their Hong Kong study. They found that visiting a blue space for recreation at least once a week was associated with better mental health. This is consistent with research documenting positive effects of regular recreational visits to natural environments in general on outcomes including blood pressure (Shanahan et al., 2016), self-reported general health (White et al., 2019), depression (Cox et al., 2017, 2018), vitality (van den Berg et al., 2016), eudaimonic well-being (White et al., 2017), life satisfaction (Laffan, 2018), and general mental well-being (Kruize et al., 2020).

One type of repeated intentional visit to blue spaces that is receiving more research attention is outdoor (or wild) swimming. Wild swimming can reduce fatigue (Huttunen et al., 2004), promote mental health (Foley, 2015, 2017; Denton and Aranda, 2019), and may be able to be used in treating major depressive disorder (MDD, van Tulleken et al., 2018). There is also tentative evidence that it can promote immune functioning (Tipton et al., 2017), treatment of inflammation-related conditions (Huttunen et al., 2004; Tipton et al., 2017) and support higher insulin sensitivity (Gibas-Dorna et al., 2016). Individuals who swim outdoors regularly also report experiencing increased connection to place and the natural environment (Denton and Aranda, 2019; Foley, 2015, 2017), which may in turn lead to behaviours aimed at protecting the health promoting aspects of these blue spaces.

2.5. Exposure, planetary health and pro-environmental behaviours

Although we know of few studies which have explored exposure to blue spaces and the kind of individual and community level pro-environmental behaviours which could be beneficial for planetary health, there are nonetheless some indications. Milfont et al. (2014), for instance, found that New Zealanders who lived closer to the coast had greater belief in climate change and, greater support for government regulation of carbon emissions. The authors argued this was because the risks of climate related events such as storms, floods and sea level rise were more salient for coastal dwellers. A recent English study with over 24,000 participants found that living near the coast (<5 km vs. >20 km) was associated with higher likelihoods of a number of pro-environmental behaviours including: recycling, buying local/-seasonal produce, walking/cycling instead of using a car for short journeys, and being a member of an environmental organisation (Alcock et al., 2020). Importantly, the associations were mediated by not just the frequency with which the participants visited natural environments such as the coast, but also how connected they felt with the natural world. Living near the coast was associated with greater psychological connection to the natural world, and in turn this greater connection was associated with more pro-environmental behaviours.

Feeling more connected to the natural world also accounted for the results of a controlled laboratory study that experimentally manipulated nature exposure and explored the effects on a pro-environmental behaviour with direct relevance to the health of blue space environments. Zelenski et al. (2015) showed participants an informative video of either urban street architecture in New York or blue/green spaces (i.e. BBC's Planet Earth) before asking them to play a fishing simulation game. Participants showed greater self-regulation and fished less intensively following the nature than the urban videos, with the effect significantly mediated thorough increased nature connectedness. A related finding was found following a visit to a large aquarium in the UK where visitors who were provided with additional information on fish stock sustainability were more likely to make sustainable fish choices in a later simulated restaurant scenario (Wyles et al., 2013). Whether or not the effects of such short-term exposures in experimental studies last in the mid-to long-term, the kind of timeline needed for real environmental effects, is less clear.

3. Mechanisms/pathways

This section focuses on the centre of Fig. 1 and the pathways and mechanisms linking exposure to outcomes, using Markevych et al.'s (2017) three broad, but inter-related, mechanisms of mitigation, instoration and restoration. Although positive emotional states, which may build creativity and resilience (Fredrickson, 2001), might be included under instoration, for clarity we reserve discussion of emotional and cognitive states to the restoration pathway.

3.1. Mitigation (harm reduction)

Urban heat island. With average global temperatures set to rise, urban settings are particularly vulnerable because they both generate and retain heat more than natural settings (Heaviside et al., 2017). Blue spaces, especially in the urban context, offer important temperature regulation processes, absorbing heat during the day when air temperatures exceed water temperatures and releasing heat during the night when water temperatures exceed air temperatures (Gunawardena et al., 2017). In a review of 27 urban blue space versus non-blue comparison sites (mostly in China, Japan and South Korea), Völker et al. (2013) found an average cooling effect of 2.5 K during May–October. Cooler temperatures were observed across a broad range of aquatic environments including rivers, lakes, wetlands, ponds and the sea, and across a range of climate zones including maritime, subtropical and tropical. The capacity of urban blue space to mitigate urban heat islands has also been shown to be connected with positive human health impacts such as reductions in heat-related mortality amongst vulnerable populations in Portugal who live within 4 km of water (Burkart et al., 2015).

Noise. In itself water can significantly increase the level of sound in an environment, so in that sense it may have the opposite effect of green space which may absorb sound (Rådsten-Ekman et al., 2013). The question however is whether these aquatic sounds counts as 'noise' (i.e. unwanted sound). In a number of experimental studies water-based sounds, either in isolation (Thoma et al., 2013, 2018), or in combination, with other natural sounds such as birdsong (Alvarsson et al., 2010; Annerstedt et al., 2013), tend to reduce experimentally induced stress faster than either urban sounds, silence, or conditions that were specifically designed to reduce stress such as calming music (Thoma et al., 2013, 2018). Adding pleasant water sounds (e.g. stream, waterfall, sea) to unpleasant traffic sounds (effectively increasing the overall volume) can also improve positivity ratings (Rådsten-Ekman et al., 2013). Thus, while an advantage of green spaces is that they may mitigate noise, blue spaces may actually increase sound but nonetheless result in more positive health states if these water sounds effectively 'drown out' more unpleasant sounds such as traffic. Nevertheless, although waterscapes in themselves are unlikely to be damaging for hearing, when combined with background traffic noise, for example, they may tip the cumulative sound levels over a safe threshold, so this would need to be investigated before adopting such interventions.

Air pollution. The picture for blue spaces and air pollution is highly complex and a detailed discussion is beyond the scope of this paper. Several papers have looked at the effect of sea breezes in terms of potential pollution dispersal (e.g. Clappier et al., 2000; Grossi et al., 2000; Liu and Chan, 2002), for instance, but conclude that the exact wind direction and speed, the spatial layout and height of urban buildings, as well as the type of pollution (e.g. NO_3 *vs.* ozone), all play a role. Further, there are several sources of air pollution emanating from blue spaces, most obviously from diesel powered shipping (e.g. Viana et al., 2014), but also from industries sited on the shores of waterbodies which in addition to direct waste-disposal practices result in air-borne pollution (e.g. Wong et al., 2003). However, this is not the 'fault' of blue spaces *per se*, it is how people use these spaces that is the issue. Nonetheless, it seems unlikely that blue spaces have the kind of direct air pollution mitigation effects that green spaces might have. Nonetheless green spaces' need water to maintain their greenness, thus ultimately water is needed for even greenspace's ability to reduce air pollution (Salmond et al., 2016).

Aerosols and negative ions. Taking the "sea air" for one's health has been recommended by physicians for centuries (e.g. Reed, 1884; Fortescue Fox and Lloyd, 1938). Recent research in both coastal and inland waters, especially high force waterfalls (Grafstätter et al., 2017), suggests that the mists and sprays created in these settings may help reduce breathing difficulties, e.g. among children with asthma, in part through reduced inflammation and improved lung function (Gaisberger et al., 2012). Although the precise mechanisms are still not fully understood some authors claim that the negative ions produced by crashing water (e.g. Kolarz et al., 2012) may also play a role. The direct effects of negative ions on human health are disputed (Perez et al., 2013), however there is some evidence of lower depression scores at high-density exposure, which is consistent with lower stress reported by participants in Grafstätter et al.'s (2017) study of exposure to waterfalls (versus similarly attractive alpine settings) in Austria. Given that the benefits to lung function may last for several months post exposure (Gaisberger et al., 2012), further high quality research in this area seems warranted.

Aerosolized toxins. A different issue, with respect to aerosols concerns aerosolized toxins, e.g. brevetoxins, that come from 'harmful algal blooms' (Fleming et al., 2011). Natural water bodies contain a wide variety of micro-organisms which can become airborne in water spray at critical places such as waterfalls and ocean shores (Asselman et al., 2019). In some instances, for example Florida Red Tide caused by the dinoflagellate Karenia brevis, the organisms produce potent natural toxins. These toxins can cause or aggravate symptoms among those with asthma (Kirkpatrick et al., 2011; Fleming et al., 2011). However, it has also been argued that at low concentrations some of these toxins (as well as other substances in marine aerosols) may have positive effects on health. For instance, there is evidence that yessotoxin produced by marine dinoflagellates such as *Protoceratium reticulatum*, may reduce inflammation and improve immunoregulation (Asselman et al., 2019; Moore, 2015). The possibility that, at low levels, these blue space aerosolized toxins may be beneficial for health echoes arguments in the greenspace literature (Rook, 2013; Kuo, 2015) with respect to some airborne tree compounds (e.g. phytoncides, Li et al., 2009; Li, 2010). Far more research is needed, however, to fully understand these processes.

Solar irradiance. Finally, blue spaces are also associated with higher levels of solar irradiance, leading to higher ultraviolet exposure of those exposed. On the one hand this can increase the risk of skin cancer (Stenbeck et al., 1990), but it can also lead to higher vitamin D synthesis which is associated with a reduced risk of certain auto-immune and cardio-vascular diseases, some cancers, and poor mental health (Cherrie et al., 2015). Clearly, individual behaviors are key with respect to time of day, exposure duration, self-protection measures etc.

3.2. Instoration (capacity building)

In an early review of 36 small-scale survey studies and experiments, Völker and Kistemann (2011) identified four 'dimensions of appropriation' which relate to the way blue spaces are perceived and interacted with to achieve 'salutogenic' (i.e. health promoting) potential. They labelled these: 'activity' space, 'experienced' space, 'social' space, and 'symbolic' space; and they approximate respectively to blue spaces as places to engage in physical activity, to build positive emotions/memories, to engage in positive social relations, and to form attachment bonds and personal meanings to specific locations.

Encouraging physical activity. Greater levels of physical activity among people who live near the coast or other waterside locations is one of the strongest findings in the blue space literature (Gascon et al., 2017). Many of the early studies were conducted in Australia and New Zealand, and suggested that people who lived near the coast had higher levels of self-reported physical activity, mostly walking (Ball et al., 2007; Bauman et al., 1999; Humpel et al., 2004; Wilson et al., 2011; Witten et al., 2008). Although subsequent research in England (White et al., 2014a) and France (Karusisi et al., 2012; Perchoux et al., 2015) provided further support, studies in the US (Gilmer et al., 2003) and China (Ying et al., 2015) found no differences among those who lived close to, versus further from, blue spaces. Although statistical power may have been an issue, as these two studies had relatively small samples compared to the others, the Ying et al. (2015) study is particularly important because it used pedometer measures and thus had a more objective measure of physical activity. In a similar vein, a recent paper by Garrett et al. (2020) in England found statistically higher self-reported physical activity among those living at the coast, but also no difference in objectively measured physical activity using accelerometers among a sub-sample. Again, power issues may have been a factor due to the reduced sub-sample, but it does raise the issue that self-reported findings may be biased among those who live near water for some reason.

What is clearer, is that much of the activity in blue spaces, at least in developed countries, is not water-based but occurs on land, e.g. beach walks (Elliott et al., 2018; White et al., 2016b); and it is this activity that predominantly explains any link between coastal proximity and health (Pasanen et al., 2019). There is also experimental and survey evidence that when people undertake exercise in blue spaces, they tend to exercise for longer than in green or urban settings (Elliott et al., 2015), in part because perceptions of time are different (White et al., 2015). Attempts have been made to put economic values on blue space activities by calculating how the level of physical activity undertaken there is likely to improve health and well-being (Papathanasopoulou et al., 2016; Vert et al., 2019a). This kind of framing is particularly important for policy makers who have to make budgetary decisions, such as for local urban planners when considering river regeneration interventions (Vert et al., 2019b), or those in charge of marine spatial planning who need to be aware of the 'value' of such recreational activities (Elliott et al., 2018).

Supporting *positive social relations*. There is growing evidence that compared to greenspaces, blue spaces may be particularly important for promoting positive social relationships. Qualitative studies in Germany (Völker and Kistemann, 2015), Iran (Vaeztavakoli et al., 2018), Ireland (Foley, 2015), and the UK (Ashbullby et al., 2013; Bell et al., 2015), all found evidence suggesting that blue space environments are ideal locations for people to spend high quality time with friends and family. In the words of a participant in the study of Iran's Isfahan's Niasarm canal: "*When the weather is good, the canal is full of people from the neighborhood. Women, children, and old people all prefer to socialize together alongside the canal*" (Vaeztavakoli et al., 2018, p. 13). Survey data also suggest that spending time with others is a key motivation for visits to both coastal (Elliott et al., 2018) and inland (de Bell et al., 2017) waters, and a study in Spain suggested that social support was higher for those who had access to blue, but not green, spaces (Triguero-Mas et al., 2015).

Building place/nature connectedness. Although not in Markeyvch et al.'s (2017) original model, we believe place/nature connectedness is nonetheless an important potential instoration pathway. People have a deep innate need to feel connected to other people or something bigger than themselves (Baumeister and Leary, 1995). When interpersonal connections are lacking or attenuated, connections/attachment to places (Scannell and Gifford, 2010) and natural environments in particular (Clayton, 2003) may buffer people against the poor mental health that tends to be associated with loneliness (Cartwright et al., 2018). Korpela and colleagues (e.g. Korpela et al., 2010, 2020), in particular, have conducted research exploring people's 'favourite places', the places that have particular meaning for them, and ones where they often go to 'feel better' or self-regulate their emotional states. Importantly such emotional states seem to be particularly enhanced in blue space settings

(MacKerron and Mourato, 2013; White et al., 2013a), and they are also among many people's favourite places (Korpela et al., 2010; Vaeztavakoli et al., 2018). Nonetheless, it is also important to recognise that there are socio-demographic inequalities in blue space access (Haeffner et al., 2017), and as such it may be difficult for marginalized groups (e.g. persons with disabilities) to 'learn to love' blue spaces, especially if historically they have only had access to more dangerous ones (Bell et al., 2019).

Nature connectedness can be considered as both an enduring dispositional trait (some people tend to feel more connected to nature than others in general) and as a more ephemeral state (the same individual can feel more or less connected depending on context [Capaldi et al., 2014]). People who live at the coast tend to have higher trait nature connectedness (or appreciation, Alcock et al., 2020); and visits to blue spaces, especially those of high quality, tend to be associated with higher levels of state nature connectedness (Wyles et al., 2019). We know of only one published study that adapted a standard nature connectedness tool (the Inclusion of Nature in the Self scale, Schultz, 2001) to focus exclusively on blue spaces (Hignett et al., 2018). This study measured children's marine connectedness, as well as health and pro-environmental outcomes, before and after a multi-week surf programme. Although there were benefits for key health outcomes such as resting heart rate and pro-environmental behaviors, these were not mediated by improved marine connectedness. Further studies are needed that explore marine and inland water connectedness in particular, as something different from nature connectedness in general.

3.3. Restoration (capacity restoration)

In terms of restoration two influential theories argue that modern urban environments in particular pose demands on our emotional (Stress Reduction Theory, Ulrich et al., 1991) and cognitive/attentional (Attention Restoration Theory, Kaplan & Kaplan, 1989) resources, that need opportunities to recover and 're-charge'. Both theories argue that non-threatening nature environments (including potentially blue spaces) offer many of the characteristics for supporting such restoration from stressful and cognitively demanding situations.

Stress reduction. As early as 1981, Ulrich (1981) demonstrated that experimental exposure to aquatic versus green space scenes may be particularly relaxing by measuring neural oscillations in the 8–12 Hz spectrum (i.e. alpha waves) using an electroencephalograph (EEG). He suggested that "*the fact that alpha during the water exposures was on average lower than during the vegetation scenes may be due to the attention-holding properties of the water views*" (p. 546). In a subsequent study Ulrich et al. (1991) showed that watching natural scenes (including an aquatic one) could help participants recover faster (as measured using galvanic skin response, heart rate and frown muscle activation) from a stressful situation than watching urban scenes. However the green space and blue space scenes were collapsed for analysis due to similar effects, so it did not appear that blue space had any marginal advantage.

Since these early studies by Ulrich and colleagues, work in terms of blue space has tended to explore the self-reported mood states of those making intentional recreational visits to a range of urban, green and blue spaces, under the assumption that many recreational visitors to nature are urban residents with habitually high levels of arousal and stress. Comparisons of visits across a range of contexts has repeatedly shown that blue spaces are among the most restorative contexts (Barton and Pretty, 2010; White et al., 2013a), with a study by MacKerron and Mourato (2013) being particularly persuasive. These authors developed an iPhone app (Mappiness) which contacted people at several points during the day over several days to ask how they were feeling, tagging their responses to their geolocations. Results found that people were happiest in marine/coastal settings, but that inland waters were more similar to green spaces such as woodlands and grasslands.

A few experimental studies have also looked at emotions in relation to physical activity in urban, blue and/or green/control settings. Vert et al. (2020), found that subjective well-being and feelings of vitality among office walkers taking an experimentally selected blue space walk during lunchtime were higher than following either an urban walk or seated control condition. However, two similar walking studies (Gidlow et al., 2016; Triguero Mas et al., 2017) and a simulated cycling study using an indoor bike and large outdoor screen projections (White et al., 2015) found that while blue space walks/cycles were associated with better mood outcomes than an urban walk/cycle, green space activity provided similar benefits. Finally, in-depth qualitative studies (e.g. Bell et al., 2015) have tried to uncover why people report feeling less stressed in aquatic settings, with people reporting that the light, the soundscapes, the quickly changing patterns, and/or meaningful histories and personal associations are all potentially important.

Cognitive Restoration. Despite the large number of studies that have looked at the potential of green spaces to restore depleted cognitive ability, predominantly attention (Ohly et al., 2016; Stevenson et al., 2018), there have been very few studies which have looked at blue spaces in particular. Nevertheless, several important experimental studies that compared 'nature' and 'urban' settings (e.g. Berman et al., 2008; Berto, 2005; van Hedger et al., 2019) actually used predominantly blue space imagery and/or sounds in their 'nature' conditions, but systematically (though presumably accidently) excluded water from their 'urban' conditions (White et al., 2010). Thus findings that exposure to the 'natural' images/sounds results in better performance on a range of attentional tests, might be better framed in terms of blue spaces than nature in general. Although, as with Ulrich et al. (1991) it may be that natural spaces without water may have been as good, we suspect that these researchers chose natural environments containing water because they intuitively felt that the presence of water added to the potentially restorative effects (Kaplan and Kaplan, 1989).

Two experimental studies, one lab-based (Emfield and Neider, 2014) and one field based (Gidlow et al., 2016) did attempt to explore impacts of urban versus specifically blue space exposure on cognitive outcomes. Emfield and Neider (2014) found no improvements on a range of cognitive tasks after viewing blue space images and/or listening to blue space sounds compared to comparable urban (non-blue) stimuli. However, given that there was no prior cognition depletion task over and above completing the tools themselves, it may be that people were not sufficiently depleted to begin with to allow for restoration (Hartig et al., 1991). Gidlow et al. (2016) compared Backward Digit Span scores before and after a 30 min' walk in either urban, green or blue space (a river path) settings, as well as employing a delayed post-test 30 min after the walk. The pre to delayed post-test comparison suggests that only in the blue space condition did BDS scores improve significantly. Further research differentiating blue from green spaces with respect to attention restoration is needed to clarify these and other findings.

4. Effect modifiers

Following Hartig et al. (2014), who identified two types of effect modifier of the relationships between nature in general and health, we identify similar potential modifiers for blue spaces in particular; and categorise them as situational (pertaining to environmental circumstances) and individual (pertaining to the individual being exposed to the blue spaces). The role of modifiers is shown at the top of Fig. 1.

4.1. Situational

Blue space type. Much of the blue space and health research has focused on marine/coastal settings (White et al., 2016a; Gascon et al., 2017). However, there are also studies that focus on rivers (de Bell et al., 2017; Vert et al., 2019; Völker and Kistemann, 2013), canals (Vaeztavakoli, 2018), and lakes, both large (Pearson et al., 2019) and small (Pearson et al., 2019; Völker and Kistemann, 2015). When looked at independently it is hard to compare different types of blue space, but a few studies have included both marine and inland waters in the same research. Elliott et al. (2020) find similar distance decay effects for the relationships between home location and visits to coasts and lakes. Both White et al. (2013) and McKerron and Mourato (2013) found that people reported being more relaxed and happier, respectively, in coastal than inland water settings, at least in England.

Quality. Objective water quality, in both inland and marine waters, is vitally important for a range of health and well-being outcomes (Landrigan et al., 2018; Fleming et al., 2019). The European Union, for instance, has an extensive programme for monitoring water quality at over 22,000 coastal and inland designated bathing waters across Europe (European Environment Agency, 2019: https://ec.europa.eu/environment/water/water-bathing/index_en.html). One of the chief threats to health comes from human and animal faecal matter in the water which carries harmful pathogens including bacteria such as *Escherichia coli* (*E. coli*) which can lead to gastrointestinal and other illnesses (Prüss, 1998). Further, perceived quality, irrespective of actual quality, is also important because it can influence behaviour leading to either avoidance of waters that are of good quality (Vert et al., 2019), or exposure to waters that are of poor quality (Rowles et al., 2018). As early as 1980, the World Health Organisation recognised that perceived quality could affect the psychological benefits of interacting with blue spaces (WHO, 1980).

In one of the earliest studies to look at the importance of perceived water quality systematically, Wilson et al. (1995) showed participants photographs of different waterscapes with and without photo-shopped signs of pollution (e.g. foam), algal blooms, etc. As expected, the images with indicators of poor water quality were consistently rated less positively and people said they would be less likely to use them for recreation purposes, irrespective of the fact that they were given no objective data on water quality. In a similar study Wyles et al. (2016) experimentally manipulated the amount and type of litter on a beach and showed images of these to participants. Although all forms of litter reduced preference ratings of the scene, visitor generated litter (e.g. food cartons) had a more negative impact than fishing litter (e.g. discarded nets). Therefore, it is necessary to consider perceptions of blue space quality alongside more objective indicators when considering the impacts on health and well-being.

Other indicators of blue space quality include actual and perceived levels of biodiversity. For instance, in a study of over 4500 visits to natural environments in England (Wyles et al., 2019), nature connectedness and experienced well-being/stress reduction were higher in marine settings that had some form of protected or designated status (e.g. Site of Special Scientific Interest) indicating higher objective quality in terms of biodiversity. Although the association between actual and perceived biodiversity at inland (Dallimer et al., 2012) and coastal (White et al., 2017b) blue spaces is weak, again perceived biodiversity is related to more positive ratings, higher feelings of well-being, and greater intentions to visit (Dallimer et al., 2012; White et al., 2017b). Several experimental studies that deliberately manipulated levels of marine biodiversity have also demonstrated greater interest in more biodiverse blue spaces (Fairchild et al., 2018), and greater perceived stress reduction from more biodiverse settings (Cracknell et al., 2018).

Nevertheless, in an aquarium study with different levels of biodiversity, although physiological data did suggest that adding some biodiversity to an empty aquarium was beneficial for stress reduction in terms of heart rate and blood pressure, greater levels of biodiversity did not result in more substantial benefits suggesting there was not a linear dose-response effect (Cracknell et al., 2016). More research is needed to explore these patterns in more detail, including qualitative approaches to understand how, for instance, the importance of blue space biodiversity changes over the life-course (e.g. feeding the ducks might become more important when one has small children [Bell et al., 2018]).

Weather. The weather is arguably a more important factor for blue space than green space exposure. Blue spaces become especially attractive in hot and sunny conditions since, as noted in section 3.1 above, they tend to be cooler, but possibly less attractive in rainy or windy conditions. Supporting this suggestion, landscape preferences in an experimental study using photographs were more affected by the weather for blue spaces than for either green or urban ones (White et al., 2014b). Analysis of over 40,000 visits to different natural settings in England also suggested that people are likely to do more physical activity under warmer temperatures at the coast, but not at inland waters (Elliott et al., 2019). It is also important, to take into account the context when considering the weather. In England, temperatures are relatively low compared to California, where lower than mean temperatures at the beach were seen as preferable and more restorative (Hipp and Ogunseitan, 2011), precisely because it was not 'too hot'.

Country/cultural context. Systematic reviews of inland blue spaces (Volker and Kistemann, 2011), home proximity to blue space (Gascon et al., 2017), and blue activity interventions (Britton et al., 2020) suggest that most studies have been conducted in high income countries including Europe, the US, Australia and New Zealand, Japan and China. Similar issues exist in the green space literature where the vast majority of research has also been conducted in high-income countries. More work is needed in low to middle income countries were water quality may be less regulated (Borja et al., 2020) and threats to health and well-being from water-borne diseases, jellyfish, parasites, predators (e.g. crocodiles), as well as the risk of drowning, may be heightened (WHO, 2014).

4.2. Individual

The green space and health literature is replete with papers exploring the moderating role of individual level differences such as age (Astell-Burt et al., 2014), gender (Richardson and Mitchell, 2010) and ethnicity (Gentin, 2011). One of the most important is socio-economic status, with a number of studies suggesting that the benefits of green space are greater for poorer than richer individuals (Mitchell and Popham, 2008; Mitchell et al., 2015). As noted in Section 2.2, a similar effect has been found with respect to home proximity to the coast, with the relationship to general health being stronger for those in more deprived communities (Wheeler et al., 2012), and the relationship to mental health stronger for those in lower income households (Garrett et al., 2019b). Less work, however, has been conducted to explore other factors such as age, gender and ethnicity, and how these may interact with blue space exposure to affect health and well-being.

Age. Some blue space studies have been conducted with specific age groups. Amoly et al. (2014) explored 7–10 year old Spanish children's emotional coping and behaviour, as well as symptoms of Attention Deficit Hyperactivity Disorder (ADHD, Amoly et al., 2014), as a function of time spent in different settings. The more time the children spent at the beach in the last 12 months, the fewer emotional problems and more pro-social behaviors they exhibited, but there were no associations with ADHD symptoms (Amoly et al., 2014). Crucially, pro-social behaviours were only related to beach, but not green space, time. This finding echoes adult studies suggesting that blue spaces seem to be particularly important for supporting good quality social relationships. A further study explored childhood obesity in England and found that children who lived near the coast, especially rural coasts, were less likely to be obese than children who lived inland, possibly because of more physical activity (Woods et al., 2016).

At the other end of the age spectrum, several blue space studies have focused on older adults. As noted in Section 2.3, Dempsey et al. (2018), Garrett et al. (2019a), and Helbich et al. (2019) all report positive associations between having blue space views from the home or local streets and general and mental health, respectively, among older adults. Coleman and Kearns (2015) have argued that blue space views become increasingly important as people get older and mobility issues emerge. As both Aspinall et al. (2010) and Finlay et al. (2015) point out, however, although water features are an attractor for older people to public places, other factors such as accessibility, feelings of safety and the presence of facilities (such as toilets and benches) tend to be considered as even more important. Although it is often hard to disaggregate the effects of green and blue space, including for older adults (de Keisjzer et al., 2019), blue spaces do offer certain characteristics, such as heat reduction potential that may be particularly important in older age (Burkart et al., 2015).

Gender. Elliott et al. (2018) found that females in England were more likely to visit beach settings, while men were more likely to visit inland waterways. Similar findings were reported in Spain, where extensive visitor observations reported more than twice as many men than women using an urban river pathway (Vert et al., 2019b). Nevertheless, the proportion of women increased slightly, and proportion of men decreased slightly, following extensive renovations, perhaps because the improvements increased perceptions of safety (Vert et al., 2019b). Further, the activities engaged in at blue space settings also show systematic differences: while women are more likely to engage in activities such as paddling and sunbathing, they are less likely to report fishing or water sport activities, with the exception of swimming which is similar across both genders (Elliott et al., 2018). Differences in activities are important because they are associated with different levels of energy expenditure (Vert et al., 2019a); and since it tends to be the higher energy activities which are likely to be undertaken by men, women may be missing out on health-related physical activity gains from a more diverse set of activities in blue spaces.

As Britton and colleagues point out (Britton, 2017; Britton et al., 2018) this may, in part, reflect a certain 'masculinity' associated with many water-based activities such as surfing, which may put some women off from engaging with them in the first place, or undermine their enjoyment of them when being patronised or actively discouraged by men. However, apart from these more physically active endeavours, there is little evidence in the broader literature that men and women benefit differently from blue space exposures. Again, the issue is probably about ensuring fair, equitable, and respectful access to all, rather than trying to conduct lots of further research which sets out to demonstrate that the two genders react differently to blue spaces.

Ethnicity. There is evidence that individuals from minority ethnic backgrounds in the US tend to visit blue spaces less than their white counterparts (Leeworthy, 2011; Wolch and Zhang, 2004), even if they live nearer them (Haeffner et al., 2017). There is also evidence that this may have deep historic roots in racial segregation (Bell et al., 2019; Hollenbeck, 2016), as opposed to perceptions that the potential benefits to their health and well-being are any less (Bush, 2016). In part the issue may be related to the fact that individuals from minority ethnic groups are less likely to be able to swim than their white counterparts (Pilgaard et al., 2019), and thus drownings also tend to be higher (Wiltse, 2007).

In other contexts, blue spaces may have even deeper historical roots linked to cultural identity and practices. Wheaton et al. (2020), for instance, discuss traditional Māori beliefs and practices with respect to the natural world, and blue spaces in particular, in Aoterea, New Zealand. While many colonial European settlers in New Zealand see the coastal waters as places of recreation and leisure, Māori communities in Aoterea have a concept called "kaitiakitanga," which is similar to a sense of guardianship towards the natural world for the good of both future generations but also the natural world in and of itself (Selby et al., 2010). Relationships between blue spaces and health/well-being among these traditional marine communities, as well as among many other island nations and coastal communities today, may be quite different from those where most of the research has been conducted to date and thus further work is needed to explore these issues.

5. Actions/interventions/changes

Aware of some benefits of blue spaces for the promotion of good health and well-being, policy makers, planners, and practitioners around the world have implemented numerous actions, initiatives and changes to improve safe access to high quality water environments. Although many of these actions are multi-faceted and operate at several levels, our model (bottom of Fig. 1) groups them loosely into three types: a) national or international societal-level interventions; b) local/regional infrastructure interventions; and c) personal level interventions with specific groups of people. We recognise that there are thousands of infrastructure projects to improve water quality as well as regulations to reduce discharges of pollution etc. into inland and marine waters, but these are beyond the scope of the current work because their aim is predominantly to reduce harm, rather than promote benefits *per se* (WHO, 2003).

5.1. Societal actions

One example relates to improved quality. The EU, for instance, has a multi-country initiative to monitor bathing water quality, and in Section 4.1 we discussed this in the context of understanding how differences in quality might affect people's willingness to use bathing waters for health promoting recreation. Here, we point out that although the programme is mainly to reduce harms (i.e. exposure to faecal matter in the water), it is also consciously trying to promote the use of these setting for active, healthy recreation, i.e. intentional exposure (EEA, 2019). Until the introduction of the first EU Bathing Water Directive in 1976 (EU, 1976), there were large quantities of uncontrolled or partially controlled discharges of a range of pollutants into bathing waters across the continent. The directive identified a range of indicators by which bathing water quality could be assessed, with the current focus on levels of microbial pollution, especially *E. coli* and Enterococci emerging after the 2006 revision, based on the best available epidemiological evidence of harm from these bacteria (EU, 2006). As a direct consequence of the original and revised directives, bathing water quality in the EU and similarly monitored countries such as Albania and Switzerland, has improved dramatically and use of these spaces increased (EEA, 2019).

A second type of national level intervention is improved access. In the UK, Section 9 of the Marine and Coastal Access Act 2009 (UK Government, 2009) states that: "*Natural England and the Secretary of State must … secure the following objectives: 1) … a route for the whole of the English coast which consists of one or more long-distance routes along which the public are enabled to make recreational journeys on foot or by ferry, and … 2) that, in association with that route …, a margin of land along the length of the English coast is accessible to the public for the purposes of its enjoyment by them, except to the extent that the margin of land is relevant excepted land*" (Paragraph 296,). In other words, the Act called for a 2800 mile long England Coast Path that allowed access to the entire coast surrounding the country, with a few exceptions (e.g. military and power facilities). The aim was quite explicit, to increase direct exposure to the coast through improved access, which, based on the evidence discussed, may in turn influence a range of health and well-being outcomes.

5.2. Local/regional actions

A recent review of local blue space interventions that were planned and designed to improve access to coastal and inland waters around the world by Bell (2019) found 172 recent high profile examples (e.g. had won awards). These included design interventions such as waterfront promenades, conversion of former docks, and improved access to bathing waters. Many of the interventions were designed to improve the aesthetic quality of the area (to make them more attractive for visitors) and/or to explicitly encourage physical activity (e.g. by encouraging walking, cycling and swimming). Several sites where entry into the water was undesirable due to safety (e.g. canalized rivers) were nevertheless designed to improve the visual experience and promote relaxation by building seating and viewing platforms of various types. Many of these were designed to specifically facilitate the kind of social interactions discussed in Section 3.2.

Although the benefits to health and well-being of such improvements may seem self-evident, Bell and colleagues (Bell et al., 2020) have developed a range of assessment tools to more systematically assess their impacts. These range from detailed assessments of blue space environmental quality (Mishra et al., 2020), to observational tools designed to specifically observe how people interact with these blue space interventions, and local community surveys that are conducted before and after the interventions take place to assess change (Bell et al., 2020). Further details on these resources, can be found on the Horizon 2020 funded 'BlueHealth' project website https://bluehealth2020.eu/resources/toolbox/, which also links to a WHO co-designed tool for decision makers attempting to weigh up the risks and benefits of blue spaces for health and wellbeing. Results using these novel assessment tools across a range of local interventions are expected soon.

5.3. Personal actions

A wide range of programs have been developed to specifically increase people's exposures to safe blue spaces, primarily to engage in water sports or so called 'blue gym' activities (Depledge and Bird, 2009). A recent systematic review of 33 such programs (Britton et al., 2020) suggests they are mainly targeted at people experiencing difficulties of some kind such as post-traumatic stress disorder (e.g. among army veterans), breast cancer, cognitive impairments, and broader mental health issues (Britton et al., 2020). The most common intervention activity was surfing, followed by dragon boat racing, sailing, kayaking, and fishing. About half of the interventions took place in marine, and half in inland waters. As many of the studies were qualitative in nature, or if quantitative had relatively small sample sizes, finding clear benefits to health and well-being was difficult. Nonetheless, several suggestive findings emerged including improvements in self-esteem and social relationships. Although there were some indications of improved physical health, the authors suggest these were probably more due to the nature of the activities undertaken, rather than attributable to the blue spaces themselves; and they called for more systematic assessments of such interventions using standardized tools in future.

A very different type of personal blue space intervention for health and well-being has also been investigated in indoor health and care facilities, following on from the pioneering work of Ulrich (1984), who found that recovery from surgery was quicker among those in hospital rooms with green space views. In practice, many indoor nature-based interventions have used images and sounds of blue spaces (e.g. Kweon et al., 2008; White et al., 2010). Particularly popular historically have been aquariums, which can help people recover from stress (Cracknell et al., 2017), as well as help people manage subsequently stressful situations (Wells, 2005), such as electroconvulsive therapy (ECT) (Barker et al., 2003) more effectively. They have also been used in dementia care, where they have been found to help calm older adults, as well as encourage healthy levels of eating and the promotion of social interactions (Edwards and Beck, 2002).

Another area where blue spaces have been used deliberately is in dental care. In a study by Katcher et al. (1984), patients awaiting dental treatment showed greater relaxation and lower anxiety levels ahead of treatment if they had been watching an aquarium, compared to sitting quietly with no stimulus or being asked to focus on a waterfall picture. Extending this logic, Tanja-Dijkstra et al. (2018) used Virtual Reality (VR) technology to enable patients to undertake a simulated walk along a beach *during* treatment in a randomized controlled trial. Patients wore a head mounted display and were able to navigate along a digital reconstruction of a local beach using a hand-held controller. Patients who 'walked' along the beach reported lower levels of pain and anxiety than those in the standard care condition and also reported lower pain and anxiety than those who were able to walk around a clean and pleasant virtual city. The distraction from treatment that engaging in a VR walk was not sufficient in itself; it was important that it took place in a blue space setting.

6. Summary and limitations

Research into the potential health and well-being benefits of living near, and spending time in and around, 'green space' is widespread (Twohig-Bennett and Jones, 2018; Markevych et al., 2017; van den Bosch et al., 2017; van den Berg et al., 2015). However, much of the earlier green space research effectively classified blue spaces as a form of green space and assumed the relationships would be similar. To some extent this is true. Blue spaces do appear to offer similar benefits in terms of mitigation of urban heat island effects, support for physical activity (instoration), and the potential to help people de-stress, calm and relax (restoration). Further, green and blue spaces rarely occur in isolation so it is not always easy to untangle them. Green spaces need sources of water to remain green, and many blue spaces are part of green infrastructure (e.g. park lakes, canal towpaths, sand dunes etc.). Nevertheless, blue spaces within these landscapes have their own set of risks and benefits for human health and well-being and it is important to recognise these issues as distinct.

Many of the benefits of blue spaces are obvious, the need for freshwater for drinking and irrigation, the existence of food sources (e.g. fish). The aim of the current chapter was not to revisit these already well-documented benefits but to summarise some of the more subtle, but potentially no less important benefits, or salutogenic effects, for human health and well-being. To help navigate the literature we developed a conceptual model (Fig. 1) to reflect how research into these salutogenic effects are inter-connected. The framework drew on several existing frameworks from the green space and health literature to identify types of exposure (e.g. indirect, incidental and intentional Keniger et al., 2013), pathways linking exposure to outcomes (mitigation, instoration, restoration, Markevych et al., 2017), and situational (e.g. weather) and individual (e.g. age) effect modifiers (Hartig et al., 2014). But it also went beyond these models by recognising the importance of pro-environmental outcomes associated with blue space exposure (e.g. Milfont et al., 2014; Alcock et al., 2020), nature connectedness (e.g. Martin et al., 2020), and feedback loops from health outcomes to actions, interventions and changes that are undertaken to increase exposure.

A strength of the reviewed literature was the breadth of research methodologies used including: large scale epidemiological studies (e.g. Gascon et al., 2017); longitudinal work (White et al., 2013); visitor surveys (Barton and Pretty, 2010); experience sampling methods (MacKerron and Mourato, 2013); laboratory experiments (e.g. Ulrich et al., 1991), field experiments (e.g. Gidlow et al., 2016), randomized controlled trials (e.g. Tanja-Dijkstra et al., 2018); infrastructure interventions (e.g. Vert et al., 2019a/b); behavioural interventions (Britton et al., 2020); and in-depth qualitative work (Bell et al., 2015). The range of methods reflects the highly inter-disciplinary nature of the work to date with collaborations between natural, behavioural and social scientists. Results are not all clear cut, but there is evidence across these mixed methodologies that access to safe, clean and attractive blue spaces has a range of potential health and well-being benefits, due to a variety of mechanisms (e.g. lower temperatures, increased physical activity, lower stress, encouraging quality time with friends and family), and for a wide range of people.

Nevetheless we remain cautious. Because of its breadth, the review lacked depth, and we were unable to conduct the kind of systematic literature searches, thorough quality appraisals, or quantitative meta-analyses of specific studies that papers with smaller, more targeted research questions are able to conduct (cf Britton et al., 2020; Gascon et al., 2017; Völker and Kistemann, 2011). Consequently, relevant literature may have been missed, and we recognise that our selection is indicative but by no means exhaustive. Studies with null or negative effects, which do not find a link between blue space exposure and positive health and well-being outcomes in particular may have been missed, because it is often harder to find such studies (e.g. may require grey literature searches). We also did not attempt to provide estimates of the balance of evidence across multiple studies (e.g. effect sizes), again because our overview was too broad to conduct this systematically. We leave such efforts to future work that is able to concentrate on a specific part of our proposed model in more detail and acknowledge that at this stage our review was more about providing an overarching structure than an attempt to provide definitive answers about the level of quantitative support for these associations.

We also recognise that most of the studies reviewed here were conducted in middle to high-income countries, mainly in North America, Europe and Australasia. Studies such as Vaeztavakoli et al.'s (2018) in Iran are the exception rather than the rule. Given that the majority of the world's population lives in Asia, Africa and South America further investigation into the potential salutogenic benefits of blue spaces for these populations is crucial, especially when blue space risks such as flooding, drowning, and disease may be more pronounced in these countries.

A key limitation of our review was that we did not explore the risks in any detail or attempt to compare or trade-off the benefits and the risks more generally. We recognise that these risks affect millions around the world annually. Mitigation of them is often at the heart of substantial engineering projects to, for instance, channelize/canalise rivers, as well as eliminate water altogether (e.g. swamp drainage to reduce mosquito numbers and malaria risk). Ultimately, whether interacting with blue spaces is good for health and well-being will depend on weighing up these risks with the benefits discussed. At this stage, however, it is too early to conduct such an integrative syntheses, in part due to the partial nature of the benefits literature.

7. Concluding comments

The aim of the current narrative review and synthesis was to provide an overview of the growing, but highly disparate, literature that informs our understanding of the potential benefits to health and wellbeing from exposures to aquatic (blue space) environments such as rivers, lakes and the coast. The aim was not to provide definitive answers but rather to outline the breadth of work conducted to date and structure it into a framework that could be used to better identify research gaps and future opportunities. Such a framework, we believe, can also help researchers think more about critical points where risks and benefit trade-offs for health and well-being can occur, considerations of which may be especially important for blue space settings.

CRediT Statement

Mathew P. White: Conceptualization, Writing - original draft, Funding acquisition. Lewis R. Elliott: Writing - review & editing. Mireia Gascon: Writing - review & editing. Bethany Roberts: Writing - review & editing. Lora E. Fleming: Writing - review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Support for the writing of this manuscript was provided by the BlueHealth project, funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 666773.

References

Alcock, I., White, M.P., Wheeler, B.W., Lovell, R., Higgins, S., Osborne, N., Depledge, M., 2015. Mental health and land cover in rural England: what accounts for "England's green and pleasant land"? Landsc. Urban Plann. 142, 38–46.
Alcock, I., White, M.P., Pahl, S., Duarte-Davidson, R., Fleming, L.E., 2020. Associations between pro-environmental behaviour and neighbourhood nature, nature visits and nature appreciation: evidence from a nationally representative survey in England. Environ. Int. 136, 105441.
Ali, M., Nelson, A.R., Lopez, A.L., Sack, D.A., 2015. Updated global burden of cholera in endemic countries. PLoS Neglected Trop. Dis. 9 (6), e0003832.
Alvarsson, J.J., Wiens, S., Nilsson, M.E., 2010. Stress recovery during exposure to nature sound and environmental noise. Int. J. Environ. Res. Publ. Health 7, 1036–1046.
Amoly, E., Dadvand, P., Forns, J., López-Vicente, M., Basagaña, X., Julvez, J., et al., 2014. Green and blue spaces and behavioral development in Barcelona schoolchildren: the BREATHE project. Environ. Health Perspect. 122 (12), 1351–1358.
Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., et al., 2013. Inducing physiological stress recovery with sounds of nature in a virtual reality forest—results from a pilot study. Physiol. Behav. 118, 240–250.
Ashbullby, K.J., Pahl, S., Webley, P., White, M.P., 2013. The beach as a setting for families' health promotion: a qualitative study with parents and children living in coastal regions in Southwest England. Health Place 23, 138–147.
Aspinall, P.A., Thompson, C.W., Alves, S., Sugiyama, T., Brice, R., Vickers, A., 2010. Preference and relative importance for environmental attributes of neighbourhood open space in older people. Environ. Plann. Plann. Des. 37 (6), 1022–1039.
Asselman, J., Van Acker, E., De Rijcke, M., Tilleman, L., Van Nieuwerburgh, F., Mees, J., et al., 2019. Marine biogenics in sea spray aerosols interact with the mTOR signaling pathway. Sci. Rep. 9 (1), 1–10.
Astell-Burt, T., Mitchell, R., Hartig, T., 2014. The association between green space and mental health varies across the lifecourse. A longitudinal study. J. Epidemiol. Community Health 68 (6), 578–583.
Aylward, B., Bandyopadhyay, J., Belausteguigotia, J.C., Borkey, P., Cassar, A.Z., Meadors, L., et al., 2005. Freshwater ecosystem services. In: Ecosystems and Human Well-Being: Policy Responses, 3, pp. 213–256.
Ball, K., Timperio, A., Salmon, J., Giles-Corti, B., Roberts, R., Crawford, D., 2007. Personal, social and environmental determinants of educational inequalities in walking: a multilevel study. J. Epidemiol. Community Health 61, 108–114.
Ballesteros-Olza, M., Gracia-de-Rentería, P., Pérez-Zabaleta, A., 2020. Effects on General Health Associated with Beach Proximity in Barcelona (Spain). Health Promotion International. https://doi.org/10.1093/heapro/daaa013.
Barker, S.B., Rasmussen, K.G., Best, A.M., 2003. Effect of aquariums on electroconvulsive therapy patients. Anthrozoös 16, 229–240.
Barton, J., Pretty, J., 2010. What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. Environ. Sci. Technol. 44, 3947–3955.
Bauman, A., Smith, B., Stoker, L., Bellew, B., Booth, M., 1999. Geographical influences upon physical activity participation: evidence of a 'coastal effect. Aust. N. Z. J. Publ. Health 23, 322–324.
Baumeister, R.F., Leary, M.R., 1995. The need to belong: desire for interpersonal attachments as a fundamental human motivation. Psychol. Bull. 117, 497–529.
Bell, S., 2019. Health and well-being aspects of urban blue space: the new urban landscape research field. In: Landscape Architecture: Special Edition - Resilient Landscapes, 26, pp. 113–119.
Bell, S., Mishra, H.S., Elliott, L.R., Shellock, R., Vassiljev, P., Porter, M., Sydenham, Z., White, M.P., 2020. Urban blue acupuncture: protocol for evaluating of a complex landscape design intervention to improve health and wellbeing in a coastal community. Sustainability 12, 4084.
Bell, S.L., Phoenix, C., Lovell, R., Wheeler, B.W., 2015. Seeking everyday well-being: the coast as a therapeutic landscape. Soc. Sci. Med. 142, 56–67.
Bell, S.L., Westley, M., Lovell, R., Wheeler, B.W., 2018. Everyday green space and experienced well-being: the significance of wildlife encounters. Landsc. Res. 43, 8–19.
Bell, S.L., Hollenbeck, J., Lovell, R., White, M.P., Depledge, M.H., 2019. The shadows of risk and inequality within salutogenic coastal waters. In: Foley, R., Kearns, Kistemann T., Wheeler, B. (Eds.), Blue Space, Health and Well-Being: Hydrophilia Unbounded (Chp. 10, Pp133-156). Routledge, Oxford.
Berman, M.G., Jonides, J., Kaplan, S., 2008. The cognitive benefits of interacting with nature. Psychol. Sci. 19 (12), 1207–1212.
Berto, R., 2005. Exposure to restorative environments helps restore attentional capacity. J. Environ. Psychol. 25 (3), 249–259.
Bloom, D., Cafiero, E., Jané-Llopis, E., Abrahams-Gessel, S., Bloom, L., Fathima, S., Feigl, A., Gaziano, T., Mowafi, M., Pandya, A., et al., 2011. The Global Economic Burden of Noncommunicable Diseases. WHO, Geneva, Switzerland.
Boers, S., Hagoort, K., Scheepers, F., Helbich, M., 2018. Does residential green and blue space promote recovery in psychotic disorders? A cross-sectional study in the province of Utrecht, The Netherlands. Int. J. Environ. Res. Publ. Health 15, 2195.
Borja, A., White, M.P., Berdalet, E., Bock, N., Eatock, E., Kristensen, P., Leonard, A., Lloret, J., Pahl, S., Parga, M., Vera Prieto, J., Wuijts, S., Fleming, L.E., 2020. Moving towards an agenda on ocean health and human health. Front. Mar. Sci. 7, 37.
Boyd, F., White, M.P., Bell, S., Burt, J., 2018. Who doesn't visit natural environments for recreation and why: a population representative analysis of spatial, individual and temporal factors among adults in England. Landsc. Urban Plann. 175, 102–113.
Brereton, F., Clinch, J.P., Ferreira, S., 2008. Happiness, geography and the environment. Ecol. Econ. 65 (2), 386–396.

Britton, E., 2017. 'Be like water': reflections on strategies developing cross-cultural programmes for women, surfing and social good. In: Caudwell, J., Mansfield, L., Wheaton, B., Watson, R. (Eds.), Handbook of Feminisms in Sport, Leisure and Physical Education. Palgrave, London, England, pp. 793–807.
Britton, E., Olive, R., Wheaton, B., 2018. Surfer and leisure: freedom' to surf? Contested spaces on the coast. In: Brown, M., Peters, K. (Eds.), Living with the Sea: Knowledge, Awareness and Action. Routledge, London & New York, pp. 147–166.
Britton, E., Kindermann, G., Domegan, C., Carlin, C., 2020. Blue care: a systematic review of blue space interventions for health and well-being. Health Promot. Int. 35, 50–69.
Burkart, K., Meier, F., Schneider, A., Breitner, S., Canário, P., Alcoforado, M.J., Scherer, D., Endlicher, W., 2015. Modification of heat-related mortality in an Elderly urban population by vegetation (urban green) and proximity to water (urban blue): evidence from Lisbon, Portugal. Environ. Health Perspect. 124, 927–934.
Bush, G.A., 2016. White Sand Black Beach: Civil Rights, Public Space, and Miami's Virginia Key. University Press of Florida.
Capaldi, C.A., Dopko, R.L., Zelenski, J.M., 2014. The relationship between nature connectedness and happiness: a meta-analysis. Front. Psychol. 5, 976.
Cartwright, B., White, M.P., Clitherow, T.J., 2018. Nearby nature 'buffers' the effect of low social connectedness on adult subjective well-being over the last 7 days. Int. J. Environ. Res. Publ. Health 15, *1238*.
Cherrie, M.P.C., Wheeler, B., White, M.P., Sarran, C.E., Osborne, N.J., 2015. Coastal climate is associated with elevated solar irradiance and higher 25(OH)D level in coastal residents. Environ. Int. 77, 76–84.
Clappier, A., Martilli, A., Grossi, P., Thunis, P., Pasi, F., Krueger, B.C., et al., 2000. Effect of sea breeze on air pollution in the greater Athens area. Part I: numerical simulations and field observations. J. Appl. Meteorol. 39 (4), 546–562.
Clayton, S., 2003. Environmental Identity: conceptual and operational definition. In: Clayton, S., Opotow, S. (Eds.), Identity and the Natural Environment: the Psychological Significance of Nature. MIT Press, Cambridge, MA, pp. 45–65.
Coleman, T., Kearns, R., 2015. The role of bluespaces in experiencing place, aging and well-being: insights from Waiheke Island, New Zealand. Health Place 35, 206–217.
Cox, D.T., Shanahan, D.F., Hudson, H.L., Fuller, R.A., Gaston, K.J., 2018. The impact of urbanisation on nature dose and the implications for human health. Landsc. Urban Plann. 179, 72–80.
Cox, D.T., Shanahan, D.F., Hudson, H.L., Fuller, R.A., Anderson, K., Hancock, S., Gaston, K.J., 2017. Doses of nearby nature simultaneously associated with multiple health benefits. Int. J. Environ. Res. Publ. Health 14, 172.
Cracknell, D., White, M.P., Pahl, S., Nichols, W.J., Depledge, M.H., 2016. Sub-aquatic biodiversity and psychological well-being: a preliminary examination of dose-response effects in an aquarium setting. Environ. Behav. 48, 1242–1269.
Cracknell, D., White, M.P., Pahl, S., Depledge, M.H., 2017. Aquariums as restorative environments and the influence of species diversity. Landsc. Res. 42, 18–32.
Cracknell, D.L., Pahl, S., White, M.P., Depledge, M.H., 2018. Reviewing the role of aquaria as restorative settings: how subaquatic diversity in public aquaria can influence preferences, and human health and well-being. Hum. Dimens. Wildl. 23 (5), 446–460.
Dallimer, M., Irvine, K.N., Skinner, A.M., Davies, Z.G., Rouquette, J.R., Maltby, L.L., et al., 2012. Biodiversity and the feel-good factor: understanding associations between self-reported human well-being and species richness. Bioscience 62 (1), 47–55.
de Bell, S., Graham, H., Jarvis, S., White, P., 2017. The importance of nature in mediating social and psychological benefits associated with visits to freshwater blue space. Landsc. Urban Plann. 167, 118–127.
Depledge, M.H., Bird, W.J., 2009. The Blue Gym: health and well-being from our coasts. Mar. Pollut. Bull. 58, 947.
Depledge, M.H., Lovell, R., Wheeler, B., Morrissey, K., White, M.P., Fleming, L.E.F., 2017. Review of evidence: health and well-being of coastal communities. In: Government Office of Science Foresight 'Future of the Sea' Project. GOSF, London.
Depledge, M.H., White, M.P., Maycock, B., Fleming, L.E., 2019. Time and tide: our future health and well-being depends on the Oceans. Br. Med. J. 366, l4671.
de Keijzer, C., Tonne, C., Sabia, S., Basagaña, X., Valentín, A., Singh-Manoux, A., Antó, J. M., Alonso, J., Nieuwenhuijsen, M.J., Sunyer, J., Dadvand, P., 2019. Green and blue spaces and physical functioning in older adults: longitudinal analyses of the Whitehall II study. Environ. Int. 122, 346–356.
Dempsey, S., Devine, M.T., Gillespie, T., Lyons, S., Nolan, A., 2018. Coastal blue space and depression in older adults. Health Place 54, 110–117.
Denton, H., Aranda, K., 2019. The wellbeing benefits of sea swimming. Is it time to revisit the sea cure? Qual. Res. Sport Exerc. Health 1–17. https://doi.org/10.1080/2159676X.2019.1649714.
de Vries, S., Ten Have, M., van Dorsselaer, S., van Wezep, M., Hermans, T., de Graaf, R., 2016. Local availability of green and blue space and prevalence of common mental disorders in The Netherlands. BJPsych Open 2, 366–372.
Edwards, N.E., Beck, A.M., 2002. Animal-assisted therapy and nutrition in Alzheimer's disease. West. J. Nurs. Res. 24, 697–712.
Elliott, L.R., White, M.P., Taylor, A.H., Herbert, S., 2015. Energy expenditure on recreational visits to different natural environments: implications for public health. Soc. Sci. Med. 139, 56–60.
Elliott, L.R., White, M.P., Grellier, J., Rees, S., Waters, R., Fleming, L.E.F., 2018. Recreational visits to inland and coastal waters in England: who, where, when, what and why. Mar. Pol. 97, 305–314.
Elliott, L.R., White, M.P., Smalley, A., Sarran, C., Scoccimarro, E., Grellier, J., Garrett, J. K., Fleming, L.E., 2019. The effects of meteorological conditions and daylight on nature-based recreational physical activity in England. Urban For. Urban Green. 42, 39–50.
Elliott, L.R., White, M.P., Grellier, J., Garrett, J.K., Cirach, M., Wheeler, B.W., Bratman, G.N., van den Bosch, M.A., Ojala, A., Roiko, A., Lima, M.L., O'Connor, A., Gascon, M., Nieuwenhuijsen, M., Fleming, L.E., 2020. Defining residential blue space distance categories: modelling distance-decay effects across eighteen countries. Landsc. Urban Plann. 198, 103800.
Emfield, A.G., Neider, M.B., 2014. Evaluating visual and auditory contributions to the cognitive restoration effect. Front. Psychol. 5, 548.
European Union, 1976. Council Directive 76/160/EEC of 8 December 1975 Concerning the Quality of Bathing Water. EU. https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:31976L0160. (Accessed 17 July 2019).
European Union, 2006. Council Directive 2006/7/EC concerning the management of bathing water quality and repealing Directive 76/160/EEC. Orkesterjournalen L 64, 37–51. EU. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0007. (Accessed 17 July 2019), 4.3.2006.
European Environment Agency, 2019. European Bathing Water Quality in 2018. EEA Report No 3/2019.
Fairchild, T.P., Fowler, M.S., Pahl, S., Griffin, J.N., 2018. Multiple dimensions of biodiversity drive human interest in tide pool communities. Sci. Rep. 8 (1), 1–11.
Finlay, J., Franke, T., McKay, H., Sims-Gould, J., 2015. Therapeutic landscapes and wellbeing in later life: impacts of blue and green spaces for older adults. Health Place 34, 97–106.
Fleming, L.E., Kirkpatrick, B., Backer, L.C., Walsh, C.J., Nierenberg, K., Clark, J., Reich, A., Hollenbeck, J., Benson, J., Cheng, Y.S., Naar, J., Pierce, R., Bourdelais, A. J., Abraham, W.M., Kirkpatrick, G., Zaias, J., Wanner, A., Mendes, E., Shalat, S., Hoagland, P., Stephan, W., Bean, J., Watkins, S., Clarke, T., Byrne, M., Baden, D.G., 2011. Review of Florida Red Tide and human health effects. Harmful Algae 20, 224–233.
Fleming, L.E., McDonough, N., Austen, M., Mee, L., Moore, M., Depledge, M., White, M. P., Philippart, K., Bradbrook, P., Smalley, A., 2014. Oceans and human health: a rising tide of challenges and opportunities for Europe. Mar. Environ. Res. 99, 16–19.
Fleming, L.E., Depledge, M., McDonough, N., White, M., Pahl, S., Austen, M., Goksoyr, A., Solo-Gabriele, H., Stegeman, J.J., 2015. The Oceans and Human Health. In: Oxford Encyclopedia of Environmental Science, Environment and Human Health. Oxford University Press.
Fleming, L.E., Maycock, B., White, M.P., Depledge, M.H., 2019. Sustainable oceans needed to protect and foster human health in the 21st century. People and Nature. https://doi.org/10.1002/pan3.10038.
Foley, R., 2015. Swimming in Ireland: immersions in therapeutic blue space. Health Place 35, 218–225.
Foley, R., 2017. Swimming as an accretive practice in healthy blue space. Emotion, space and Society 22, 43–51.
Fortescue Fox, R., Lloyd, W.B., 1938. Convalescence on the coast. Lancet 232, 37–39.
Fredrickson, B.L., 2001. The role of positive emotions in positive psychology: the broaden-and-build theory of positive emotions. Am. Psychol. 56, 218.
Gaisberger, M., Šanović, R., Dobias, H., Kolarž, P., Moder, A., Thalhamer, J., et al., 2012. Effects of ionized waterfall aerosol on pediatric allergic asthma. J. Asthma 49, 830–838.
Garrett, J., White, M.P., Huang, J., Ng, S., Hui, Z., Leung, C., Tse, S., Fung, F., Elliott, L. R., Depledge, M.H., Wong, M.C.S., 2019a. The association between blue space exposure, health and well-being in Hong Kong. Health Place 55, 100–110.
Garrett, J.K., Clitherow, T.J., White, M.P., Elliott, L.R., Wheeler, B.W., Fleming, L.E., 2019b. Coastal proximity and mental health among urban adults in England: the moderating effect of household income. Health Place 59, 102200.
Garrett, J.K., White, M.P., Elliott, L.R., Wheeler, B.W., Fleming, L.E., 2020. Neighbourhood Nature and Physical Activity: Self-Report and Accelerometer Findings from the Health Survey for England. Environmental Research (in press).
Gascón, M., Zijlema, W., Vert, C., White, M.P., Nieuwenhuijsen, M.J., 2017. Blue spaces, human health and well-being: a systematic review. Int. J. Hyg Environ. Health 1207–1221.
Gascon, M., Sánchez-Benavides, G., Dadvand, P., Martínez, D., Gramunt, N., Gotsens, X., et al., 2018. Long-term exposure to residential green and blue spaces and anxiety and depression in adults: a cross-sectional study. Environ. Res. 162, 231–239.
Gentin, S., 2011. Outdoor recreation and ethnicity in Europe—a review. Urban For. Urban Green. 10 (3), 153–161.
Gibas-Dorna, M., Checinska, Z., Korek, E., Kupsz, J., Sowinska, A., Wojciechowska, M., Krauss, H., Piątek, J., 2016. Variations in leptin and insulin levels within one swimming season in non-obese female cold water swimmers. Scand. J. Clin. Lab. Investig. 76, 486–491.
Gibbons, S., Mourato, S., Resende, G.M., 2014. The amenity value of English nature: a hedonic price approach. Environ. Resour. Econ. 57, 175–196.
Gidlow, C.J., Jones, M.V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M.P., et al., 2016. Where to put your best foot forward: psycho-physiological responses to walking in natural and urban environments. J. Environ. Psychol. 45, 22–29.
Gilmer, M.J., Harrell, J.S., Miles, M.S., Hepworth, J.T., 2003. Youth characteristics and contextual variables influencing physical activity in young adolescents of parents with premature coronary heart disease. J. Pediatr. Nurs. 18, 159–168.
Grafetstätter, C., Gaisberger, M., Prossegger, J., Ritter, M., Kolarž, P., Pichler, C., et al., 2017. Does waterfall aerosol influence mucosal immunity and chronic stress? A randomized controlled clinical trial. J. Physiol. Anthropol. 36, 10.
Grellier, J., White, M.P., Albin, M., Bell, S., Elliott, L.R., Gascón, M., Gualdi, S., Mancini, L., Nieuwenhuijsen, M.J., Sarigiannis, D.A., Van den Bosch, M., Wolf, T., Wuijts, S., Fleming, L.E., 2017. BlueHealth: a study programme protocol for mapping and quantifying the potential benefits to public health and well-being from Europe's blue spaces. BMJ Open 7, e016188.

Grossi, P., Thunis, P., Martilli, A., Clappier, A., 2000. Effect of sea breeze on air pollution in the greater Athens area. Part II: analysis of different emission scenarios. J. Appl. Meteorol. 39 (4), 563–575.

Gunawardena, K.R., Wells, M.J., Kershaw, T., 2017. Utilising green and bluespace to mitigate urban heat island intensity. Sci. Total Environ. 584, 1040–1055.

Guthold, R., Stevens, G.A., Riley, L.M., Bull, F.C., 2018. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1-9 million participants. Lancet Global Health 6, e1077–e1086.

Haeffner, M., Jackson-Smith, D., Buchert, M., Risley, J., 2017. Accessing blue spaces: social and geographic factors structuring familiarity with, use of, and appreciation of urban waterways. Landsc. Urban Plann. 167, 136–146.

Hartig, T., Mang, M., Evans, G.W., 1991. Restorative effects of natural environment experiences. Environ. Behav. 23 (1), 3–26.

Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Publ. Health 35, 207–228.

Heaviside, C., Macintyre, H., Vardoulakis, S., 2017. The urban heat island: implications for health in a changing environment. Current Environmental Health Reports 4 (3), 296–305.

Helbich, M., De Beurs, D., Kwan, M.P., O'Connor, R.C., Groenewegen, P.P., 2018. Natural environments and suicide mortality in the Netherlands: a cross-sectional, ecological study. Lancet Planetary Health 2 (3), e134–e139.

Helbich, M., Yao, Y., Liu, Y., Zhang, J., Liu, P., Wang, R., 2019. Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. Environ. Int. 126, 107–117.

Hignett, A., White, M.P., Pahl, S., Jenkin, R., Lefroy, M., 2018. Can participating in a surfing programme promote young people's well-being and connectedness to the natural environment? J. Adventure Educ. Outdoor Learn. 18, 53–69.

Hipp, J.A., Ogunseitan, O.A., 2011. Effect of environmental conditions on perceived psychological restorativeness of coastal parks. J. Environ. Psychol. 31 (4), 421–429.

Hollenbeck, J.A., 2016. Marine access and understanding in a disadvantaged, urban coastal community: implications for health, well-being and ecosystem management. Doctoral Thesis, University of Exeter Medical School.

Hooyberg, A., Roose, H., Grellier, J., Elliott, L.R., Lonneville, B., White, M.P., Michels, N., De Henauw, S., Vandegehuchte, M., Everaert, G., 2020. General health and residential proximity to the coast in Belgium: results from a cross-sectional health survey. Environ. Res. 184, 109225.

Humpel, N., Owen, N., Iverson, D., Leslie, E., Bauman, A., 2004. Perceived environment attributes, residential location and walking for particular purposes. Am. J. Prev. Med. 26, 119–125.

Huttunen, P., Kokko, L., Ylijukuri, V., 2004. Winter swimming improves general well-being. Int. J. Circumpolar Health 63, 140–144.

Jim, C.Y., Chen, W.Y., 2009. Value of scenic views: hedonic assessment of private housing in Hong Kong. Landsc. Urban Plann. 91, 226–234.

Kaplan, R., Kaplan, S., 1989. The Experience of Nature: A Psychological Perspective. CUP Archive.

Karusisi, N., Bean, K., Oppert, J.M., Pannier, B., Chaix, B., 2012. Multiple dimensions of residential environments, neighborhood experiences, and jogging behavior in the RECORD Study. Prev. Med. 55, 50–55.

Katcher, A., Segal, H., Beck, A., 1984. Comparison of contemplation and hypnosis for the reduction of anxiety and discomfort during dental surgery. Am. J. Clin. Hypn. 27, 14–21.

Keniger, L.E., Gaston, K.J., Irvine, K.N., Fuller, R.A., 2013. What are the benefits of interacting with nature? Int. J. Environ. Res. Publ. Health 10, 913–935.

Kirkpatrick, B., Fleming, L.E., Bean, J.A., Nierenberg, K., Backer, L.C., Cheng, Y.S., Abraham, W.M., 2011. Aerosolized red tide toxins (brevetoxins) and asthma: continued health effects after 1 h beach exposure. Harmful Algae 10, 138–143.

Kolarz, P., Gaisberger, M., Madl, P., Hofmann, W., Ritter, M., Hartl, A., 2012. Characterization of ions at Alpine waterfalls. Atmos. Chem. Phys. 12, 3687.

Korpela, K.M., Ylén, M., Tyrväinen, L., Silvennoinen, H., 2010. Favorite green, waterside and urban environments, restorative experiences and perceived health in Finland. Health Promot. Int. 25 (2), 200–209.

Korpela, K., Korhonen, M., Nummi, T., Martos, T., Sallay, V., 2020. Environmental self-regulation in favourite places of Finnish and Hungarian adults. J. Environ. Psychol. 67, 101384.

Kruize, H., van Kamp, I., van den Berg, M., van Kempen, E., Wendel-Vos, W., Ruijsbroek, A., et al., 2020. Exploring mechanisms underlying the relationship between the natural outdoor environment and health and well-being–Results from the PHENOTYPE project. Environ. Int. 134, 105173.

Kweon, B.S., Ulrich, R.S., Walker, V.D., Tassinary, L.G., 2008. Anger and stress: the role of landscape posters in an office setting. Environ. Behav. 40 (3), 355–381.

Kuo, M., 2015. How might contact with nature promote human health? Promising mechanisms and a possible central pathway. Front. Psychol. 6, 1093.

Laffan, K., 2018. Every breath you take, every move you make: visits to the outdoors and physical activity help to explain the relationship between air pollution and subjective well-being. Ecol. Econ. 147, 96–113.

Landrigan, P.J., Fuller, R., Acosta, N.J., Adeyi, O., Arnold, R., Baldé, A.B., Bertollini, R., Bose-O'Reilly, S., Boufford, J.I., Breysse, P.N., Chiles, T., 2018. The Lancet Commission on pollution and health. Lancet 391, 462–512.

Lange, E., Schaeffer, P.V., 2001. A comment on the market value of a room with a view. Landsc. Urban Plann. 55, 113–120.

Leeworthy, V.R., 2001. Preliminary estimates from versions 1-6: coastal recreation participation. In: National Survey on Recreation and the Environment (NSRE) 2000. Department of Commerce, US.

Li, Q., 2010. Effect of forest bathing trips on human immune function. Environ. Health Prev. Med. 15 (1), 9–17.

Li, Q., Kobayashi, M., Wakayama, Y., Inagaki, H., Katsumata, M., Hirata, Y., et al., 2009. Effect of phytoncide from trees on human natural killer cell function. Int. J. Immunopathol. Pharmacol. 24, 951–959.

Liu, H., Chan, J.C., 2002. An investigation of air-pollutant patterns under sea–land breezes during a severe air-pollution episode in Hong Kong. Atmos. Environ. 36 (4), 591–601.

Luttik, J., 2000. The value of trees, water and open space as reflected by house prices in The Netherlands. Landsc. Urban Plann. 48, 161–167.

MacKerron, G., Mourato, S., 2013. Happiness is greater in natural environments. Global Environ. Change 23 (5), 992–1000.

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A.M., et al., 2017. Exploring pathways linking greenspace to health: theoretical and methodological guidance. Environ. Res. 158, 301–317.

Martin, L., White, M.P., Hunt, A., Richardson, M., Pahl, S., Burt, J., 2020. Nature contact, nature connectedness and associations with health, well-being and pro-environmental behaviours: results from a nationally representative survey in England. J. Environ. Psychol. 68, 101389.

Martínez, M.L., Intralawan, A., Vázquez, G., Pérez-Maqueo, O., Sutton, P., Landgrave, R., 2007. The coasts of our world: ecological, economic & social importance. Ecol. Econ. 63 (2–3), 254–272.

Mayer, F.S., Frantz, C.M., 2004. The connectedness to nature scale: a measure of individuals' feeling in community with nature. J. Environ. Psychol. 24, 503–515.

Milfont, T.L., Evans, L., Sibley, C.G., Ries, J., Cunningham, A., 2014. Proximity to coast is linked to climate change belief. PloS One 9 (7), e103180.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-Being. Synthesis. MEA. https://www.millenniumassessment.org/en/index.html.

Mishra, H.S., Bell, S., Vassiljev, P., Kuhlmann, F., Niin, G., Grellier, J., 2020. The development of a tool for assessing the environmental qualities of urban blue space. Urban For. Urban Green. 49, 126575.

Mitchell, R., Popham, F., 2008. Effect of exposure to natural environment on health inequalities: an observational population study. Lancet 372 (9650), 1655–1660.

Mitchell, R.J., Richardson, E.A., Shortt, N.K., Pearce, J.R., 2015. Neighborhood environments and socioeconomic inequalities in mental well-being. Am. J. Prev. Med. 49 (1), 80–84.

Moore, M.N., 2015. Do airborne biogenic chemicals interact with the PI3K/Akt/mTOR cell signalling pathway to benefit human health and well-being in rural and coastal environments? Environ. Res. 140, 65–75.

Nelson, A.R., Lopez, A.L., Sack, D.A., 2015. Updated global burden of cholera in endemic countries. PLoS Neglected Trop. Dis. 9 (6).

Neumann, B., Vafeidis, A.T., Zimmermann, J., Nicholls, R.J., 2015. Future Coastal Population Growth and Exposure to Sea-Level Rise and Coastal Flooding: A Global Assessment. PLoS ONE, e0118571.

Nutsford, D., Pearson, A.L., Kingham, S., Reitsma, F., 2016. Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. Health Place 39, 70–78.

Ohly, H., White, M.P., Wheeler, B., Bethel, A., Ukomunne, O., Nikolaou, V., Garside, R., 2016. Attention restoration theory: a systematic review of the attention restoration potential of exposure to natural environments. J. Toxicol. Environ. Health, Part B 19, 305–343.

Papathanasopoulou, E., White, M.P., Hattam, C., Lannin, A., Harvey, A., Spencer, A., 2016. Valuing the health benefits of physical activities in the marine environment and their importance for marine spatial planning. Mar. Pol. 63, 144–152.

Pasanen, T., White, M.P., Wheeler, B., Garrett, J., Elliott, L., 2019. Neighbourhood blue space, health and well-being: the mediating role of different types of physical activity. Environ. Int. 131, 105136.

Pearson, A.L., Bottomley, R., Chambers, T., Thornton, L., Stanley, J., Smith, M., et al., 2017. Measuring blue space visibility and 'blue recreation' in the everyday lives of children in a capital city. Int. J. Environ. Res. Publ. Health 14 (6), 563.

Pearson, A.L., Shortridge, A., Delamater, P.L., Horton, T.H., Dahlin, K., Rzotkiewicz, A., et al., 2019. Effects of freshwater blue spaces may be beneficial for mental health: a first, ecological study in the North American Great Lakes region. PloS One 14 (8), e0221977.

Perchoux, C., Kestens, Y., Brondeel, R., Chaix, B., 2015. Accounting for the daily locations visited in the study of the built environment correlates of recreational walking (the RECORD Cohort Study). Prev. Med. 81, 142–149.

Perez, V., Alexander, D.D., Bailey, W.H., 2013. Air ions and mood outcomes: a review and meta-analysis. BMC Psychiatr 13, 29.

Pilgaard, F.I., Östergren, P.O., Olin, A., Kling, S., Albin, M., Björk, J., 2019. Socioeconomic differences in swimming ability among children in Malmö, southern Sweden: initial results from a community-level intervention. Scand. J. Publ. Health 1403494818821478.

Pritchard, A., Richardson, M., Sheffield, D., McEwan, K., 2019. The relationship between nature connectedness and eudaimonic well-being: a meta-analysis. J. Happiness Stud. 21 (1145), 1167.

Prüss, A., 1998. Review of epidemiological studies on health effects from exposure to recreational water. Int. J. Epidemiol. 27 (1), 1–9.

Qiang, Y., Shen, S., Chen, Q., 2019. Visibility analysis of oceanic blue space using digital elevation models. Landsc. Urban Plann. 181, 92–102.

Rådsten-Ekman, M., Axelsson, Ö., Nilsson, M.E., 2013. Effects of sounds from water on perception of acoustic environments dominated by road-traffic noise. Acta Acustica united Acustica 99 (2), 218–225.

Reed, B., 1884. The effects of sea air upon diseases of the respiratory organs, including a study of the influence upon health of changes in the atmospheric pressure. Transactions of the Annual Meeting of the American Climatological Association 1, 51–59.

Richardson, E.A., Mitchell, R., 2010. Gender differences in relationships between urban green space and health in the United Kingdom. Soc. Sci. Med. 71 (3), 568–575.
Rook, G.A., 2013. Regulation of the immune system by biodiversity from the natural environment: an ecosystem service essential to health. Proc. Natl. Acad. Sci. Unit. States Am. 110, 18360–18367.
Rowles III, L.S., Alcalde, R., Bogolasky, F., Kum, S., Diaz-Arriaga, F.A., Ayres, C., et al., 2018. Perceived versus actual water quality: community studies in rural Oaxaca, Mexico. Sci. Total Environ. 622, 626–634.
Salmond, J.A., Tadaki, M., Vardoulakis, S., Arbuthnott, K., Coutts, A., Demuzere, M., et al., 2016. Health and climate related ecosystem services provided by street trees in the urban environment. Environ. Health 15, 95–111.
Science Advice for Policy by European Academies, 2019. Scientific Perspective on Microplastics in Nature and Society. SAPEA, Berlin. SAPEA.
Scannell, L., Gifford, R., 2010. Defining place attachment: a tripartite organizing framework. J. Environ. Psychol. 30, 1–10.
Schipperijn, J., Ekholm, O., Stigsdotter, U.K., Toftager, M., Bentsen, P., Kamper-Jørgensen, F., Randrup, T.B., 2010. Factors influencing the use of green space: results from a Danish national representative survey. Landsc. Urban Plann. 95, 130–137.
Schultz, P.W., 2001. Assessing the structure of environmental concern: concern for self, other people, and the biosphere. J. Environ. Psychol. 21, 1–13.
Selby, R., Moore, P., Mulholland, M. (Eds.), 2010. Māori and the Environment: Kaitiaki. Huia, Wellington, New Zealand.
Shanahan, D.F., Bush, R., Gaston, K.J., Lin, B.B., Dean, J., Barber, E., Fuller, R.A., 2016. Health benefits from nature experiences depend on dose. Sci. Rep. 6, 28551.
Shuval, H., 2003. Estimating the global burden of thalassogenic diseases: human infectious diseases caused by wastewater pollution of the marine environment. J. Water Health 1, 53–64.
Solomon, S., 2010. Water: the Epic Struggle for Wealth, Power, and Civilization. Harper Collins.
Stenbeck, K.D., Balanda, K.P., Williams, M.J., Ring, I.T., MacLennan, R., Chick, J.E., Morton, A.P., 1990. Patterns of treated non-melanoma skin cancer in Queensland—the region with the highest incidence rates in the world. Med. J. Aust. 153, 511–515.
Stevenson, M.P., Schilhab, T., Bentsen, P., 2018. Attention Restoration Theory II: a systematic review to clarify attention processes affected by exposure to natural environments. J. Toxicol. Environ. Health, Part B 21 (4), 227–268.
Tanja-Dijkstra, K., Pahl, S., White, M.P., Andrade, J., May, J., Stone, R.S., Bruce, M., Mills, I., Melissa Auvrey, M., Gabe, R., Moles, D.R., 2018. The soothing sea: a virtual walk on the coast reduces experienced and recollected pain. Environ. Behav. 50, 599–625.
Thoma, M.V., La Marca, R., Brönnimann, R., Finkel, L., Ehlert, U., Nater, U.M., 2013. The effect of music on the human stress response. PloS One 8, e70156.
Thoma, M.V., Mewes, R., Nater, U.M., 2018. Preliminary evidence: the stress-reducing effect of listening to water sounds depends on somatic complaints: a randomized trial. Medicine 97 (8).
Tipton, M.J., Collier, N., Massey, H., Corbett, J., Harper, M., 2017. Cold water immersion: kill or cure? Exp. Physiol. 102, 1335–1355.
Triguero-Mas, M., Dadvand, P., Cirach, M., Martínez, D., Medina, A., Mompart, A., et al., 2015. Natural outdoor environments and mental and physical health: relationships and mechanisms. Environ. Int. 77, 35–41.
Triguero-Mas, M., Gidlow, C.J., Martínez, D., De Bont, J., Carrasco-Turigas, G., Martínez-Íñiguez, T., Jones, M.V., 2017. The effect of randomised exposure to different types of natural outdoor environments compared to exposure to an urban environment on people with indications of psychological distress in Catalonia. PloS One 12 (3), e0172200.
Twohig-Bennett, C., Jones, A., 2018. The health benefits of the great outdoors: a systematic review and meta-analysis of greenspace exposure and health outcomes. Environ. Res. 166, 628–637.
Ulrich, R.S., 1981. Natural versus urban scenes: some psychophysiological effects. Environ. Behav. 13 (5), 523–556.
Ulrich, R.S., 1984. View through a window may influence recovery from surgery. Science 224 (4647), 420–421.
Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A., Zelson, M., 1991. Stress recovery during exposure to natural and urban environments. J. Environ. Psychol. 11 (3), 201–230.
United Kingdom UK Government, 2009. Marine and Coastal Access Act 2009. https://www.legislation.gov.uk/ukpga/2009/23/contents.
Vaeztavakoli, A., Lak, A., Yigitcanlar, T., 2018. Blue and green spaces as therapeutic landscapes: health effects of urban water canal areas of Isfahan. Sustainability 10 (11), 4010.
Van den Berg, M., van Poppel, M., van Kamp, I., Andrusaityte, S., Balseviciene, B., Cirach, M., et al., 2016. Visiting green space is associated with mental health and vitality: a cross-sectional study in four european cities. Health Place 38, 8–15.
Van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., Maas, J., 2015. Health benefits of green spaces in the living environment: a systematic review of epidemiological studies. Urban For. Urban Green. 14, 806–816.
van den Bosch, M., Sang, Å.O., 2017. Urban natural environments as nature-based solutions for improved public health–A systematic review of reviews. Environ. Res. 158, 373–384.
Van Hedger, S.C., Nusbaum, H.C., Clohisy, L., Jaeggi, S.M., Buschkuehl, M., Berman, M. G., 2019. Of cricket chirps and car horns: the effect of nature sounds on cognitive performance. Psychonomic Bull. Rev. 26 (2), 522–530.
Van Tulleken, C., Tipton, M., Massey, H., Harper, C.M., 2018. Open water swimming as a treatment for major depressive disorder. BMJ Case Rep. https://doi.org/10.1136/bcr-2018-225007.
Vert, C., Nieuwenhuijsen, M., Gascon, M., Grellier, J., Fleming, L.E., White, M.P., Rojas-Rueda, D., 2019a. Health risk assessment of community riverside regeneration in Barcelona. Int. J. Environ. Res. Publ. Health 16 (3), 1.
Vert, C., Carrasco-Turigas, G., Zijlema, W., Espinosa, A., Cano-Riu, L., Elliott, L.R., et al., 2019b. Impact of a riverside accessibility intervention on use, physical activity, and well-being: a mixed methods pre-post evaluation. Landsc. Urban Plann. 190, 103611.
Vert, C., Gascon, M., Ranzani, O., Márquez, S., Triguero-Mas, M., Carrasco-Turigas, Lourdes Arjona, G.L., Koch, S., Llopis, M., Donaire-Gonzalez, D., Elliott, L.R., Mark Nieuwenhuijsen, M., 2020. Physical and mental health effects of repeated short walks in a blue space environment: a randomised crossover study. Environmental Research (in press).
Viana, M., Hammingh, P., Colette, A., Querol, X., Degraeuwe, B., de Vlieger, I., Van Aardenne, J., 2014. Impact of maritime transport emissions on coastal air quality in Europe. Atmos. Environ. 90, 96–105.
Völker, S., Kistemann, T., 2011. The impact of blue space on human health and well-being–Salutogenetic health effects of inland surface waters: a review. Int. J. Hyg Environ. Health 214, 449–460.
Völker, S., Baumeister, H., Classen, T., Hornberg, C., Kistemann, T., 2013. Evidence for the temperature-mitigating capacity of urban blue space—a health geographic perspective. Erdkunde 355–371.
Völker, Kistemann, 2015. Developing the urban blue: comparative health responses to blue and green urban open spaces in Germany. Health Place 35, 196–205.
Webb, S., Ternes, T., Gibert, M., Olejniczak, K., 2003. Indirect human exposure to pharmaceuticals via drinking water. Toxicol. Lett. 142, 157–167.
Wells, D.L., 2005. The effect of videotapes of animals on cardiovascular responses to stress. Stress Health 21 (3), 209–213.
Wheaton, B., Waiti, J., Cosgriff, M., Burrows, L., 2020. Coastal blue space and well-being research: looking beyond western tides. Leisure Stud. 39 (1), 83–95.
Wheeler, B., White, M.P., Stahl-Timmins, W., Depledge, M.H., 2012. Does living by the coast improve health and well-being? Health Place 18, 1198–1201.
Wheeler, B.W., Lovell, R., Higgins, S.L., White, M.P., Alcock, I., Osborne, N.J., Husk, K., Sabel, C.E., Depledge, M.H., 2015. Beyond Greenspace: an ecological study of population general health and indicators of natural environment type and quality. Int. J. Health Geogr. 14, 17.
White, M.P., Smith, A., Humphryes, K., Pahl, S., Snelling, D., Depledge, M., 2010. Blue space: the importance of water for preference, affect and restorativeness ratings of natural and built scenes. J. Environ. Psychol. 30, 482–493.
White, M.P., Pahl, S., Ashbullby, K.J., Herbert, S., Depledge, M.H., 2013a. Feelings of restoration from recent nature visits. J. Environ. Psychol. 35, 40–51.
White, M.P., Alcock, I., Wheeler, B.W., Depledge, M.H., 2013b. Coastal proximity and health: a fixed effects analysis of longitudinal panel data. Health Place 23, 97–103.
White, M.P., Wheeler, B.W., Herbert, S., Alcock, I., Depledge, M.H., 2014a. Coastal proximity and physical activity. Is the coast an underappreciated public health resource? Prev. Med. 69, 135–140.
White, M.P., Cracknell, D., Corcoran, A., Jenkinson, G., Depledge, M.H., 2014b. Do preferences for waterscapes persist in inclement weather conditions and extend to sub-aquatic scenes? Landsc. Res. 39, 339–358.
White, M.P., Pahl, S., Ashbullby, K.J., Burton, F., Depledge, M.H., 2015. The effects of exercising in different natural environments on psycho-physiological outcomes in post-menopausal women: a simulation study. Int. J. Environ. Res. Publ. Health 12, 11929–11953.
White, M.P., Pahl, S., Wheeler, B.W., Fleming, L.E.F., Depledge, M.H., 2016a. The 'Blue Gym': what can blue space do for you and what can you do for blue space? JMBA (J. Mar. Biol. Assoc.) 96, 5–12.
White, M.P., Bell, S., Elliott, L., Jenkin, R., Wheeler, B.W., Depledge, M.H., 2016b. The health effects of blue exercise in the UK. In: Barton, J., Bragg, R., Wood, C., Pretty, J. (Eds.), *Green Exercise: Linking Nature, Health and Well-Being (*Chp 7. Routledge, Oxford, pp. 69–78.
White, M.P., Pahl, S., Wheeler, B.W., Depledge, M.H., Fleming, L.E.F., 2017a. Natural environments and subjective well-being: different types of nature exposure are associated with different aspects of well-being. Health Place 45, 77–84.
White, M.P., Weeks, A., Hooper, T., Bleakley, L., Cracknell, D., Lovell, R., Jefferson, R., 2017b. Marine wildlife as an important component of coastal visits: the role of biodiversity and behaviour. Mar. Pol. 78, 80–89.
White, M.P., Lovell, R., Wheeler, B., Pahl, S., Völker, S., Depledge, N.H., 2018. Blue landscapes and public health. Chp. 5.2. In: van den Bosch, M., Bird, W. (Eds.), Landscape and Public Health (Pp154-159). OUP, Oxford.
White, M.P., Alcock, I., Grellier, J., Wheeler, B.W., Hartig, T., Warber, S., Bone, A., Depledge, M.H., Fleming, L.E., 2019. 120 minutes of nature contact per week is positively related to health and wellbeing. Sci. Rep. 9, *7730*.
Whitmee, C., Haines, A., Beyrer, C., Boltz, F., Capon, A.G., de Souza Dias, B.F., et al., 2015. Safeguarding human health in the Anthropocene epoch: report of the Rockefeller Foundation–Lancet Commission on planetary health. Lancet 386, 1973–2028.
Wilson, L.A.M., Giles-Corti, B., Burton, N.W., Giskes, K., Haynes, M., Turrell, G., 2011. The association between objectively measured neighborhood features and walking in middle-aged adults. Am. J. Health Promot. 25, e12–e21.
Wilson, M.I., Robertson, L.D., Daly, M., Walton, S.A., 1995. Effects of visual cues on assessment of water quality. J. Environ. Psychol. 15, 53–63.
Wiltse, J., 2007. Contested Waters: A Social History of Swimming Pools in America. The University of North Carolina Press, North Carolina.
Witten, K., Hiscock, R., Pearce, J., Blakely, T., 2008. Neighbourhood access to open spaces and the physical activity of residents: a national study. Prev. Med. 47, 299–303.

Wong, C.S.C., Li, X.D., Zhang, S. H. Qi, Peng, X.Z., 2003. Atmospheric deposition of heavy metals in the pearl river delta, China. Atmos. Environ. 37, 767–776.
Wolch, J., Zhang, J., 2004. Beach recreation, cultural diversity and attitudes toward nature. J. Leisure Res. 36 (3), 414–443.
Wood, S.L., Demougin, P.R., Higgins, S., Husk, K., Wheeler, B.W., White, M.P., 2016. Exploring the relationship between childhood obesity and proximity to the coast: a rural/urban perspective. Health Place 40, 126–136.
World Health Organisation, 1980. Environmental sanitation in European tourist areas. Copenhagen, WHO regional office for Europe. In: EURO Reports and Studies No. 18, p. 33.
World Health Organisation, 2003. Guidelines for safe recreational water environments. In: Coastal and Fresh Waters, vol. 1. World Health Organization, Geneva, Switzerland.
World Health Organisation, 2013. Mental Health Action Plan 2013–2020. World Health Organization, Geneva, Switzerland.
World Health Organisation, 2014. Global Report on Drowning: Preventing a Leading Killer (Geneva, Switzerland).
World Health Organisation, 2018. Physical Activity. [Factsheet.]. World Health Organization, Geneva, Switzerland.
World Health Organisation, 2019. Environmental Health Inequalities in Europe: Second Assessment Report. World Health Organization, Geneva, Switzerland.
Wüstemann, H., Kalisch, D., Kolbe, J., 2017. Accessibility of urban blue in German major cities. Ecol. Indicat. 78, 125–130.
Wyles, K., Pahl, S., White, M.P., Morris, S., Cracknell, D., Thompson, R.C., 2013. Enhancing the "Marine Mindset": the effects of an aquarium visit and information booklet on attitudes and intentions about fish sustainability and marine pollution. Visitor Studies 16, 95–110.
Wyles, K.J., Pahl, S., Thomas, K., Thompson, R.C., 2016. Factors that can undermine the psychological benefits of coastal environments: exploring the effect of tidal state, presence, and type of litter. Environ. Behav. 48 (9), 1095–1126.
Wyles, K., White, M.P., Hattam, C., Pahl, S., Austin, M., 2019. Nature connectedness and well-being from recent nature visits: the role of environment type and quality. Environ. Behav. 51 (2), 111–143.
Ying, Z., Ning, L.D., Xin, L., 2015. Relationship between built environment, physical activity, adiposity, and health in adults aged 46–80 in Shanghai. Chinese J. Phys. Activ. Health 12, 569–578.
Zelenski, J.M., Dopko, R.L., Capaldi, C.A., 2015. Cooperation is in our nature: nature exposure may promote cooperative and environmentally sustainable behavior. J. Environ. Psychol. 42, 24–31.
Zijlema, W.L., Avila-Palencia, I., Triguero-Mas, M., Gidlow, C., Maas, J., Kruize, H., et al., 2018. Active commuting through natural environments is associated with better mental health: results from the PHENOTYPE project. Environ. Int. 121, 721–727.