Chapter 2: Potential benefits of blue space for human health and well-being

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Introduction¹

This chapter follows on from the story told in Chapter 1, where the emphasis was on the historical development of and current ideas about the relationship between human health and well-being and the environment. It provided a “big picture” overview to place the subject of this chapter in context, and it also discussed models – especially the general model used in the BlueHealth project. Aquatic environments pose a wide range of threats to human health and well-being. There are an estimated 370,000 drownings globally per year, and water-borne diseases such as cholera account for nearly two million deaths annually, mostly among children under five years (World Health Organisation [WHO], 2014, 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). Chemical pollution from mining, agriculture and industry; harmful algal blooms; and emerging threats such as pharmaceuticals and micro-plastics may all undermine human health and well-being (Borja et al., 2020; Fleming et al., 2019; Depledge et al., 2017).

However, 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. Coastal and marine waters also have considerable value in terms of their “ecosystem services”, 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. 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 (Markevych et al. 2017; van den Bosch & Sang, 2017).

Aims and scope

The aim of this chapter, therefore, is 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 & Bird, 2009; Grellier et al., 2017; White et al., 2016a). The aim is 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. Rather, the focus is on integrating the emerging research on the potential benefits to health and well-being, 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.

Figure 2.1

A model of BlueHealth – a conceptual diagram of the relationships between blue space and health and well-being
(Source: Mathew P. White and Anna Wilczyńska)

These include common mental health disorders such as anxiety and depression (Bloom et al., 2011) and a lack of physical activity 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. This overview and synthesis draws on a range of research methodologies, including large epidemiological studies, visitor surveys and field and laboratory experiments as well as in-depth qualitative research, as it meant to be representative rather than systematic or authoritative.

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 (Figure 2.1). First, we deconstruct blue space exposure/contact into four types:

1. Home/work proximity; then building on Keniger et al. (2013),
2. Indirect exposure (e.g. window views or TV programmes);
3. Incidental exposure (i.e. exposure that occurs even though the main activity was for a different purpose, e.g. commuting);
4. 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:

1. Mitigation (i.e. reduction of harm, e.g. urban heat island effect);
2. Instoration (e.g. promotion of positive outcomes such as improved mood or greater physical activity);
3. 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):

1. Situational (e.g. access, quality, weather, culture, etc.);
2. Individual (e.g. personal characteristics such as age, gender, socio-economic status [SES]).

As well as extending previous models to blue spaces in particular, we make three additional contributions. First, we include '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 feed back to changes in exposure. Here, we propose three broad types of intervention/action:

1. Societal;
2. Local;
3. Personal.

Finally, we include the psychological concept of nature connectedness in two different ways. First, we include it as a dispositional *trait* (e.g. Mayer & 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 (Pritchard et al., 2019). The remainder goes through each section in turn.

Exposure, health and well-being

We begin by exploring issues of exposure (the left of Figure 2.1), including evidence of exposure-outcomes that did not consider intermediate pathways.

Proximity and 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 <1.5km (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) and England (White et al., 2014b) 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 socioeconomic 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 (Haefner 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).

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 lives 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, such as 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 et al., 2016). Several studies have also shown a positive relationship with home proximity to water bodies and self-reported general health, for example, in Belgium (Hooyberg, 2020), England (Wheeler et al., 2012) and Spain (Ballesteros-Olza et al., 2020), as well as mortality (Crouse et al., 2018). A longitudinal study in England found that over time, the same people report better mental and general health in the years when they lived close to the coast (<5 km) versus inland (White et al. 2013a).

A systematic review of 35 different studies around the world by Gascón 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). 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 socioeconomic-related inequalities in health.

In many developed countries, homes close to inland and coastal waters, especially those with blue space views, tend to be more expensive (Gibbons et al., 2014). 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 (White et al., 2018).

Indirect and 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 & Kearns, 2015).

We expect more research in this area as innovations in ‘viewshed’ analysis develop that take into account both elevation and obstruction (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). As with viewsheds, we suspect that innovations in analysing 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.

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 in the later section on restoration. In terms of the potential longer-term benefits discussed here, Garrett et al. (2019a) 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.

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) and promote mental health (Foley 2015, 2017; Denton & Aranda, 2020) and may be able to be used in treating major depressive disorder (van Tulleken et al., 2018). There is also evidence that it can promote immune functioning (Tipton et al., 2017) and treatment of inflammation-related conditions (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 (Foley, 2015, 2017), which may in turn lead to behaviours aimed at protecting the health-promoting aspects of these blue spaces.

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 not just by 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.

Mechanisms/pathways

This section focuses on the centre of Figure 2.1 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.

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. 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. 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 Kelvin 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 count as 'noise' (i.e. unwanted sound). In a number of experimental studies, water-based sounds, either in isolation (Thoma et al., 2018) or in combination with other natural sounds such as birdsong (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., 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.

Aerosols and negative ions

Taking the "sea air" for one's health has been recommended by physicians for centuries (e.g. Fortescue Fox and Lloyd, 1938) (see Chapter 12). Recent research in both coastal and inland waters, especially high-force waterfalls, suggests that the mists and sprays created in these settings may help reduce breathing difficulties, for example, 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; Pawar 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.

Aerosolised toxins

A different issue with respect to aerosols concerns aerosolised toxins, such as 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, in the 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 (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), but far more research is needed 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 cardiovascular diseases, some cancers and poor mental health (Cherrie et al., 2015). Clearly, individual behaviours are key with respect to time of day, exposure duration, self-protection measures and so on.

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 correspond 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 (Gascón et al., 2017; White et al., 2014a). Nevertheless, most studies are self-reported, and there is emerging evidence that more objective data using accelerometers may not show the effect (e.g. Garrett et al., 2020). What is clear is that much of the activity in blue spaces is not water based but occurs on land, such as 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 green spaces, blue spaces may be particularly important for promoting positive social relationships. Qualitative studies in Germany (Völker & Kistemann, 2015), Iran (Vaeztavakoli et al., 2018), Ireland (Foley, 2015) and the United Kingdom (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 the Niasarm canal in Isfahan, Iran: “When the weather is good, the canal is full of people from the neighbourhood. Women, children, and old people all prefer to socialise 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 & Leary, 1995). When interpersonal connections are lacking or attenuated, connections/attachment to places and natural environments in particular 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., 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 & Mourato, 2013; White et al., 2013a), and they are also among many people’s favourite places (Vaeztavakoli et al., 2018). Nonetheless, it is also important to recognise that there are sociodemographic inequalities in blue space access (Haeffner et al., 2017), and as such, it may be difficult for marginalised 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 both an enduring dispositional trait (some people tend to feel more connected to nature than others in general) and 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 behaviours, 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.

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 and that we 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 and colleagues (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 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 & 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, 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 actually used predominantly blue space imagery and/or sounds in their ‘nature’ conditions but systematically (though presumably accidentally) 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 & Kaplan, 1989).

Two experimental studies, one lab based (Emfield & Neider, 2014) and one field based (Gidlow et al., 2016), explored 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. Gidlow et al. (2016) compared backward digit span (BDS) scores before and after a 30-minute walk in either urban, green or blue space (a river path) settings, as well as employing a delayed post-test 30 minutes 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.

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 Figure 2.1.

Situational

Blue space type

Much of the blue space and health research has focused on marine/coastal settings (White et al., 2016a). However, there are also studies that focus on rivers (de Bell et al., 2017; Vert et al., 2019a, 2019b; Völker & Kistemann, 2011), canals (Vaeztavakoli, 2018) and lakes (Pearson et al., 2019; Völker & 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) found similar distance decay effects for the relationships between home location and visits to coasts and lakes. Both White et al. (2013b) 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 (Fleming et al., 2019). 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., 2019b) or exposure to waters that are of poor quality (Rowles et al., 2018). As early as 1980, the World Health Organization 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 and so on. 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.

Weather

Blue spaces become especially attractive in hot and sunny conditions, since, as noted, 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 & Ogunseitan, 2011), precisely because it was not 'too hot'.

Country/cultural context

Systematic reviews of inland blue spaces (Völker & Kistemann, 2011), home proximity to blue space (Gascón 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 United States, 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, where water quality may be less regulated (Borja et al., 2020) and threats to health and well-being from water-borne diseases, jellyfish, parasites and predators (e.g. crocodiles), as well as the risk of drowning, may be heightened (WHO, 2014).

Individual

The green space and health literature is replete with papers exploring the moderating role of individual-level differences such as age, gender and ethnicity. One of the most important is socioeconomic status, with a number of studies suggesting that the benefits of green space are greater for poorer than richer individuals (Mitchell & Popham, 2008). As noted earlier, 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 behaviours 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.

At the other end of the age spectrum, several blue space studies have focused on older adults. As earlier, 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 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 even more important. Although it is often hard to disaggregate the effects of green and blue space, 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 the 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 (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. 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 United States tend to visit blue spaces less than their white counterparts (Leeworthy, 2001), even if they live nearer them (Haefner et al., 2017). There is also evidence that this may have deep historic roots in racial segregation, as opposed to perceptions that the potential benefits to their health and well-being are any less (Bell et al., 2019). 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).

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 Aotearoa/New Zealand. While many colonial European settlers see the coastal waters as places of recreation and leisure, Māori communities 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. Relationships between blue spaces and health/well-being among these traditional marine communities may be quite different from those where most of the research has been conducted to date.

Actions/interventions/changes

Aware of some benefits of blue spaces for the promotion of good health and well-being, policy makers, planners and practitioners have implemented numerous actions, initiatives and changes to improve safe access to high-quality water environments. Although many of these actions operate at several levels, our model (bottom of Figure 2.1) groups them loosely into three types:

1. National/international societal-level interventions;
2. Local/regional infrastructure interventions; and
3. 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 discharge of pollution and so on 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).

Societal actions

An excellent example of an international-level intervention that applies to multiple nation states is the EU's Bathing Water Directive (EU, 1976). Before the BWD, 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. Although the aim of the directive was mainly to reduce harms (i.e. exposure to faecal matter in the water), it is also consciously trying to promote the use of these settings for active, healthy recreation (EEA, 2019). 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).

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. they 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. canalised 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 earlier. Further discussion of all these issues can be found elsewhere (Bell et al., 2020) and across the other chapters in the current volume.

Personal actions

A wide range of programmes 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 & 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. 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.

A different type of personal blue space intervention for health and well-being has also been investigated in indoor health and care facilities. In practice, many indoor nature-based interventions have used images and sounds of blue spaces (e.g. Kweon et al., 2008). Particularly popular historically have been aquariums, which can help people recover from stress (Cracknell et al., 2017), as well as helping people manage subsequently stressful situations 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 encouraging healthy levels of eating and the promotion of social interactions (Edwards & Beck, 2002).

Summary and limitations

Many of the benefits of blue spaces are obvious, such as the need for freshwater for drinking and irrigation and 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 (Figure 2.1) to reflect how research into these salutogenic effects is interconnected. 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), 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, longitudinal work, visitor surveys, experience sampling methods, laboratory experiments, field experiments, randomised controlled trials, infrastructure interventions, behavioural interventions and in-depth qualitative work. The range of methods reflects the highly interdisciplinary nature of the work. 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), for a wide range of people.

Nevertheless, 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; Gascón et al., 2017; Völker & Kistemann, 2011). 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.

Concluding comments

The aim of this narrative review was to provide an overview of the growing but disparate literature that examines the potential benefits to health and well-being 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.

Note

- 1 This chapter is an abridged version of White et al. (2020). Please see the original paper for more complete referencing on all the topics discussed here.

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