

## **Physiotherapy and ecosystem services: improving the health of our patients, the population, and the environment**

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## **ABSTRACT**

**Introduction:** The relevance of ecosystems to physiotherapy has traditionally been overlooked, despite its potential for positive health impacts relevant to conditions often

managed by physiotherapists. **Purpose:** The purpose of this article is to introduce the concept of ecosystem services to physiotherapists, and to discuss how understanding ecosystem services may improve patient care, and population and planetary health.

**Discussion and Conclusion:** Physiotherapists with an understanding of ecosystem services may improve patient care by value-adding to management through patient education, empathy, advocacy, and broader population health approaches.

Physiotherapists are also well placed to promote the conservation and restoration of ecosystem through participation, advocacy, and the development of public health measures, to the benefit of global sustainability and population health. Further research is required into how physiotherapists currently use nature-based interventions, and the barriers and enablers to their use. To be adequately prepared to meet the challenges that climate change and environmental degradation pose to patient care, population health and health systems, both current and future physiotherapists need to take a broader view of their practice. By including consideration of the potential role of the environment and green space exposure in particular on their patient's health, physiotherapists can ultimately contribute more to population and planetary health.

**Keywords:** physiotherapy; physical therapy; environment; ecohealth; planetary health; ecosystem services

## **INTRODUCTION**

Environmental health has traditionally focused on the elements of the environment that may lead to adverse health outcomes. These elements include pollution and the weather (e.g. heat), but there has been a recent shift towards considering the beneficial aspects of the natural environment to human health, which has implications for physiotherapists. There are several frameworks for understanding the relationship between ecosystem health and human health, including ecosystem services (Millennium Ecosystem Assessment 2005) and nature's contribution to people (Díaz et al. 2018). Both terms essentially refer to the benefits to health and wellbeing that humans derive from functioning, healthy ecosystems (Díaz, Pascual, Stenseke, Martín-López, Watson, Molnár, Hill, Chan, Baste, Brauman, Polasky, Church, Lonsdale, Larigauderie, Leadley, van Oudenhoven, van der Plaats, Schröter, Lavorel, Ameeruddy-Thomas, Bukvareva, Davies, Demissew, Erpul, Failler, Guerra, Hewitt, Keune, Lindley and Shirayama 2018, Millennium Ecosystem Assessment 2005). These frameworks share common elements, and there has been much debate surrounding them (Braat 2018, Ellis, Pascual and Mertz 2019, Faith 2018, Kadykalo et al. 2019, Kenter 2018, Maes, Burkhard and Geneletti 2018, Peterson et al. 2018, Pires et al. 2020). For the purposes of this paper we have used the Millennium Ecosystem Assessment's (2005) ecosystem services conceptual framework, for it was developed with broad stakeholder engagement (Millennium Ecosystem Assessment 2005), has a wealth of supporting evidence (Braat 2018, Millennium Ecosystem Assessment 2005), and places the relationship between ecosystem services and human wellbeing within a broader context. This broader context includes different spatial (e.g. local, region, global) and temporal (e.g. short- and long-term) scales, with acknowledgement of the indirect and direct drivers of change (e.g.

economic, socio-political, cultural and religious, land use changes, climate change) (Millennium Ecosystem Assessment 2005).

The outdoor environment is an important determinant of human health, but its relevance to physiotherapy has traditionally been overlooked. The outdoor environment encompasses both the natural and built environment. Historically, humans have tried to protect themselves from the hazards of the natural environment through the development of shelters (to protect them from the weather and animals), culminating in the built environment as we know it today. Yet, despite its initial purpose, the built environment now degrades the natural environment and subsequently the ecosystem services that support human health and wellbeing (Millennium Ecosystem Assessment 2005). Furthermore, the built environment also has a range of associated health hazards, such as exposure to pollution, which may in part be mitigated by the buffering provided by ecosystem services from natural environments. For example, urban green spaces can reduce the heat island effect (Markevysh et al. 2017), as well as exposure to pollution (noise, air (Markevysh, Schoierer, Hartig, Chudnovsky, Hystad, Dzhambov, de Vries, Triguero-Mas, Brauer, Nieuwenhuijsen, Lupp, Richardson, Astell-Burt, Dimitrova, Feng, Sadeh, Standl, Heinrich and Fuertes 2017), and light pollution (Stanhope, Liddicoat and Weinstein 2021), which may therefore improve human health outcomes (see Box 1 for an example).

In this article, we discuss how the ecosystem services provided by healthy, natural environments can both mitigate the adverse effects of urbanization and provide direct health benefits, and how this relates to the role of physiotherapists. We highlight how

physiotherapists can capitalize on opportunities to improve patient care, population health, and ecosystem health concurrently.

## **ECOSYSTEM SERVICES**

Ecosystem services are the functions of an ecosystem that provide benefits to humans (Millennium Ecosystem Assessment 2005), with the opposite being termed ecosystem disservices (Saunders 2020). Both mitigation of the potentially harmful elements of the environment, and optimisation of the benefits of exposure to the outdoor environment are reliant on ecosystems capable of providing corresponding ecosystem services. The Millennium Ecosystem Assessment (2005) divides such ecosystem services into four basic and not necessarily mutually exclusive categories: provisioning services (e.g. the production of food, clean water, and wood for fuel and construction), regulating services (e.g. climate control, disease suppression), cultural services (e.g. spirituality, sense of place, recreation), and supporting services (e.g. nutrient cycling and soil formation). Supporting services do not have a direct link with human health, but supporting services are required for the provisioning, regulating, and cultural services to occur.

Ecosystem services are eroded through multiple human-driven activities, including land clearing and pollution, consequently impacting human health (Figure 1). Several of the health outcomes related to ecosystem services are managed by physiotherapists (Table 1, and Boxes 1-2 for specific examples). Ecosystem services can, however, be maintained through conservation<sup>1</sup> and recovered through ecosystem restoration<sup>2</sup>

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<sup>1</sup> “the protection, care, management and maintenance of ecosystems, habitats, wildlife species and populations, within or outside of their natural environments, in order to safeguard the

(Speldewinde, Slaney and Weinstein 2015) using a range of interventions including urban greening, planting of vegetation along and within waterways, and reductions in the emission of pollutants.

## **ECOSYSTEM SERVICES AND THE ROLE OF PHYSIOTHERAPISTS**

There are three key ways in which ecosystem services are relevant to the role of physiotherapists: 1) To improve patient care; 2) To advocate for and/or develop public health strategies to enhance population health through ecosystem conservation and ecological restoration; and 3) To promote and enhance sustainable physiotherapy practice that reduces the burden of healthcare provision on global resources. The relationship between these three elements: individual health, population health and ecosystem services related outcomes is illustrated in Figure 2, and discussed below. Importantly, physiotherapists must still work within their scope of practice, which may differ between jurisdictions and level of training, and which may involve non-clinical physiotherapy roles, and operate at all levels, from individual- through to systems-level. These non-clinical physiotherapy roles may include policy development, social marketing, advocacy and consultation (Giuffre, Domholdt and Keehan 2020).

### Improving Patient Care

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natural conditions for their long-term permanence” IUCN definitions - English

[https://www.iucn.org/sites/dev/files/iucn-glossary-of-definitions\\_en.pdf](https://www.iucn.org/sites/dev/files/iucn-glossary-of-definitions_en.pdf)

<sup>2</sup> “the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed” Society for Ecological Restoration Australasia 2018 National standards of the practice of ecological restoration in Australia Australia.

Individual patient care can be improved through physiotherapists having an understanding of the role of the environment in their patient's health conditions (Table 1 and Boxes 1-2). This understanding may lead to more comprehensive patient education that incorporates the role of ecosystems and the erosion of the essential contributions these make to health. Furthermore, physiotherapists with a more complete understanding of the condition, including factors beyond the patient's control, are arguably more likely to be empathetic, and not engage in victim blaming. For example, chronic respiratory diseases are often associated with smoking, however the 2019 Global Burden of Diseases data suggest that ambient particulate matter and ozone pollution may contribute more than half of this burden (as measured by disability adjusted life years) (Institute for Health Metrics and Evaluation (IHME) 2020); hence smoking is not the main cause of this disease burden. The additional environmental attributed burden is beyond the control of the individual patient, and understanding this may result in greater empathy on the part of the physiotherapist, rather than making assumptions about the individuals' level of personal control over their health.

Physiotherapists may already incorporate some recommendations regarding environmental exposures in advice to their patients, such as suggesting a person with asthma stay inside with windows shut during bushfires. However, a broader knowledge of the environmental exposures relevant to their patients may lead to additional recommendations to reduce risk or exacerbation of a health condition, and may provide opportunities for novel treatment approaches. For example, inadequate green space exposure, such as gardens, parks, yards and forests (Taylor and Hochuli 2017), has been associated with a range of health conditions. These conditions include , adverse birth outcomes (Kondo, Fluehr, McKeon and Branas 2018, Twohig-Bennett and Jones 2018,

Zhan et al. 2020), deficits in motor development (Twohig-Bennett and Jones 2018), poor mental health (Kondo, Fluehr, McKeon and Branas 2018, Lai, Flies, Weinstein and Woodward 2019, Rautio, Filatova, Lehtiniemi and Miettunen 2018, Shuvo, Feng, Akaraci and Astell-Burt 2020, Twohig-Bennett and Jones 2018), sleep disorders (Shin, Parab, An and Grigsby-Toussaint 2020), cancer (Kondo, Fluehr, McKeon and Branas 2018, Twohig-Bennett and Jones 2018), allergies (Kondo, Fluehr, McKeon and Branas 2018, Lai, Flies, Weinstein and Woodward 2019), obesity (de Keijzer, Bauwelinck and Dadvand 2020, Kondo, Fluehr, McKeon and Branas 2018, Lai, Flies, Weinstein and Woodward 2019, Luo et al. 2020), metabolic conditions (de Keijzer, Bauwelinck and Dadvand 2020, Twohig-Bennett and Jones 2018), respiratory conditions (Kondo, Fluehr, McKeon and Branas 2018, Liddicoat et al. 2018, Twohig-Bennett and Jones 2018), poor cardiovascular outcomes (de Keijzer, Bauwelinck and Dadvand 2020, Kondo, Fluehr, McKeon and Branas 2018, Twohig-Bennett and Jones 2018), stroke (Twohig-Bennett and Jones 2018), and pain (Li et al. 2021, Stanhope, Breed and Weinstein 2020, Wells, Rollings, Ong and Carrington Reid 2019) (see Boxes 1-2 for detailed examples). Several mechanisms may link green space exposure and human health outcomes. These mechanisms may include exposure to the sights and sounds of nature (a cultural ecosystem service) and sunlight (Flies et al. 2017), and reduced exposure to pollution and heat (Markevysh, Schoierer, Hartig, Chudnovsky, Hystad, Dzhambov, de Vries, Triguero-Mas, Brauer, Nieuwenhuijsen, Lupp, Richardson, Astell-Burt, Dimitrova, Feng, Sadeh, Standl, Heinrich and Fuertes 2017) (as regulating ecosystem services). Furthermore, being in green space also encourages physical activity and social integration (Flies, Skelly, Negi, Prabhakaran, Liu, Liu, Goldizen, Lease and Weinstein 2017) (a cultural ecosystem service). In addition, there are two mechanisms that are closely linked to the plants, animals and microbes present in the



green space: exposure to biodiverse environmental microbiota and biogenic volatile organic compounds (Flies, Skelly, Negi, Prabhakaran, Liu, Liu, Goldizen, Lease and Weinstein 2017) (both provisioning and regulating services). The environmental microbiota influences the human microbiota (Roslund et al. 2020) and therefore human health (Liddicoat, Waycott and Weinstein 2016), including pain (Guo, Chen, Xing and Liu 2019), depression and anxiety (Simpson et al. 2021), stroke, multiple sclerosis, Parkinson's disease and autism spectrum disorder (Cryan et al. 2020). Importantly, more biodiverse environments have more microbes that are associated with health benefits and fewer pathogenic microbes (Liddicoat et al. 2019). Biogenic volatile organic compounds are released by both plants (i.e. phytoncides) and microbes. These compounds have an antimicrobial effect and can therefore aid in maintaining health microbial communities (Franco, Shanahan and Fuller 2017), thereby also influencing human health (Cheng et al. 2009, Li et al. 2008). The extent to which exposure to green spaces improves human health, depends on the health of the ecosystem, and its capacity to deliver ecosystem services.

Blue space exposure (i.e. outdoor visible surface water (Gascon et al. 2017, Grellier et al. 2017)) is also thought to improve mental health, cardiovascular and diabetes outcomes (Gascon, Zijlema, Vert, White and Nieuwenhuijsen 2017), although the evidence is not as well established as it is for green space. Physiotherapists may therefore be able to utilise green and blue space as part of treatment recommendations to improve health outcomes.

### Advocacy and Public Health

Traditional physiotherapy has focused on clinical practice, however the increasing role of physiotherapists in advocacy and public health is now recognised (Besette, Génereux, Thomas and Camden 2020, Foo 2016, Giuffre, Domholdt and Keehan 2020, Kelland et al. 2014). Public health interventions provided by physiotherapists have largely occurred in sports and occupational settings; both of which may involve environmental exposures. For example, there is an emerging body of evidence which suggests that extreme heat may also contribute to an increasing risk of occupational injury (Adam-Poupart et al. 2015, Ricco, Vezzosi, Odone and Signorelli 2018, Tawatsupa et al. 2013). Similarly, in sport, climatic conditions may adversely affect the health of players; both directly (e.g. heat) (Gamage, Fortington and Finch 2020), and indirectly (e.g. drought impacting the quality of the field, resulting in increased injury risk (Dingle and Mallen 2021)). But physiotherapists' public health role should not be restricted to sports and occupational health, and may extend to several other settings and health conditions.

Physiotherapists may be involved in advocacy with regards to the needs of their individual patients, the local population, or on a global scale. For instance, physiotherapists may advocate for and contribute to the design and creation of accessible, biodiverse green spaces for their individual patients, with consideration given to safety (Boyd, White, Bell and Burt 2018, Cronin-de-Chavez, Islam and McEachen 2019, Sefcik et al. 2019, Selby et al. 2019), transport (Boyd, White, Bell and Burt 2018, Cronin-de-Chavez, Islam and McEachen 2019, Fretwell and Greig 2019, Sefcik, Kondo, Klusaritz, Sarantschin, Solomon, Roepke, South and Jacoby 2019), amenities (Cronin-de-Chavez, Islam and McEachen 2019, Sefcik, Kondo, Klusaritz, Sarantschin, Solomon, Roepke, South and Jacoby 2019), and proximity (Selby, Hayes,

O'Sullivan, O'Neil and Harmon 2019), for their individual patients and local community. While others may advocate for and, sometime in the future maybe even entirely shift their 'clinical' practice toward action on climate change, pollution and biodiversity loss, to improve health at local, regional and global scales (Cook, Jardine and Weinstein 2004), through the re-establishment of ecosystem services. Furthermore, patients and their families, who appreciate the role of environmental degradation in adversely affecting health, may themselves become advocates for and participants in conservation, restoration, and sustainability.

### Sustainable Physiotherapy Practice

In addition to physiotherapists' and their patients' personal impact on ecosystems, sustainable approaches to physiotherapy practice should also be implemented, for the sake of both population and ecosystem health (Maric, Synne Groven, Banerjee and Dahl Michelsen 2021). 'Green' physiotherapy was discussed as early as 2009 (Jones 2009), with more recent calls for sustainable practice having been made (Maric and Nicholls 2019, Maric, Synne Groven, Banerjee and Dahl Michelsen 2021). One of the challenges to 'green' physiotherapy reported in 2009 was a lack of understanding of the environmental impact of physiotherapy practices, which would inform decision making (Jones 2009). Unfortunately, this challenge still remains for many physiotherapy practice decisions, although guidance is now available for clinical decision making that integrates environmental considerations (Maric, Synne Groven, Banerjee and Dahl Michelsen 2021).

Some physiotherapy interventions may integrate the environment, and therefore encourage both physiotherapists and patients to value the environment, and sustainable

behaviours. Physiotherapy interventions may integrate green (Stanhope, Breed and Weinstein 2020, Toner, Lewis, Stanhope and Maric 2021) or blue space exposure (Britton, Kindermann, Domegan and Carlin 2020, Toner, Lewis, Stanhope and Maric 2021), or nature play (Dankiw, Tsiros, Baldock and Kumar 2020), while others may also have planetary health co-benefits, including active transport<sup>3</sup> (Toner, Lewis, Stanhope and Maric 2021), participation in gardening (Kamioka et al. 2014, Kunpeuk et al. 2020), restoration (Nabhan, Orlando, Monti and Aronson 2020), and conservation activities (Husk et al. 2016) as meaningful, therapeutic activities; activities that physiotherapists themselves may also engage in.

Health professionals can contribute to ecosystem health and therefore human health through sustainable practice. ‘Green’ dentistry (Khanna and Dhaimade 2019), pharmacy (Bijl 2019), and surgery (Gill, Hampton and Sharma 2020) have all been promoted, and ‘green’ physiotherapy should follow. While the 4 R’s (reduce, reuse, recycle and rethink) have been promoted for green practice for other health professionals (Khanna and Dhaimade 2019), it should be noted that sustainable practice is complex.

Judicious decision making can contribute to reducing consumption, particularly for single use equipment. For example, despite the widespread use of incentive spirometry, particularly in post-operative care following abdominal or thoracic surgery, there is little support for the use of this single-use piece of plastic equipment, over other types of breathing exercises that do not involve equipment, or indeed no respiratory treatment (Agostini and Singh 2009, do Nascimento Junior et al. 2014). Similarly,

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<sup>3</sup> Active transport refers to physical activities, such as walking or cycling, that replace motorised transport.

physiotherapists with rights to prescribe medication and order diagnostic imaging (which may be extended scope physiotherapists in some jurisdictions (Stanhope, Beaton, Grimmer-Somers and Morris 2012, Stanhope et al. 2012)) should consider the environmental cost of these interventions, and only utilise them where evidence-based practice dictates these interventions are required. This point is particularly pertinent for potential low-value care options, which may include diagnostic imaging and medications (Buchbinder, Underwood, Hartvigsen and Maher 2020, Foster et al. 2018) for some conditions treated by physiotherapists. As part of multidisciplinary health teams, physiotherapists can also advocate for the use of high-value, sustainable diagnostic and therapeutic approaches, both in clinical practice and research. .- Importantly, more sustainable models of healthcare should focus on prevention, self-management, and health promotion (Barna, Goodman and Mortimer 2012), which typically require less consumption, and therefore protect ecosystem and human health.

Reusing equipment in both clinical settings and for our patients' self-management should be considered. For instance, physiotherapists may prescribe exercises and other therapeutic activities that either involve no equipment or the use of household items (e.g. bottles or cans as weights) instead of suggesting the purchase of new equipment. While reusing equipment should also be considered, it is acknowledged that this approach is not always appropriate in clinical settings due to the potential difficulty in implementing adequate infection control measures.

The recycling of products and the purchase of recycled products are also recommended for sustainable practice, however there are likely limitations based on the local recycling facilities and the products available. Nonetheless, small changes like the recycling of

paper and the use of recycled paper may make a difference. Critically, reducing consumption and reusing products is preferable. While recycling does reduce ecosystem destruction (e.g. for mining and forestry) and the consumption of non-renewable resources, the process of recycling does contribute to both consumption (e.g. energy) and pollution, including greenhouse gas emissions (Acuff and Kaffine 2013); hence other options should first be considered.

Finally, rethinking consumption may also assist physiotherapists in sustainable practice; however like recycling, 'rethinking' often comes a cost. Replacing one option with another seemingly 'green' option requires careful consideration of the outcome of interest and potential side effects. For example, practices may consider moving towards electronic notes because paperless approaches are widely viewed as being more environmentally friendly. Paperless approaches reduce our reliance on extractive forestry, thereby protecting ecosystems. Nevertheless, replacing paper with electronic options can also result in increased fossil fuel consumption and pollution. Firstly, electronic options require the additional purchasing of equipment which degrades ecosystems through the mining of resources (e.g. lithium ion batteries where the mining results in deforestation (Liu, Agusdinata and Myint 2019)), and the consumption of resources and production of greenhouse gases in their production (Gombiner 2011). Furthermore, greenhouse gases are produced when cooling the servers used to store and access information (Gombiner 2011). Similarly, active transport (e.g. physical activity for transport) which is thought to be a greener option than motorised transport, actually produces similar quantities of greenhouse gas emissions to driving a car, due to the increased energy intake required (Mizdrak et al. 2020). Importantly, the greenhouse gases produced through food production are less damaging than those produced by

vehicles and may depend on the individuals' diet (Mizdrak, Cobiac, Cleghorn, Woodward and Blakely 2020), whereby meat-free diets result in less greenhouse gas emissions (Chai et al. 2019, Reynolds, Buckley, Weinstein and Boland 2014). Rethinking consumption as part of 'green' physiotherapy is complex. We are not suggesting that these approaches are inappropriate, but rather that physiotherapists should be cognisant of the 'side effects' of these approaches, and should opt for reduces, reusing and recycling where appropriate.

## **RECOMMENDATIONS FOR PRACTICE AND EDUCATION**

It has been stated that "health professionals are inadequately prepared to meet the challenges that climate change and environmental degradation pose to health systems" (Madden, McLean, Brennan and Moore 2020). Like other health professionals (Barna, Goodman and Mortimer 2012, Barna et al. 2020, Hackett et al. 2020, Madden, McLean, Brennan and Moore 2020, Madden, McLean and Horton 2018, Maxwell and Blashki 2016, Thompson et al. 2014, Walpole et al. 2017), physiotherapists should be educated about environmental health, and sustainable health care. This education may be based on recently proposed learning outcomes for medical students: 1) "describe how the environment and human health interact at different levels" (Thompson, Walpole, Braithwaite, Inman, Barna and Mortimer 2014); 2) "show the knowledge and skills needed to improve the environmental sustainability of health systems" (Thompson, Walpole, Braithwaite, Inman, Barna and Mortimer 2014); and 3) "discuss how the duty of a doctor to protect and promote health is affected by the dependence of human health on the local and global environment" (Thompson, Walpole, Braithwaite, Inman, Barna and Mortimer 2014).

The currently ongoing Environmental Physiotherapy Agenda 2023, serves as a call to action and collaboration for the inclusion of environmental physiotherapy in entry-level physiotherapy programs internationally (Maric et al. 2020). Launched in March 2020, the Environmental Physiotherapy Agenda 2023 is supported by over 30 physiotherapy, sustainable healthcare and planetary health associations from around the world and has already gathered 30 participating physiotherapy education institutions that are now integrating environmental physiotherapy into their programs (Maric et al. 2021). Through quarterly meetings, representatives from these physiotherapy education institutions share ideas and experiences of teaching environmental physiotherapy and are now developing an open-access database on environmental physiotherapy education to advance the further development of the field (Maric, Chance-Larsen, Chevan, Jameson, Nicholls, Opsommer, Perveen, Richter, Stanhope, Stone, Strimpakos, Vieira, Williams, Zuber and Söderlund 2021). Topics already being integrated into education include outdoor exercise, green space exposure, sustainable practice, and the inclusion of indigenous approaches to planetary health (Maric, Chance-Larsen, Chevan, Jameson, Nicholls, Opsommer, Perveen, Richter, Stanhope, Stone, Strimpakos, Vieira, Williams, Zuber and Söderlund 2021). These topics can most often be integrated into existing courses, competencies and learning outcomes without tacking up significant additional curriculum space, for example discussing outdoor exercise as part of exercise prescription, discussing environmental determinants of health when covering other determinants of health, and the explicit consideration of environmental factors in theoretical and applied learning with the International Classification of Functioning, Disability and Health (ICF) framework (World Health Organization 2002).



Current physiotherapists must also act, and should also be supported accordingly. Several sources of information regarding the relationship between human health and the environment already exist (McMichael, Woodruff and Hales 2006, Whitmee et al. 2015), and professional physiotherapy associations (including the Environmental Physiotherapy Association) have a role to play in providing relevant continuing professional development and research opportunities on this topic.

### **RECOMMENDATIONS FOR RESEARCH**

Conceptual research, including where the links between physiotherapy, health, environment and sustainability are explored, is necessary if we are to achieve the transformative social, political, technological, and economic changes that have been identified as critical to sustainable global futures (Díaz et al. 2019). There is already a wealth of evidence supporting the association between functioning, biodiverse ecosystems and human health (Whitmee, Haines, Beyrer, Boltz, Capon, de Souza Dias, Ezeh, Frumkin, Gong, Head, Horton, Mace, Marten, Myers, Nishtar, Osofsky, Pattanayak, Pongsiri, Romanelli, Soucat, Vega and Yach 2015), but some topics remain under-investigated (e.g. the impact of nature-based therapies (Wilkie and Davinson 2021)), and physiotherapists may contribute positively to research in this field. Furthermore, physiotherapists may play an important role in public health interventions based on ecosystem services. For example, the development of urban green spaces for human health must involve stakeholder engagement, and multidisciplinary teams, in which physiotherapists should be involved. Critically, environmental interventions should be evaluated (ideally *a priori*) for potential negative impacts on non-target health conditions, other ecosystem services, and on other sectors (e.g. a human health focused environmental intervention may in fact result in poorer ecosystems).

There is also a need for research into how physiotherapists, and other health professionals, currently utilise nature-based interventions (e.g. rehabilitation and exercise in biodiverse green spaces, gardening), and the perceived barriers and enablers of such interventions, as well as the effectiveness of such interventions as part of physiotherapy treatments. Research in this field may provide support to reduce barriers to nature-based interventions. For example, the provision of safe green spaces for recreation and rehabilitation for inpatients in hospitals, and residents in aged and palliative care.

## **CONCLUSION**

Environmental physiotherapy is a critical new development in our profession, and an important aspect of that development is understanding the role of ecosystem services in human health. We have a responsibility to adapt our practices to the emerging environmental threats and the growing evidence that links the environmental degradation to human health. Physiotherapists must take a broader view of their practice, considering the potential role of the environment on their patient's health, and how their own actions may ultimately be contributing to their patient's (and the population's) poor health. Importantly, we need to consider how to capitalise on the natural environment to enhance patients' health directly (e.g. green space exposure) or indirectly (e.g. reducing exposure to pollution). Through educating ourselves, and future generations of physiotherapists, we have the opportunity to contribute significantly to all of our patients' health, population health, ecosystem health, and planetary sustainability.

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## Box 1: Ecosystem services and adverse birth outcomes

Maternal exposure to trihalomethanes (THMs) is associated with a range of birth outcomes, including increased risk of low birth weight, small for gestational age (Grellier et al. 2010, Mashau, Ncube and Voyi 2018), any congenital anomaly, and ventricular septal defects (Nieuwenhuijsen et al. 2009), as well as pregnancy loss (Mashau, Ncube and Voyi 2018) and stillbirth (Rivera-Núñez, Wright and Meyer 2018). Trihalomethanes are by-products resulting from water disinfection, when contaminants and natural organic matter react with halogen-based compounds (Richardson et al. 2007), and are present in public drinking supplies (Stanhope et al. 2020) and some bottled water (Stanhope, McAuley, Cook and Weinstein 2020). Exposure may be via ingestion, inhalation and transdermal absorption (Kim, Little and Chiu 2004). These by-products can be cytotoxic, mutagenic and genotoxic, depending on the THM species present (Medeiros et al. 2019). Several factors influence the concentrations of THMs in treated water, including temperature (Feungpean, Panyapinyopol, Elefsiniotis and Fongsatitkul 2014, Rodriguez, Sérodes and Levallois 2004) and the concentration of halide ions, natural organic matter and dissolved organic matter in the source water (e.g. the water from the reservoir) (Richardson 2003). Critically, average THM concentrations are predicted to increase by 39% by 2050 due to climate change (Valdivia-Garcia, Weir, Graham and Werner 2019). To reduce THMs in public water supplies we therefore need to address climate change, as well as ecosystem health in water catchment areas. The health of the ecosystem will determine the regulating ecosystem service delivered by the catchment; in this case water purification (Millennium Ecosystem Assessment 2005). The water purification in healthy ecosystems occurs via natural filtration of the water, slowing the flow of the water so

the pathogen half-life is exceeded by the time the water is treated, and through regulation of pathogens at a microbial level. The risk of adverse birth outcomes related to maternal THM exposure may therefore be reduced through removing concreted waterways with concurrent restoration of riparian vegetation, and addressing climate change. Physiotherapists may advise pregnant women about how to reduce their personal exposure to THMs, which may include having shorter showers (Afzal 2006, Téllez Tovar and Rodríguez 2021), and allowing drinking water to sit for at least an hour before drinking (Afzal 2006); however public health approaches addressing the root environmental causes will more likely be effective, and benefit the broader community as well. Physiotherapists may play a role in terms of direct participation in or advocacy for ecosystem conservation and restoration activities, advocating for climate change action, and engaging in sustainable practice.



## Box 2: Ecosystem service and pain outcomes

There is emerging evidence to suggest that exposure to Nature or elements of Nature may improve pain outcomes. For example, pleasant sights (Ulrich 1984, Vincent, Battisto, Grimes and McCubbin 2010) and sounds (Farzaneh et al. 2019, Saadatmand et al. 2015) of Nature (including virtual reality (Kucher et al. 2020, Tanja-Dijkstra et al. 2018)) have resulted in reduced pain for a range of populations, and that the combination of visual and auditory stimuli is more effective at reducing pain than either stimulus individually (Kline 2009). Furthermore, a recent study found that spending time in green space resulted in higher pain thresholds and tolerance for pain elicited with electrical simulation, in otherwise pain-free individuals (Li, Zhang, Bi, Cao and Zhang 2021). More than 40% of people who have visited protected areas (a more natural type of green space) reported that doing so reduced their pain (Jiricka-Pürerer et al. 2019). The findings from spatial epidemiological studies regarding residential green space and pain and musculoskeletal disorder outcomes, is mixed (Donovan, Gatzolis and Douwes 2019, Ihlebæk et al. 2018, Ihlebæk, Næss and Stefansdottir 2021, Maas et al. 2009), but may relate to differences in the green space characteristics and exposure measures, the pain outcome measures and the population characteristics. Importantly, one of these studies found that in the 12 months following hip arthroplasty, people who lived in areas with more residential green space took fewer opioids than those with less green space (Donovan, Gatzolis and Douwes 2019). Indeed, residential green space was recently found to moderate the relationship between both pain-related rumination and catastrophizing, and pain intensity (Wells, Rollings, Ong and Carrington Reid 2019).

Exposure to elements of nature may influence pain outcomes via a range of mechanisms, including through our affinity to nature (biophilia), exposure to sunlight, biogenic volatile organic compounds, negative air ions and environmental microbiota, as well as increased physical activity and social integration that occur in green space (Stanhope, Breed and Weinstein 2020). Readers interested in further information about the linkage mechanisms are

referred to Stanhope, Breed and Weinstein (2020). Physiotherapists may improve pain outcomes by encouraging their patients to spend time in green spaces, or by conducting therapy sessions in such spaces. Furthermore, physiotherapists may advocate for and be directly involved in the development and/or enhancement of local, accessible green spaces. Green spaces can also be enhanced to improve ecosystem health and the associated ecosystem service provided. For example, environmental microbiota in biodiverse environments are more health-giving than those in less biodiverse environments (Liddicoat, Weinstein, Bissett, Gellie, Mills, Waycott and Breed 2019). Through improving access to optimised green spaces, physiotherapists may improve the pain outcomes of their patients, and the broader community.



Table 1. Examples of health conditions commonly seen by physiotherapists that are affected by poor environmental conditions

<b>Exposure and its environmental origins</b>	<b>Associated health conditions that physiotherapists may encounter</b>
<p><b><i>Insufficient exposure to green space</i></b>                      Urbanisation has decreased our exposure to biodiverse green spaces (Aronson et al. 2014), and with it exposures that might improve human health, including biodiverse environmental microbiota, biogenic volatile organic compounds, and sunlight (Flies, Skelly, Negi, Prabhakaran, Liu, Liu, Goldizen, Lease and Weinstein 2017), and reduced exposure to heat and pollution (Markevych, Schoierer, Hartig, Chudnovsky, Hystad, Dzhambov, de Vries, Triguero-Mas, Brauer, Nieuwenhuijsen, Lupp, Richardson, Astell-Burt, Dimitrova, Feng, Sadeh, Standl, Heinrich and Fuertes 2017). Additionally, being in green space encourages social integration and physical activity (Flies, Skelly, Negi, Prabhakaran, Liu, Liu, Goldizen, Lease and Weinstein 2017). Developing accessible urban green spaces with higher levels of diversity may increase the health benefits of green space exposure, as well as ecosystem health.</p>	<p>Adverse birth outcomes (Kondo, Fluehr, McKeon and Branas 2018, Twohig-Bennett and Jones 2018, Zhan, Liu, Lu, Yue, Zhang and Jian 2020)                      Deficits in motor development in children (Twohig-Bennett and Jones 2018)                      Poor mental health (Kondo, Fluehr, McKeon and Branas 2018, Lai, Flies, Weinstein and Woodward 2019, Rautio, Filatova, Lehtiniemi and Miettunen 2018, Shuvo, Feng, Akaraci and Astell-Burt 2020, Twohig-Bennett and Jones 2018)                      Sleep disorders (Shin, Parab, An and Grigsby-Toussaint 2020)                      Cancer (Kondo, Fluehr, McKeon and Branas 2018, Twohig-Bennett and Jones 2018)                      Obesity (de Keijzer, Bauwelinck and Dadvand 2020, Kondo, Fluehr, McKeon and Branas 2018, Lai, Flies, Weinstein and Woodward 2019, Luo, Huang, Liu, Markevych, Bloom, Zhao, Heinrich, Yang and Dong 2020)                      Metabolic conditions (de Keijzer, Bauwelinck and Dadvand 2020, Twohig-Bennett and Jones 2018)                      Chronic pain (Li, Zhang, Bi, Cao and Zhang 2021, Stanhope, Breed and Weinstein 2020, Wells, Rollings, Ong and Carrington Reid 2019)                      Allergies (Kondo, Fluehr, McKeon and Branas 2018, Lai, Flies, Weinstein and Woodward 2019)                      Respiratory conditions (Kondo, Fluehr, McKeon and Branas 2018, Liddicoat, Bi, Waycott, Glover, Lowe and Weinstein 2018, Twohig-Bennett and Jones 2018)                      Poor cardiovascular outcomes (Kondo, Fluehr, McKeon and Branas 2018, Twohig-Bennett and Jones 2018)                      Stroke (Twohig-Bennett and Jones 2018)</p>
<p><b><i>Insufficient exposure to blue space</i></b>                      Climate change leads to drought, and biodiversity loss (e.g. riparian vegetation) may reduce available blue spaces, and urbanisation may alter our proximity to blue space through reclaimed land, changes in water-courses, and water management strategies. Furthermore, urban-sprawl has pushed residential areas further from key water-sources around which settlements are typically established.</p>	<p>Poor mental health (Gascon, Zijlema, Vert, White and Nieuwenhuijsen 2017)                      Cardiovascular disease (Gascon, Zijlema, Vert, White and Nieuwenhuijsen 2017)                      Diabetes (Gascon, Zijlema, Vert, White and Nieuwenhuijsen 2017)</p>

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**Exposure and its environmental origins*****Exposure to more extreme weather events***

Climate change leads to more extreme weather events, including drought, heat waves, cyclones, and floods (Whitmee, Haines, Beyrer, Boltz, Capon, de Souza Dias, Ezeh, Frumkin, Gong, Head, Horton, Mace, Marten, Myers, Nishtar, Osofsky, Pattanayak, Pongsiri, Romanelli, Soucat, Vega and Yach 2015), and protecting and restoring ecosystems may reduce climate change (Millennium Ecosystem Assessment 2005, Whitmee, Haines, Beyrer, Boltz, Capon, de Souza Dias, Ezeh, Frumkin, Gong, Head, Horton, Mace, Marten, Myers, Nishtar, Osofsky, Pattanayak, Pongsiri, Romanelli, Soucat, Vega and Yach 2015).

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**Associated health conditions that physiotherapists may encounter**

Poor mental health (Alderman, Turner and Tong 2012, Cruz, White, Bell and Coventry 2020, Rezayat et al. 2020, Wang, Wu, et al. 2019)  
Adverse birth outcomes (Alderman, Turner and Tong 2012)  
Infectious diseases (Alderman, Turner and Tong 2012, Saulnier, Ribacke and von Schreeb 2017, Suk, Vaughan, Cook and Semenza 2020, Tall, Gattton and Tong 2014) (that may lead to secondary conditions, such as Guillain-Barre and postviral arthralgia)  
Respiratory conditions (Kondo et al. 2019, Liu et al. 2015)  
Cardiovascular conditions (Liu, Pereira, Uhl, Bravo and Bell 2015, Saulnier, Ribacke and von Schreeb 2017)  
Stroke (Saulnier, Ribacke and von Schreeb 2017)  
Systematic inflammation (Liu, Pereira, Uhl, Bravo and Bell 2015)  
Injury (Alderman, Turner and Tong 2012, Saulnier, Ribacke and von Schreeb 2017)

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***Exposure to trihalomethanes in drinking water***

With forest clearing and increasing drought, regulating ecosystem services, such as water quality are lost. To ensure drinking water is safe, chlorination is required, resulting in the presence of chlorination by-products, including trihalomethanes. Trihalomethane concentrations are expected to increase with climate change (Cool et al. 2019, Valdivia-Garcia, Weir, Graham and Werner 2019). Protecting and restoring ecosystems may reduce climate change (Millennium Ecosystem Assessment 2005, Whitmee, Haines, Beyrer, Boltz, Capon, de Souza Dias, Ezeh, Frumkin, Gong, Head, Horton, Mace, Marten, Myers, Nishtar, Osofsky, Pattanayak, Pongsiri, Romanelli, Soucat, Vega and Yach 2015). Water quality can be improved through ecosystem restoration,(Millennium Ecosystem Assessment 2005) including vegetation along and within waterways.

Adverse birth outcomes (Grellier, Bennett, Patelarou, Smith, Toledano, Rushton, Briggs and Nieuwenhuijsen 2010, Mashau, Ncube and Voyi 2018, Nieuwenhuijsen, Martinez, Grellier, Bennett, Best, Iszatt, Vrijheid and Toledano 2009, Rivera-Núñez, Wright and Meyer 2018)  
Cancer (Evlampidou et al. 2020, Sadeghi et al. 2019, Villanueva et al. 2017)

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***Exposure to air pollution***

Air pollution has resulted from industrialisation and urbanisation. Ecosystem restoration improves ecosystem services, including the regulation of air quality (Millennium Ecosystem Assessment 2005), while appropriate tree planting can improve air quality in urban areas (Xing, Brimblecombe, Wang and Zhang 2019).

Poor mental health (Rautio, Filatova, Lehtiniemi and Miettunen 2018)  
Sleep disorders (Liu et al. 2020)  
Dementia (Livingston et al. 2020, Oliveira et al. 2020)  
Multiple sclerosis (Oliveira, Padrão, Ramalho, Lobo, Teodoro, Gonçalves and Freitas 2020)  
Increased respiratory signs and symptoms of cystic fibrosis (Szczesniak et al. 2020)  
Obesity (An, Ji, Yan and Guan 2018, Wang, Zhao, et al. 2019)

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***Exposure to noise pollution***

Noise pollution has resulted from industrialization and urbanization. Appropriately designed urban green spaces may reduce exposure to noise pollution (Margaritis and Kang 2017).

Obesity (Foraster et al. 2018, Pyko et al. 2015, Wang, Zhao, Huang, Hong, Yu, Xiao, Zou, Ji, Zhang, Zou, Ning, Zhang and Jia 2019)

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***Exposure to light pollution***

Light pollution has resulted from industrialization and urbanization. Tree planting in residential areas may reduce exposure to outdoor artificial light at night.

Poor mental health (Svechkina, Portnov and Trop 2020)  
Sleep disorders (Svechkina, Portnov and Trop 2020)  
Cancer (Svechkina, Portnov and Trop 2020)  
Obesity (Lai et al. 2020, Svechkina, Portnov and Trop 2020)

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**Exposure and its environmental origins*****Exposure to disease vectors***

Climate change, land clearing and biodiversity loss increase human exposure to disease vectors (O'Sullivan, Jardine, Cook and Weinstein 2008, Speldewinde, Slaney and Weinstein 2015). Addressing climate change and improving ecosystem functioning, and biodiversity may lead to improved disease regulating services (Millennium Ecosystem Assessment 2005).

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**Associated health conditions that physiotherapists may encounter**

Post-viral arthralgia (Liu et al. 2019, Tappe et al. 2017)

Lyme disease (Speldewinde, Slaney and Weinstein 2015, Stanek, Wormser, Gray and Strle 2012)

COVID-19 (Gibb, Franklinos, Redding and Jones 2020)

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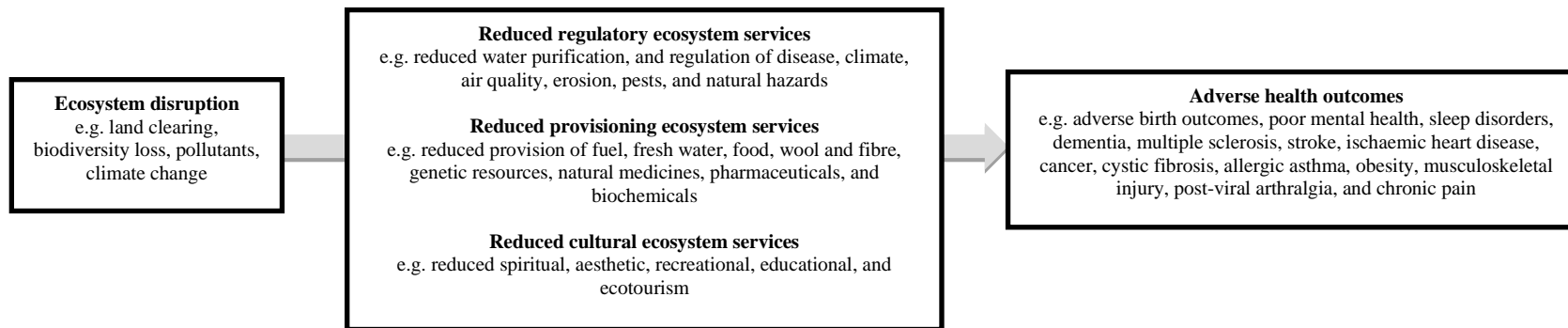


Figure 1. The relationship between ecosystem disruption, reduced ecosystem services, and adverse health outcomes.





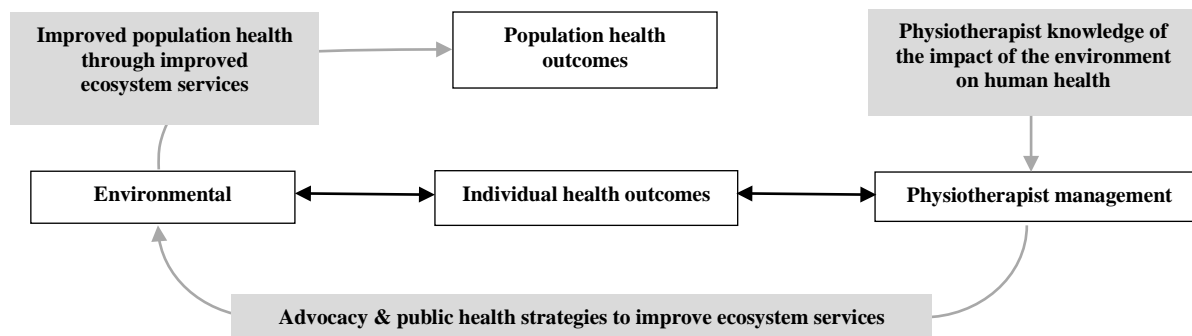


Figure 2. The relationship between environmental exposure, human health, and physiotherapy management

Notes: The black arrows indicate the interaction between environmental exposure, adverse health outcomes, and physiotherapy management. The grey arrows demonstrate how physiotherapists' knowledge of the impact of the environment on human health may influence physiotherapy management (e.g. education, empathy, and advocacy), how advocacy on the part of the physiotherapist and patient (driven by education from the physiotherapist) may improve environmental exposure, which may in turn improve population health.

