Freshwater blue space, health and well-being: A multiscale investigation

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Thesis submitted for the degree of Doctor of Philosophy in Environmental Science

University of Stirling

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Abstract

There is growing evidence that exposure to bodies of water or 'blue spaces' can result in benefits to human health and well-being. However, most blue space and health research has focused on the health and well-being impact of exposure to coastal environments and freshwater blue spaces have received significantly less research attention. Understanding the potential health and well-being benefits of freshwater blue space exposure is vitally important as more than 50% of the global population live within 1km of a body of freshwater and as freshwater and coastal environments differ significantly in their physical and hydrological properties. This thesis aimed to use multiscale and multidisciplinary approaches to quantify the health and well-being impact of access and exposure to freshwater blue space in Scotland. Both qualitative and quantitative methods were adopted, including semi-structured interviews and focus groups (qualitative) and stated preference and national scale subjective health and well-being surveying (quantitative). The key thesis findings suggest Scotland's freshwater blue spaces are important health-promoting assets. Specifically, living in neighbourhoods with high blue space availability was associated with lower uptake of antidepressant medication and self-reported visits to freshwater blue was associated with significant improvements in mental well-being. Furthermore, loch swimming can provide a wide variety of physical, social and mental well-being benefits. The thesis contains a number of novel contributions, including the first published studies to (i) quantify the non-market value of protecting lochside environments; (ii) combine national antidepressant prescribing and freshwater blue space availability data; (iii) establish the health and well-being impacts and risks of loch swimming; and (iiii) quantify the health and well-being benefits of spending time in different types of freshwater blue (e.g. lakes, rivers and canals). Collectively, the thesis findings suggest spending time in and around freshwater blue space can provide a variety of mental health and well-being benefits. It is, therefore, recommended that promoting freshwater blue space usage and accessibility receives greater consideration in urban planning and public health policy, both in Scotland and internationally. However, it is of critical importance that policies aiming to increase freshwater blue space access and usage ensure the health and well-being benefits offered by freshwater blue space are available to all.

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List of Abbreviations

AIC	Akaike information criterion
ART	Attention Restoration Theory
BEAT	BlueHealth Environmental Assessment Tool
BIC	Bayesian information criterion
BNF	British National Formulary
BS	Blue space
C	Chapter
CEH	Centre for Ecology & Hydrology
CI	Confidence interval
CV	Contingent Valuation
DZ	Data Zone
EU	European Union
GES	Good ecological status
GIS	Geographic Information Systems
GPS	Global Positioning System
GS	Green space
IRR	Incidence Rate Ratio
KG	Knowledge gap
LWTP	Lower-bound WTP
NHS	National Health Service
NNR	National Nature Reserve
NPF	National Planning Framework
OS	Ordnance Survey
PPGIS	Public Participation Geographic Information Systems

PR	Prevalence Rate
PRISMS	Prescribing Information System for Scotland
PWC	Population weighted centroid
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SDG	Sustainable Development Goal
SE	Standard Error
SEPA	Scottish Environmental Protection Agency
SIMD	Scottish Index of Multiple Deprivation
SOPHIE	Seas, Oceans and Public Health in Europe
SPA	Special Protected Area
SSSI	Site of Special Scientific Interest
TZ	True zero
UWTP	Upper-bound WTP
UK	United Kingdom
UN	United Nations
VG	Valuation gap
VIF	Variance inflation factor
WFD	European Union's Water Framework Directive
WHO	World Health Organisation
WTA	Willingness-to-accept
WTP	Willingness-to-pay

Chapter 1 - Introduction

1.1 Overview

This thesis has been submitted to obtain the degree of Doctor of Philosophy in Environmental Science from the University of Stirling. The overarching aim of the thesis is to use multiscale and multidisciplinary approaches to quantify the health and well-being impact of proximity and exposure to freshwater blue space in Scotland. The research was funded by the Scottish Government Hydro Nation Scholars Programme.

1.2 Project rationale

A wealth of evidence suggests spending time in and around nature can benefit human health and well-being (Bratman et al., 2019, Frumkin et al., 2017, Hartig et al., 2014). At the time of writing, the vast majority of nature-health research has focused on the health impact of access and exposure to green spaces, such as parks and woodlands. Green space exposure has been associated with a wide range of physical and mental health benefits (Twohig-Bennett and Jones, 2018) and consequently, the provision of urban green space is now an established component of urban planning and public health policies in cities across the globe (Shanahan et al., 2015). There is also growing interest in the health-promoting potential of other natural environments, such as bodies of water or 'blue spaces' (White et al., 2020; Gascon et al., 2017; White et al., 2010).

Blue spaces are 'outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans' (Grellier et al., 2017). In the last decade, interest in the health-promoting potential of blue space has accelerated rapidly (Foley and Kistemann, 2015; White et al., 2020). This acceleration is partly due to the establishment of a number of large-scale research programmes dedicated to the study of blue space exposure and health, including the UK-based Blue Gym project and the pan-European BlueHealth research initiative.

In the last year alone, a number of important blue space and health studies have been published, further highlighting the potential of blue space exposure to promote health and well-being. An eighteen-country study, which included the United Kingdom (UK), suggests visiting blue spaces is associated with greater mental well-being and reduced mental distress (White et al., 2021). Furthermore, living nearby blue space has been associated with greater general health (Huang et al., 2022).

To date, most blue space and health research has focused on the health and well-being impact of access and exposure to coastal blue spaces (Gascon et al., 2017). Consequently, our understanding of the potential of freshwater blue space to promote health and well-being remains somewhat limited. Understanding the health and well-being impact of exposure to freshwater blue space is of crucial importance given the vastly different physical and hydrological characteristics of freshwater and coastal environments (Mavoa et al., 2019) and as these environments differ in their capacity to provide recreational opportunities and ecosystem services (McDougall et al., 2020a).

1.3 Knowledge gaps

Although growing steadily, the freshwater blue space and health evidence base has a number of key knowledge gaps, which this thesis aims to address. In Chapter 2 (C2), a suite of research priorities is presented to advance the current freshwater blue space exposure and health evidence base. Three categories of research priorities are proposed; (i) establishing a methodological framework for freshwater blue space and health research; (ii) broadening and advancing the current freshwater blue space and health empirical evidence base; and (iii) promoting and sustaining opportunities to promote public health via freshwater blue space exposure. Many of these recommendations exceed the scope of this PhD project and are applicable to the wider research and policy audience. A number of knowledge gaps (KGs) which this thesis aims to address have been identified and are discussed below.

KG 1: There is limited understanding of the health-promoting potential of different freshwater blue space types (e.g., lakes, rivers and canals).

Most freshwater blue space and heath research classifies different types of freshwater (e.g. lakes, rivers and canals) collectively (e.g. Pasanen et al., 2019; Garrett et al., 2019a). Some studies have considered the health benefits of exposure to a single freshwater blue space type, such as canals (Tieges et al., 2020) or lakes (Pearson et al., 2019). However, there is a very limited understanding of the health and well-being impact of exposure to multiple different freshwater blue space types. Addressing KG1 can provide opportunities for evidence-based policymaking to maximise the health-promoting potential of different types of freshwater blue space.

KG2: Empirical studies of the relationship between freshwater blue space exposure and health and well-being using actual exposure data, not proxies (e.g., residential proximity) are lacking.

To date, most freshwater blue and health research has adopted proxies for exposure to freshwater, such as the presence or absence of freshwater in a neighbourhood or residential proximity to freshwater (Gascon et al., 2017). Such approaches are useful, but are limited in their accuracy, as residing in close proximity to freshwater does not confirm exposure and does now allow the amount or intensity of exposure to be quantified (Helbich, 2018). Alternatively, self-reported accounts if exposure can provide detail on actual visitation patterns. Addressing KG2 provides an opportunity to progress the current evidence base by utilising more robust methodologies, which allow for more detailed quantification of freshwater blue space exposure.

KG3: The health and well-being impact of freshwater activities that involve freshwater immersion, e.g., swimming, remains unclear.

In the UK, most visits to blue space do not involve direct water contact (Elliott et al., 2018) and freshwater blue space exposure and health studies rarely account for different types of blue space usage. As such, the potential benefits of freshwater blue space interactions which involve direct water contact are somewhat unknown.

A wealth of evidence outlines the health and well-being impact of aquatic activities such as swimming and surfing in coastal environments (Britton and Foley, 2020). However, studies of the health and well-being impact of freshwater blue space immersion are lacking, despite the growing popularity of freshwater swimming in many countries, including the UK (Wood et al., 2022). Addressing KG3 can broaden current understanding of the health-promoting potential of immersion in freshwater blue space.

KG4: Little is known about the relationship between freshwater blue space exposure and health and well-being for different demographic groups.

Over the course of the last decade, many green space and health studies have focused on a variety of different demographic and socioeconomic groups, including children, older adults, ethnic minority communities and individuals with a variety of physical and mental disabilities. Understanding the potential of green and blue spaces to promote health and well-being among diverse populations is of critical importance, particularly given that many of these groups often benefit most from green and blue space exposure (Ward Thompson et al., 2012). To date, freshwater blue space and health studies have been mostly limited to general populations, with little consideration of the potentially differing health and well-being impacts of freshwater blue space exposure among different socioeconomic and demographic groups. Addressing KG4 provides an opportunity to widen the freshwater blue space and health evidence base and to advance current understanding of the health and well-being impact of freshwater blue space exposure among different population groups.

KG5: The non-market value of many important components of freshwater environments is not fully understood.

The economic value of changes to water quality or the ecological status of water bodies is frequently quantified in environmental economics research (Šebo et al., 2019; Börger et al., 2021; Van Houtven et al., 2014). However, improved water quality and water conditions do not necessarily enhance the cultural ecosystem services offered by freshwater blue spaces (Ziv et al., 2016). There is a need to better understand the economic impact of changes to a wider variety of freshwater attributes, including in waterside spaces, where most blue space visits occur (Elliott et al., 2018). Adequate consideration of the economic impact of changes to freshwater environments is critical in ensuring public preference and cost-effectiveness are accounted for in decision making and freshwater management. Addressing KG5 provides an opportunity to better understand the potential economic impacts of often overlooked changes to freshwater environments.

1.4 Aim and objectives

The overarching aim of this thesis is to use multiscale and multidisciplinary approaches to quantify the health and well-being impact of proximity and exposure to freshwater blue space in Scotland. The specific objectives relate to the key knowledge gaps outlined above:

Objective 1: To quantify the health and well-being impact of residential proximity and exposure to different freshwater blue space types

Objective 2: To identify the health-promoting potential of freshwater blue space exposure for different demographic groups

Objective 3: To establish the health and well-being benefits and risks of immersion in freshwater blue space

Objective 4: To contextualise the health and well-being impacts of freshwater blue space exposure relative to coastal blue space and green space exposure and a variety of demographic and socioeconomic indicators

Objective 5: To establish the non-market value of preserving waterside spaces surrounding freshwater blue space

1.5 Thesis structure

This thesis is composed of six chapters following this brief introduction. C2 is a critical review outlining key research priorities to improve our understanding of the relationship between freshwater blue space and health and well-being. C3-6 are empirical data chapters. C3 is a nationwide ecological study of neighbourhood freshwater blue space availability and mental health, with a specific focus on older adults. C4 is an individual-level study which quantifies the relationship between exposure to different freshwater blue space types (lakes, canals and rivers), general health and mental well-being. C5 uses semi-structured interviews to determine the health and well-being impact of loch swimming and to establish the importance of place and risk in the experience of wild swimmers. C6 quantifies public preference of freshwater blue space management via a nationwide contingent valuation survey. Finally, C7 provides a synthesis of the research findings and provides recommendations for future research and opportunities to improve policy.

1.6 COVID-19 statement

The COVID-19 pandemic occurred at the midpoint of this PhD and led to a number of key changes to the project. C3 relied solely on secondary data due to the nationwide COVID-19 lockdown. The submission of the survey used in C4 was delayed by two years and additional COVID-19-related variables were included to account of the potential impact of COVID-19 on general health and mental well-being. Semi-structured interviews for C5 were conducted via Zoom (rather than in-person) due to ongoing COVID-19 restrictions. C2 and C6 were not impacted by COVID-19.

1.7 Author / publication statement

Five of the chapters of this thesis have been accepted for publication in peer-reviewed academic journals. Table 1.1 provides the details of each publication and the corresponding chapter. The doctoral candidate (Craig McDougall) was the lead author on all publications and author contributions for each publication are detailed at the beginning of each chapter.

I declare that the work contained in this thesis is my own and has not been submitted for an award at this or any other university.

Craig McDougall (02.08.2022)

Table 1.1. Manuscript details of published chapters.

Chapter	Publication details
2	**McDougall CW**, Quilliam RS, Hanley N & Oliver DM (2020). Freshwater blue space and population health: An emerging research agenda. Science of the Total Environment, 737, 140196.
3	**McDougall CW**, Hanley N, Quilliam RS, Bartie P, Robertson T, Griffiths M & Oliver DM (2021). Neighbourhood blue space and mental health: A nationwide ecological study of antidepressant medication prescribed to older adults. *Landscape and Urban Planning*, 214, 104132.
4	**McDougall CW**, Hanley N, Quilliam RS, & Oliver DM (2022). Blue space exposure, health and well-being: Does freshwater type matter? *Landscape and Urban Planning* 224, 104446.
5	**McDougall CW**, Foley R, Hanley N, Quilliam RS, & Oliver DM (2022). Freshwater wild swimming, health and well-being: Understanding the importance of place and risk. Sustainability, 14, 6364.
6	**McDougall CW**, Hanley N, Quilliam RS, Needham K & Oliver DM (2020). Valuing inland blue space: A contingent valuation study of two large freshwater lakes. Science of the Total Environment, 715, 136921.

Chapter 2 - Freshwater blue space and population health: An emerging research agenda

Published in Science of the Total Environment (2020)

Manuscript details: **McDougall CW**, Quilliam RS, Hanley N, Oliver DM. Freshwater blue space and population health: An emerging research agenda. Science of the Total Environment; 737; 140196

Author Contributions: CW. McDougall conceptualised the rationale and methodology of this review, carried out the review and wrote the manuscript. RS. Quilliam, N. Hanley and DM. Oliver acquired the funding, provided general supervision and suggested improvements to the manuscript.

Abstract

Growing evidence suggests that access and exposure to water bodies or blue spaces can provide a variety of health and well-being benefits. Attempts to quantify these ‘blue-health’ benefits have largely focused on coastal environments, with freshwater blue spaces receiving far less attention despite over 50% of the global population living within 3km of a body of freshwater and populations living in landlocked areas having limited coastal access. This critical review identifies opportunities to improve our understanding of the relationship between freshwater blue space and health and well-being and outlines key recommendations to broaden the portfolio of emerging research needs associated with the field of blue-health. Recognising fundamental distinctions in relationships between health outcomes and access and exposure to freshwater versus coastal blue space is critical and further research is required to determine the mechanisms that link exposure to freshwater blue space with tangible health outcomes and to understand how such mechanisms vary across a range of freshwater environments. Furthermore, methodological improvements are necessary as spatial approaches adopted to quantify access and exposure to freshwater blue space often fail to account for the unique physical characteristics of freshwater and come with a variety of limitations. Based on the findings of this review, a suite of research needs are proposed, which can be categorised into three broad themes: (i) establishing a freshwater blue-health methodological framework; (ii) advancing the empirical freshwater blue-health evidence base; and (iii) promoting freshwater blue-health opportunities. When taken together, these research themes offer opportunities to advance current understanding and better integrate freshwater blue space into the wider nature-health research agenda.

2.1 Introduction

Interest in the relationship between access and exposure to the natural environment and human health is growing globally (Frumkin et al., 2017; Hartig et al., 2014). Nature-health research has mainly focused on exposure to green space, which has been associated with a number of positive physical and mental health outcomes (Twohig-Bennett and Jones, 2018). This growing evidence base has seen green space provision become an established component of public health and landscape planning policies across the globe (Rutt and Gulsrud, 2016; Wolch et al., 2014). The health-promoting potential of water bodies or 'blue spaces' has received less attention in comparison, despite a small but growing body of evidence suggesting that access and exposure to blue space can provide a variety of health and well-being benefits (Gascon et al., 2017; Völker and Kistemann, 2011).

Although the term 'blue space' has emerged relatively recently, the health and well-being benefits of human-water interactions have been studied for decades across a number of disciplines including environmental psychology (Herzog, 1985; Kaplan and Kaplan, 1989) and human geography (Gesler, 1992; Gesler, 1996). In research concerned with nature and population health, blue space is often excluded (O'Callaghan-Gordo et al., 2020) or classified as green space (Van den Berg et al., 2016). However, the establishment of a number of large-scale research programmes (e.g. Depledge and Bird, 2009; Grellier et al., 2017) coupled with a renewed interest in water-health relations in human geography (Foley and Kistemann, 2015) has seen the study of blue space and health shift from a by-product of therapeutic landscape and environmental psychology research towards an established academic field in its own right.

Blue space is generally understood to encompass both freshwater and marine settings (Grellier et al., 2017; Foley and Kistemann, 2015). However, with the exception of large or saline lakes and estuaries where freshwater and marine settings merge, these two environments substantially differ in their physical and hydrological properties and the ecosystem services and amenity values they provide. Furthermore, experiences at freshwater blue space are likely to consist of different scenery, smells, sounds and opportunities for recreation than experiences in coastal environments (Mavoa et al., 2019). Current research attempting to quantify the health and well-being benefits of access and exposure to blue space (henceforth blue-health benefits) has largely focused on coastal environments, with freshwater blue spaces receiving far less attention (Gascon et al., 2017). Living in close proximity to the coast has shown an association with greater physical and mental health (Hooyberg et al., 2020; Pasanen et al., 2019; Wheeler et al., 2012) and being able to see the coast from one's home has also been associated with positive effects on mental well-being (Dempsey et al., 2018).

A review of 36 research articles exploring human-freshwater interactions identified that freshwater has a variety of salutogenic properties that can induce health and well-being benefits (Völker and Kistemann, 2011), although the data used for this review were mainly comprised of experimental and qualitative studies. This has exposed a significant gap in research that explores the benefits of access and exposure to freshwater from a population health perspective. Although some studies have suggested that access and exposure to freshwater blue space can provide benefits to population health (Pasanen et al., 2019; Pearson et al., 2019; MacKerron and Mourato, 2013; Garrett et al., 2019a), this is not always the case (White et al., 2013; Bezold et al., 2018; Mavoa et al., 2019). The volume and spatial coverage of freshwater is substantially smaller than marine environments; however, investigating the health-promoting potential of freshwater blue space is imperative as over 50% of the global population lives within 3km of a body of freshwater and populations living in landlocked areas have limited coastal access (Kummu et al., 2011). Therefore, a better understanding of the relationship between access and exposure to freshwater blue space and indicators of health, and the mechanisms underlying these relationships, are fundamental to supporting a more holistic assessment of blue space as a public health resource.

This critical review aims to identify opportunities to improve understanding of the relationship between freshwater blue space, health and well-being and thus broaden the portfolio of emerging research needs associated with the field of blue-health. Specifically, the objectives of this review are to (i) evaluate current issues in freshwater blue-health thinking; (ii) critically appraise the contrasting empirical methods adopted to quantify access and exposure to freshwater blue space; and (iii) propose recommendations for novel avenues of future research to advance our understanding of freshwater blue-health.

2.2 Issues in current freshwater blue-health thinking

2.2.1. Understanding pathways to positive health outcomes

The underlying mechanisms or 'pathways' that link access and exposure to natural environments and tangible health outcomes have often been overlooked (Dzhambov et al., 2018). The most commonly cited pathways to improved health via access and exposure to the natural environment are stress reduction and restoration, social interaction, improved air quality and physical activity (Hartig et al., 2014). Grellier et al. (2017) hypothesise that health and well-being benefits from blue space exposure will follow pathways similar to other natural environments. Blue spaces also have a number of distinctive health-promoting and therapeutic properties, e.g. opportunities for physical immersion and water-based activities (Foley, 2015).

There is a growing need to better understand the pathways that link exposure to freshwater blue space to positive physical and mental health outcomes as this has been overlooked in previous research. Table 2.1 explores the nature-health pathways proposed by Hartig et al. (2014) in relation to freshwater blue space specifically - the improved air quality pathway has been adapted to consider a wider variety of environmental improvements. Exposure to freshwater can reduce stress and provide cognitive restoration as aquatic environments are highly restorative (Maund et al., 2019; Wilkie and Stavridou, 2013; Wang et al., 2016; White et al., 2010) and relaxing (Grassini et al., 2019). Furthermore, water is an important and highly valued aesthetic component in terms of landscape preference (Velarde et al., 2007; Faggi et al., 2013; Kaltenborn and Bjerke, 2002; Burmil et al., 1999). The presence of freshwater alone may induce health benefits by improving a number of environmental attributes, e.g. improving soundscapes by buffering anthropogenic noise (Jeon et al., 2012; Axelsson et al., 2014) and providing restorative or pleasant sounds, such as flowing water or bird song (White et al., 2010; De Coensel et al., 2011). The presence of freshwater can also enhance thermal comfort by reducing the urban heat island effect (Gunawardena et al., 2017) and provide a variety of ecosystem services, including carbon absorption (Apostolaki et al., 2019).

Social interaction (de Bell et al., 2017; Pitt, 2018; Völker and Kistemann, 2015) and physical activity (Vert et al., 2019; Jansen et al., 2017), which are associated with a variety of health and well-being benefits, are expected to increase with greater access, exposure and usage of freshwater blue space; however, the importance of these pathways in facilitating blue-health benefits is still relatively unknown. For coastal blue space, physical activity has been shown to be a key pathway in facilitating positive mental health outcomes, however, further research to understand the different mechanisms that cause freshwater blue space to positively influence health is required (Pasanen et al., 2019). Investigating the relationship between individual pathways and their contribution to specific health outcomes can assist health officials, landscape planners and policymakers in designing and managing blue space to optimise the provision of health and well-being benefits (Gascon et al., 2018). Furthermore, improved understanding of how different types of engagement with freshwater interact with each health pathway, and the strength of these interactions relative to green space and coastal blue space can underpin effective nature-based health interventions, advancing the wider nature-health research agenda.

Table 2.1. Summary of freshwater blue-health pathways.

Pathway	Explanation	Exemplar reference
Stress reduction/restoration	High restorative potential	Ulrich et al., 1991; White et al., 2010; Grassini et al., 2019;
	Opportunities for immersion within water	
	Considered relaxing, attractive and calming	
Environmental improvement	Enhance thermal comfort and reduce urban heat island	Gunawardena et al., 2017; Jeon et al., 2012;Apostolaki et al., 2019
	Improve soundscapes and buffer anthropogenic noise	
	Provide ecosystem services, e.g. carbon absorption	
Physical activity (PA)	Unique opportunities for PA e.g. swimming and fishing	Foley,2015; Perchoux et al., 2015; Vert et al., 2019
	Water-based PA preferred outdoors than indoors	
	Encourage non-water based physical activity	
Social interaction	Opportunities for planned and unplanned social contact	Pitt, 2018; Völker and Kistemann, 2015; Thomas, 2015;
	More relaxed ambience than urban areas	
	Opportunities for group exercise and leisure	

2.2.2 Classifying freshwater blue space

While the term 'blue space' is generally well understood in current nature-health literature, the treatment of coastal and freshwater environments in studies concerned with access and exposure to blue space and health varies widely. Access and exposure to freshwater and coastal blue space can be tested against health outcomes and reported as individual categories (Choe et al., 2018; Wheeler et al., 2012; Pasanen et al., 2019; Garrett et al., 2019b) or as a combined 'blue space' category (de Vries et al., 2016; Garrett et al., 2019b; Huynh et al., 2013). The study of blue space can relate specifically to freshwater if, for example, the study location is landlocked (Dzhambov et al., 2018). Variations in blue space definitions and how blue-health findings are reported make comparisons among studies challenging and limit opportunities for evidence synthesis via meta-analyses and systematic review (Taylor and Hochuli, 2017). While combining freshwater and coastal blue space may be appropriate in order to address some research questions, the approach can be problematic, particularly when attempting to draw conclusions related to access and exposure to freshwater specifically. As exposure to coastal blue space may have a stronger health and well-being effect than exposure to freshwater (Garrett et al., 2019b) and as the physical properties of coastal waters can dominate the combined blue space category (Nutsford et al., 2016), caution should be taken when assuming that combined blue space findings are transferable to the freshwater evidence base. In order to better understand how access and exposure to freshwater blue space impacts health and well-being, blue space categories need to be clearly defined, whilst the relationships between health and access and exposure to freshwater and coastal blue spaces need to be reported independently.

2.2.3 Considering multiple freshwater blue space typologies

There is currently little understanding of how different typologies of freshwater blue space (e.g., lakes, rivers, canals, wetlands, ponds, streams, waterfalls and even fountains) interact with health pathways and consequently, how different typologies can impact health and well-being (Mavoa et al., 2019). Previous research suggests different freshwater typologies may have varying potential for stress reduction and restoration. For example, humans prefer views of rivers, lakes and ponds compared to more swampy waterscapes, such as creeks or bogs (Herzog, 1985). To date, research directly investigating interactions between different freshwater blue space typologies and the environmental improvement, social interaction and physical activity health pathways has been sparse. For the environmental improvement pathway, larger water bodies are expected to provide greater effects on surrounding temperatures (Wu et al., 2018) and the cooling effect of lakes is often higher than that of rivers (Du et al., 2016). Different freshwater typologies will also vary in their ability to buffer noise and impact soundscapes, as the sound of water is mainly driven by hydrology, i.e., the volume and speed of water flow (Putland and Mensinger, 2020). Consequently, flowing rivers may have a more significant effect on soundscapes than bodies of relatively still freshwater (Wysocki et al., 2007).

Types of freshwater also vary in their ability to facilitate certain opportunities for physical activity and social interaction. Swimming and paddling are often associated with lakes (Angradi et al., 2018) and outdoor swimming is more likely to occur in lakes than narrow waterways (Lankia et al., 2019). Indeed, swimming is often prohibited in urban waterways and canals due to health risks associated with immersion in these bodies of water (Pitt, 2018). An improved understanding of how access and exposure to different freshwater typologies impacts health and well-being will likely assist in developing site-specific health interventions and integrating a variety of freshwater blue space typologies into public health strategies. Consequently, recognising the mechanisms that affect the health-promoting capabilities of different freshwater blue space typologies and how these vary across different socio-demographic groups is a key priority for future research.

2.2.4 Freshwater blue space quality

The perceived quality of the natural environment can impact how that environment is used (Giles-Corti et al., 2005; Akpinar, 2016) and poor environmental quality is a deterrent of use for both children (McCracken et al., 2016) and adults (Wright Wendel et al., 2012). Research focussing on access and exposure to freshwater blue space and health often fails to consider the varying quality of different spaces, with little attention given to characteristics, such as accessibility, parking facilities, water conditions, recreational opportunities, or other salutogenic properties (Pitt, 2018). Water quality can influence the likelihood of swimming (Lankia et al., 2019), boating (Curtis et al., 2017) and impact the experience of anglers (Pulford et al., 2017). In addition to traditional bacteriological or chemical indicators of water quality, the suitability of blue spaces for water-based recreation can be influenced by user preferences for specific water conditions, such as temperature, flow and visibility (Bertram et al., 2019; Johnstone and Markandya, 2006). However, recent evidence from England suggests that the majority of visitors to inland water bodies do not make direct contact with water (Elliott et al., 2018) and improved water quality and water conditions do not necessarily enhance the cultural ecosystem services offered by freshwater blue spaces (Ziv et al., 2016). Blue-health benefits commonly occur in terrestrial locations, e.g. due to non-water based physical activity (Vert et al., 2019), reduced psychological distress from viewing water (Nutsford et al., 2016) and social interaction in waterside environments (de Bell et al., 2017). Furthermore, waterside features, such as high quality paths (Verbič et al., 2016) and easily accessible waterside spaces (McDougall et al., 2020b) can enhance the overall experience at a range of different freshwater blue space typologies. Consequently, it is clear that measures of freshwater blue space quality must account for both aquatic characteristics and surrounding terrestrial attributes.

A number of dedicated systems (Ariza et al., 2010; Palazón et al., 2019) and a robust international framework exists for assessing the quality of coastal environments and beaches, including beach certification schemes such as the “Blue Flag” (Lucrezi et al., 2015). Whilst some indicators of coastal and beach quality may be transferable to certain freshwater environments, such as large lakes with beaches and shorelines, many are specific to marine settings and are, therefore, inadequate for assessing freshwater blue space quality. Currently, the BlueHealth Environmental Assessment Tool (BEAT) is the only dedicated tool for assessing the quality of coastal and freshwater blue space (Mishra et al., 2020). BEAT uses a questionnaire-based approach to examine physical, social, aesthetic and environmental aspects of blue space, which relate to opportunities for improved health and well-being. While BEAT is highly suitable for assisting policymakers in designing and managing blue spaces to facilitate public health benefits, the tool requires site visits and questionnaires, thus making it challenging to implement at a population health scale. Moving forward, there is scope to establish ex-situ indicators to quantify blue space quality that can be readily combined with geographic information system (GIS) based approaches. Ex-situ indicators can be complemented by existing spatial data sources such as area-level socio-economic data (Rigolon and Németh, 2018) or the presence of surrounding services and green/open spaces, which are useful indicators of blue-health opportunities (Mishra et al., 2020). Combining freshwater blue space quality data, alongside metrics of access and exposure and health outcomes, would improve our understanding of which elements of freshwater blue space are most important for the provision of blue-health benefits.

2.3 Quantifying access and exposure to freshwater blue space: a critical appraisal

Quantifying access and exposure to freshwater blue space is a crucial component of studies that attempt to relate these variables to population health outcomes. Commonly, access and exposure are measured using GIS and combined with individual or area-level health data (e.g., Bezold et al., 2018; Pasanen et al., 2019; Mavoa et al., 2019; Pearson et al., 2019; Wheeler et al., 2015; White et al., 2013). Assessing the capability of these methods to account for the unique physical and spatial properties of freshwater blue space would benefit future research.

2.3.1 Proximity-based approaches

Proximity-based approaches (e.g. Pearson et al., 2019; Hooyberg et al., 2020; Pasanen et al., 2019; White et al., 2013) are concerned with the distance relative to blue space and can be divided into two key approaches: (i) determining the distance to the nearest blue space from a particular point (commonly the residence); and (ii) identifying the presence of a blue space within a defined distance or 'buffer'. Proximity buffers are commonly applied around the residence, although, there may be some merit in considering proximity to blue space in other locations such as schools, hospitals or workplaces, in order to capture the health effects of access and exposure to freshwater blue space in non-residential contexts (Koohsari et al., 2015). Proximity can be calculated as a linear distance or network distance. Linear distance approaches calculate the shortest distance from a selected location to the edge of the nearest blue space or buffer boundary, whereas network distance calculates the shortest distance from a selected location to the edge of the nearest blue space or buffer boundary along a street network, simulating walkability (Fig. 2.1). Network distance may be more appropriate for research focused on health outcomes that require access and visitation such as physical activity (Labib et al., 2020) or when investigating distance to freshwater blue space in urbanised areas with complex street networks. Network distance approaches may also be particularly useful when considering freshwater blue space with inaccessible sections, as linear methods cannot consider this issue (Fig. 2.1). Linear distance methods may be more appropriate when considering health benefits that can occur irrespective of access, i.e. viewing blue space from a distance or environmental improvements such as noise reduction and temperature mitigation.

A variety of different buffer sizes have been adopted in order to quantify differences in access and exposure to freshwater blue space among populations (Bezold et al., 2018; Dzhambov et al., 2018). Heterogeneity among buffer sizes makes comparing the results of studies and evidence synthesis challenging and the adoption of standardised distance buffers would benefit future freshwater blue space research (Gascon et al., 2017). Standardised buffer distances should be underpinned by empirical evidence and will likely differ from those adopted for coastal blue space, as much smaller distances influence the usage and visitation of freshwater blue space (Völker et al., 2018) and as these distance thresholds vary across different freshwater typologies (Elliott et al., 2020). The adoption of differing buffer distances in coastal and freshwater blue space research reinforces the variance in scale of both resources and further highlights the risks of combining the findings of studies that examine the health effect of access and exposure to coastal and freshwater collectively.

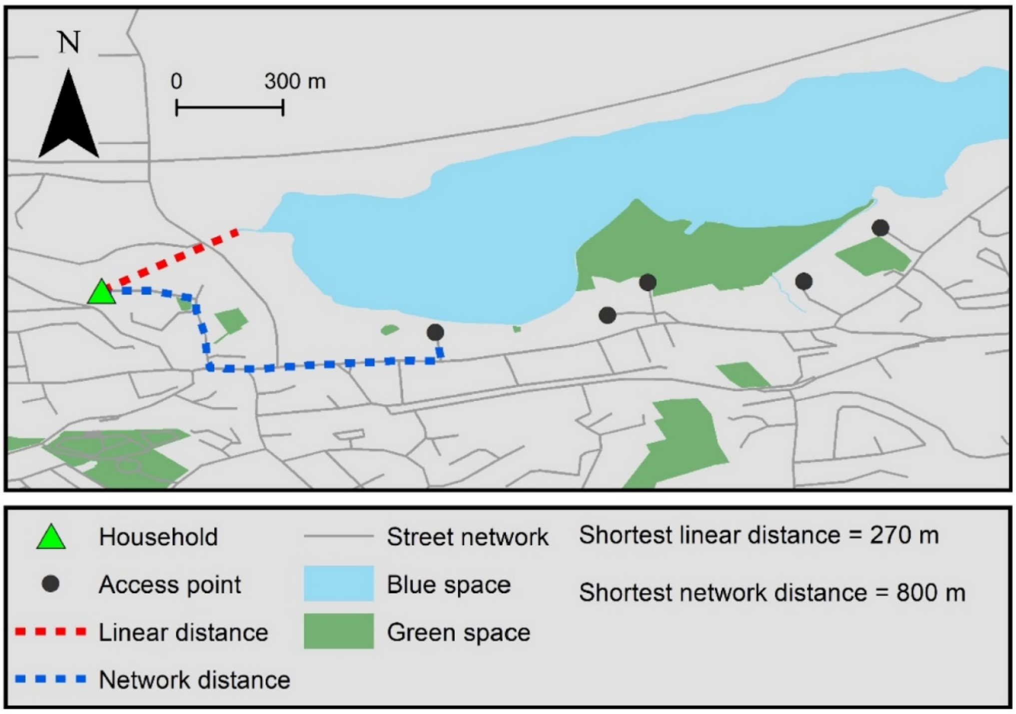

Figure 2.1. Summary of linear and network distance approaches for quantifying access to blue space.

2.3.2 Area-based approaches

Area-based methods use land cover data to determine the percentage of surface water within a predefined area or administrative boundary, such as a zip code area or census tract (Pearson et al., 2019; Alcock et al., 2015; de Vries et al., 2003; Garrett et al., 2019b). Such methods indicate both the presence and quantity of blue space within an area, which can assist in answering research questions concerning the effect of varying levels of blue space exposure on health. However, the use of area-based methods to quantify exposure and access to freshwater blue space comes with a number of limitations. Area-based methods are better suited to larger bodies of freshwater and certain freshwater typologies such as lakes, which are likely to have greater surface areas (Fig. 2.2). Such methods may, therefore, underestimate the health effects of typologies with lower surfaces areas such as rivers and canals, which also offer valuable opportunities for health and well-being (Vert et al., 2019; Pitt, 2018). There is an absence of empirical evidence to justify the notion that access and exposure to certain freshwater typologies are likely to result in greater positive health outcomes than others. Moreover, land cover data is commonly used to identify the presence of freshwater (de Vries et al., 2016) and narrow water bodies (e.g. river corridors and canals) are more likely to be misclassified than larger and more spatially explicit bodies of freshwater, highlighting a further bias. If sufficient data are available, future research may benefit from considering the perimeter of freshwater (Pasanen et al., 2019) or the percentage of surface area covered by freshwater relative to the number of freshwater blue spaces, which can account for the presence of different freshwater typologies and begin to address issues related to their misrepresentation.

The adoption of administrative zones when quantifying exposure to freshwater blue space can also be problematic as administrative zones vary in size (Wheeler et al., 2015). Area-based methods often represent blue space as a percentage; therefore, freshwater blue spaces of equal size may be deemed to have different health-promoting capabilities depending on the size of the administrative zone it is located within (Fig. 2.2). As administrative zones are often based on population density, the physical properties of certain blue spaces are likely to be favoured over others. Freshwater blue spaces in densely populated urban areas, such as rivers and canals, are likely to be in smaller administrative zones, whilst lakes and wetlands are less likely to be present in densely populated areas due to their physical properties and are more likely to be located on the urban fringe (Liu et al., 2007). Consequently, the use of administrative zones may underrepresent exposure and access to large lakes, which are important for providing benefits to mental health (Pearson et al., 2019). Administrative zones also notably differ in size across countries (Labib et al., 2020) making international transferability of area-based research and comparison among studies challenging.

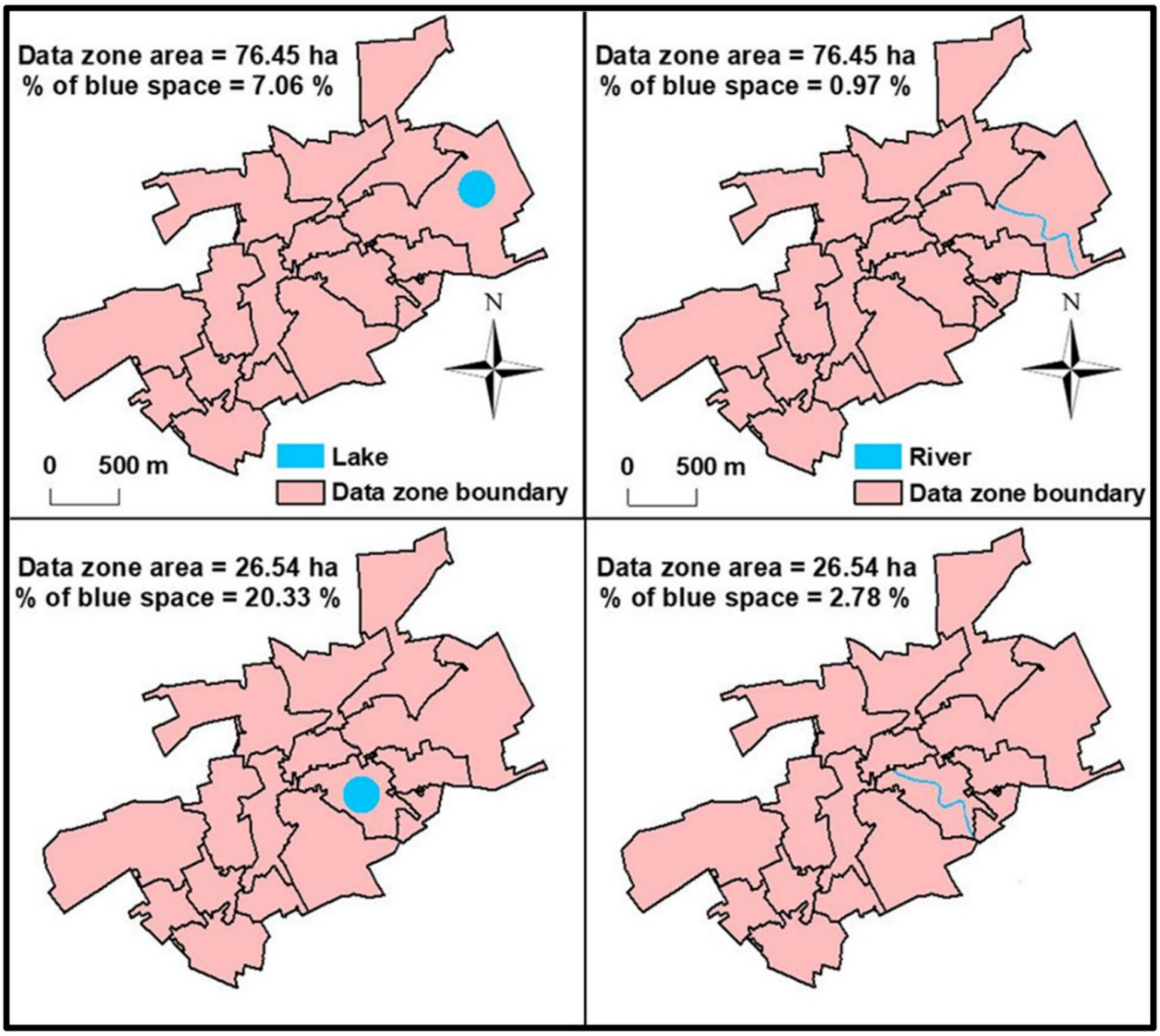

Figure 2.2. Area-based representations of freshwater blue space are dependent on blue space typology (e.g., river or lake) and the size of the administrative (data zone) boundary.

2.3.3 Visibility-based approaches

Visibility-based methods consider topographic and built landscape features in order to determine what areas are likely to be visible to humans from a certain point in the landscape, commonly a household (Qiang et al., 2019). Visible exposure to blue space aligns closely with the stress reduction and restoration health pathway and relates to improved health without actual visitation, as positive health outcomes can be obtained from viewing water from a distance (Nutsford et al., 2016). Incorporating visibility-based methods into freshwater blue-health research may be challenging as freshwater and vegetation (or green space) are often intertwined in landscapes.

Indeed, when a blue space becomes a green space and vice versa is often unclear, with no criteria yet defined to aid our understanding of this transition. This issue may be further complicated as definitions of blue space tend to include waterside space and vegetation. Why the relationship between blue and green space has been somewhat overlooked in research is unclear but may relate to: (i) methodological issues of unpacking complex interactions between these spatial zones; or (ii) that most blue space research has focused on the coast, thus providing a relatively more defined blue-green split. Generally, the distinct physical properties of coastal landscapes make defining coastal blue space interaction simpler than for freshwater blue space typologies where interactions between water and vegetation are more common.

Acquiring sufficient and appropriate quality vegetation data and accounting for the seasonal, semi-transparent and non-uniform characteristics of vegetation is a key challenge of visibility-based approaches (Murgoitio et al., 2014). Previous studies of blue space visibility have excluded the effect of vegetation in their analysis (Dempsey et al., 2018; Qiang et al., 2019). It may be the case that vegetation has negligible effects on coastal visibility, however, given that vegetation can substantially reduce human views of freshwater (McDougall et al., 2020b) it is imperative that future studies attempting to quantify freshwater visibility account for vegetation. Quantifying freshwater visibility in non-residential settings such places of work or education is needed in order to provide a more realistic representation of total freshwater exposure. Determining freshwater visibility throughout one's daily activities could be assisted by innovative approaches such as analysing street view imagery (Helbich et al., 2019) or utilising camera-based methods (Pearson et al., 2017).

2.3.4 Self-reported access and exposure

Self-reported methods provide insight into actual blue space usage and engagement, which cannot be achieved using objective measures of access and exposure alone, such as understanding the importance of certain freshwater blue space features in facilitating health outcomes (de Bell et al., 2017). Such methods can be useful for understanding relationships between different types of freshwater blue space and health, which are often difficult to consider due to a lack of available data (Mavoa et al., 2019). Self-reported methods also provide an understanding of blue space exposure in non-residential contexts and allow for multiple types of exposure to be considered. The latter can include: (i) indirect exposure, e.g. views of blue space from the residence; (ii) incidental exposure, e.g. contact with a blue space during daily life activities such as commuting; and (iii) intentional exposure, e.g. deliberately visiting a blue space (Garrett et al., 2019a). While self-reported methods offer a number of interesting research opportunities, these methods have some limitations. Attaining a representative sample of a study area or study population can be challenging (Völker et al., 2018; Garrett et al., 2019a). To date, studies using self-reported methods have been relatively limited in their sample size in comparison to studies that use objective quantifications of access and exposure (i.e. Alcock et al., 2015; Pasanen et al., 2019). As self-reported methods often rely on respondents to identify the presence of blue space and quantify exposure to these spaces, there is some scope for human error and subjectivity, which may introduce bias and limit comparability among studies.

2.4 Recommendations for future research

Research concerned with blue space and health has largely focused on coastal environments. Freshwater blue space has received substantially less research attention and consequently, there are significant gaps in our understanding of the health-promoting capabilities of these spaces. In order to fully understand the role of blue space as a public health resource a concerted effort is required for greater and more nuanced consideration of freshwater blue space in future research. Thus, a suite of research recommendations have been identified that, when taken together, offer opportunities to advance current understanding and better integrate freshwater blue space into the wider blue-health research agenda (Table 2.2). Primarily, there is a need to: (i) establish a methodological framework for freshwater blue-health research; (ii) broaden and advance the current freshwater blue-health empirical evidence base; and (iii) promote and sustain opportunities for freshwater blue-health.

Table 2.2. Overview of key research recommendations.

Establishing a methodological framework	Advancing the blue-health evidence base	Promoting freshwater blue-health opportunities
Define the spatial dimensions of freshwater blue space considered in research	Broaden research landscape to consider diverse climatic and human geographies	Develop communication pathways between research and public health professionals
Establish standardised metrics for quantifying access and exposure	Further empirical research with focus on general health	Provide blue-health focused guidance for managing freshwater sites
Report results for freshwater and coastal blue space exposure independently	Prioritise longitudinal research to establish causation	Understand barriers of accessing freshwater blue space
Adopt multiscale approaches to quantify access and exposure	Utilise big data from social media or activity tracking applications	Explore wider socio-economic consequences of blue-health strategies

2.4.1 Developing methodological framework for freshwater blue-health research

Establishing a methodological framework to underpin future research that accounts for the unique characteristics of human-freshwater interactions is a precursor to a better understanding of the relationship between freshwater blue space access and exposure and population health. Such a framework, promoting scale-appropriate and empirically tested methods, can complement conceptual research on the salutogenic benefits of freshwater conducted by Völker and Kistemann (2011) and begin to integrate freshwater blue-health evidence into the public health and landscape planning discourse.

Opportunities for evidence synthesis and meta-analyses can be increased by clearly defining the spatial dimensions of freshwater blue space and the freshwater typologies considered within each study. By testing and reporting exposure to freshwater and coastal blue space, there is an opportunity not only to better understand the relationship between exposure and access to freshwater blue space and health, but to also understand the strength of this relationship relative to coastal blue space, which is a crucial research need (Pasanen et al., 2019). This is currently hindered by a lack of consensus on the most suitable approach to quantify access and exposure in the freshwater blue-health literature. Establishing multiple standardised metrics for quantifying access and exposure is recommended; however, these should be grounded in empirical evidence and allow for a variety of research questions to be tested. Such methods should not only account for the quantity of freshwater, but also consider varying quantities of waterside space, which is essential for understanding many freshwater blue space interactions.

Developing exposure and accessibility metrics that are able to account for freshwater blue spaces of varying scale, quality and perceived importance within the same study area is a significant challenge. One option is to identify freshwater blue spaces that may have particular value or health-promoting potential and ensure these spaces are analysed independently, as demonstrated by Pearson et al. (2017) for the 'Great Lakes'. Multiscale approaches that use multiple methods to quantify accessibility and exposure have been proposed for green and blue space (Labib et al., 2020) and such approaches are likely to help to account for the varying scale and unique spatial characteristics of freshwater.

2.4.2 Broadening and advancing the freshwater blue-health evidence base

The ecosystem services offered by freshwater blue spaces vary substantially based on climatic and social contexts (Sterner et al., 2020). However, freshwater and coastal blue space research is predominantly carried out in developed industrialised countries (Gascon et al., 2017). Despite recent studies in developed areas of Asia (Garrett et al., 2019a; Helbich et al., 2019), further work is required to examine the effects of access and exposure to freshwater blue space in more diverse geographies in order to globalise the evidence base. Underrepresented human geographies that merit further study include areas where freshwater has deep cultural and religious significance e.g. the Ganges River catchment (Sharma et al., 2019), and low-income countries, where research has been sparse. An improved knowledge of freshwater blue-health in diverse physical geographies such as areas where freshwaters regularly freeze, are visibly contaminated with, for example, plastics or where water quality is generally unsafe for recreation will further advance the evidence base. Furthermore, research focusing specifically on access and exposure to estuaries, where freshwater and marine environments merge, and unique lakes that share oceanic characteristics, such as size, expansive views (e.g. Lake Malawi, Malawi and Lake Michigan, USA) and salinity (e.g. Great Salt Lake, USA and Lake Urmia, Iran) offers potential to expand current knowledge of both freshwater and coastal blue-health and understand better the overlapping conceptual space that arises from classifying blue space as two distinct categories.

With a limited number of studies having investigated the relationship between access and exposure to freshwater blue space and health, there is clearly a need for more empirical research. Randomised control trial experiments, such as clinical trials of blue space exposure can be particularly valuable for advancing current understanding of freshwater blue-health, but are costly to implement (Frumkin et al., 2017). Natural experiments (also known as quasi-experimental approaches), in which circumstances suitable for experimentation occur without researcher influence, such as observing physical activity levels prior to and after the regeneration of an urban riverside setting (Vert et al., 2019), offer a cost-effective alternative to randomised control trial experiments. If well-designed, natural experiments can be highly effective for eliminating self-selection bias and understanding causation (Greenstone and Gayer, 2009), although such research is often subject to significant logistical challenges (Frumkin et al., 2017).

Population health studies focusing on general health outcomes are particularly sparse relative to mental health research and merit greater consideration in future research. Longitudinal study design should be prioritised (Gascon et al., 2017) as longitudinal research can allow causation to be established and negates issues of self-selection, which is often present with cross sectional study designs (de Keijzer et al., 2016). Cross sectional studies would be improved by operating within an established framework of methods as outlined above, negating issues of self-selection by adopting residential sorting approaches to model neighbourhood demand for blue space (Klaiber and Phaneuf, 2010) and integrating data on blue space quality.

By establishing an understanding of how frequency and duration of freshwater blue space exposure and the type of activity carried out in or around blue space relate to health outcomes, there are opportunities to quantitatively understand dose-response relationships (Shanahan et al., 2015; White et al., 2019). Understanding the so called, 'dosage' of nature that is required in order to return tangible health benefits is a key objective of the wider nature-health research agenda (Frumkin et al., 2017); however, very little is known about dosage in a freshwater blue space context. Furthermore, an improved understanding of the relationship between specific health pathways and different physical and mental health outcomes and the strength of these relationships relative to green space and coastal blue space is required. Such research can be supported, for example, by structural equation modelling, which has proved to be a particularly effective methodology for quantifying the role of different pathways in supporting positive health outcomes as a result of exposure to natural environments (Dzhambov et al., 2018; Yang et al., 2020).

A number of novel research opportunities have become available through emerging technology. The use of virtual reality technology can advance experimental research by simulating a variety of senses at freshwater blue spaces, which may be particularly useful for comparing the blue-health opportunities offered by different freshwater typologies and building upon environmental psychology research that utilised static images of water (e.g., Herzog, 1985 and White et al., 2010). Furthermore, the exploitation of Big Data may provide useful avenues for research. The use of global positioning system (GPS) data that can be acquired from fitness wearables and activity tracking applications (e.g., Strava) may also provide new insight for understanding physical activity levels surrounding freshwater blue space. Such methods can deliver accurate high resolution data on actual exposure to complement high resolution spatial data which is used to infer exposure, but falls short of understanding how people engage with nearby blue space. Furthermore, natural language processing of text from social media posts, e.g., Flickr, represents a novel approach for understanding how freshwater blue spaces are used and valued among populations (Figueroa-Alfaro and Tang, 2017; Gosal et al., 2019).

2.4.3 Promoting freshwater blue-health opportunities

In addition to growing the freshwater blue-health evidence base, there is a parallel need to communicate these findings to policymakers and the general public effectively. Establishing communication pathways between research and public health professionals is useful for exploring opportunities to integrate freshwater blue-health into ongoing public health strategies. A clear priority for research is to provide guidance on managing, conserving and in some cases developing freshwater blue spaces in order to fully exploit their health-promoting capacity. However, this cannot be achieved without a detailed understanding of how different characteristics and types of freshwater blue space interact with health and well-being. Policymakers may benefit from the use of in-situ assessment tools such as BEAT, which provides a highly practical resource for evidence-based planning and management to maximise the health-promoting potential of freshwater blue spaces. Furthermore, a wealth of interdisciplinary research opportunities exist in order to complement the provision of freshwater blue-health benefits with synergistic outcomes. This would necessitate the consideration of economic, social and environmental issues to enable a more holistic approach to future decision-making that accounts for the diverse needs of freshwater ecosystems. In particular, the integration of environmental economics methods, such as stated and revealed preference approaches, can assist in understanding preferences among the general public and different water users on how best to manage these spaces (Hanley et al., 2019). Crucially, these approaches allow monetary values to be attached to policy decisions meaning the highest value investments in terms of positive health outcomes and cost-effectiveness can be assessed. However, economic valuation approaches may be unable to capture many qualitative elements of human-blue space interactions (Foley et al., 2019).

Longer-term research priorities should be framed around ensuring freshwater blue-health opportunities are available to all. Research to understand barriers of access to blue space and consequently, the provision of blue-health benefits is limited and may require a variety of qualitative approaches. Barriers to access may occur due to socio-economic factors such as housing status, which may lead to unfamiliarity with the amenities in an area (Haeffner et al., 2017) or more nuanced issues like fear of accessing waterside spaces due to an inability to swim (Pitt, 2019). The impact of swimming ability on perceived access to freshwater blue space may be a particularly useful area of study as socio-economic status could be a significant driver of swimming ability (Irwin et al., 2009; Pharr et al., 2018). Finally, exploring the wider socio-economic, and sometimes unintended, consequences of improving and managing freshwater blue spaces is of high importance. For example, access to water tends to increase house prices (Dahal et al., 2019) and consequently, increasing access to freshwater blue space may induce gentrification and the displacement of residents (Vert et al., 2019). The use of public participation geographic information systems (PPGIS) may be particularly useful in remediating these unintended consequences and developing inclusive freshwater blue-health strategies that can cater to the needs of a number of different water-users (Raymond et al., 2016).

2.5 Conclusion

There is emerging evidence that access and exposure to freshwater blue space can provide health and well-being benefits. However, despite growing evidence, freshwater remains underrepresented in blue-health research. More in-depth understanding of the relationships between population health and freshwater blue space requires moving beyond traditional disciplinary collaborations and approaches. While environmental science and health research agendas have aligned in the past, our understanding of freshwater blue spaces and health and well-being interactions is often partial, or conflicting. This stems from the frequent failure of research to span traditional disciplinary boundaries in order to fully integrate disciplinary paradigms, e.g., due to philosophical, methodological and communication barriers. Moving forward, researchers across multiple and diverse fields face the challenge of refining the empirical methods used to quantify access and exposure to freshwater blue space and addressing a number of conceptual issues in current freshwater blue-health thinking. The evidence base supporting the health and well-being benefits of exposure to freshwater requires further empirical testing and future interdisciplinary research should seek to fully understand the potential of freshwater blue space as a public health resource.

Chapter 3 - Neighbourhood blue space and mental health: A nationwide ecological study of antidepressant medication prescribed to older adults

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Author Contributions: CW. McDougall conceptualised the rationale and designed the methodology of this manuscript, acquired the data, carried out the geospatial and statistical analysis and wrote the manuscript. PJ. Bartie provided recommendations on the geospatial analysis. T. Robertson provided specific supervision related to social epidemiology. RS. Quilliam, N. Hanley, M. Griffiths and DM. Oliver acquired the funding, provided general supervision and suggested improvements to the manuscript.

Abstract

As global populations age rapidly, older adult mental health is becoming an increasingly important public health issue. The consequences of poor mental health in later life are severe and include reduced physical and cognitive functioning and greater risk of morbidity and mortality. Neighbourhood characteristics, such as the presence of aquatic environments - or ‘blue spaces’ - can positively impact mental health. However, evidence supporting the potential of neighbourhood blue space to promote mental health among older adults remains tentative. This study used negative binomial regression modelling to quantify the association between multiple metrics of neighbourhood blue space availability and antidepressant medication prevalence among older adults in Scotland. The study combined nationwide antidepressant prescription data for over two million older adults and geospatial data of blue space availability for over six thousand neighbourhoods and adjusted for a range of demographic and socioeconomic covariates. The availability of both freshwater and coastal blue space was associated with lower antidepressant medication prevalence among older adults in Scotland. Specifically, high neighbourhood freshwater coverage (>3%) ($p < 0.001$) and residing in close proximity (<1km) to the coast ($p < 0.001$) and large freshwater lakes ($p < 0.05$) was associated with lower antidepressant medication prevalence. Our findings also suggest that neighbourhood blue space availability may have a greater impact on antidepressant medication prevalence among older adults than neighbourhood green space availability. Freshwater and coastal blue space, therefore, merit greater consideration in public health and urban planning policy and in the design of environments that aim to promote mental health and healthy aging.

3.1 Introduction

Globally, almost one in three adults (29%) will experience a common mental disorder, such as depression, at some point in their lifetime (Steel et al., 2014). Older adult mental health is becoming an increasingly important public health concern as global populations age rapidly (United Nations, 2019). The consequences of mental ill-health in older adulthood are severe and include reduced physical and cognitive functioning, lower quality of life and greater risk of dementia, morbidity and mortality (Fiske et al., 2009, Blazer, 2003, Wu et al., 2020). Despite this, older adults are often overlooked in mental health research (Villagrasa et al., 2019).

The environments or neighbourhoods where individuals live have been shown to affect both physical and mental health (Duncan and Kawachi, 2018, Dempsey et al., 2018, Aerts et al., 2020). Neighbourhood environments may be particularly important for the health and well-being of older adults, as reductions in mobility and lifestyle changes in older age can increase time spent in the neighbourhood and result in greater reliance on neighbourhood resources (Glass and Balfour, 2003, Yen et al., 2009, Barnett et al., 2020). Neighbourhoods that encourage and facilitate contact with nature and the multiple ecosystem services offered by the natural environment may be highly suited to promoting mental health (Bratman et al., 2019, Frumkin et al., 2017). Indeed, positive mental health outcomes have been reported as a result of living in greener neighbourhoods (Beyer et al., 2014, Gascon et al., 2015) and neighbourhoods with more accessible public green spaces (Wood et al., 2017, Nutsford et al., 2013). Greater neighbourhood green space availability has also been associated with improved mental health for older adults specifically (Astell-Burt et al.,, 2013).

Neighbourhoods that support interactions with water bodies or ‘blue spaces’ may also provide benefits for mental health (Gascon et al., 2017, Völker and Kistemann, 2011, White et al., 2020: Foley and Kistemann, 2015). Blue spaces are frequently defined as ‘outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans’ (Grellier et al., 2017). A systematic review of 36 studies, 12 focusing specifically on mental health, found limited evidence supporting a positive influence of blue space exposure on mental health (Gascon et al., 2017). However, a number of more recent studies have highlighted significant associations between access and exposure to neighbourhood blue space and positive mental health outcomes (Vert et al., 2020, Pasanen et al., 2019, Pearson et al., 2019), although such a relationship is not always observed (Gascon et al., 2018, Dzhambov et al., 2018).

There is a small but growing body of evidence demonstrating the potential mental health benefits of engaging with blue space in later life. Interacting with blue space regularly can promote emotional well-being during ageing (Coleman and Kearns, 2015) and provide restorative psychological effects and a sense of relaxation for older adults (Finlay et al., 2015). Older adults who regularly visit blue space report higher subjective well-being than older adults who never visit blue space (Garrett, et al., 2019a). Older adults who live in residences with coastal views exhibit reduced symptoms of depression (Dempsey et al., 2018), whilst older adults living in neighbourhoods with higher freshwater availability (Chen and Yuan, 2020) and streets with visible blue space (Helbich et al., 2019) report more positive mental health outcomes. Despite this growing evidence base, research exploring the mental health promoting potential of blue space at different stages of older adulthood is lacking. Such research may be highly valuable given that mobility and accessibility related issues are common barriers to blue space usage in older adulthood (Pitt, 2018) and these barriers may increase with age (Yen et al., 2009).

Furthermore, some studies of blue space availability and older adult mental health focus solely on coastal (Dempsey et al., 2018) or freshwater environments (Chen and Yuan, 2020). In order to more fully understand the impact of neighbourhood blue space availability on older adult mental health, there is a growing need to independently quantify the potential for freshwater and coastal blue space to promote mental health and to contextualise these effects relative to each other and relative to a variety of other neighbourhood characteristics (McDougall et al., 2020a). The current evidence base would also be enhanced by establishing variations in the mental health-promoting potential of different freshwater blue space typologies. However, acquiring sufficient data to undertake this analysis remains a significant challenge (Mavoa et al., 2019). Indeed, studies of blue space availability and self-reported mental health can lack statistical power due to limited numbers within the sample living in close proximity to blue space (Triguero-Mas et al., 2015).

The use of objective health data, such as prescription or hospitalisation data, is becoming an increasingly popular method for quantifying the health and well-being effects of different neighbourhood characteristics, including blue and green space availability (Aerts et al., 2020, Pearson et al., 2019, Gidlow et al., 2016, Tarkiainen et al., 2020). Antidepressant medication is regularly prescribed in the treatment of common mental disorders (NHS Scotland, 2018) and small-area antidepressant prescription prevalence can, therefore, provide a useful indicator for ecological health research (Helbich et al., 2018). In a nationwide study of adults aged 15–65 in England, Gidlow et al. (2016) did not observe a significant association between antidepressant prescription volumes and the availability of blue and green space. Conversely, greater tree density (Taylor et al., 2015) and greater quantities of green space (Helbich et al., 2018) in residential areas in England and the Netherlands have been associated with lower antidepressant prescription rates. By providing large sample sizes and nationwide spatial coverage, antidepressant prescription data may be well suited to addressing knowledge gaps related to neighbourhood blue space availability and older adult mental health.

The aim of this study was to quantify the association between neighbourhood blue space availability and antidepressant medication prevalence for older adults in Scotland. The specific objectives were to: (i) quantify the effect of neighbourhood freshwater and coastal blue space availability on antidepressant medication prevalence among older adults; (ii) compare the effects of neighbourhood blue space availability on antidepressant medication prevalence between two older adult age categories (50–64 year-olds and > 65 year-olds); and (iii) contextualise the effects of different metrics of neighbourhood blue space availability on antidepressant medication prevalence relative to green space availability and a range of other demographic and socioeconomic neighbourhood characteristics.

3.2 Methodology

3.2.1 Study overview

This study adopted a nationwide cross-sectional ecological approach using a variety of 'small-area' statistics for Scotland. Data Zones (DZs) are the census geography and primary geographic unit for the dissemination of small-area statistics in Scotland (n = 6976). DZs are composed of approximately 500 to 1000 individuals. Antidepressant medication data for older adults was obtained for each DZ and analysed using zero-truncated negative binomial regression models to explore associations with metrics of blue and green space availability and a variety of socioeconomic and demographic covariates.

3.2.2 Study population

To identify potential differences in the effect of neighbourhood blue space availability on mental health at different stages of older adulthood, two older adult age categories (50–64-year-old and > 65-year-old) were analysed separately. Older adults are often categorised as individuals above the age of 60 for research purposes (Wolitzky-Tayloret al., 2010). However, a wider definition was adopted given the need to understand the impact of blue space availability on mental health along the spectrum of older adulthood and in facilitating healthy aging (Finlay et al., 2015). The > 50-year-old threshold also coincides with previous blue space and health research (de Keijzer et al., 2019, Garrett et al., 2019a).

3.2.3 Antidepressant prescription data

Healthcare in Scotland is primarily provided via the National Health Service (NHS) which offers a variety of health services and medication freely at the point of delivery to patients. The number of 50–64-year-old and > 65-year-old individuals in each DZ that were prescribed at least one unit of antidepressant medication between 1st January and 31st December 2019 were the dependent variables in this study. Data was obtained from the Prescribing Information System for Scotland (PRISMS) and provided by Public Health Scotland. PRISMS holds data on NHS medication prescribed and dispensed in the community in Scotland and has a 98.8% capture rate for antidepressant medication (NHS Scotland, 2018). Antidepressant medication was identified using British National Formulary (BNF) section 4.3, which includes; (4.3.1) tricyclic and related antidepressant drugs; (4.3.2) monoamine-oxidase inhibitors; (4.3.3) selective serotonin re-uptake inhibitors; and (4.3.4) other antidepressant drugs.

3.2.4 Neighbourhood natural environment availability

Neighbourhoods are regularly defined using Geographic Information Systems (GIS) by creating circular buffers surrounding the central point of an administrative zone, such as DZs or census tracts, or around an individual's residence (Labib et al., 2020). Multiple buffer sizes are often adopted in neighbourhood-health research (Duncan et al., 2018), but there remains little consensus on the most appropriate buffer size for quantifying blue space availability (Gascon et al., 2017). In this study, immediate and wider neighbourhood boundaries were represented by buffers around the most densely populated point, or population-weighted centroid (PWC), of each DZ (Fig. 3.1.). The immediate neighbourhood was defined as a circular buffer with a radius of 800 m (Jansen et al., 2018) which is approximately indicative of ten-minutes walking time (Dalton et al., 2013) and the wider neighbourhood was defined using a 1600 m buffer (Mavoa et al., 2019).

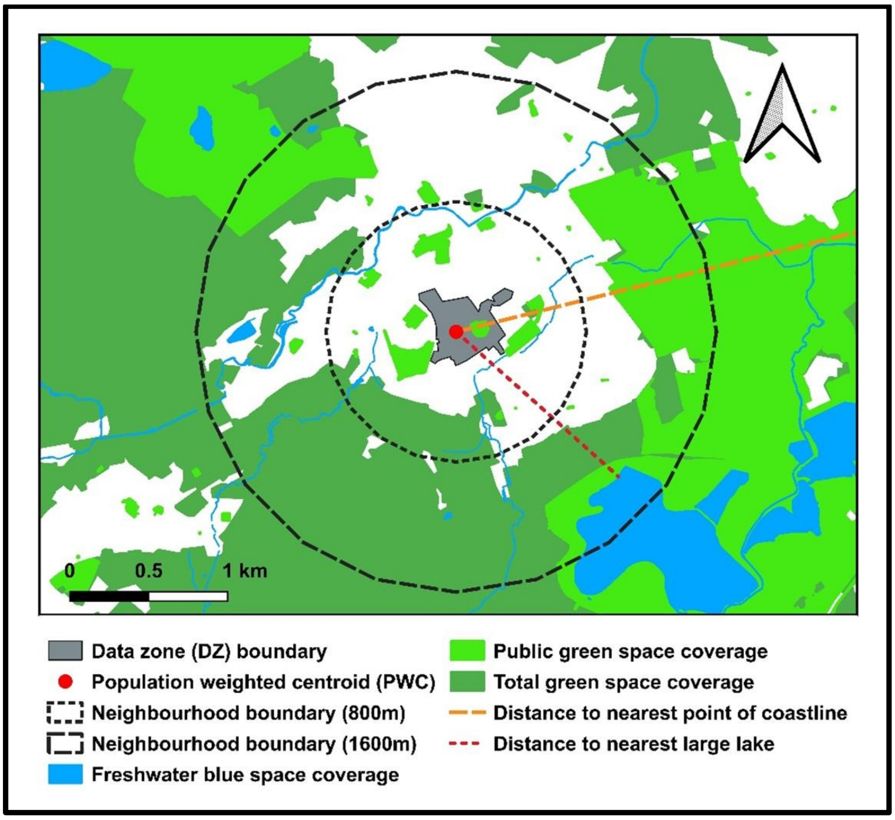

Figure 3.1. Immediate (800 m) and wider (1600 m) neighbourhood boundaries and metrics of blue and green space availability.

3.2.4.1 Freshwater blue space

Following previous studies, neighbourhood freshwater coverage was calculated as a metric of freshwater blue space availability (Chen and Yuan, 2020, de Vries et al., 2016). Freshwater coverage was derived from the Ordnance Survey (OS) Open Map - Local dataset (Ordnance Survey, 2020a) and calculated as a percentage of surface area coverage in the immediate and wider neighbourhoods for each DZ. Previous research has analysed the presence vs absence of freshwater blue space (Pasanen et al., 2019), whilst other studies have categorised freshwater blue space coverage categorically (e.g. Garrett et al., 2019b). Given the abundance of freshwater resources in Scotland (>30,000 lakes) and the availability of high-resolution spatial data, this study considered a spectrum of freshwater blue space coverage. Neighbourhood freshwater coverage was defined using five categories to aid interpretation: (1) 0–0.25% (reference category); (2) > 0.25–0.75%; (3) > 0.75–1.5%; (4) > 1.5–3%; and (5) > 3%.

3.2.4.2 Large freshwater lakes

Proximity to large freshwater lakes was considered as an independent factor, since emerging evidence suggests living in close proximity to such features may provide mental health benefits (Pearson et al., 2019). Large lakes were defined as those with a surface area > 0.5km^2 (50 ha), which includes approximately 350 of the largest freshwater lakes in Scotland. Proximity to large freshwater lakes was quantified by calculating the linear distance from the DZ PWC to the edge of the nearest large freshwater lake (Fig. 3.1.). Proximity was operationalised using five categories: (1) > 20km (reference category); (2) > 10 – 20km; (3) > 5 – 10km; (4) > 1 – 5km; and (5) < 1km. Distance categories were selected based upon an eighteen country study of blue space visitation patterns (Elliott et al., 2020) and extended to account for increased willingness to travel to large lakes in Scotland (McDougall et al., 2020b).

3.2.4.3 Coastal blue space

Coastal proximity was adopted as a metric of blue space availability as previous studies suggest that living in close proximity to the coast is associated with improved mental health among general populations (White et al., 2013, Pasanen et al., 2019) and older adults specifically (Dempsey et al., 2018). Proximity to the coast was quantified as the linear distance from the DZ PWC to the nearest point of coastline. Due to the absence of an established defining point between freshwater and coast, Wheeler et al. (2012) define the beginning of the English coastline when the width of an estuary exceeds 1km. However, given Scotland's fairly unique coastline, which encompasses multiple sea lochs (fjords) and wide inland river estuaries (e.g. the Firth of Forth), only estuaries with a width > 3km were classified as coastal. Coastal proximity was defined using five categories; (1) 0–1km; (2) > 1–5km; (3) > 5–20km; (4) > 20–40km; (5) > 40km (reference category) (Wheeler et al., 2012, Garrett et al., 2019b).

3.2.5 Covariates

3.2.5.1 Neighbourhood green space

The analysis adjusted for potential effects of green space coverage on the outcome variables, as greater green space coverage has previously been associated with lower antidepressant medication prevalence (Helbich et al., 2018, Taylor et al., 2015). Both total green space and public green space coverage were considered as the effects on mental health of exposure to each category can differ (Nutsford et al., 2013; Richardson and Mitchell, 2010). The OS Open Greenspace dataset (Ordnance Survey, 2020b) was used to identify the presence of public green space and included the following categories; allotments or community growing spaces, bowling greens, golf courses, other sports facilities, play spaces, playing fields and public parks. Public green space coverage was classified as the following; (1) 0–2.5% (reference category); (2) > 2.5–5%; (3) > 5–10%; (4) > 10–15%; and (5) > 15%. Data on total green space availability was derived from the Centre for Ecology & Hydrology (CEH) Land Cover Map 2015 (minimum mappable unit: 0.5 ha) (Rowland et al., 2017) and converted to a percentage of immediate and wider neighbourhood coverage. In accordance with Dalton et al., (2016) total green space was defined as locations in which the dominant land use category was broadleaved or coniferous woodland, arable land, improved grassland, semi-natural grassland, mountain, heath or bog. Total green space coverage was defined using five categories; (1) 0–20% (reference category); (2) > 20–40%; (3) > 40–60%; (4) > 60 – 80%; (5) > 80% (Pasanen et al., 2019, Garrett et al., 2019b).

3.2.5.2 Urbanicity

The analysis adjusted for potential differences in common mental health disorder prevalence (Zijlema et al., 2015, Helbich et al., 2018) and antidepressant usage (Tarkiainen et al., 2020) related to neighbourhood urbanicity. The urbanicity of each DZ was designated using the Scottish Government Urban Rural Classification, which defines urban and rural areas as settlements with populations >3,000 people and <3,000 people, respectively (Scottish Government, 2018).

2.2.5.3 Demographic covariates

The analysis adjusted for area-level gender differences between DZs as older females are more likely to suffer from common mental disorders (Wolitzky-Taylor et al., 2010, Kiely et al., 2019) and are more likely to receive antidepressant medication than older males (NHS Scotland, 2018). The percentage of females in each age category in each DZ was established using the Mid-2018 Small Area Population Estimates dataset, which provides population estimates by sex and age for small areas across Scotland (National Records of Scotland, 2019). Higher older adult mental health has been reported in neighbourhoods with a higher proportions of > 65-year-olds (Kubzansky et al., 2005). The proportion of adults above 65, which corresponds with current state pension age in Scotland, was calculated for each DZ to control for potential effects of DZ age composition on antidepressant medication prevalence.

2.2.5.4. Socioeconomic covariates

Neighbourhood socioeconomic characteristics have been found to impact older adult mental health (Yen et al., 2009). A variety of area-level socioeconomic indicators were derived from the 2020 release of the Scottish Index of Multiple Deprivation (SIMD) for each DZ. The proportion of income-deprived individuals was calculated for each DZ, as low socioeconomic status is a risk factor of common mental health disorders (Assari, 2017). Housing characteristics and living arrangements can also affect mental health and are particularly important to health and well-being for older adults (Howden-Chapman et al., 2011). The percentage of individuals in each DZ living in overcrowded housing was derived from the 2020 SIMD release. The analysis adjusted for crime rates as neighbourhood crime is a determinant of older adult mental health (Wilson-Genderson and Pruchno, 2013; Won et al., 2016). Higher neighbourhood crime rates have been associated with increased antidepressant medication prevalence in Scotland; however, this relationship is primarily attributed to the effects of crime on young and middle-aged adults (Baranyi et al., 2020). Crime rates for each DZ were extracted from the 2020 release of the SIMD. In instances where crime rate data was unavailable (n = 501), the crime rate from the nearest DZ was used.

Statistical and geospatial analyses were carried out in Stata (version 16.1) and QGIS (version 3.12 - București). Associations between antidepressant medication prevalence, metrics of blue space availability and potential covariates were analysed using zero-truncated negative binomial regression models due to the count nature of the dependent variable. Poisson models were rejected as overdispersal was present in the antidepressant medication data (Hilbe, 2011). Zero-truncation was required as data sensitivity restrictions disallowed antidepressant medication counts of zero in the dataset. The total population in the 50–64 and > 65 age brackets were included in the corresponding models as an offset variable (Mitchell and Popham, 2008, Wang and Tassinary, 2019). Associations between antidepressant medication prevalence and the explanatory variables were communicated using prevalence ratios (PR) (analogous to the risk ratio) and their respective confidence intervals (95% CI).

3.2.6 Statistical analysis

In total, four models were created which analysed associations between antidepressant medication prevalence and blue space availability for both age categories of older adults, using the immediate and wider neighbourhood definitions. The variables included in the modelling process and their hypothesised relationship with antidepressant medication prevalence are described in Table 3.1. Theoretical justification for the inclusion of each variable in the modelling process is provided in Section 3.2.4 Neighbourhood natural environmental availability and Section 3.2.5 Covariates. Inclusion of explanatory variables was reinforced by evaluating model performance using the Akaike information criterion (AIC) and Bayesian information criterion (BIC). Variance inflation factors (VIF) were analysed during the development of the final models to test for multicollinearity among variables.

Table 3.1. Description of variables used in the modelling process and hypothesised relationship with antidepressant medication prevalence.

Variable (expected direction of relationship)	Description
Antidepressant medication	Number of 50–64-year-old and > 65-year-old individuals within a DZ prescribed antidepressant medication in 2019.
Freshwater BS coverage (-)	Surface area of freshwater within neighbourhood.0–0.25% (ref); >0.25–0.75%; >0.75–1.5%; >1.5–3%; >3%
Distance to large lake (-)	Distance from neighbourhood PWC to large lake edge.>20km (ref); >10 – 20km; >5 – 10km; >1 – 5km; <1km
Distance to coast (-)	Distance from neighbourhood PWC to coastline.>40km (ref); >20 – 40km; >5 – 20km; >1 – 5km; <1km
Public GS coverage (-)	Surface area of public green space within neighbourhood.0–2.5% (ref); >2.5–5%; >5–10%; >10–15%; >15%
Total GS coverage (-)	Surface area of total green space within neighbourhood.0–20% (ref); >20–40%; >40–60%; >60–80%; >80%

Variable (expected direction of relationship)	Description
Urbanicity (-)	Urbanicity of DZ. Urban (ref); rural
Proportion female (+)	Number of females in age category as a percentage of the total age group population.
Proportion state pension (-)	Percentage of DZ population above state pension age (>65).
Proportion low income (+)	Percentage of DZ population classified as income deprived.
Proportion overcrowded (+)	Percentage of DZ population living in overcrowded housing.
Crime rate (+)	DZ crime rate based on number of crimes per 1,000 people.

3.3 Results

3.3.1 Descriptive statistics

Data protection required DZs with less than ten individuals being prescribed antidepressant medication in either age category to be excluded from the analysis. For the 50–64-year-old age category 6,891 DZs were included in the final analysis and 85 (1.2%) were removed. For the > 65-year-old age category 6,567 DZs were included in the final analysis and 409 (5.9%) were removed. The majority of removed DZs were in the lowest decile of population count for 50–64-year-olds (81.8%) and > 65-year-olds (88.1%). Given that missing antidepressant medication counts were, therefore, likely to be driven by low population in the relevant age category, rather than particularly low antidepressant medication prevalence, it was deemed appropriate to remove these DZs from further analysis.

Table 3.2. Summary statistics for DZs used in the analysis of each older adult age category.

Variable	**DZ mean 50–64 (n = 6891)**	**Std. Dev. 50–64**	**DZ mean 65+ (n = 6567)**	**Std. Dev. 65+**
Antidepressant medication count	41.16	16.16	35.67	17.03
Freshwater BS coverage (800 m) (%)	2.13	5.53	2.14	5.60
Freshwater BS coverage (1600 m) (%)	0.53	1.38	0.54	1.40
Distance to large lake (km)	11.32	7.46	11.34	7.54
Distance to coast (km)	20.03	16.30	20.08	16.31
Public GS coverage (800 m) (%)	7.51	7.61	7.48	7.56
Public GS coverage (1600 m) (%)	7.65	6.58	7.61	6.57
Total GS coverage (800 m) (%)	36.59	27.16	37.12	27.15
Total GS coverage (1600 m) (%)	46.90	27.44	47.61	27.27
Proportion age group female (%)	51.50	4.75	55.03	4.90
Proportion state pension (%)	19.53	7.74	20.17	7.35
Proportion low income (%)	12.39	9.61	12.52	9.57
Proportion overcrowded (%)	10.80	7.65	10.52	7.17
Crime rate (per 1000)	29.44	34.52	28.80	30.00

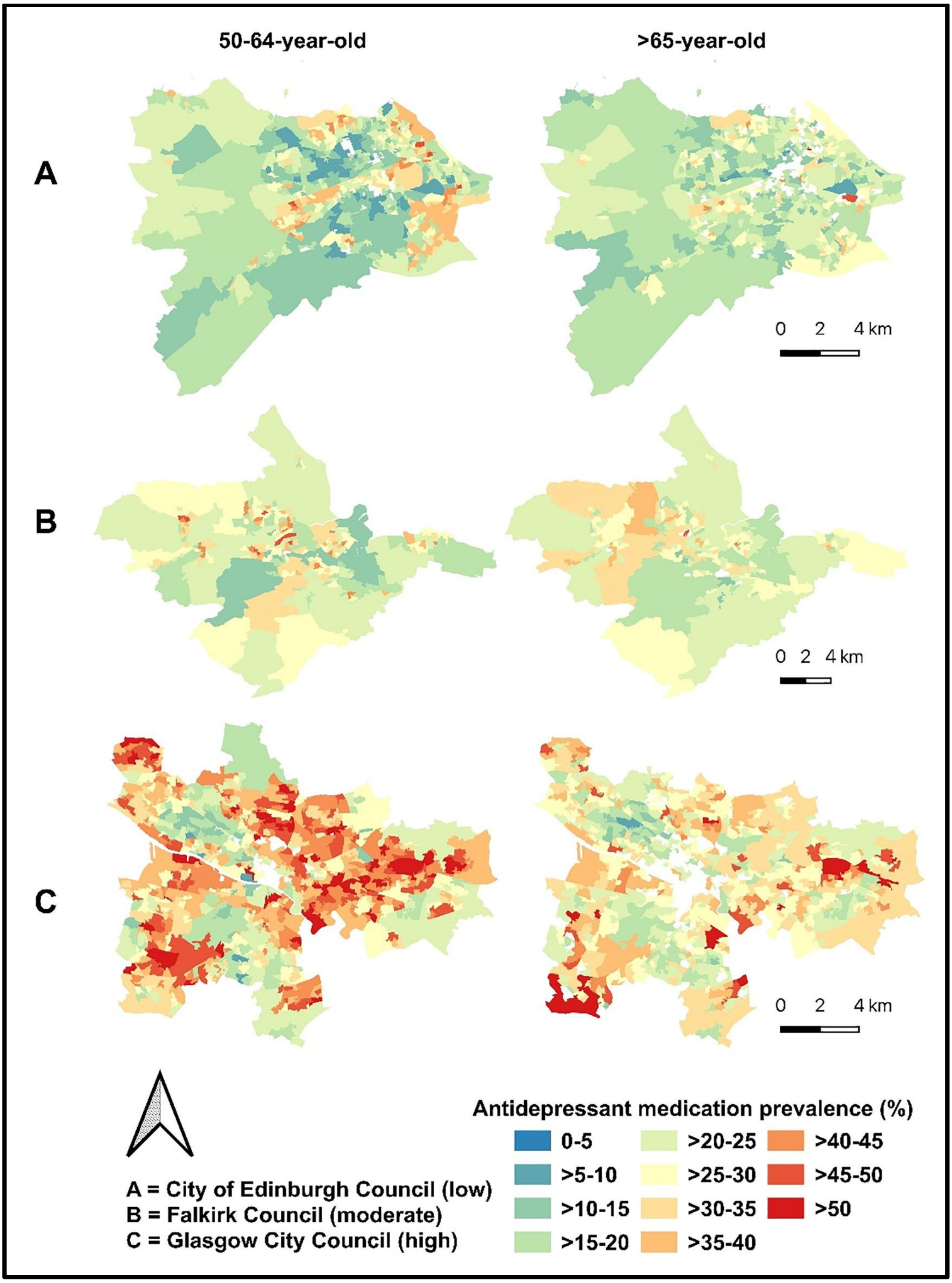

Figure 3.2. Comparison of low (City of Edinburgh), moderate (Falkirk) and high (Glasgow City) antidepressant medication prevalence across council areas and age categories.

In total, data of 2,128,997 older adults were included in the final analysis, of which 517,856 (24.3%) received at least one unit of antidepressant medication in 2019. Table 3.2 displays descriptive statistics for all variables used in the modelling process for both age categories. On average the count of individuals in each age category in each DZ who received antidepressant medication was 41.16 for 50–64-year-olds and 35.67 for > 65-year-olds. When considered as proportion of the respective DZ population, antidepressant medication prevalence was higher among 50–64-year-olds (26.04%) than > 65-year-olds (23.72%). Fig. 3.2 compares three council areas (regional authorities) in Scotland that are representative of low (City of Edinburgh), moderate (Falkirk) and high (City of Glasgow) antidepressant medication prevalence. In the DZs considered in the 50–64-year-old analysis, mean freshwater blue space coverage was 2.13% in the immediate neighbourhood and 0.53% in the wider neighbourhood. On average DZs considered in the 50–64-year-old analysis were 11.32km from a large lake and 20.03km from the coast. Metrics of blue space availability in DZs used in the > 65-year-old analysis displayed virtually identical values (Table 3.2).

3.3.2 Antidepressant medication prevalence (50–64-year-olds)

The results of the regression analysis suggest all metrics of blue space availability were associated with lower antidepressant medication prevalence among 50–64-year-olds after controlling for potential demographic and socioeconomic confounders, with all results presented below including control for these confounders. A significant negative association was observed between high freshwater blue space coverage (>3%) and antidepressant medication prevalence in the immediate (Table 3.3) and wider neighbourhood models (Table 3.4). DZs with high freshwater blue space coverage in the immediate neighbourhood were significantly ($p < 0.001$) associated with 3.5% (PR = 0.9649, 95% CI 0.9498–0.9803) lower antidepressant medication prevalence than DZs with low freshwater blue space coverage (0–0.25%). In the wider neighbourhood model high freshwater blue space coverage was significantly ($p < 0.001$) associated with lower antidepressant medication prevalence by 5.5% (PR = 0.9421, 95% CI 0.9171–0.9678). Moderate freshwater blue space coverage (>1.5–3%) in immediate neighbourhood was associated with a 1.2% (PR = 0.9808, 95% CI 0.9648–0.9971) reduction in antidepressant medication prevalence (p = 0.021); however, no significant relationship was observed in the wider neighbourhood model.

DZs within 20km of a large lake exhibited lower antidepressant medication prevalence in both the immediate and wider neighbourhood models. Based upon the immediate neighbourhood model, DZs within 1km (p = 0.021) and 1 – 5km (p = 0.003) of large lakes were significantly associated with 5.8% (PR = 0.9710, 95% CI 0.8947–0.9911) and 2.9% (PR = 0.9710, 95% CI 0.9522–0.9901) lower antidepressant medication prevalence, respectively, than DZs > 20km from large lakes. Living between 10km and 20km (p < 0.001) and between 5km and 10km from large lakes (p = 0.004) was also associated with lower antidepressant medication prevalence relative to DZs > 20km from large lakes. A similar relationship was observed for DZs within close proximity to the coast, although this was highly significant for all proximity categories (p < 0.001) and smaller confidence interval values were observed. Based on the immediate neighbourhood model, DZs within 1km and > 1km – 5km of the coast reported reduced antidepressant medication prevalence by 4.5% (PR = 0.9508, 95% CI 0.9361–0.9747) and 5% (PR = 0.9508, 95% CI 0.9334–0.9685), respectively, relative to DZs > 40km from the coast.

Mixed relationships were observed between neighbourhood green space coverage and antidepressant medication prevalence. In both the immediate and wider neighbourhood models, high public green space coverage (>15%) was significantly (p < 0.001) associated with lower prevalence of antidepressant medication among 50–64-year-olds. However, these values differed substantially between neighbourhood definitions. High public green space coverage in the immediate neighbourhood was associated with a 3.25% (PR = 0.9675, 95% CI 0.9509–0.9844) reduction in antidepressant medication prevalence, whilst public green space coverage in the wider neighbourhood was associated with a 6.2% (PR = 0.9383, 95% CI 0.9188–0.9582) reduction. Increasing total green space coverage in both the immediate and wider neighbourhood was positively associated with antidepressant medication prevalence, relative to low total neighbourhood green space coverage (0–20%). In the wider neighbourhood model all total green space categories were positively associated with antidepressant medication prevalence (p < 0.001). A similar relationship was observed for total green space coverage in the immediate neighbourhood model, with the exception of high green space coverage (>80%), which was associated with a 2.3% (PR = 0.9726, 95% CI 0.9441–1.0018) reduction in antidepressant medication prevalence. However, this was result was not significant at the 95% level (p = 0.066).

In both the immediate and wider neighbourhood models, all covariates (excluding crime rate and proportion of adults above state pension age) were highly significantly (p < 0.001) associated with antidepressant medication prevalence among 50–64-year-olds in the hypothesized direction proposed in Table 3.2. Based on the immediate neighbourhood model, 4.5% (PR = 0.9555, 95% CI 0.9347–0.9768) lower antidepressant medication prevalence was observed in rural DZs compared to urban DZs (p < 0.001). The immediate neighbourhood model also suggests that a 1% increase in the percentage of income deprived adults in a DZ was associated with a 2.5% (PR = 1.0244, 95% CI 1.0236–1.0251) increase in antidepressant medication prevalence among 50–64-year-olds (p < 0.001).

Table 3.3. Immediate neighbourhood determinants of antidepressant medication prevalence (50–64-year-old) displayed as prevalence ratios (PRs).

50–64 (immediate neighbourhood)	**PR**	**p value**	**95% CI**
Freshwater BS coverage			
0–0.25% **(ref) (low coverage)**	1.0000	.	.
>0.25–0.75%	0.9941	0.391	0.9807–1.0077
>0.75–1.5%	0.9914	0.265	0.9765–1.0066
>1.5–3%	0.9808	0.021	0.9648–0.9971
>3% **(high coverage)**	0.9649	<0.001	0.9498–0.9803
Distance to large lake			
>20km **(ref)**	1.0000	.	.
>10–20km	0.9523	<0.001	0.9364–0.9685
>5–10km	0.9750	0.004	0.9582–0.9920
>1–5km	0.9710	0.003	0.9522–0.9901
<1km	0.9417	0.021	0.8947–0.9911
Distance to coast			

50–64 (immediate neighbourhood)	**PR**	**p value**	**95% CI**
>40km **(ref)**	1.0000	.	.
>20–40km	0.9832	0.027	0.9686–0.9981
>5–20km	0.9797	0.011	0.9644–0.9953
>1–5km	0.9508	<0.001	0.9334–0.9685
<1km	0.9552	<0.001	0.9361–0.9747
Public GS coverage			
0–2.5% **(ref) (low coverage)**	1.0000	.	.
>2.5–5%	0.9958	0.608	0.9800–1.0119
>5–10%	0.9941	0.446	0.9792–1.0093
>10–15%	1.0045	0.619	0.9868–1.0225
>15% **(high coverage)**	0.9675	<0.001	0.9509–0.9844
Total GS coverage			
0–20% **(ref) (low coverage)**	1.0000	.	.
>20–40%	1.0267	<0.001	1.0127–1.0409
>40–60%	1.0220	0.004	1.0068–1.0374
>60–80%	1.0412	<0.001	1.0192–1.0637
>80% **(high coverage)**	0.9726	0.066	0.9441–1.0018
Urban	0.9555	<0.001	0.9347–0.9768
Proportion female (%)	1.0074	<0.001	1.0063–1.0085
Proportion state pension (%)	0.9988	0.002	0.9981–0.9996
Proportion low income (%)	1.0244	<0.001	1.0236–1.0251
Proportion living overcrowded (%)	1.0081	<0.001	1.0071–1.0092
Crime rate	0.9998	0.011	0.9996–0.9999
Constant	0.1276	<0.001	0.1196–0.1362
Observations	6891		
Pseudo R^2	0.1351		

Table 3.4. Wider neighbourhood determinants of antidepressant medication prevalence (50–64-year-old) displayed as prevalence ratios (PRs).

50–64 (wider neighbourhood)	**PR**	**p value**	**95% CI**
Freshwater BS coverage			
0–0.25% **(ref) (low coverage)**	1.0000	.	.
>0.25–0.75%	0.9914	0.168	0.9792–1.0037
>0.75–1.5%	0.9804	0.055	0.9608–1.0004
>1.5–3%	0.9770	0.097	0.9505–1.0042
>3% **(high coverage)**	0.9421	<0.001	0.9171–0.9678
Distance to large lake			
>20km **(ref)**	1.0000	.	.
>10–20km	0.9508	<0.001	0.9350–0.9670
>5–10km	0.9744	0.003	0.9575–0.9915
>1–5km	0.9666	<0.001	0.9478–0.9858
<1km	0.9528	0.065	0.9052–1.0030
Distance to coast			
>40km **(ref)**	1.0000	.	.
>20–40km	0.9859	0.063	0.9713–1.0008
>5–20km	0.9839	0.045	0.9684–0.9996
>1–5km	0.9558	<0.001	0.9382–0.9737
<1km	0.9592	<0.001	0.9394–0.9794
Public GS coverage			
0–2.5% **(ref) (low coverage)**	1.0000	.	.
>2.5–5%	1.0041	0.648	0.9865–1.0221
>5–10%	0.9923	0.366	0.9759–1.0090
>10–15%	0.9861	0.158	0.9672–1.0054
>15% **(high coverage)**	0.9383	<0.001	0.9188–0.9582
Total GS coverage			
0–20% **(ref) (low coverage)**	1.0000	.	.
>20–40%	1.0471	<0.001	1.0306–1.0640

50–64 (wider neighbourhood)	PR	p value	95% CI
>40–60%	1.0518	<0.001	1.0345–1.0693
>60–80%	1.0557	<0.001	1.0363–1.0755
>80% **(high coverage)**	1.0427	<0.001	1.0152–1.0708
Urban	0.9355	<0.001	0.9161–0.9553
Proportion female (%)	1.0075	<0.001	1.0064–1.0086
Proportion state pension (%)	0.9989	0.005	0.9982–0.9997
Proportion low income (%)	1.0240	<0.001	1.0233–1.0248
Proportion living overcrowded (%)	1.0092	<0.001	1.0082–1.0103
Crime rate	0.9998	0.034	0.9996–1.0000
Constant	0.1229	<0.001	0.1151–0.1312
Observations	6891		
Pseudo R^2	0.1358		

3.3.3 Antidepressant medication prevalence (>65-year-olds)

A significant ($p < 0.05$) negative association was observed between high freshwater blue space coverage in the immediate neighbourhood and antidepressant medication prevalence among > 65-year-olds (Table 3.5). High freshwater blue space coverage in the immediate neighbourhood was associated with a 1.9% (PR = 0.9810, 95% CI 0.9640–0.9984) reduction in antidepressant medication prevalence. In contrast to the 50–64-year-old model, no significant associations were observed for high freshwater blue space coverage in the wider neighbourhood (Table 3.6). Furthermore, no lower quantities of freshwater coverage (<3%) were significantly associated with antidepressant medication prevalence at the 95% level in the immediate or wider neighbourhood models.

Significantly lower antidepressant medication prevalence among > 65-year-olds was observed in DZs located in close proximity (<1km) to large freshwater lakes ($p = 0.013$). The immediate neighbourhood model suggests DZs in close proximity to large lakes exhibit antidepressant medication prevalence 7% (PR 0.9299, 95% CI 0.8784–0.9845) lower than DZs > 20km from large freshwater lakes. DZs between 10km and 20km from large freshwater lakes also exhibited 2.4% (PR 0.9764, 95% CI 0.9586–0.9944) reductions in antidepressant medication prevalence ($p = 0.011$).

However, in contrast to the 50–64-year-old age category, no significant relationship was observed for DZs located between 1km and 10km from large freshwater lakes.

In accordance with the results of the 50–64-year-old age category models, decreasing coastal proximity was related to lower antidepressant medication prevalence. The immediate neighbourhood model suggests DZs closest to the coast (<1km) exhibit 6.5% (PR = 0.9352, 95% CI 0.9147–0.9563) lower antidepressant medication prevalence ($p < 0.001$) relative to inland DZs (>40km). Whilst DZs between > 1 – 5km ($p < 0.001$) and > 5 – 20km ($p = 0.011$) from the coast report 5.5% (PR = 0.9453, 95% CI 0.9258–0.9653) and 3% (PR = 0.9709, 95% CI 0.9537–0.9883) lower antidepressant medication prevalence, respectively.

The relationship between neighbourhood green space coverage and antidepressant medication prevalence among over 65-year olds was similar to that observed for 50–64-year olds. High public green space coverage in the wider neighbourhood was significantly ($p < 0.05$) associated with lower antidepressant medication prevalence, relative to low public green space coverage in the immediate neighbourhood. High public green space coverage in the immediate neighbourhood was associated with a 1.7% reduction in antidepressant medication prevalence; however, this was result was not significant at the 95% level ($p = 0.089$). With the exception of high total green space coverage in the immediate neighbourhood, all categories of total green space coverage were significantly associated with higher antidepressant medication prevalence relative to DZs with low total green space coverage.

In both the immediate and wider neighbourhood models, all confounding variables (except crime rate and percentage of DZ population above state pension age) were significantly ($p < 0.001$) associated with antidepressant medication prevalence in the direction hypothesized in Table 3.1. A higher percentage of adults above state pension age was associated with lower antidepressant prevalence in both the immediate ($p = 0.081$) and wider neighbourhood ($p = 0.069$) models; however, these results were not significant at the 95% level. No significant relationship was observed between crime rate and antidepressant medication prevalence among over 65-year-olds in either model.

Table 3.5. Immediate neighbourhood determinants of antidepressant medication prevalence (>65-year-old) displayed as prevalence ratios (PRs).

>65 (immediate neighbourhood)	**PR**	**p value**	**95% CI**
Freshwater BS coverage			
0–0.25% **(ref) (low coverage)**	1.0000	.	.
>0.25–0.75%	0.9985	0.853	0.9834–1.0140
>0.75–1.5%	0.9936	0.457	0.9769–1.0106
>1.5–3%	0.9908	0.323	0.9729–1.0091
>3% **(high coverage)**	0.9810	0.032	0.9640–0.9984
Distance to large lake			
>20km **(ref)**	1.0000	.	.
>10–20km	0.9764	0.011	0.9586–0.9944
>5–10km	0.9957	0.656	0.9770–1.0148
>1–5km	1.0017	0.880	0.9804–1.0234
<1km	0.9299	0.013	0.8784–0.9845
Distance to coast			
>40km **(ref)**	1.0000	.	.
>20–40km	0.9987	0.878	0.9817–1.0159
>5–20km	0.9709	<0.001	0.9537–0.9883
>1–5km	0.9453	<0.001	0.9258–0.9653
<1km	0.9352	<0.001	0.9147–0.9563
Public GS coverage			
0–2.5% **(ref) (low coverage)**	1.0000	.	.
>2.5–5%	0.9983	0.851	0.9804–1.0164
>5–10%	1.0054	0.534	0.9885–1.0226
>10–15%	1.0050	0.626	0.9851–1.0253
>15% **(high coverage)**	0.9834	0.089	0.9645–1.0026
Total GS coverage			
0–20% **(ref) (low coverage)**	1.0000	.	.
>20–40%	1.0243	0.002	1.0087–1.0401
>40–60%	1.0303	<0.001	1.0131–1.0477

>65 (immediate neighbourhood)	PR	p value	95% CI
>60–80%	1.0435	<0.001	1.0188–1.0688
>80% **(high coverage)**	1.0004	0.980	0.9681–1.0338
Urban	0.9424	<0.001	0.9202–0.9651
Proportion female (%)	1.0119	<0.001	1.0107–1.0132
Proportion state pension (%)	0.9992	0.081	0.9983–1.0001
Proportion low income (%)	1.0119	<0.001	1.0109–1.0128
Proportion living overcrowded (%)	1.0042	<0.001	1.0028–1.0055
Crime rate	0.9999	0.440	0.9997–1.0001
Constant	0.1058	<0.001	0.0981–0.1141
Observations	6567		
Pseudo R^2	0.0611		

Table 3.6. Wider neighbourhood determinants of antidepressant medication prevalence (>65-year-old) displayed as prevalence ratios (PRs).

>65 (wider neighbourhood)	PR	p value	95% CI
Freshwater BS coverage			
0–0.25% **(ref) (low coverage)**	1	.	.
>0.25–0.75%	0.993	0.357	0.9799–1.0073
>0.75–1.5%	0.9902	0.394	0.9680–1.0129
>1.5–3%	0.9797	0.197	0.9496–1.0107
>3% **(high coverage)**	0.9795	0.165	0.9513–1.0086
Distance to large lake			
>20km **(ref)**	1.0000	.	.
>10–20km	0.9762	0.010	0.9584–0.9942
>5–10km	0.9977	0.812	0.9789–1.0169
>1–5km	1.0030	0.785	0.9816–1.0249
<1km	0.9393	0.032	0.8870–0.9947
Distance to coast			
>40km **(ref)**	1.0000	.	.
>20–40km	1	0.999	0.9830–1.0173

>5–20km	0.973	0.003	0.9556–0.9906
>1–5km	0.9489	<0.001	0.9291–0.9691
<1km	0.9427	<0.001	0.9212–0.9647
Public GS coverage			
0–2.5% **(ref) (low coverage)**	1.0000	.	.
>2.5–5%	1.0070	0.490	0.9873–1.0270
>5–10%	1.0112	0.237	0.9927–1.0301
>10–15%	1.0150	0.178	0.9933–1.0372
>15% **(high coverage)**	0.9741	0.028	0.9515–0.9972
Total GS coverage			
0–20% **(ref) (low coverage)**	1.0000	.	.
>20–40%	1.0234	0.011	1.0052–1.0420
>40–60%	1.0410	<0.001	1.0220–1.0603
>60–80%	1.0382	<0.001	1.0169–1.0600
>80% **(high coverage)**	1.0546	<0.001	1.0239–1.0862
Urban	0.9287	<0.001	0.9078–0.9502
Proportion female (%)	1.0122	<0.001	1.0109–1.0135
Proportion state pension (%)	0.9992	0.069	0.9983–1.0001
Proportion low income (%)	1.0117	<0.001	1.0108–1.0126
Proportion living overcrowded (%)	1.0046	<0.001	1.0032–1.0060
Crime rate	0.9999	0.422	0.9997–1.0001
Constant	0.1022	<0.001	0.0947–0.1104
Observations	6567		
Pseudo R^2	0.0613		

3.4 Discussion

Our study used a national dataset of antidepressant medication prescriptions to examine the relationship between neighbourhood blue space availability and older adult mental health. The study combined antidepressant prescription data for over two million older adults (over 50 years of age) and geospatial data of blue space availability for over six thousand neighbourhoods across Scotland. The findings suggest that neighbourhoods with higher blue space coverage and neighbourhoods located in close proximity to the coast and large freshwater lakes have lower antidepressant medication prevalence among older adults, even after controlling for potential demographic and socioeconomic confounders. By considering multiple metrics of blue space availability and utilising a large objective mental health dataset focused on older adults, our study makes novel contributions to current understanding of the potential of different natural environments (Finlay et al., 2015), blue space typologies (Mavoa et al., 2019) and neighbourhood characteristics (Motoc et al., 2019) to promote mental health among older populations.

3.4.1 Principal findings

Collectively, the results of our study suggest greater neighbourhood blue space availability is associated with lower prevalence of antidepressant medication and consequently, lower prevalence of mental ill-health, among a nationwide sample of older adults in Scotland. These findings are in contrast to previous research which failed to observe a significant relationship between access to blue space and common mental disorders or antidepressant usage among middle to older aged adults in Spain (Gascon et al., 2018). However, the findings are in alignment with a variety of studies that suggest access and exposure to blue space can benefit older adult mental health (Chen and Yuan, 2020, Dempsey et al., 2018, Helbich et al., 2019, Finlay et al., 2015).

Despite growing evidence of blue space engagement providing mental health benefits, researchers are often unable to quantify the precise mechanisms or pathways underlying this relationship. Potential pathways can be classified into three domains (Markevych et al., 2017) and include; (1) restoring capacities, e.g. blue space promoting relaxation, stress reduction and cognitive restoration (White et al., 2010; Felsten, 2009; Herzog, 1985; Finlay et al., 2015); (2) building capacities, e.g. blue space promoting social interaction (de Bell et al., 2017, Pitt, 2018) and encouraging physical activity (Vert et al., 2019, Perchoux et al., 2015), which can support mental health in later life (Steinmo et al., 2014); and (3) reducing harm, e.g. blue space negating environmental stressors, such as noise, which can negatively affect older adult mental health (Pun et al., 2019). However, these pathways cannot be established from the data in our study and further research is required to confirm the mechanisms underlying the relationship between neighbourhood blue space availability and older adult mental health.

The results of our study also suggest neighbourhood blue space availability may have a greater impact on antidepressant medication prevalence than neighbourhood green space availability, replicating the findings of previous blue/green space exposure and mental health research (Nutsford et al., 2016, Pasanen et al., 2019, de Vries et al., 2016). For example, de Vries et al. (2016) observed generally stronger associations between neighbourhood blue space coverage and mental health metrics than those observed for neighbourhood green space coverage in the Netherlands. Our findings may be explained by the adoption of relatively coarse measures of green space availability (Pasanen et al., 2019). Our study does not account for varying accessibility to green space or varying levels of green space quality, which are both important in terms of mental health promotion (Feng and Astell-Burt, 2018). Alternatively, experimental research suggests that blue space may be more effective than green space in terms of promoting cognitive restoration (White et al., 2010). Indeed, qualitative research suggests blue spaces may be particularly suited to promoting mental health, relaxation and stress reduction for older adults, whilst green spaces are highly suited to facilitating social interaction and exercise (Finlay et al., 2015). Despite this, current evidence is tentative and further research is required to fully understand the varying potential of exposure to blue and green space to promote mental health (Pasanen et al., 2019). Irrespective of any potential differences, exposure to blue and green space simultaneously is preferred to either individually (White et al., 2010) and both green and blue space are important components of environments that promote mental health and cognitive restoration (Deng et al., 2020).

3.4.2 Metrics of blue space availability

Despite growing evidence that access and exposure to blue space can offer health and well-being benefits, there has been little discussion on the potential of freshwater specifically to positively impact mental health (McDougall et al., 2020a). Our study suggests high neighbourhood freshwater coverage is associated with lower antidepressant medication prevalence among older adults. Other studies comparing mental health among neighbourhoods with and without freshwater, with no consideration of freshwater quantity, have obtained mixed results (Dzhambov et al., 2018, Pasanen et al., 2019). However, high freshwater coverage, but not low freshwater coverage, has been associated with fewer symptoms of depression and anxiety (Garrett et al., 2019). Our research, therefore, further supports the notion that high neighbourhood blue space coverage is particularly suited to providing mental health benefits. Higher freshwater coverage may increase opportunities for engaging with freshwater incidentally or visually, which are key mechanisms in which blue space exposure can improve older adult mental health (Garrett et al., 2019b, Helbich et al., 2019).

High freshwater coverage in the wider (as distinct from immediate) neighbourhood was only associated with lower antidepressant prevalence among 50–64-year-olds, with no significant association observed for > 65-year-olds. A possible explanation for this might be related to less frequent blue space visitation beyond 10 min walking time (Völker et al., 2018), which coincides with the definition of the 'wider neighbourhood' adopted in this study. Increasing distance may be particularly important for the > 65-year-old age category as mobility is expected to reduce with increasing age (Gale et al., 2011). Indeed, older adults identify accessibility and mobility related issues as significant barriers to blue space usage and engagement (Pitt, 2018). In contrast to the wider neighbourhood, high freshwater coverage in the immediate neighbourhood may support more frequent blue space visitation, which has been associated with higher subjective well-being among older adults (Garrett et al., 2019a). High freshwater coverage in the immediate neighbourhood may also facilitate frequent and routine exposure to blue space, which can be particularly beneficial for > 65-year-old adults as such engagement can stimulate feelings of familiarity and security (Coleman and Kearns, 2015). The differing effects on antidepressant medication prevalence observed between older adult age categories in the wider neighbourhood models indicate a need for further research to quantify the impact of changing mobility patterns on freshwater blue space engagement throughout older adulthood.

Living in close proximity to large freshwater lakes has been associated with lower rates of anxiety / mood disorder related hospitalisation in North America (Pearson et al., 2019). In our study, living in close proximity to large lakes was associated with lower antidepressant medication prevalence among both age categories of older adults. This effect was most prominent in communities<1km from large freshwater lakes, which is expected as visitation and, therefore, likelihood of exposure, decreases with increasing distance between the lake and residence (Elliott et al., 2020). This result contributes to a small body of evidence that suggests large freshwater lakes are particularly suitable for mental health promotion. This may be explained by the physical characteristics of large freshwater lakes. Firstly, an abundance of freshwater coverage makes large freshwater lakes highly visible relative to smaller waterbodies and, therefore, increases the likelihood of visually engaging with freshwater from the residence, during blue space visitation and throughout day-to-day activities, which can directly result in improved mental health among older adults (Helbich et al., 2019). Secondly, humans prefer views of blue spaces with larger surface areas compared to blue spaces with smaller surface areas (Herzog, 1985) and greater preference for larger blue spaces increases the likelihood of obtaining restorative benefits from engaging with these environments (van den Berg et al., 2003). Thirdly, most large freshwater lakes in Scotland are likely to be surrounded by vegetation and the combination of blue and green space has higher restorative potential than either environment in isolation (Deng et al., 2020; White et al., 2010).

Alternatively, the large freshwater lakes considered in our study may generally be of high blue space quality. Blue space quality refers to the potential of an aquatic environment to promote health and well-being and combines environmental considerations such as scale of water views and sense of wildness, with social and physical characteristics related to the availability of facilities, safety, accessibility and quality of the surrounding road network (Mishra et al., 2020). Given that many large freshwater lakes in Scotland are national tourist attractions and popular recreational sites, higher blue space quality and, therefore, greater mental health and well-being promoting potential can be expected. Indeed, high quality facilities are a key driver of blue space visitation among older adults (Garrett et al., 2019a).

As expected, lower antidepressant medication prevalence was observed for DZs in close proximity to the coast, aligning with previous studies demonstrating a positive coastal effect on mental health among general populations (White et al., 2013, Garrett et al., 2019b, Pasanen et al., 2019) and older adults (Dempsey et al., 2018).

Given that low antidepressant medication prevalence is indicative of the absence of poor mental health rather than the presence of high mental well-being, the results of this study further reinforce the potential of coastal access to reduce negative mental health outcomes (Garrett et al., 2019b, White et al., 2013). Interestingly, similar reductions in antidepressant medication prevalence were observed for DZs in close proximity to the coast and DZs in close proximity to large freshwater lakes. This may be explained by the physical and visual similarities of these environments e.g. abundance of water coverage and expansive water views. Furthermore, the results of our study suggest coastal proximity has a greater effect on antidepressant medication prevalence than high neighbourhood freshwater coverage for both categories of older adults. This is in contrast to previous research which noted similar mental health impacts of coastal proximity and high freshwater coverage in England (Pasanen et al., 2019). Our study, therefore, contributes towards identifying differences in the mental health promoting-capacity of coastal and freshwater blue space, which is required to fully understand the potential of blue space to improve health and well-being (Mavoa et al., 2019) and to underpin future policy (McDougall et al., 2020a).

3.4.3 Policy implications and future work

Although, it is important to note that the ecological design of our study does not allow conclusions to be drawn at an individual health-level (Aerts et al., 2020), the findings suggest the availability of both freshwater and coastal blue space may be beneficial for older adult mental health and reinforce suggestions that blue space merits greater consideration in public health and urban planning policy (Finlay et al., 2015). Indeed, promoting blue space engagement offers policy makers opportunities to improve mental health and facilitate healthy ageing among older adults (Costello et al., 2019). Moreover, the physical, psychological and social benefits of blue space exposure may be particularly valuable for the treatment of common mental health disorders, such as depression, as effective treatment in older adults requires the consideration of issues related to both psychosocial and physical morbidity (Büchtemann et al., 2012).

Given the potential of blue space to promote public health, policymakers are faced with the challenge of increasing opportunities for blue space exposure and reducing barriers for blue space access for older adults and general populations. This can be achieved partly by placing greater emphasis on blue space accessibility and visual and auditory blue space exposure in the urban design (Deng et al., 2020) and by considering blue space provision in the location of new settlements; however, this will only likely be appropriate in urbanising and developing areas. Environmental restoration and urban regeneration projects could also place greater focus on blue (or blue/green) space provision and enhancement. Where possible, such approaches should seek to identify opportunities to pair blue space provision with synergistic environmental solutions, e.g., the use of blue space in sustainable urban drainage systems. A greater challenge is ensuring opportunities for blue space access are equitable and available to all. Unique barriers to blue space access are present for certain demographic groups, including older adults (Pitt, 2018) and blue space visitation is less likely for socially disadvantaged groups (de Bell et al., 2017, Haeffner et al., 2017). Identifying and mitigating barriers to blue space access is, therefore, a critical policy step that is required to ensure the health and well-being benefits of blue space are available to all.

3.4.4 Limitations and considerations

As our study is cross sectional, causality cannot be established and future research using antidepressant medication data with longitudinal study design offers opportunities to establish casual links between neighbourhood blue space availability and older adult mental health. Despite efforts to adjust our models for major covariates, insufficient data availability did not allow the consideration of some potentially important socioeconomic indicators and environmental stressors that may impact antidepressant medication prevalence among older adults. For example, although our models adopt an area-based indicator of current income, we were not able to adjust for potential differences in wealth across households, which may be particularly important consideration given our focus on older adults. Furthermore, as our study utilised area-based data, individual-level covariates and individual exposures/interactions with blue and green space could not be considered and future research using individual-level and exposure data is encouraged. However, the data used in this study provides a unique and national-scale picture of associations between the natural environment and antidepressant medication prevalence.

Despite providing a valuable proxy for the prevalence of common mental health disorders, our dependent variable (antidepressant medication prevalence) is unable to account for individuals who do not seek medical treatment (Helbich et al., 2018) or in cases where purely non-pharmaceutical treatments, such as cognitive behavioural therapy, are adopted. Although the primary purpose of antidepressant medication is to treat common mental disorders, antidepressants can also be prescribed to treat other conditions, e.g. chronic pain and migraines (NHS Scotland, 2018). While this poses a risk of misclassification, the numbers are likely small. Furthermore, as only one type of medication (antidepressant medication) was considered in our study, we could not take into account other co– and multi-morbidities within the study population that may confound some of the relationships identified. Finally, our study did not consider the issue of blue space quality. Dedicated tools for measuring blue space quality, such as the BlueHealth Environmental Assessment Tool (BEAT) (Mishra et al., 2020), require site visits and this was not feasible given the national coverage of our study. The development and usage of GIS-based ex-situ indicators of blue space quality alongside health data offers scope to improve understanding of the importance of blue space quality in the promotion of health and well-being.

3.5 Conclusion

Our study utilised a national antidepressant prescription dataset to quantify the effects of neighbourhood blue space availability on older adult mental health. The findings suggest that multiple metrics of neighbourhood blue space availability are associated with lower antidepressant prevalence among older adults in Scotland. Neighbourhoods with high freshwater blue space coverage and neighbourhoods in close proximity to large lakes and coastal environments consistently show lower antidepressant prevalence among the older adult population. These findings make several important contributions to current understanding of blue space availability and mental health. Collectively, the results of our study contribute towards a growing body of evidence that suggests access and exposure to both coastal and freshwater blue space can play an important role in promoting mental health in later life. Freshwater and coastal blue space, therefore, merit greater consideration in public health and urban planning policy and in the design of environments that aim to promote mental health and healthy aging.

Chapter 4 - Blue space exposure, health and well-being: Does freshwater type matter?

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Abstract

There is growing evidence that spending time in or around water bodies or ‘blue spaces’ can result in improved human health. To date, investigations of the health-promoting potential of blue space exposure have mostly focused on coastal environments. Despite their vital role in many urban landscapes, freshwater blue spaces have received less research attention and very little is known about the potential of different freshwater blue space types to impact health and well-being. This study used logistic and negative binomial regression modelling to quantify the association between proximity and exposure to different freshwater blue space types and general health and mental well-being in Scotland. A nationwide online panel survey (n = 1392) was used to determine how far respondents lived from lakes, rivers and canals and to establish how often they visited these blue spaces. Living within a ten minute walking distance of lakes, rivers or canals was not associated with greater general health or mental well-being. However, frequently visiting rivers and canals but not lakes, in the last month, was associated with greater mental well-being. Frequent green space visitation, but not blue space visitation, was associated with higher odds of reporting good general health. Taken together, our findings suggest that freshwater blue space exposure can provide mental well-being benefits. However, the provision of these benefits may vary among different freshwater blue space types. Understanding the health and well-being impact of different freshwater environments, therefore, offers opportunities for evidence-based policymaking to maximise the health-promoting potential of urban blue spaces.

4.1. Introduction

An extensive body of evidence suggests that contact between humans and the natural environment can result in a range of health and well-being benefits (Bratman et al., 2019, Frumkin et al., 2017, Hartig et al., 2014). Nature-health research has predominantly focused on the health-promoting potential of urban green space, which has been associated with a wide variety of physical and mental health benefits (Beyer et al., 2014, Gascon et al., 2016, Kondo et al., 2018). Consequently, strategies to improve green space accessibility and promote green space usage are becoming increasingly prominent in urban planning and public health policy (Shanahan et al., 2015). There is also growing interest in the health-promoting potential of other elements of the natural environment, such as water bodies or ‘blue spaces’.

Blue spaces are defined as ‘outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans’ (Grellier et al., 2017). It has been reported that exposure to blue space can result in improved health outcomes for both adults (Gascon et al., 2017, Smith et al., 2021) and children (Engemann et al., 2020). The mechanisms (or pathways) connecting blue space exposure to improved health outcomes are likely to be similar to those proposed for green space, e.g., promoting physical activity, social interaction, stress reduction and mental restoration. (Markevych et al., 2017, White et al., 2020). However, it has also been hypothesised that blue spaces offer a range of unique therapeutic and health-promoting properties (Foley and Kistemann, 2015, Völker and Kistemann, 2011).

To date, the majority of blue space and health research has focused on the health and well-being benefits of visiting or living in close proximity to the sea (coastal blue space) (Gascon et al., 2017). Visiting coastal blue space has been associated with improved mental well-being and reduced mental distress (White, 2021). Individuals who live in close proximity to the coast report more positive general health (Hooyberg et al., 2020) and mental health (White, 2013), reduced antidepressant medication usage (McDougall et al., 2021) and higher levels of physical activity (Pasanen et al., 2019) relative to individuals who live further inland. Furthermore, living in a residence with views of the sea can also result in improved mental health outcomes (Dempsey et al., 2018) and reduced symptoms of psychological distress (Nutsford et al., 2013).

Despite 50% of the global population living within 3km of a body of freshwater (Kummu et al., 2011) and freshwater ecosystems being vital components of human settlements, the effects of freshwater blue space exposure on physical and mental health remain underexplored relative to marine environments. However, a small but growing evidence base suggests exposure to freshwater blue space can also lead to improved health outcomes (Völker and Kistemann, 2011). Visiting freshwater can lead to improved mental well-being and reduced mental distress (White, 2021) and people report high levels of happiness when spending time in or near freshwater (de Vries et al., 2021). Living in neighbourhoods with higher freshwater blue space availability has also been associated with increased likelihood of reporting positive mental health outcomes (Chen and Yuan, 2020, McDougall et al., 2021, Pasanen et al., 2019).

Although interest in the health-promoting potential of freshwater blue space is growing, empirical studies of the topic remain sparse, and a number of key knowledge gaps are yet to be investigated. Very little is known about the potential of different freshwater blue space types, such as lakes, rivers and canals, to promote health and well-being. Freshwater blue space types vary substantially in their physical and hydrological properties and offer different opportunities for recreation and usage (Mavoa et al., 2019). As such, freshwater blue space types will likely vary in their potential to facilitate pathways to improved health (e.g., physical activity and social interaction) and may, therefore, vary in their capacity to promote health and well-being (McDougall, 2020a). Some ecological (area-level) studies have investigated the health and well-being effect of living in close proximity to canals (Tieges et al., 2020) and lakes (Pearson, 2019). However, individual-level research investigating the health and well-being impact of exposure to multiple different freshwater blue space types, whilst controlling for exposure to other categories of the natural environment (e.g., coastal blue space and green space), is lacking.

The majority of blue space exposure and health studies adopt objective proxies for exposure, such as proximity to blue space or neighbourhood blue space coverage

(Gascon et al., 2017). Such approaches are limited in their capability to quantify actual exposure (Helbich, 2018) or to establish varying levels of exposure to different blue space types. Self-reported accounts of blue space exposure, such as recalled visit frequency or contact time, offer an opportunity to quantify an individual's exposure to different freshwater blue space types in a way which captures the heterogeneity of individual exposure. Self-reported accounts of exposure are, therefore, well-suited to addressing a number of the aforementioned knowledge gaps in current freshwater blue space and health research.

Our study quantifies the association between multiple metrics of self-reported exposure to different freshwater blue space types (lakes, rivers and canals) and general health and mental well-being for a large sample of adults living in Scotland. The specific objectives were to (i) establish the impact of living in close proximity to different freshwater blue space types on self-reported general health and mental well-being; (ii) quantify the association between freshwater blue space exposure, self-reported general health and mental well-being; and (iii) contextualise observed general health and mental well-being impacts relative to proximity and exposure to coastal blue space and green space.

4.2. Methodology

4.2.1. Study overview

A nationwide survey-based approach was used to quantify associations between proximity and exposure to freshwater blue space and self-reported general health and mental well-being. Logistic (general health) and negative binomial (mental well-being) regression modelling was used to determine associations between proximity and exposure to lakes, rivers and canals and both health outcomes. All analyses controlled for the potential effects of coastal blue space and green space exposure and a variety of individual and area-level covariates.

4.2.2. Sampling and recruitment

Survey respondents were recruited via an online panel provided by Qualtrics (www.qualtrics.com). Members of the online panel provide consent to participate in surveys and receive invitations to participate via email. Online panel surveying has been adopted in recent blue space (White, 2021) and nature exposure (Tester-Jones et al., 2020) and health research. A quota-based non-random sampling approach, which aimed to obtain a sample which aligned with the gender and age distribution of the population of Scotland, was adopted. Before gaining full access to the survey, panel members were subject to a screening process to ensure they were 18-years old or above and currently resided in Scotland.

4.2.3. Survey administration

The survey instrument (see Appendix 1) comprised three key sections, which are described in detail below; health and well-being (see Section 2.4); natural environment engagement (see Section 2.5) and background information (see Section 2.6). The survey instrument was pre-tested in seven focus groups across central Scotland. A 150-respondent pilot study was also conducted via Qualtrics, to test and refine the survey instrument. The main survey was active between 10th September 2021 and 23rd September 2021. During this period, minimal Coronavirus (COVID-19) restrictions were in place in Scotland. Legal requirements on physical distancing or gathering sizes were removed in early August 2021, although, some protective measures such as the use of face coverings in public indoor spaces remained in place.

4.2.4. Health and well-being outcomes

To increase the comparability of the results obtained in this study with the existing evidence base, validated instruments that have previously been adopted in blue space and health research were used to quantify mental well-being and general health (Gascon et al., 2017). Mental well-being was assessed using the World Health Organisation Five Well-being Index (known as WHO-5) (Topp et al., 2015). The WHO-5 has been used to explore associations between blue space exposure and mental well-being in a variety of different countries (Garrett et al., 2019a, van den Bogerd et al., 2021, Vert et al., 2020, White et al., 2021). Survey respondents were asked to recall how often they experienced five positive emotional states in the past two weeks. Specifically, respondents were asked how often in the past two weeks; (i) they felt cheerful and in good spirits; (ii) they felt calm and relaxed; (iii) they woke up feeling fresh and rested; (iiii) they felt active and vigorous; and (v) their daily life had been filled with things that interest them. Respondents were asked to rate the frequency of experiencing each statement in the last two weeks on a six-point scale ranging from; 0 (At no time) to 5 (All of the time). Respondent's scores for each positive emotional state were then combined and multiplied by four to produce a mental well-being score between 0 and 100 (Topp et al., 2015).

Self-reported general health was quantified using a single question 'How is your health in general?' (SF-1) which has previously been adopted in blue space and health research (Garrett et al., 2019a, Hooyberg et al., 2020, Pasanen et al., 2019). Survey respondents were presented with five response options; (i) Very bad; (ii) Bad; (iii) Fair; (iiii) Good; and (v) Very Good. To account for a small number of respondents selecting the 'Very bad' health category (n = 13), this data was transformed into two response types: good health (which combined 'Good' and 'Very Good' responses) and bad health (which combined 'Very bad', 'Bad' and 'Fair' responses). Several blue and green space exposure studies have adopted a similar dichotomisation of general health (Garrett et al., 2019a, Hong et al., 2021).

4.2.5. Freshwater blue exposure

There remains no consensus on the most appropriate approach of quantifying exposure to blue space (Gascon et al., 2017). Consequently, three metrics of exposure; perceived proximity, visit frequency and contact time were adopted to assess associations with general health and mental well-being.

4.2.5.1. Perceived proximity

Survey respondents were asked which freshwater blue space types (canal, river and lake) were within a ten minute walk of their home. Walking time was preferred to distance-based proximity measures to account for differences in respondent's mobility and walking speeds (Völker, 2018). A walking time of ten minutes was selected to align with common definitions of neighbourhood size (Dalton et al., 2013) and because the likelihood of visiting freshwater blue space decreases when walking time exceeds ten minutes (Völker, 2018). Proximity models were adjusted for visit frequency to each freshwater blue space type.

4.2.5.2. Visit frequency

Respondents were presented with three freshwater blue space types (lakes, rivers and canals) and asked how many times they had visited each type in the last month. Visitation frequency to each freshwater blue space type was categorised as either; (i) 'Zero visits' – zero visits in the last month (reference category); (ii) 'Occasional visitor' – between one and three visits in the last month; or (iii) 'Frequent visitor' – greater than three visits in the last month. These categories were used to aid interpretation, as relationships between blue space visitation and health are often non-linear (White, 2021).

4.2.5.3. Contact time

Respondents were asked, based on the last month, how long an average visit to each freshwater blue space type lasted. Average visit times for each freshwater blue space type were multiplied by the frequency of visits to determine the number of hours a respondent spent in contact with each type in the last month. Contact time was categorised as either; (i) 'Zero hours' – zero hours of contact time in the last month (reference category); (ii) '>0–2 h' – between zero and two hours of contact time in the last month; and (iii) '>2 h' – greater than two hours of contact time in the last month. A threshold (or dosage) of two hours of nature contact time per week has been found to lead to improved health and well-being (White, 2019). However, this threshold was not adopted given our focus on contact times with multiple different types of blue space and green space. Furthermore, a recall period of a month was preferred to a one week recall period to ensure consistency with our measure of visit frequency.

4.2.6. Covariates

Our regression models included a number of important individual-level and area-level covariates that have been associated with general health and mental well-being. However, it should be noted that our models do not control for all potential determinants of general health and mental well-being.

4.2.6.1. Coastal blue space and green space

The potential effects of coastal blue space and green space proximity, visit frequency and contact time on general health and mental well-being were controlled for in each regression model. In accordance with the metrics adopted for freshwater blue space, proximity models controlled for the presence or absence of coastal blue space or green space within ten minutes walking distance of a respondent's home. Models of visit frequency and contact time also adjusted for coastal blue space and green space visit frequency and contact time in the last month, using the same categories adopted for freshwater blue space.

4.2.6.2. Individual-level covariates

In accordance with previous blue and green space exposure research, all models were adjusted for several demographic and socioeconomic covariates which have been shown to cause variations in health and well-being. These included age, gender, household income, educational status, marital status, dog ownership and car ownership (de Bell et al., 2017, Garrett et al., 2019a, Pasanen et al., 2019, Poulsen et al., 2022). The analysis adjusted for the presence of long-limiting illness, which has been shown to reduce visitation to natural environments (Boyd et al., 2018). Given the established relationship between mental well-being and general health, WHO-5 was included as a determinant of general health, and general health score as a determinant of WHO-5 (Garrett et al., 2019a). The potential health and well-being effects of physical activity (Penedo and Dahn, 2005) and social interaction (Day, 2008) were also adjusted for. Respondent's 'moderate' and 'vigorous' physical activity levels during the last week were obtained via the Short Form International Physical Activity Questionnaire (IPAQ-SF). Respondents were then classified as either meeting or failing to meet the WHO physical activity guidance for adults of 150 mins of moderate or 75 min of vigorous physical activity per week (WHO, 2020). Social interaction was quantified as the self-reported number of days within the last two weeks that a respondent had ‘met up’ with a friend or neighbour (Maas et al., 2009). Analyses also controlled for negative impacts of COVID-19 on household income, which has been associated with deteriorations in health and well-being (Yue and Cowling, 2021).

4.2.6.3. Area-level covariates

A number of self-reported area-level covariates which have previously been associated with health and well-being were controlled for, including neighbourhood air pollution (Manisalidis et al., 2020) and noise annoyance (Basner et al., 2014). In accordance with Dzhambov et al. (2018) respondents were asked to what extent their neighbourhood air was polluted and to what extent they were bothered by noise outside their home. For each question, respondents were presented with an eleven-point response scale ranging from; 0 (not at all) to 10 (extremely). The analysis also adjusted for potential health and well-being effects of urbanicity (Zijlema, 2015). The urbanicity of each respondent’s postcode was determined based on the Scottish Government Urban Rural Classification, which defines urban and rural areas as communities with populations > 3,000 people and < 3,000 people, respectively.

4.2.7. Statistical analysis

All statistical analyses were carried out in Stata (version 16.1) (College Station, USA). Given the count nature of the dependent variable (WHO-5), associations between mental well-being and freshwater blue space proximity and exposure were analysed using negative binomial regressions. Overdispersion was observed in the data and Poisson regression was, therefore, unsuitable (Hilbe, 2011). Associations between mental well-being and independent variables were reported as Incidence Rate Ratios (IRRs) with 95% Confidence Intervals (CIs). Multiple logistic regression was used to analyse associations between general health and freshwater blue space proximity and exposure. Associations were reported as Odds Ratios (OR) with 95% CIs.

In total, six models were developed to analyse associations between perceived proximity to each freshwater blue space type, visit frequency, contact time and general health and mental well-being. These models were; 1) perceived proximity and mental well-being; 2) perceived proximity and general health; 3) visit frequency and mental well-being; 4) visit frequency and general health; 5) contact time and mental well-being; and 6) contact time and general health. All models were adjusted for a variety of individual and area-level covariates, which were hypothesised to impact general health and mental well-being. Variables included in each model are reported in Table 4.1 and a full description of each variable is provided in Appendix 2. The inclusion of each variable was justified by evaluating Akaike information criterion (AIC) and Bayesian information criterion (BIC) to identify the best fitting and most parsimonious model. A number of variables including local authority area, area-level deprivation, the number of children in the household and employment status reduced model performance and were excluded. Variance inflation factors (VIF) were analysed in the development of each model to identity multicollinearity.

Table 4.1. Summary of socioeconomic and demographic statistics of sample.

Variable	**Category**	**Number / frequency**	**Mean / % of total**	**SD**
Mental Well-being (0–100)	–	1392	51.12	24.0
General Health	Good	796	57.2	
	Bad	596	42.8	
Ill Health	Yes	338	24.3	
	No	1054	75.7	
Gender	Male	585	42.0	
	Female	807	58.0	
Age	–	1392	46.2	15.2
Household Income	–	1392	36,791	21,384

Variable	**Category**	**Number / frequency**	**Mean / % of total**	**SD**
COVID-19 Impacted Income	Yes	424	30.5	
	No	968	69.5	
WHO Weekly Exercise	Yes	486	34.9	
	No	906	56.1	
Relationship Status	Yes	868	62.4	
	No	524	37.6	
Education Status	Yes	541	38.9	
	No	851	61.1	
Social Interaction (0–14)	–	1392	4.1	4.3
Dog Ownership	Yes	496	35.6	
	No	896	64.4	
Car Ownership	Yes	1027	73.8	
	No	365	26.2	
Noise Annoyance (0–10)	–	1392	4.2	2.9
Air Pollution (0–10)	–	1392	4.1	2.6
Urbanicity	Urban	1203	86.4	
	Rural	189	13.6	

4.3. Results

4.3.1. Descriptive statistics

In total, the online panel survey was completed by 1511 respondents. The final sample consisted of 1392 respondents once those with missing data (n = 119) were removed. Most respondents who were removed from the sample failed to provide a full postcode, which prevented further analysis. The socioeconomic and demographic profile of respondents who were removed from further analysis did not differ from the final sample. Table 4.1 summarises the socioeconomic and demographic statistics of the final sample. The mean mental well-being (WHO-5) score of the sample was 51.1 (SD 24.0) and the majority (57.2%) of respondents reported good general health. As a result of the quota-based sampling approach, the sample broadly reflected the national population of Scotland in terms of age and gender. The sample was composed of 817 females (58%) and 585 males (42%), which aligns with the female majority (52%) in the adult population (National Records of Scotland, 2019). The mean age of the sample was 46-years old, which is slightly above the national median age of 42-years old (National Records of Scotland, 2019). In the week prior to completing the survey, the majority (66.1%) of respondents did not meet WHO recommendations for moderate and vigorous physical activity.

Table 4.2 summarises perceived proximity to each type of blue and green space and visit frequencies and contact times for each type in the month prior to completing the survey. Approximately 10% of the sample lived within 10-minutes walking distance of a lake (10.9%), canal (10.3%) or the sea (14%) and around a third (30.2%) of respondents reported living within a 10-minute walk of a river. The majority (76.3%) of respondents lived with a 10-minutes walking distance of a green space.

Varied patterns of visitation were reported for each freshwater blue space type. Slightly less than half of respondents had visited a river (44.3%) or the sea (45.1%) in the last month and 20.1% and 17.7% of respondents visited these environments frequently (more than three times). Considerably lower numbers of respondents reported visits to lakes (31.4%) or canals (17.7%) in the last month. Around 20% (21.2%) of the sample visited lakes occasionally (between one and three times in the last month), whilst 142 respondents (10.2%) visited lakes frequently. Over 80% (82.2%) of the sample made at least one green space visit in the last month and 59.7% of the sample reported frequent green space visitation.

Self-reported contact time with each blue space type and green space was similar to patterns observed for visit frequency. Around 10% of respondents reported contact times of more than two hours with canals (7%) and lakes (13.1%) in the last month. Approximately 20% of the sample reported contact times of more than two hours with rivers (20.2%) and the sea (24.4%). More than half of respondents (56%) had visited green spaces for more than two hours in the last month.

Table 4.2. Summary statistics of proximity and exposure to each blue space type and green space.

Variable	Category	Frequency	% of total
Lake (10-minute walk)	Yes	151	10.9
	No	1241	89.1
River (10-minute walk)	Yes	421	30.2
	No	971	69.8
Canal (10-minute walk)	Yes	143	10.3
	No	1249	89.7
Sea (10-minute walk)	Yes	195	14.0
	No	1197	86.0
Green Space (10-min walk)	Yes	1062	76.3
	No	330	23.7
Lake Visits	Zero Visits	955	68.6
	Occasional Visitor	295	21.2
	Frequent Visitor	142	10.2
River Visits	Zero Visits	775	55.7
	Occasional Visitor	337	24.2
	Frequent Visitor	280	20.1
Canal Visits	Zero Visits	1146	82.3
	Occasional Visitor	160	11.5
	Frequent Visitor	86	6.2
Sea Visits	Zero Visits	764	54.9
	Occasional Visitor	382	27.4
	Frequent Visitor	246	17.7
Green Space Visits	Zero Visits	248	17.8
	Occasional Visitor	313	22.5
	Frequent Visitor	831	59.7
Lake Contact Time	Zero	977	70.2
	>0–2 h per month	232	16.7
	>2 per month	183	13.1

Variable	Category	Frequency	% of total
River Contact Time	Zero	793	57.0
	>0–2 h per month	318	22.8
	>2 per month	281	20.2
Canal Contact Time	Zero	1158	83.2
	>0–2 h per month	137	9.8
	>2 per month	97	7.0
Sea Contact Time	Zero	792	56.9
	>0–2 h per month	260	18.7
	>2h per month	340	24.4
Green Space Contact Time	Zero	270	19.4
	>0–2 h per month	287	20.6
	>2h per month	835	56.0

4.3.2. Perceived proximity

The results of the negative-binomial (mental well-being) and logistic (general health) regression models focusing on proximity to each blue space type are presented in Table 4.3. Living near (within 10 min walking distance) a canal, lake or river had no significant association with mental well-being as measured by the WHO-5 scale. Living near to lakes and canals was associated with higher mental well-being, although, these associations were not significant ($p > 0.05$). No significant associations were observed between general health and living within 10-minutes walking distance of rivers, canals, lakes, green spaces or the sea.

Table 4.3. Model of proximity to blue and green space, mental well-being and general health displayed as Incidence Rate Ratios (IRRs) and Odds Ratios (ORs) with 95% Confidence Intervals (CIs). See Appendix 3 and Appendix 4 for full model specification.

	Mental Well-being		General Health	
Variable	**IRR**	**95% CI**	**OR**	**95% CI**
Lake Proximity	1.012	0.935–1.095	0.937	0.587–1.495
River Proximity	0.978	0.926–1.032	1.435	1.012–2.035
Canal Proximity	1.072	0.988–1.163	0.798	0.471–1.353
Sea Proximity	1.018	0.942–1.099	0.877	0.578–1.328
Green Space Proximity	1.027	0.967–1.09	1.084	0.76–1.545

*** $p < 0.001$, ** p.0.01, * $p < 0.05$.

Models adjusted for ill-health, gender, age, household income, COVID-19 impact on income, physical activity, relationship status, education status, weekly interaction, dog ownership, car ownership, neighbourhood noise annoyance, neighbourhood air pollution, urbanicity and blue and green space visits.

4.3.3. Visit frequency

The results of the negative-binomial (mental well-being) and logistic (general health) regression models focusing on visitation to each blue space type and green space in the last month are presented in Table 4.4. No significant associations were observed between mental well-being and the number of visits a respondent made to lakes or green spaces in the last month. Frequent visitation (more twice in the last month) to rivers (IRR 1.07; 95% CI 1.01–1.13; $p < 0.05$) and canals (IRR 1.09; 95% CI 1.01–1.19; $p < 0.05$) was associated with higher mental well-being scores relative to respondents who did not visit rivers and canals. However, no significant differences were observed between the mental well-being scores of respondents who did not visit rivers or canals and respondents who visited rivers and canals only occasionally (1–2 times in the last month). Relative to respondents who had not visited the sea in the last month, respondents who had visited the sea occasionally (IRR 1.07; 95% CI 1.02–1.14; $p < 0.01$) and frequently (IRR 1.06; 95% CI 1.01–1.12; $p < 0.01$) reported higher mental well-being scores. However, no significant associations were observed between visiting any blue space type and general health. Respondents who visited green spaces frequently were over two times more likely to report good health (OR 2.01; 95% CI 1.30–3.11; $p < 0.01$) than respondents who had not visited a green space in the last month.

Table 4.4. Model of visit frequency to blue and green space, mental well-being and general health displayed as Incidence Rate Ratios (IRRs) and Odds Ratios (ORs) with 95% Confidence Intervals (CIs). See Appendix 5 and Appendix 6 for full model specification.

	Mental Well-being		**General Health**	
Variable	**IRR**	**95% CI**	**OR**	**95% CI**
Lake Visits (z)	(ref)	.	(ref)	.
Lake Visits (o)	1.022	0.967–1.079	1.12	0.758–1.656
Lake Visits (f)	1.031	0.96–1.107	0.803	0.502–1.283
River Visits (z)	(ref)	.	(ref)	.
River Visits (o)	1.047	0.988–1.11	0.781	0.544–1.122
River Visits (f)	**1.065***	1.003–1.132	0.827	0.544–1.257
Canal Visits (z)	(ref)	.	(ref)	.
Canal Visits (o)	1.063	0.994–1.137	0.913	0.571–1.459
Canal Visits (f)	**1.095***	1.007–1.19	0.766	0.401–1.463
Sea Visits (z)	(ref)	.	(ref)	.
Sea Visits (o)	**1.078****	1.022–1.136	0.908	0.643–1.283
Sea Visits (f)	**1.06****	1.003–1.122	1.014	0.672–1.532
Green Space Visits (z)	(ref)	.	(ref)	.
Green Space Visits (o)	1.032	0.949–1.123	1.499	0.952–2.359
Green Space Visits (f)	1.009	0.934–1.09	**2.017****	1.305–3.117

*** p < 0.001, ** p.0.01, * p < 0.05.

Models adjusted for ill-health, gender, age, household income, COVID-19 impact on income, physical activity, relationship status, education status, weekly interaction, dog ownership, car ownership, neighbourhood noise annoyance, neighbourhood air pollution and urbanicity.

4.3.4. Contact time

Negative-binomial (mental well-being) and logistic (general health) regressions focusing on contact time with each blue space type and green space in the last month were derived (Table 4.5). The contact time models displayed broadly similar results to those focusing on associations between visit frequency and both health outcomes. No significant associations were observed between mental well-being and contact time in the last month with either lakes, rivers or green spaces. However, respondents who reported contact times with canals of over two hours in the last month reported significantly higher mental well-being scores (IRR 1.10; 95% CI 1.02–1.91; $p < 0.05$) than individuals who reported no contact time with canals. No significant association was observed between individuals who did not report any contact time with canals and respondents who reported between zero and two hours of contact time. Respondents who had visited the sea for over two hours in the last month reported higher mental well-being scores (IRR 1.058; 95% CI 1.01–1.12; $p < 0.05$) than respondents who reported no contact time with the sea over this period.

No significant association was observed between contact time in the last month with any blue space type and self-reported general health. However, respondents who spent more than two hours visiting green spaces in the last month were more likely to report good health (OR 1.57; 95% CI 1.04–2.38; $p < 0.05$) than individuals who reported no contact with green space. The likelihood of reporting good general health status did not differ significantly between those who reported zero hours of contact time with green space in the last month and those who reported between zero and two hours of contact time.

Table 4.5. Model of contact time with blue and green space, mental well-being and general health displayed as Incidence Rate Ratios (IRR) and Odds Ratios (OR) with 95% Confidence Intervals (CIs). See Appendix 7 and Appendix 8 for full model specification.

	Mental Well-being		**General Health**	
Variable	**IRR**	**95% CI**	**OR**	**95% CI**
Lake Time (zero)	(ref)	.	(ref)	.
Lake Time (>0–2 h)	1.049	0.989–1.113	1.233	0.797–1.907
Lake Time (>2 h)	1.024	0.96–1.092	0.862	0.556–1.336
River Time (zero)	(ref)	.	(ref)	.
River Time (>0–2 h)	1.032	0.975–1.092	0.914	0.632–1.323
River Time (>2 h)	1.054	0.989–1.124	0.886	0.584–1.343
Canal Time (zero)	(ref)	.	(ref)	.
Canal Time (>0–2 h)	1.037	0.965–1.114	1.035	0.617–1.737
Canal Time (>2 h)	**1.099***	1.014–1.191	0.666	0.369–1.204
Sea Time (zero)	(ref)	.	(ref)	.
Sea Time (>0–2 h)	1.052	0.992–1.117	0.842	0.573–1.238
Sea Time (>2 h)	**1.058***	1.003–1.116	1.033	0.718–1.486
Green Space Time (zero)	(ref)	.	(ref)	.
Green Space Time (>0–2 h)	1.047	0.964–1.137	1.319	0.836–2.08
Green Space Time (>2 h)	1.016	0.944–1.093	**1.572***	1.037–2.382

*** p < 0.001, ** p.0.01, * p < 0.05.

Models adjusted for ill-health, gender, age, household income, COVID-19 impact on income, physical activity, relationship status, education status, weekly interaction, dog ownership, car ownership, neighbourhood noise annoyance, neighbourhood air pollution and urbanicity.

4.4. Discussion

4.4.1. Overview

Our study examined the relationship between proximity and exposure to multiple freshwater blue space types and self-reported general health and mental well-being. Our analyses controlled for proximity and exposure to coastal blue space and green space and for a variety of individual and area-level covariates that can also impact health and well-being. Our findings suggest that frequently visiting rivers, canals and the sea, but not green spaces or lakes, is associated with greater mental well-being. Frequently visiting green spaces, but no type of blue space, increases the likelihood of reporting better general health. Our findings also suggest spending more than two hours per month in contact with canals and the sea is associated with greater mental well-being relative to individuals who spend no time in these settings.

4.4.2. Principal findings

Of the three freshwater blue space types considered in our analysis, only exposure to rivers and canals was associated with greater mental well-being. No association was observed between exposure to lakes and mental well-being or exposure to any freshwater blue space type and general health. These findings highlight the potential of different freshwater blue space types to vary in their contribution to improved health and well-being. Findings from studies that combine multiple freshwater blue space types into a single category should, therefore, be interpreted with a degree of caution, as such approaches may not fully reveal the health and well-being effects of exposure to each freshwater blue type on the study population. An improved understanding of the health and well-being benefits from exposure to different freshwater blue space types within an area of interest (e.g., on a city scale) offers opportunities to prioritise investment and for evidence-based urban planning and delivery of public health policies to maximise the health and well-being benefits offered by freshwater environments.

Respondents who frequently visited canals and rivers reported 9% and 7% higher mental well-being (WHO-5) scores than respondents who did not visit these environments. When contextualised alongside our control variables, the relative value of freshwater blue space as a health-promoting resource is apparent. For example, respondents who achieved the WHO recommendations for physical activity in the last seven days, reported 12% higher WHO-5 scores than respondents who did not meet these recommendations. The benefits for mental well-being of frequent canal and river visitation are smaller, yet comparable to the well-being benefits of meeting WHO physical activity guidance, which has well established associations with physical and mental health and plays an important role in global public health policy (WHO, 2020). Indeed, our findings may have particular public health importance as protecting and promoting positive mental well-being (or positive mental health) can play an important role in public health strategies to reduce mental illness (Keyes, 2014).

Of the freshwater blue space types considered in our analysis, frequent visitation to canals had the greatest positive impact on mental well-being. Spending time on and around canals may be particularly suited to improved mental well-being as these environments can facilitate relaxation and stress reduction (Vaeztavakoli et al., 2018). Canals can also provide opportunities for physical activity, social interaction and are valued for their ability to provide access to nature in dense urban settings and buffer harmful conditions often present in urban environments, e.g. road traffic noise (Smith et al., 2022). Interestingly, public preference data suggest the amenity value of canals is lower than other freshwater blue space types (Haeffner et al., 2017). Canals in the UK can also be perceived negatively due to associations with uncleanliness and antisocial behaviour (Pitt, 2018). Nevertheless, our findings reinforce suggestions that canals can be health-promoting assets in urban areas (Smith et al., 2022).

Frequently visiting rivers was also associated with greater mental well-being. Riverside locations may be particularly restorative as they can facilitate exposure to the sound of flowing water (Milligan and Bingley, 2007). Improved health and well-being may also be explained by the active recreational opportunities e.g., walking, running and cycling (Vert et al., 2019) and passive recreational opportunities associated with riverside visits e.g., relaxing while watching the flow of water or ‘people-watching’ (Völker and Kistemann, 2013). Although our data suggests frequently visiting rivers is associated with greater mental well-being, unlike canals and the sea, this relationship was not observed when contact time in the last month was considered. Whilst identifying dose–response relationships is beyond the scope of this research, our findings tentatively indicate different dose–response relationships among blue space types (Shanahan et al., 2015).

Our analysis did not identify any significant associations between simply living near lakes or self-reported exposure to lakes in the last month and mental well-being or general heath. This result was unexpected, as lakes provide a wide variety of ecosystem services, unique recreational opportunities and are viewed as landscape components that are particularly important for health and well-being (Elbakidze et al., 2017). Furthermore, living in close proximity to large lakes has been associated with lower antidepressant medication usage in Scotland (McDougall et al., 2021). There are some potential explanations for this finding. Firstly, it has been suggested that living in close proximity to large, but not small lakes, is associated with improved mental health outcomes (Pearson, 2019). Our study did not consider lake size, which may play an important role in the provision of health and well-being benefits, as larger lakes may be more likely to attract investment and generally be of greater blue space quality and, consequently, more likely to positively impact health and well-being (McDougall et al., 2021). Secondly, although our analysis adopted a relatively coarse control for urbanicity, lakes in Scotland are rarely located in urban environments, unlike rivers and canals. Urban waterways often provide an ‘escape’ from harmful urban conditions (e.g., road traffic noise) (Smith et al., 2022) and in Scotland this may be less likely to be the case for lakes, which could explain the greater mental well-being impact observed for river and canal visitation in our sample. However, these potential explanations are speculative and further research on the effect of proximity and exposure to lakes on health and well-being is an important area for future study.

4.4.3. Blue space, green space and health

Despite only identifying significant associations between two of the three freshwater blue space types considered in our analysis and mental well-being, our findings corroborate suggestions that freshwater blue space exposure can promote health. Our findings align with a recent study which found an association between visiting freshwater blue space within the last month and lower psychological distress and higher mental well-being across eighteen countries, including the UK (White, 2021). Völker (2018) also found that frequent freshwater blue space visitation was associated with higher mental health in Germany. Indeed, mental well-being benefits are viewed as one of the most important benefits of visiting freshwater blue spaces (de Bell et al., 2017). Three key pathways are likely to mediate these mental well-being benefits. These include (i) harm reduction, whereby freshwater blue space leads to the reduction of detrimental environmental conditions such as noise or excessive urban heat; (ii) capacity building, whereby freshwater usage increases the likelihood of social interactions and physical activity; and (iii) capacity restoration, whereby exposure to freshwater facilitates and promotes cognitive restoration, stress reduction and relaxation (Markevych et al., 2017, White et al., 2020). The contribution of each pathway to improved health and well-being may vary among different freshwater blue space types (McDougall, 2020a); however, our sample was not of sufficient size to conduct mediation analysis.

Our findings suggest a mixed relationship between blue and green space exposure, mental well-being and general health. Proximity or exposure to freshwater or coastal blue space was not associated with general health. However, respondents who occasionally or frequently visited green spaces or reported more than two hours of contact time with green spaces in the last month were more likely to report good general health. Garrett et al. (2019a) also found green space, but not blue space, visitation to be associated with greater odds of reporting good general health in a study of older adults. Collectively, these findings suggest green space exposure may be more suited to general health promotion than blue space exposure. Green space may be more likely than blue space to reduce environmental harms related to physical health outcomes e.g., air pollution (Wang et al., 2020) and exposure to green space has been associated with a variety of improved physical health outcomes including reductions in high blood pressure, improved cardiovascular health and reduced mortality (Twohig-Bennett and Jones, 2018). Very little evidence suggests an association between physical and cardiovascular health outcomes and blue space exposure (Gascon et al., 2017), which may explain why only green space exposure was associated why general health in our sample.

Unlike canals, rivers and the sea, greater green space exposure in the last month was not associated with higher mental well-being. Higher mental well-being has been associated with increased blue space visitation, but not green space visitation, in urban settings in Germany (Völker, 2018) and Hong Kong (Garrett et al., 2019a). Whilst Nutsford et al. (2013) found blue space visibility from one's home, but not green space visibility, was associated with reduced psychological distress in Auckland, New Zealand. Our findings add to a growing body of literature that suggests blue space exposure may be more beneficial for mental well-being than green space exposure. Indeed, environmental psychology research suggests blue spaces are preferred to green spaces and are more likely to promote feelings of happiness (White, 2010). Blue spaces may also be more suited to promoting stress reduction and relaxation relative to other natural environments (Finlay et al., 2015), whilst also offering unique therapeutic opportunities (Foley, 2015). Although a number of studies have suggested blue space exposure may provide greater mental well-being benefits than green space exposure, evidence of this relationship remains tentative (Pasanen et al., 2019). Furthermore, it should be noted that our study did not account for a variety of green space metrics that may be associated with mental well-being e.g., green space type, green space quality or residential greenness (Lee and Maheswaran, 2011).

4.4.4. Policy implications

The findings of our study offer a number of valuable implications for urban planning, landscape design and public health policy. There is a need for freshwater blue space to receive greater consideration as a resource that can promote health and well-being; however, policy makers should be aware of the potential for different freshwater types to vary in their contribution to health promotion. Social media, sports tracking and mobile data offers a cost-effective opportunity for policy makers to better understand how, when and by whom different freshwater blue space types are used (Heikinheimo et al., 2020). This is important, since our findings suggest that intentional exposure is more relevant than mere residential proximity for mental well-being. Our findings may be particularly timely given that exposure to blue space can offer a buffer to many of the negative mental health impacts of COVID-19, such as 'lockdown' restrictions (Pouso et al., 2021). Strategies to increase freshwater blue space access offer scope to attain public health benefits and, where possible, should be coupled alongside the provision of a variety of other freshwater ecosystem services.

Whilst increased blue space accessibility is important, policymakers also face the challenge of addressing inequities in blue space usage (de Bell et al., 2017). For example, although low-income and Hispanic residents of Utah live closer to blue spaces, high-income and white residents are more likely to visit blue spaces (Haeffner et al., 2017). Crucially, policymakers should ensure strategies to increase blue space usage mitigate potentially negative health impacts e.g., increased exposure to harmful algal blooms or increased water-related fatalities. The possibility of negative socioeconomic outcomes as a result of improved blue space provision or quality, such as blue (environmental) gentrification, should also be also considered (Anguelovski et al., 2018).

4.4.5. Strengths, limitations and future work

By considering multiple freshwater blue space types, our approach addresses a key knowledge gap related to freshwater blue space and health and provides empirical data to reinforce suggestions that different freshwater blue space types may vary in their health-promoting potential. Our use of validated tools for quantifying general health and mental well-being, which have been previously adopted in blue space and health research, allows for close comparability to other studies (Gascon et al., 2017). By adopting self-reported contact time and visitation to freshwater blue space in the last month, our study was able to account for actual exposure to these environments and was not restricted to proxies of exposure, overcoming a common limitation of nature-health research (Helbich, 2018). Finally, our study controlled for a wide variety of established and emerging individual and area-based covariates which have been associated with general health and mental well-being, including the negative effects of COVID-19 on household income.

Our study was also subject to limitations, many of which offer opportunities for future research. Although our sample was representative of the population of Scotland in terms of age, gender and household income, the non-random sampling approach adopted in this study may limit the generalisability our findings. Additionally, our online panel surveying approach prevented gathering information on individuals who declined to participate in the survey, potentially introducing non-response bias (Boyle, 2016). The cross-sectional design of our study does not allow causation to be established and longitudinal studies of freshwater blue space exposure, health and well-being offer scope to better understand causality (Gascon et al., 2017). Furthermore, our analysis did not account for differences in blue space quality (e.g., accessibility, water quality or perceptions of safety), which can influence the potential of a blue space to positively impact health (Mishra et al., 2020). Research examining the health and well-being effects of exposure to different freshwater blue space types, whilst controlling for differences in blue space quality in these environments, offers an interesting area of future study. Another limitation of our study is the short period of time in which survey responses were collected. Multi-seasonal research can account for differences in weather and freshwater visitation patterns (White, 2021) and it may be of particular interest to replicate our investigation during winter when freshwater environments in Scotland are likely to freeze and when daylight and, consequently, feelings of safety around blue spaces is reduced (Smith et al., 2022). Our study only considered proximity and exposure to three freshwater blue space types. Although, these are the three most common freshwater blue space types found in landscapes across Scotland, investigations of the health and well-being effects of exposure to less common freshwater blue space types (e.g., waterfalls, wetlands and fountains) offers scope to build upon our findings. Finally, freshwater blue space contact time and visit frequency were self-reported based on a recall period of month prior to survey completion. Our exposure data may, therefore, be subject to error and self-reporting bias and our analysis could not account for different distributions of exposure across the recall period, which could have an impact on our measured health outcomes.

4.5. Conclusion

Our study examined the relationship between proximity and exposure to multiple freshwater blue space types, general health and mental well-being in Scotland, whilst controlling for a range of individual and area-based covariates. The findings suggest that frequently visiting rivers, canals and the sea, but not lakes, is associated with greater mental well-being. Whilst frequently visiting green space, but not freshwater or coastal blue space, is associated with greater likelihood of reporting good general health. Our results contribute towards a growing body of evidence that suggests exposure to freshwater blue space can play an important role in promoting mental health and well-being. Importantly, our data reinforces suggestions that freshwater blue space types may – but not always – vary in their impact on health and well-being. Understanding the health and well-being benefits attained from exposure to different freshwater environments, therefore, offers opportunities for evidence-based policymaking to maximise the health-promoting potential of urban blue spaces.

Chapter 5 - Freshwater wild swimming, health and well-being: Understanding the importance of place and risk

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Author Contributions: CW. McDougall conceptualised the rationale and designed the methodology of this manuscript, acquired the data, designed the survey instrument and interview guide, conducted the interviews, transcribed the interviews, conducted the thematic analysis and wrote the manuscript. R. Foley provided supervision directly related to the wild swimming literature and reviewed the thematic analysis. RS. Quilliam, N. Hanley and DM. Oliver acquired the funding, provided general supervision and suggested improvements to the manuscript.

Abstract

Spending time in or around bodies of water or ‘blue spaces’ can benefit human health and well-being. A growing body of evidence suggests immersion in blue space, e.g., participating in ‘wild’ swimming, can be particularly beneficial for both physical and mental health. To date, wild swimming and health research has primarily focused on the experience of individuals who swim in the sea. Empirical studies of the health-promoting potential of swimming in freshwater environments, such as lochs and lakes, are lacking, despite the popularity of this practice in many countries and the vastly different physical and hydrological properties of freshwater and coastal environments. The aim of this study was to explore the relationship between loch (lake) swimming and health and well-being for adults living in Scotland and determine the importance of perceptions of place and risk in this relationship. Semi-structured interviews were conducted with twelve wild swimmers who regularly swim in lochs in Scotland. Interview data were analysed thematically using Nvivo. The findings suggest loch swimming has a variety of health and well-being benefits that can be categorised over three domains of health: physical, mental and social. Of these domains, mental health benefits e.g., mindfulness promotion, resilience building and increasing one’s ability to listen to their body, were particularly prominent. Our findings also highlight important physical and hydrological characteristics of loch environments, e.g., calm water conditions (relative to the sea), which contribute to positive wild swimming experiences. Finally, the perceived risks of loch swimming and mitigation strategies for these risks are established. Collectively, our findings further support the notion that wild swimming is a unique health-promoting practice. Our findings also highlight differences (in terms of experience and perceived risk) between swimming in freshwater and coastal environments, which can inform public health and water management policy.

5.1. Introduction

There is growing recognition of the health-promoting potential of spending time in and around natural environments, such as bodies of water (e.g., lakes, rivers, canals and seas) or 'blue spaces' (Gascon et al., 2017) Blue spaces are defined as 'outdoor environments—either natural or manmade—that prominently feature water and are accessible to humans' (Grellier et al., 2017) A recent eighteen country study suggests visiting blue spaces is associated with improved mental health and well-being outcomes (White et al., 2018). Living near blue space has also been associated with greater mental health and physical activity levels (Pasanen et al., 2019). However, as blue-space visits often do not necessarily involve direct water contact, blue space and health research may somewhat overlook the unique health and well-being benefits offered by activities that involve immersion in water, e.g., swimming.

The health and well-being benefits of swimming are well established, and swimming is one of the most popular forms of exercise worldwide. Swimming has been associated with the prevention of diseases and promotion of health and well-being, whilst the non-weight-bearing nature of the activity makes it a highly suitable form of exercise for elderly adults and individuals with physical challenges (Tanaka, 2009). Most evidence outlines the health and well-being benefits of swimming from a sports science perspective and predominantly focuses on swimming in indoor environments. There is also growing evidence that swimming in outdoor blue spaces, often termed 'wild' swimming, may be uniquely beneficial for health and well-being (Foley, 2015; Denton and Aranda, 2020). Throughout this study, 'wild swimming' refers to any full-body immersion in outdoor blue spaces.

In the last decade, wild swimming has rapidly grown in popularity. The growing popularity of wild swimming may be driven by an increasing focus on personal health and well-being and a growing desire to re-connect with nature (Atkinson, 2019). Despite wild swimming growing in popularity, the notion that water immersion can benefit human health is not new. Aquatic environments were central to early therapeutic landscape research (Gesler, 1992). Furthermore, outdoor blue spaces were renowned for their healing potential in ancient Greek and Roman cultures, and coastal blue spaces have been associated with medicinal bathing for centuries (Bell et al., 2015).

In recent years, a growing body of literature has highlighted the health and well-being benefits of regular wild swimming. Innovative methods, such as swim-along interviews (Denton et al., 2021) and video diaries (Bates and Moles, 2021), have produced detailed insights into the wild swimming experience. A variety of qualitative accounts highlight the potential of wild swimming to promote, restore and maintain health and well-being. For example, wild swimming has been described as an accretive practice, where participation in wild swimming leads to heightened resilience, whereby individuals have an increased capacity to maintain health and well-being amidst physically and mentally challenging circumstances (Foley, 2017). Participation in informal sea swimming groups is also recognised as being beneficial for mental health and contributing to healthy ageing (Costello et al., 2019). Other studies suggest that sea swimming can cause transformative, connecting and re-orientating effects, resulting in positive changes to swimmers' minds, bodies and identities, which enables a sense of belonging and shifts perspectives of oneself and one's surroundings (Denton and Aranda, 2020).

Quantitative evidence also highlights the potential health and well-being benefits of wild swimming. Participating in wild swimming has been associated with long-term reductions in depressive symptoms (van Tulleken et al., 2018). Regular wild swimming can reduce symptoms of negative mental health, e.g., by increasing positive mood states (Massey et al., 2020). Winter wild swimming can result in physical benefits, including reduced fatigue and improved energy levels (Huttunen et al., 2004).

Despite an expansion of the evidence base linking wild swimming and associated health benefits, critical gaps in our understanding remain. To date, almost all wild swimming and related health research has focused on the experience of swimming in the sea. A similar sea focus is apparent in the wider blue space and health literature (McDougall et al., 2020a). Freshwater and coastal environments differ in their physical and hydrological properties and their suitability for recreation and swimming. Furthermore, lake or loch swimming is popular in many countries including Finland (Lankia et al., 2019) and Scotland - the focus of this study.

Understanding the experience and potential health and well-being benefits of swimming in different geographies, such as lochs, offers an opportunity to broaden the current wild swimming and health-related evidence base and fully recognise the public health impact of wild swimming.

Although often health-promoting, swimming in outdoor environments carries a number of risks, which can lead to ill health or fatality (Tipton et al., 2017; Spiteri et al., 2011; Tipton et al., 2014; Brannigan et al., 2009; Melau et al., 2019; Miller and Wendt, 2012). Risk is an important component of the wild swimming experience and there are numerous accounts of wild swimmers discussing risks faced whilst sea swimming (Foley, 2015). However, previous accounts of the risks of wild swimming are often sea-specific, e.g., exposure to dangerous sea wildlife (Costello et al., 2019). Consequently, there is scope to widen the current understanding of the risks of wild swimming to include freshwater environments, such as lochs. This is particularly important in Scotland, where recent data suggest differences in the mortality risk of coastal and freshwater environments (Water Safety Scotland, 2018).

To address the aforementioned knowledge gaps, this study aims to determine the health and well-being impacts of loch swimming and establish the importance of perceptions of risk and place in this relationship. Specifically, the objectives are to (i) determine the health and well-being impact of regular loch swimming across a sample of loch swimmers from central Scotland; (ii) establish how characteristics of place impact the loch swimming experience; and (iii) determine key risks and mitigation strategies related to loch swimming in Scotland.

5.2. Materials and methods

5.2.1. Study overview

This study adopted a qualitative research design to explore the relationship between loch swimming, health and well-being and determine the importance of perceptions of place and risk in this relationship. Semi-structured interviews were conducted with wild swimmers, who predominantly swam in freshwater lochs in Scotland. Interview data were analysed thematically in accordance with Braun and Clarke (2012).

Ethical approval for this study was obtained from the University of Stirling General University Ethics Panel (reference: 1685).

5.2.2. Recruitment

Individuals who were 18 years old or above, resided in Scotland and currently participated in wild swimming were invited to participate in the research. An invitation to participate in a short survey followed by an online interview was distributed via a public Facebook group ('Wild Swimming—Scotland') in April 2021. Individuals interested in participating in the research were first asked to complete a short survey with a participatory mapping exercise, which was hosted by Maptionnaire. The survey had three key components: (i) demographic information (age, household income, gender); (ii) wild swimming background (frequency of participation in wild swimming, when first wild swim took place; typical wild swimming environment, e.g., loch, river or sea); and (iii) a participatory mapping exercise, where respondents were asked to pinpoint the location they swam most often and highlight areas where they typically entered and exited the water, a typical swimming route and areas that were considered dangerous or unsafe for swimming (Figure 5.1.). The short survey was used to gather background information and provided the basis for purposeful sampling for further interviewing based upon age, gender and typical swimming location.

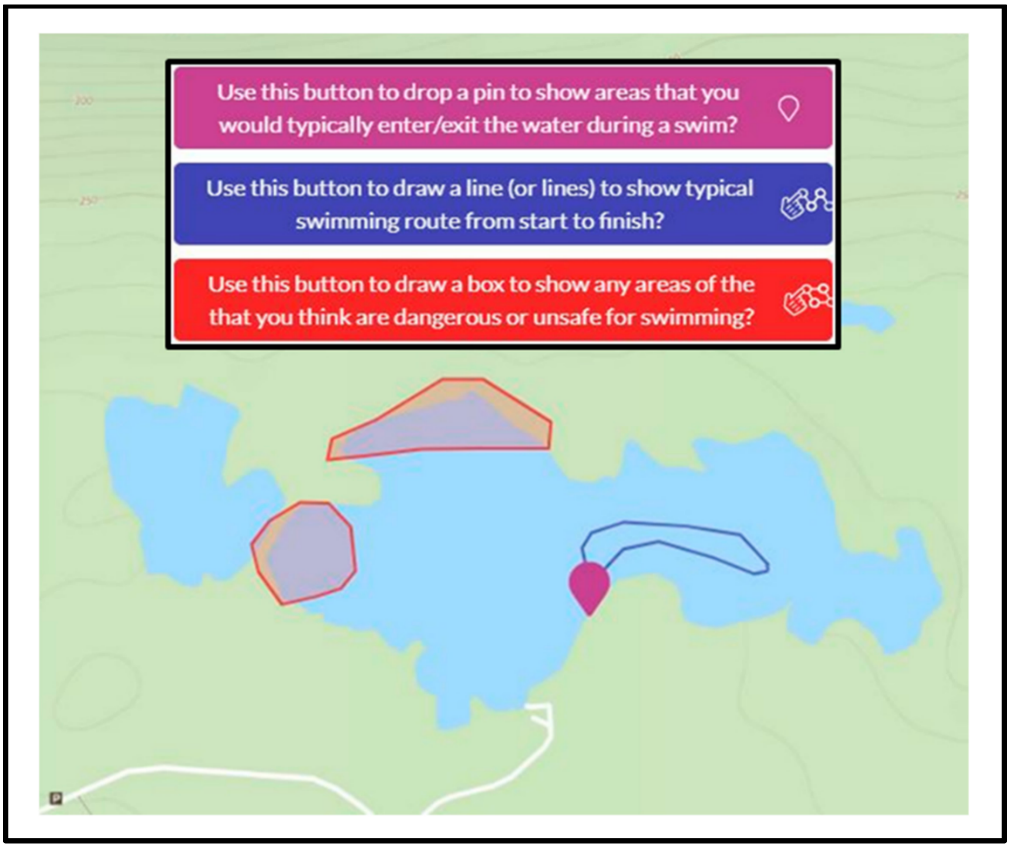

Figure 5.1. Example of participatory GIS exercise completed by participants prior to interview.

5.2.3. Sample

Semi-structured interviews were conducted with twelve wild swimmers who predominately swam in freshwater lochs. The sample consisted of seven women and five men, with most participants aged between 50 and 59 (n = 5). Participants were also aged between 18 and 29 (n = 2), 30 and 39 (n = 2) and 40 and 49 (n = 3). All participants predominately swam in lochs and had some experience swimming in the sea in Scotland. Most participants swam more than once a week (n = 8). Some participants swam once a day (n = 1), once a week (n = 2) and once every two weeks (n = 1). The length of time participants had swam varied across the sample, wherein half of the sample began wild swimming over five years ago (n = 6) and half began swimming in the last two years (n = 6). All participants resided in the Central Belt of Scotland—the collective term for Scotland's major population centres spanning three cities, Glasgow, Edinburgh and Stirling.

5.2.4. Data collection

Semi-structured interviews were conducted between the 15 of April and 17 May 2021 via the videoconferencing platform Zoom (https://zoom.us/ (accessed on 25 April 2022)). Zoom offers a user-friendly platform that is highly suitable for conducting high-quality interviews, both from the perspective of the researcher and research participant (Archibald et al., 2019). Videoconferencing was preferred to face-to-face interviews to minimise geographical, financial and time-related barriers to participation in the study, and as some COVID-19 regulations were ongoing in Scotland, making face-to-face interviews logistically challenging. Sit-down interviewing was preferred to mobile methods such as 'swim-along' interviewing as our research questions predominantly focused on recalled experiences of previous swims and wider reflections on the health and well-being benefits and risks of wild swimming, rather than participant's moment-to-moment experience (Denton et al., 2021)

The semi-structured interviews were conducted by the lead author (CM) and lasted between 31 min and 58 min. CM has previously swum in both lochs and the sea; however, is not a regular wild swimmer and, therefore, occupied both the roles of an 'insider' and 'outsider' in the context of this research (Dwyer and Buckle, 2009). A semi-structured interview guide was developed by the research team (Table 4.1). The interview guide consisted of four key themes: (i) background: developing a basic understanding of participants' wild swimming practice; (ii) health: determining how participating in wild swimming impacts each participant's perception of their own health and well-being, both positively and negatively; (iii) place: establishing factors leading to a preference for swimming in lochs and how participants' experiences of loch swimming compared to experiences of sea swimming; and (iv) risk: determining the importance of risk and risk management within each participant's wild swimming practice. Interviews were audio-recorded and transcribed verbatim by CM. Participants' names were pseudonymised, and wild swimming locations were removed to maintain privacy.

5.2.5. Data analysis

Thematic analysis was conducted to identify patterns and themes within the interview transcript data. All analyses were carried out using NVivo 12 software. NVivo is a data analysis software that assists in the organisation and analysis of qualitative data. The analysis was conducted in accordance with the six phases of thematic analysis outlined by Braun and Clarke (2012). Firstly, CM read all transcripts thoroughly to become familiar with the data and noted some initial trends. Transcripts were then subject to detailed coding and codes were grouped collectively to form themes and subthemes (CM). Initial themes were shared with a section of the research team (CM, RF and DO) with anonymised quotations from the transcripts. The definition and content of each theme were discussed between the research team to ensure rigour was achieved within the analysis. Finally, the research team selected a range of quotations best suited to represent each theme.

5.3. Results

The following section focused on the five central themes of this research: physical health, mental health, social health, place and risk. Several key subthemes are presented and discussed. Health-related themes align with the World Health Organisation (WHO) (1948) definition of health: *'Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'*.

5.3.1. Physical health

Several participants suggested that regularly participating in loch swimming provided benefits for their physical health. These benefits were primarily related to improved fitness, recovery from physical injury and health promotion during ageing.

5.3.1.1. Promoting fitness and recovery

A number of participants suggested swimming benefited their fitness. For example, James highlighted the benefits of loch swimming for his general fitness and flexibility, whilst also noting that if he is unable to swim for a period of time, he notices adverse impacts on his health:

'It keeps me fitter and stronger and more flexible… I know that if I don't get out and swim, I'm going to be sloppy and run down a bit.' (James)

In some cases, participants perceived these healing effects to be because of immersing themselves in cold water, which has been shown to reduce muscle soreness (Machado et al., 2016). However, in other cases, the physical demands of swimming resulted in the re-strengthening of participant's bodies over time:

'I had a car accident eight years ago and I've had back issues ever since… when I first started, it initially it increased my use of painkillers, but after about six months, I completely stopped taking them basically and it was mainly because it just strengthened my core muscles.' (Janet)

Janet's experience demonstrates the potential of wild swimming to contribute toward the restoration of physical health and recovery from ill health (Foley, 2017).

5.3.1.2. Enabling healthy ageing

Some participants suggested that regular loch swimming assisted in age-related health issues. In some cases, this was related to feeling able to exercise again despite health and age-related issues limiting their ability to take part in other forms of exercise. Phil, who had recently suffered a series of heart attacks, suggested that swimming offered an alternative form of physical activity to replace other exercise that was too challenging for him during his heart attack recovery period. Loch swimming also provided respite from his current physical limitations:

'When you've got your head in the water it takes my mind off, you know, not being able, because I'm still too heavy to run at the moment and I wouldn't be confident running.' (Phil)

The presence of blue space is often associated with the promotion of physical activity (McDougall et al., 2020a). However, in many instances, water not only promotes physical activity, but enables physical activity (Foley, 2017). The buoyancy of water means swimming is a non-weight bearing form of physical activity and has, therefore, proved highly suitable for elderly adults and individuals with health-limiting conditions (Tanaka, 2009). As such, numerous accounts highlight the notion of an ‘unhealthy’ body on land, transforming into a ‘healthy’ body when swimming in water (Foley, 2015).

Furthermore, some participants believed that regular loch swimming ‘eased’ several menopausal symptoms. Rachel was unsure if this easing was related to the physical or mental impact of loch swimming:

‘I’ve been having menopausal symptoms for maybe about two years, with sort of night sweats and hot flushes and mood swings and I think the wild swimming has, it’s hard for me to say if it’s been a physical or a mental thing, but I feel that my symptoms have eased.’ (Rachel)

Some anecdotal evidence also supports the notion of wild swimming easing menopausal symptoms. For example, a group of wild swimmers from near Swansea, Wales have reported reductions in menopause-related high temperatures, night sweats and anxiety (Fyfe, 2019), and randomised controlled trials have found that swimming can reduce most of the physical and mental symptoms of premenstrual syndrome (Maged et al., 2018). Collectively, the physical health benefits experienced among older respondents, suggest loch swimming can, like sea swimming, promote fitness, physical recovery and healthy ageing (Costello et al., 2019).

5.3.2. Mental health

Most participants suggested mental health and well-being benefits were the most important outcome of their loch swimming practices. Mental health and well-being benefits were more prominent in health-related discussions than physical and social health benefits.

5.3.2.1. Stimulating positive emotions and happiness

Many participants spoke of the positive emotions they experience whilst participating in loch swimming. These positive experiences have been highlighted previously in accounts of sea swimming (Britton and Foley, 2020). Sarah reflected on the happiness she feels when in water and suggested that blue spaces were environments where she felt comfortable:

'I'm really comfortable in water as well and it's just quite a nice environment for me, I guess it's just somewhere I feel happy. Like when I go swimming, when I'm in water, I feel probably like my happiest and so that's kind of the reason I do it.' (Sarah)

The enjoyment of wild swimming is often a key motivation for taking part in the activity (Wood et al., 2022) and people tend to be happier when in or near blue spaces (de Vries et al., 2021). Gould et al. (2020) suggest the happiness generated from wild swimming can go beyond the swim itself, and enjoyment is generated in other elements of swimmers' lives, e.g., during the preparation for a swim. The happiness or 'buzz' that was experienced during loch swimming also extended beyond the swim itself. Some participants suggest these positive emotional responses are extended throughout one's day or even longer-term:

'It just makes me smile, I can't tell you how (why). It makes me so much happier through the day.' (Rachel)

Phil, who, as noted previously, lost confidence and motivation in life due to ill health, suggested that loch swimming played a critical role in providing him with a more positive outlook on life:

'The swimming has just given me a buzz. Just to get back going again, you know. Positive, positive mind-set, that's what it's given me… I think the swimming is the trigger, that's what's triggered the positive mind-set.' (Phil)

This 'buzz' has also been noted among participants of water-based exercise, often after a challenging task is completed and a sense of achievement is generated (Thompson and Wilkie, 2020).

5.3.2.2. Promoting mindfulness and restoration

Many participants highlighted that loch swimming provided opportunities to be mindful and peaceful. Interestingly, some participants spoke of the notion of forced mindfulness, where the practice of loch swimming and the physical challenge of safely immersing oneself in cold water, forced the need to *‘be present’*:

‘It makes you switch off from what’s going on… It’s not a conscious decision to switch off from the stresses, I just think it makes you switch off from them because your body is having a bit of a physical adjustment to the cold water. So I don’t know if that’s just because, you know, it means you have to focus on something else other than your worries.’ (Rachel)

Tracy also suggested that being mindful and present in blue space was not a choice, but a positive consequence of the environment that you are immersed in:

‘You have to be present. Like it’s like the most mindful experience ever … you don’t have time to think about how you feel before you don’t have time to think about what’s going to come after. It’s like you’re so present.’ (Tracy)

Similar meditative states have been experienced in qualitative accounts of other blue-space immersions, such as scuba diving, where participation can lead to a clarity of thought and a focus on one’s breath (Straughan, 2012). Swimming is a rhythmic form of exercise, and the need to focus on breathing and stroke (Ward, 2017) may also explain the meditative-like experience of loch swimming. Furthermore, the meditative potential of swimming appears to be heightened by exposure to cold water and exposure to nature, which has been shown to enhance mindfulness (van Gordon et al., 2018).

Several participants suggested loch swimming was a time for ‘switching off’ and reflection:

‘It’s time on your own. It’s time to either just completely switch off or allow yourself time to think about things and kind of muddle through stuff in your head.’ (Linda)

These accounts aligned closely with the concept of ‘being away’, which is central to Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989). Being away refers to a break from one’s daily routine, activities and demands that cause attention fatigue. Consequently, being away can lead to cognitive restoration and recovery from attention fatigue (Kaplan and Kaplan, 1989). Views and sounds of water are perceived as highly restorative environmental characteristics (White et al., 2020), and the restorative potential of these characteristics appears to be heightened during loch swimming.

5.3.2.3. Stress reduction, coping and building resilience

For some participants, loch swimming helped during periods of mentally ill health or stress. Linda, detailed how her loch swimming relieved stress at the end of the week:

'*It's just a de-stress. It's a coping mechanism. But it's a definite de-stress for me at the end of the week… and it's not the same getting into a chlorinated pool as you just feel like a ping pong ball.*' (Linda)

Janet spoke of a more instantaneous mental relief as a result of loch swimming:

'*If I'm having like a bad day or anxious about something then after the swim, that kind of disappears.*' (Janet)

Failure to cope with physical and mental stressors can lead to ill health (Antonovsky, 1987), and natural environments can provide highly suitable settings for stress recovery and coping with stress (Berto, 2014). Stress reduction is hypothesised as a key pathway by which blue-space exposure can improve health and well-being (White et al., 2020). Indeed, Stress Reduction Theory (Ulrich et al., 1991) proposes that exposure to natural environments, particularly those with water, can increase one's ability to recover from stress. Furthermore, wild swimming may enhance stress reduction as a result of the euphoria experienced by participants (Buckley, 2020). Wild swimming, particularly in cold waters where the body is exposed to stressful conditions, may also build resilience to physical and mental stressors (Bottley. 2019). Interestingly, one participant spoke of the resilience generated not only by her loch swimming practice but by the knowledge of having the opportunity to engage in loch swimming in the future:

'*You're going to get to the water again, you're going to feel that again so you can hold on through whatever hardship you're going through, because you know that the water will reset. It's kind of it's like really a reset process.*' (Tracy)

The notion of wild swimming promoting resilience has been highlighted in a number of accounts of sea swimmers (Costello et al., 2019; Britton and Foley, 2020). Foley

(2015) describes building resilience as an accretive process, whereby each swim adds an additional layer of resilience to produce a growing and more resilient mental well-being. It has also been suggested that swimmers derive mental strength from the challenge of wild swimming, which provides psychological resilience and confidence to tackle challenging life problems (Denton and Aranda, 2020). Participating in adventurous forms of physical activity, which involve exposure to physical and mental stressors, such as wild swimming, can therefore build a 'mental toughness', which can benefit mental health (Clough et al., 2016).

There were a number of participants who described loch swimming as an important and beneficial component of their life, and some referred to their swimming practice as a '*rock*' in their life. This was particularly true for participants who suffered from mentally ill health or had suffered grief in recent years:

'*It (wild swimming) keeps me on a level pegging and maintains my balance sort of thing mentally as well. And because we've been through quite a lot over the last couple years, so it has given me a bit of stability*.' (Tony)

The notion of stability and balance provision are corroborated by survey research that suggests increasing one's ability to carry out day-to-day tasks is a key motivation for wild swimming participation in the United Kingdom (UK) (Wood et al., 2022). Stability may be provided by the provision of routine and purpose because of participating regularly in wild swimming (Costello et al., 2019). However, the habitual nature of wild swimming participation can also lead to adverse health and well-being impacts if participants are unable to swim (Foley, 2015). For example, James discussed the negative impact of a period in which he was unable to swim:

'*I couldn't swim much I was going through a rough patch because my father just died and I really missed getting in the water because that's my form of exercise to deal with stresses of daily life… I found it really tough to miss the water. If I don't swim three times a week, four times a week, I notice the adverse impact that has on me.*' (James)

5.3.3. Social health

Socialising and interacting with other swimmers were highly important and beneficial aspects of loch swimming, and many participants spoke of the '*supportive*' and '*welcoming*' nature of the wild swimming community in Scotland.

5.3.3.1. Shared experience

Several participants described positive shared experiences during loch swimming. These experiences were pre-, during and post-swim. Janet provided an example of the shared experience of entering a loch prior to a group swim, highlighting the enjoyment of a shared feeling of shock from exposure to cold water:

'*It's nice to see everybody and you just ask everybody how they've been? And it's always fun getting in the water because it's that bit a shock and usually we're giggling and laughing and making funny noises and then you go for a swim.*' (Janet)

Sharing the challenge of wild swimming can enhance the experience for those involved (Costello et al., 2019). Janet also provided an example of how immersion in water can promote fun and playful behaviours, which may be explained by immersion in water evoking childhood memories and childlike behaviours (Foley, 2017). Indeed, the motion and movement of water can stimulate play (Denton and Aranda, 2022).

Positive social interactions were not limited to before or during swims. Many participants spoke of post-swim activities, which were often pre-arranged as part of a weekend swim. The post-swim culture was highlighted regularly as an important component of the loch swimming experience. For example, James speaks of the importance of post-swim socialising to his group:

'*One of the key features of it is the post swim, get together, we always have a chat and you find a coffee shop if you can. A cafe has some cake, coffee, and just catch up with people and that's a vital part of the whole experience.*' (James)

Many participants suggested that the social component of their loch swimming experience outweighs the importance of the swim itself.

5.3.3.2. Unique and negative social interactions

Social interactions positively impacted most participants' loch swimming experiences. However, some participants highlighted 'unspoken rules' of their swimming interactions. For example, Tracy, suggested that whilst she enjoyed the social element of swimming, she preferred swimming with people who were not overly talkative and allowed her to enjoy her own experience:

'*I like to be alone… it's kind of a meditative experience for me, like I need it to be just me in the water. So yeah, I try to go with people who don't speak too much when they're in the water.*' (Tracy)

Moles (2021) suggests traditional forms of communication and interaction change during swimming. This type of unique interaction is described by Kevin:

'*There is a bond there when you're swimming that isn't necessarily through talking'* (Kevin)

Finally, although the majority of loch swimmers highly valued the social component of their loch swimming practice, socialising and the influence of others could also negatively impact a swimmer's experience:

'*Sometimes like I've had a swim that felt kind of disconnected and I didn't feel like I got all the benefits because I was maybe like chatting a pile and there was loads of people around and you get a bit self-conscious about whatever, like your bikini body or whatever.*' (Lucy)

5.3.4. Place

Participants described a number of important components of place that positively impacted their loch swimming experiences. Four key place-related themes emerged from the interviews: (i) calmness and stillness; (ii) feeling in control; (iii) enhanced connection to nature; and (iv) freshwater.

5.3.4.1. Calmness and stillness

Numerous participants highlighted their preference for calm water conditions when swimming in lochs and believed this improved their swimming experience. Generally, participants also perceived the wider environment surrounding the lochs that they swim in to be calm and tranquil. Sarah suggested swimming in calm water conditions improves her experience:

'*Having that kind of calm and stillness is something that I feel for me, makes it so much more enjoyable.*' (Sarah)

Lochs are likely to be calmer and stiller than other blue spaces, such as rivers and the sea, where flow and tides are present. These somewhat unique still-water conditions were discussed by a number of participants and the still water surface was often referred to as '*glass*'-like. Still conditions appeared to contribute to the mental health and well-being benefits previously discussed. Some participants found calm water conditions better for facilitating relaxation as less planning or safety considerations were required:

'*If the waters a little bit choppy, your mind gets taken away to other things like your safety in the water and other things and fight against the waves and the current and the weather elements. But see when it's nice and flat, you just feel so relaxed.*' (Tony)

Tony also suggests the stillness and calmness of water conditions enhance the relaxation benefits attainted during loch swimming:

'*As soon as I get in the water at Loch [X] and it's a nice day, there no rain, there's no wind, the water is flat, like silk, like diving into glass more or less, it just relaxes my mind.*' (Tony)

In many cases, the '*breaking glass*' moment, where a swimmer enters the loch and breaks the stillness of the surface water, appeared to be a distinct starting point for relaxation.

5.3.4.2. Feeling in control

When considering loch swimming relative to their sea swimming experiences, several participants suggested that they felt a greater feeling of control due to calmer water conditions when loch swimming. For example, Sarah described her preference for loch swimming due to feeling in control when entering the water:

‘*I actually quite like lochs because they’re less likely to have big waves as you’re obviously going out. Whereas obviously when you’re going into the sea, there’s waves coming over you quite often and I’ve never really liked that because I quite like being in control when I’m going into the water and letting myself warm up gradually.*’ (Sarah)

Sarah also suggested that feeling in control in the sea was less common due to the conditions she faced when sea swimming. This feeling of control was deemed an important component of her experience:

‘*A big thing for me is feeling like I’m in control of what I am doing whilst I’m in the water. Which I feel like when I’m in the sea, and when I’m somewhere with a strong current or tide I don’t really have that opportunity to feel like I’m in control. Whereas in a loch I do.*’ (Sarah)

Participants often suggested that the feeling of control was a result of lochs being ‘contained’ spaces, where the boundaries of a loch were normally visible, unlike the sea. Feelings of control and containment are associated with indoor pool swimming (Ward, 2017), and wild swimmers often prefer the wildness of the sea relative to indoor pools, which can be perceived as overly calm, artificial and controlled (Costello et al., 2019). Exposure to the harshness and energy of the sea often contributes to positive wild swimming experiences by providing challenging circumstances for swimmers to overcome (Foley, 2017). Enjoyment due to the challenging nature of loch environments was also demonstrated by some of our participants; however, many also enjoyed feeling a degree of control, which they did not believe could be obtained in the sea. Participants simultaneously seeking a degree of wildness and a degree of control challenge the traditional indoor vs. outdoor swimming narrative and suggest more nuanced preferences for swimming environments exist.

5.3.4.3. Enhanced nature connection

Experiencing a heightened connection to nature was observed by the majority of participants when loch swimming. This was often described as an increased closeness to nature, or in some cases, feeling part of nature:

'*I think with the swimming you feel like you're in nature rather than I don't know, I feel more of a part of it.'* (Emma)

'*I think you feel as though you're closer to nature, you're immersed in it in a medium like water. So, I feel closer to nature*.' (Colin)

Qualitative accounts suggest an enhanced connection to nature is obtained during sea swimming (Britton and Foley, 2020). An enhanced connection to nature has been associated with improved mental well-being (White et al., 2021) and may, therefore, partly explain some of the mental well-being and mindfulness benefits discussed in Section 3.2.2. Indeed, wild swimming can enhance one's ability to achieve mindfulness, whilst being mindful can increase one's connection to nature (van Gordon et al., 2018). Wild swimming is an intense multisensory activity (Denton and Aranda, 2020) and fully-body immersion in water may stimulate a unique nature engagement that is distinct to that experienced during other activities and forms of exercise.

Some participants described a connection to nature that goes beyond the loch and extends to the wider landscape and surrounding green spaces:

'*There's hills and trees and stuff everywhere and it's just green and I love the scenery and I love being able to just kind of lie back in the water and just like take in my surroundings.*' (Sarah)

As highlighted by Sarah, loch swimming provided opportunities to experience nature in ways distinct from the norm, e.g., obtaining close views of wildlife in the water or swimming to small islands where a new view of the surrounding Scottish mountains could be observed. This is somewhat unique to inland water bodies as these can be physically surrounded by nature and green spaces. The surrounding green space is less likely in coastal blue spaces given the magnitude of water and composition of coastal landscapes. The lochs in which the majority of our participants swam tend to be surrounded by woodlands and vegetation, providing a combined experience of blue space, with a backdrop of green space. This blue–green combination has been shown to be more restorative than exposure to blue or green space independently (White et al., 2010) and may partly explain the enhanced connection to nature experienced during loch swimming.

5.3.4.4. Freshwater

Although Scotland has an array of sea lochs, all participants regularly swam in freshwater lochs. The presence of freshwater emerged as an important component of place that positively influenced some participants' wild swimming experience. Some participants noted a general dislike for saltwater and a preference for freshwater:

'*If you get splashed in the face, loch water doesn't sting your eyes, doesn't taste disgusting.*' (Janet)

This preference for freshwater was highlighted by a number of participants. In other instances, freshwater allowed swimmers to experience a greater challenge. For example, James described freshwater as less buoyant than seawater, thus providing an opportunity to improve his swimming technique and challenge himself:

'*I like that it's freshwater so if you get thirsty, you can have a drink. And just the challenge of swimming in freshwater because it's more difficult in fresh water that salt water because you've got less buoyancy.*' (James)

Challenging experiences in blue space can contribute to improved enjoyment and enhanced well-being (Britton et al., 2018). A similar trend was also highlighted among water-based exercise participants, whereby a preference was observed for environments that allowed participants to challenge themselves to go beyond their comfort zones and improve their ability Thompson and Wilkie (2020). Loch swimming offered the challenge of reduced buoyancy but also was deemed by many as less risky and less challenging than sea swimming due to the presence of calmer water conditions.

5.3.5. Risk

All participants appeared to be highly aware of the risks of wild swimming. In response to questions related to risk, a number of key risks and mitigation strategies were highlighted. Some of the risk discussions were directly related to loch swimming and others relative to sea swimming.

5.3.5.1. Cold water exposure

Several participants highlighted cold water as a key risk of loch swimming. Over half of the participants had experienced negative health responses because of overexposure to cold water, such as cold-water shock. Exposure to cold water can cause a serious risk to health due to progressive hypothermia or a decrease in swimming performance, which can lead to drowning (Kolettis et al., 2003). Many participants spoke of the need to understand and listen to their bodies to monitor their reaction to the cold:

‘*I'm always a little bit afraid of the cold water… you've got to keep an eye on how long you're in (water) for and how your body is reacting.*’ (Janet)

Swimmers also discussed a growing awareness of their ‘*limits*’ as they became more experienced, often drawing upon incidents of overexposure to cold water or ‘near misses’. The notion of increased awareness of risk and the ability to listen to one's body advances Foley's (2017) theory of accretion, whereby one's ability to listen to their body and protect their health also grows with each swim. Although noted here as a risk-mitigation technique, the need to listen to one's body and breathing aligns closely with mindfulness and meditation and exemplifies the close connection between risk and health benefits experienced during wild swimming.

The risk of cold water often resulted in the adaption of swimming routes and routines. For example, James suggests swimming in lochs with multiple exit points during wintertime to ensure easy access if the body reacts negatively to cold temperatures:

‘*In the wintertime, we would particularly choose places to swim, where there's lots of exit points. So if you get into trouble, you can get out easily. We won't swim too far from shore, we might, we might go 15 min from shore, for example, because we* *know that in the wintertime, you can quickly get cold and you'll have trouble swimming.*' (James)

This type of pre-swim planning was common among most participants. Participants also described pre- and post-swim rituals that aimed to minimise the risks of cold water, including route planning and following an efficient strategy of warming up, such as preparing warm drinks and clothes and easy access to a car. Participants also relied on the support of others to minimise risk by swimming in a group or bringing along a friend or family member to accompany them from the lochside.

5.3.5.2. Other loch users

Another major perceived risk of loch swimming was other loch users, particularly in motorised vehicles, such as boats or jet-skis. Boat traffic was also a major concern among wild swimmers across the UK (Wood et al., 2022). Three of the twelve participants described incidents where they were nearly struck by motorised vehicles during a loch swim. As such, maintaining an awareness of potential traffic was an important consideration for many participants:

'*If you're crossing a big body of water, you're always conscious about traffic. Keeping an eye out for that, and your ears work pretty well to hear in the engines and jet skis.*' (James)

Most participants swam with a tow-float to increase visibility to other loch users. Tow floats are small reflective buoyancy aids that can be attached to a swimmer's ankle and are popular for reducing a variety of wild swimming risks by increasing visibility and providing additional buoyancy support in emergencies.

5.3.5.3. Site selection

Carefully selecting where to swim, both in terms of loch selection and areas within a selected loch, was another key strategy for ensuring safe wild swimming. This selection process often involved relying on the experiences of other wild swimmers, either through personal communications or through social media:

‘I always swim places that I know are popular that people swim, we don’t just swim somewhere random.’ (Karen)

Social media also played an important role in understanding developments in water quality. For example, Janet regularly uses social media to gather updates about blue–green algae in the loch that she swims in:

‘*A lot of people post things on Facebook, there’s a thing called blue green algae and you can look out for that. They’ll post pictures of it and people say that they’ve been there and walk and they’ve seen it there, so I would avoid that for a while.*’ (Janet)

Generally, water quality was not deemed a major risk among participants, and loch water in Scotland was perceived as ‘clean’. This is in contrast to the findings of Wood et al. (2022) who suggest water quality is rated as the most concerning ecosystem disservice among wild swimmers in the UK.

5.3.5.4. Loch risk relative to sea risk

Generally, participants believed the risks of swimming in the sea exceeded those of swimming in lochs. The overarching reason for this belief was the harshness of sea conditions in Scotland and the potential for these conditions to change rapidly:

‘*I think conditions can change a lot quicker in the sea than they can on a loch.’* (Colin)

‘*I think swimming in lochs is a bit safer than swimming in the sea and swimming and rivers and stuff, because I know they’re still currents and stuff in lochs, but they’re never anywhere near as strong as in the sea or in rivers.*’ (Sarah)

Although participants believed that swimming in the sea was more dangerous than swimming in lochs, all made clear that any water body could potentially be a dangerous environment. This is summarised by Janet:

‘*I think the main thing was swimming in the sea is the fact that the ocean is just so giant. It’s something that I think I would always say people need to respect the water regardless of whether they’re getting into a swimming pool or the ocean, but the ocean is just, it has a mind of its own and it can change in a heartbeat.*’ (Janet)

Some participants noted fear of the sea and suggested that this fear influenced their decision to swim in lochs. However, others suggested that they would swim in the sea more often if they lived nearer, despite believing loch swimming was safer. There was also a perception among participants that sea wildlife created an increased risk for health. In particular, the risk of encountering jellyfish was highlighted by a number of participants, whilst busy seaside hotspots were off-putting due to an abundance of other water-users and boat traffic.

5.4. Conclusions

The findings of our study suggest participating in loch swimming may provide a wide variety of physical, social and mental health and well-being benefits. Although described as distinct health and well-being benefits in our research, these benefits are often interlinked and complementary. Mental health and well-being benefits, such as enhancing mood, increasing mental resilience and reducing stress, were the most prominent benefits reported among the loch swimmers interviewed in our study. The wider social benefits that accompanied loch swimming were often considered more important than the swimming experience itself. Several participants appeared to use loch swimming to assist in their recovery from physical and mental ill health.

Generally, the health and well-being benefits obtained from loch swimming align closely with previous studies focusing especially on the health and well-being impacts of sea swimming. Despite similarities in the resultant health and well-being benefits, the experience of loch swimming and sea swimming have some distinctions. Loch conditions, which, in the experience of the loch swimmers considered in our study, tend to be calmer than the sea, offer a unique opportunity to swim in still water, which can increase a swimmer’s feeling of control, safety and relaxation. Indeed, participants often suggested swimming in still-water conditions was particularly relaxing and calming. Participants also suggested an enhanced connection to nature when immersed in loch environments due to being surrounded by nature and green space, which is unlikely during sea swimming. However, the most notable difference between loch swimming and sea swimming was in relation to risk. All participants perceived loch swimming to be safer than swimming in the sea due to the harshness and unpredictability of sea conditions.

The participants interviewed in this study appeared to be highly aware of the risks of wild swimming, although there remains scope to increase participants' awareness of the risks of exposure to poor quality water. Despite generally high risk awareness in our sample, the risk of illness and fatality as a result of wild swimming remains a growing public health concern as wild swimming becomes increasingly popular. A number of recommendations to minimise the risks of wild swimming arose from this study. Firstly, the consideration of place is crucial to effectively manage the risks associated with wild swimming. The consideration of place in relation to wild swimming risk management should be multi-scale and focus on the varying risks of swimming in different blue space types, e.g., lochs, rivers and seas, the varying risks associated with individual catchment areas and the place-related risks of each swimming location. Failure to adequately consider place in risk management may lead to over-generalised safety guidance and low compliance with this guidance among wild swimmers. For example, participants in our study often noted that a failure to provide place-specific guidance, e.g., exactly where algal blooms occurred in a particular loch, leads to guidance being ignored. Secondly, there is a need to increase public education on the risks of wild swimming and the mitigation strategies for these risks. This is particularly relevant in Scotland, where swimming is not an element of the school curriculum, unlike in other parts of the UK (Water Safety Scotland, 2018). Targeted education campaigns for novice wild swimmers may be particularly valuable given the growing popularity of the activity and the importance of wild swimming experience in managing risk. Thirdly, there is an opportunity to better combine the expertise of organisations involved in the management of water bodies and the expertise of the wild swimming community. Innovative citizen science methods, such as interactive mapping of real-time risks by combining wild swimming social media data, local knowledge and water management expertise may offer synergistic benefits that exceed the outcomes of current risk-mitigation strategies.

When risk is adequately considered, wild swimming offers an opportunity to promote public health, particularly for individuals suffering from physical and mental ill health. Wild swimming is often described as an inclusive activity because individuals with limited physical mobility can be enabled to exercise due to the generally welcoming nature of the wild swimming community. However, moving forward, there is a need to challenge this notion of inclusivity and address barriers to wild swimming participation. Inequalities in blue-space usage and access are well established, and the historical, social and political context of blue spaces can lead to significant barriers to usage among different demographic groups (Phoenix et al., 2020). Furthermore, socioeconomic and racial inequalities in swimming ability (Hastings et al., 2016) will likely impact wild swimming participation. Finally, many risk-mitigation strategies to ensure safe wild swimming (e.g., access to a wetsuit or tow float) involve some financial cost. Consequently, there is a need to not only consider the inclusivity of wild swimming but the inclusivity of safe wild swimming. Addressing issues related to risk and equity offers scope to broaden the public health benefits of wild swimming and ensure wild swimming is available and safe for all.

Chapter 6 - Valuing inland blue space: A contingent valuation study of two large freshwater lakes

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Abstract

Water bodies, or blue spaces, offer a range of health and well-being benefits. Many of these benefits occur in waterside spaces and do not require direct water contact. For example, non-water based physical activity (e.g. walking and running) and reduced stress as a result of viewing water from a distance. However, research dedicated to understanding the economic impact of changes to freshwater ecosystems predominantly focuses on water-based recreation and water quality. As a result, the economic impacts of changes to waterside space are often overlooked. This study used the contingent valuation method to determine public preference for the protection of lakeside quality, in terms of lake views, path quality and lakeside access, at two large freshwater lakes in Scotland (Loch Lomond and Loch Leven). The aim of the study was to estimate willingness to pay among a sample of adults in Scotland (n = 1056) for the protection of lakeside quality. Results indicate that the majority of respondents are willing to pay for the preservation of lakeside quality at each lake. Based upon the most conservative estimates obtained, mean willingness to pay for the protection of lakeside quality was £12.06 per household per year at Loch Lomond and £8.44 at Loch Leven. These findings provide valuable economic data and suggest that changes to waterside space at destination water bodies have nationally important economic impacts. Greater consideration of the economic impact of changes to lakeside space is recommended in order to develop cost-effective and socially optimal water resource management policies at large freshwater lakes.

6.1 Introduction

Approximately 90% of all surface freshwater on earth is contained in natural or man-made lakes (Shiklomanov and Rodda, 2004). Humans derive a range of direct and indirect benefits from freshwater lakes which contribute to well-being (Reynaud and Lanzanova, 2017). These benefits can be related to a set of ecosystem services, including regulating (e.g. water purification), provisioning (e.g. fish production), supporting (e.g. nutrient cycling) and cultural (e.g. recreational activities) services (Millennium Ecosystem Assessment, 2005; Costanza et al., 2017). Quantifying the economic value of freshwater ecosystem services has become an increasingly important priority for policy makers since the implementation of the European Union's Water Framework Directive (WFD) (Directive/2000/60/EC). The WFD aims to achieve good ecological status (GES) for all water bodies in EU member states and requires the social and economic impacts of water policies related to achieving GES to be considered in the formation of catchment management plans (Vlachopoulou et al., 2014). Indeed, understanding the economic value of freshwater ecosystem services is an important element of designing socially optimal water resource management policies (Xu et al., 2018). However, empirically estimating the economic value of freshwater ecosystem services is challenging as these services frequently generate non-market benefits (Hanley et al., 2019).

Over recent decades, economists have developed a range of methods to value non-market benefits, which typically rely on the stated or revealed preferences of individuals (Mitchell and Carson, 1989). Revealed preference approaches determine economic values by observing actual behaviour, and linking this to the availability and/or quality of environmental resources such as rivers and forests. Stated preference methods determine economic values by analysing consumer behaviour in carefully designed hypothetical markets (Hanley and Czajkowski, 2019). Given that people are commonly unfamiliar with hypothetical markets and non-market goods, stated preference valuations often reflect a degree of uncertainty (Butler and Loomes, 2007). Where such uncertainty characterises the value people place on environmental enhancements, research suggests that respondents of stated preference surveys often prefer to provide a range of economic value statements rather than a single value (Mahieu et al., 2017). Understanding the size of this range of values or “valuation gap” is useful in interpreting the economic values derived from stated preferences approaches. However, few studies have attempted to identify what determines the size of this gap (Hanley et al., 2009; Smith et al., 2019).

The Contingent Valuation (CV) method is a survey-based stated preference approach, where respondents are asked to value changes to a non-market good such as water quality (Šebo et al., 2019), or air pollution (Hammit and Zhou, 2006). The CV method determines economic values of non-market goods by asking how much respondents are willing to pay or willing to accept in compensation for specified changes to the good in question. Measures of willingness to pay (WTP) and/or willingness to accept (WTA) allow a monetary value to be placed on the environmental gain or loss, which is an estimate of the underlying gain or loss in utility to the individual (Hanley et al., 2019). The CV method has been used extensively to determine the non-market value of improving water quality at lakes in various locations (Hunter et al., 2012; Bateman et al., 2005; Cooper et al., 2004; Van Houtven et al., 2014). Whilst a substantial body of work seeks to determine the non-market benefits of changes to water quality and improvements to ecological status, less is known about changes to other important attributes of freshwater ecosystems.

Cultural ecosystem services, particularly the health and well-being benefits of spending time in the natural environment, have received increased attention across a number of disciplines in recent years. “Nature-health” research has predominantly focused on the health and well-being benefits of exposure to green space, which has been shown to improve both physical and mental health (Twohig-Bennett and Jones, 2018). The role of water bodies, recently termed “blue spaces”, for promoting health improvements has received relatively less attention, yet a growing body of evidence suggests that exposure to freshwater can provide physical and mental health benefits, e.g. by reducing anxiety (Pearson et al., 2019) and encouraging physical activity (Vert et al., 2019). Emerging evidence that freshwater may play a direct role in facilitating health and well-being benefits suggests the value of cultural ecosystem services provided by water bodies may have been previously underestimated. This may partly explain why ecosystems services provided by lakes are recurrently undervalued in decisions related to their management and conservation (Reynaud and Lanzanova, 2017).

Recent evidence suggests the majority of visitors to inland water bodies in England, UK do not make direct contact with water (Elliott et al., 2018) and that improved water quality does not necessarily enhance the ecosystem services offered by inland waters (Ziv et al., 2016). Health and well-being benefits related to blue space exposure commonly occur in terrestrial locations, e.g. due to non-water based physical activity (Vert et al., 2019), reduced psychological distress from viewing water (Nutsford et al., 2016) and social interaction in waterside environments (Bell et al., 2017). Consequently, water visibility and the condition of waterside spaces (e.g. path quality or the availability of open spaces) play an important role in the provision of health and well-being benefits, yet little is known empirically about the value of these attributes.

Having identified this knowledge gap, the present study adopted a CV approach to determine the non-market value of protecting “lakeside quality” in terms of water visibility, path quality and access to lakeside space at two large and popular freshwater lakes in Scotland: Loch Leven and Loch Lomond. The specific objectives were to: (i) quantify how the public value the protection of lakeside quality at two large water bodies in Scotland which are contrasting in physical characteristics, visitation numbers and water quality; (ii) determine how public willingness to pay for protecting lakeside quality is influenced by sociodemographic factors, visit characteristics and geographic location relative to the lake; (iii) establish what factors influence the size of the ‘valuation gap’; and (iv) inform future decision making processes at large freshwater lakes.

6.2 Case study descriptions

6.2.1 Loch Lomond

Loch Lomond is a large freshwater lake located in Central West Scotland, UK (56°05′N 4°34′W) (Fig. 6.1.). The lake has a surface area of 71km^2 and approximately 153.5km of shoreline with several beaches and lakeside settlements. Loch Lomond is located within the Loch Lomond and Trossachs National Park, which is protected under the National Parks (Scotland) Act (2000). The site is classified under a variety of conservation designations, including as a National Scenic Area (NSA), RAMSAR site, National Nature Reserve (NNR) and Special

Protected Area (SPA). Loch Lomond Woods are designated as a Special Area of Conservation (SAC) due to the presence of western acidic oak woodland. Loch Lomond offers diverse recreational opportunities and receives approximately seven million visitor days and four million visitors per year, making it of one of the most popular sites for recreation in Scotland (Friends of Loch Lomond, 2019). The lake is surrounded by designated walking routes and cycle tracks and offers a variety of water-based recreational opportunities including swimming, boating, angling and water sports.

6.2.2 Loch Leven

Loch Leven is a shallow nutrient-rich freshwater lake located in Perthshire, Scotland, UK (56°12′N, 3°22′W) (Fig. 6.1.). The lake has a surface area of 13km^2 and mean depth of 3.9 m with multiple sections that exceed 22 m (Hedger et al., 2002). In recent decades, Loch Leven has been adversely affected by nutrient inputs from surrounding commercial sources and rural septic tanks causing cyanobacterial blooms which can lead to water quality failing to meet World Health Organisation (WHO) standards for safe recreational usage (Hunter et al., 2010). The conservation importance of the lake is evidenced by its designation as a National Nature Reserve (NNR), a Site of Special Scientific Interest (SSSI), a Special Protected Area (SPA) and a RAMSAR site. Loch Leven receives approximately 200,000 visitors per year and visitor numbers are increasing annually (Reid et al., 2016). The lake is surrounded by a number of small beaches and a 22km path which is popular among walkers, dog walkers and cyclists. Bird watching is also popular due to the presence of notable bird species, e.g. pink-footed goose (*Anser brachyrhynchus*), shoveler (*Anas clypeata*), gadwall (*Anas strepera*), goldeneye (*Bucephala clangula*) and cormorant (*Phalacrocorax carbo*), whilst angling is popular due to the presence of brown trout (*Salmo trutta*).

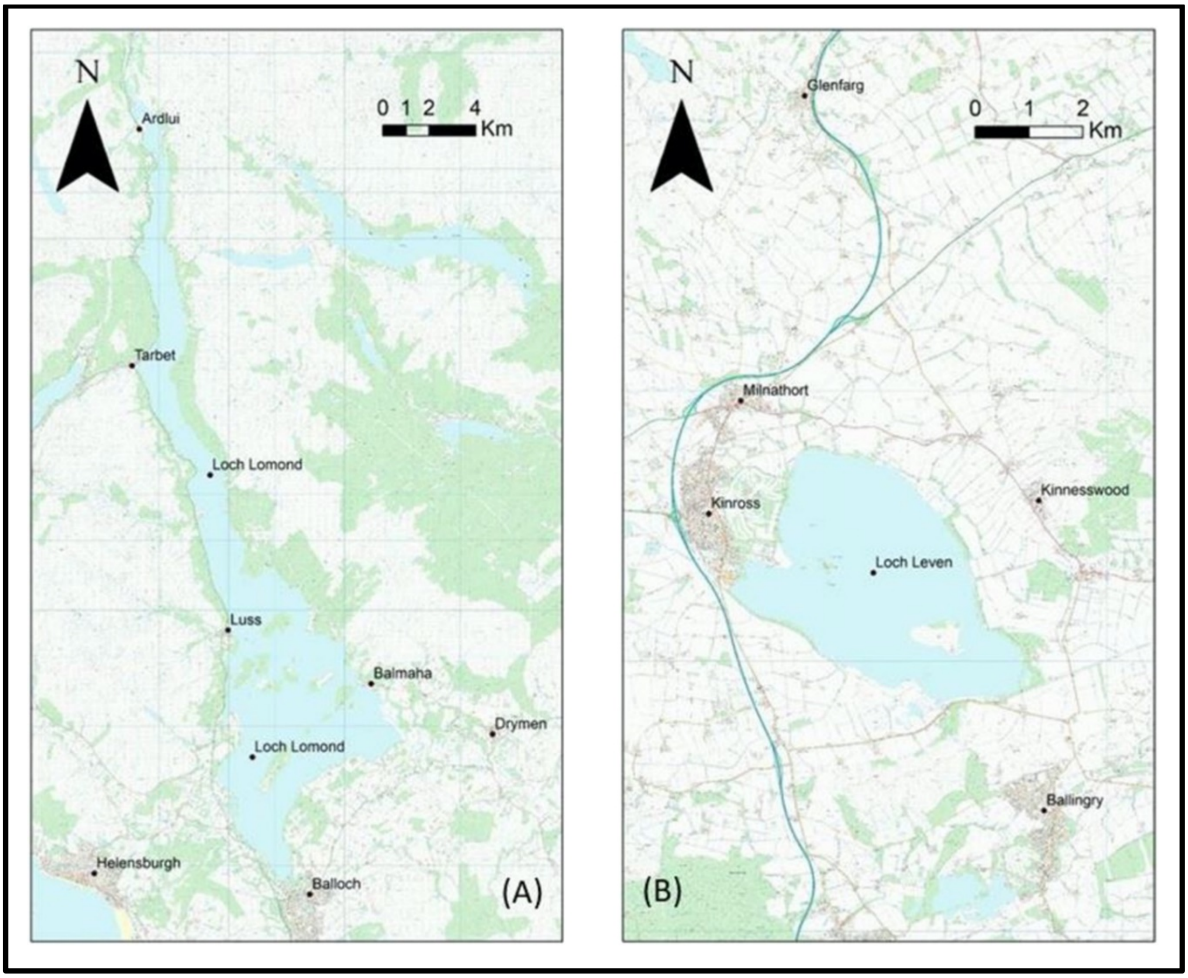

Figure 6.1. Maps of Loch Lomond (A) and Loch Leven (B).

6.2.3 Valuation scenario

The basis of any CV research is a valuation scenario which should be realistic and credible (Johnston et al., 2017). A hypothetical valuation scenario was developed to account for the objectives of this study and to take into account the differing physical characteristics of Loch Lomond and Loch Leven. The valuation scenario proposed an increase in management costs at either lake due to the need to respond to overgrowing native vegetation and increased visitor numbers. Overgrowing vegetation and increased visitor numbers provided a realistic and uncontroversial mechanism to reduce lake visibility, deteriorate path quality and limit lakeside access. A new, hypothetical lakeside management plan was thus proposed for selected areas of each lake to protect "lakeside quality" by focusing on three key issues: (1) maintaining path quality by remediating overgrowing vegetation and damage from increased footfall; (2) retaining current lake views from recreational areas and walking routes by managing overgrowing vegetation; (3) preserving access to lakeside spaces by managing aquatic and terrestrial vegetation growth. Such management plans would require additional funding from Scottish taxpayers, which generated a credible payment scenario. Further details of the valuation scenario are outlined in Section 6.3.3.

6.3 Methodology

6.3.1 Survey development and administration

Individual CV surveys were designed for Loch Lomond and Loch Leven. The content and questions of both surveys were almost identical with the exception of small technicalities related to the differing characteristics of each site. Participants for both surveys were recruited via the Qualtrics online panel (www.qualtrics.com/uk/) which is made up of adults resident in the UK. After passing screening questions to confirm eligibility for the study (i.e., residing in Scotland), panel members were randomly directed to either survey on the Qualtrics online platform. The proposed extent of the hypothetical market, i.e., the group of people whose welfare could be affected by the changes at each lake being valued in the study (Mitchell and Carson, 1989), was selected as nationwide (Scotland-wide). A sample size of 500 respondents for each case study site was targeted in the sampling period (14th–22nd August 2018), which is similar to recent nationwide CV studies that have been carried out in Scotland (Kuhfuss et al., 2016).

The survey instrument was designed in accordance with suggested best practice (Johnston et al., 2017). Prior to submission, the CV scenario and survey instrument were subject to rigorous qualitative and quantitative pre-testing. Qualitative pre-testing involved multiple focus groups made up of non-users (n = 3) and users (n = 4) of each lake in locations close to each site and further afield to account for the opinions of the wider population in Scotland. The valuation scenario and a series of landscape visualisations designed to convey visual changes were reviewed by academic experts in freshwater ecosystems from the University of Stirling (n = 7) and organisations involved in managing each lake (n = 2) to ensure the survey content was accurate and credible. Quantitative pre-testing consisted of a pilot study of 100 responses (50 per lake) from Scottish households via the Qualtrics online panel outlined above. The pre-testing process assisted in refining the valuation scenario, ensuring the survey instrument was readable and selecting appropriate payment values for eliciting WTP.

6.3.2 Background information and engagement with each lake

Prior to the survey itself, respondents were provided with background information that outlined the objectives of the survey and how the results would be used. A policy consequentiality script was included to incentivise respondents to reveal their true preferences (Vossler and Watson, 2013; Czajkowski et al., 2017). The consequentiality script stated that the survey results would be shared with the Scottish Government and relevant policy makers to inform future management plans for either lake and other water bodies across Scotland. A similar script was adopted by Needham and Hanley (2019a) in a CV study of flood defence in Scotland.

The survey was divided into five sections. In section one, respondents were asked a variety of questions about their usage of water bodies in general. These questions had two purposes; to provide intellectual stimuli prior to more cognitively challenging questions at later stages in the survey and to collect data on factors that may influence WTP (Whitehead, 2006). The second section of the survey focused on behaviours specifically related to each lake. Respondents were presented with text outlining the conservation status, recreational opportunities and visitor numbers at each lake in order to provide context to the valuation scenario (Johnston et al., 2017). Respondents were then asked a variety of questions regarding their previous visits to the lake including visit frequency, visit duration and what activities were undertaken during visits.

6.3.3 Status quo and valuation scenario

Section 3 introduced the valuation scenario and presented the status quo and “take action” options. Respondents were made aware that the costs of managing either lake were increasing in the near future due to increased pressure from rising visitor numbers and overgrowing native vegetation. Without additional management, each site would degrade in terms of loss of views of the waterbody from pathways, reduced lakeside access due to aquatic and terrestrial vegetation overgrowth and path deterioration due to erosion from increased footfall. A range of “managed” (current) and “unmanaged” landscape visualisations were included to convey each element of degradation after 10 years, if additional management procedures were not carried out (Fig. 6.2.). Managed images consisted of photographs taken on publicly accessible land and from a height of 1.65 m to simulate views from a human perspective. Unmanaged images were generated by a professional landscape architect using photo realistic layers of path deterioration and native vegetation. Visualisations are a common aid in CV studies and have been adopted to convey landscape changes due to windfarm projects (Kipperberg et al., 2019; Einarsdóttir et al., 2019), riverside regeneration (Verbič et al., 2016) and forest management strategies (Madureira et al., 2011).

Section four of the survey provided the contingent valuation scenario and question. Respondents were presented with a detailed description of the objectives of the new lakeside management plan. The lakeside management plan would last 10 years and would ensure path quality, lakeside access and lake views were preserved in their current condition. It was made clear to respondents that if the lakeside management plan did not go ahead, the impacts of vegetation overgrowth and path deterioration proposed in the “unmanaged” images were likely to occur, representing the status quo/baseline option (Johnston et al., 2017). The lakeside management plan consisted of areas of lakeside space management, view management and path management and these were depicted in a series of maps and textually.

Figure 6.2. Example of visualisation: Managed (1) and unmanaged (2) lake views at Loch Lomond.

6.3.4 Eliciting willingness-to-pay

Respondents were informed that the current land managers would pay for 80% of the costs of the new lakeside management plan if it went ahead, with the remaining 20% of funding coming from increases in income tax that would be stored in a ring-fenced fund. Some water related contingent valuation studies in Scotland have adopted local taxes as payment vehicles, however, these have focused on scenarios which predominantly impact local communities (Needham and Hanley, 2019a; Hunter et al., 2012). Income tax provides a plausible payment vehicle for this study given that it is shared between all members of the sample and has been used in previous nationwide CV research in Scotland (Kuhfuss et al., 2016). Furthermore, lakeside spaces at Loch Lomond and Loch Leven are partly managed by government funded organisations and income tax, therefore, provides an appropriate and realistic payment vehicle.

The next section of the survey used two questions to gauge respondents WTP for the new lakeside management plan. Firstly, respondents were asked if they were willing to pay anything, even a small amount, in additional annual income tax to help fund the new lakeside management plan. Respondents who were willing to contribute were presented with a payment ladder with values ranging from £0.5 (50p) to £120. Payment ladder values (see Appendix 9) were determined based on qualitative and quantitative pre-testing. For each payment value, respondents could respond by selecting “Yes” if they would be definitely willing to pay the amount in additional income tax annually to help fund the new plan, “No” if they were definitely not willing to pay the amount or “Unsure” if they were uncertain if they would be willing to pay the amount or not. The payment ladder valuation format was chosen to capture respondent uncertainty in their maximum willingness to pay (Hanley et al., 2009).

6.3.5 Attitudinal and sociodemographic questions

The final section of the survey included a range of statement-based questions to determine the environmental, cultural and health related importance of lakes in Scotland to each respondent. Based on a five-point Likert scale (Strongly Disagree, Disagree, Neither, Agree, Strongly Agree) respondents were asked how much they agreed with statements related to water bodies and health, tourism, conservation and national identity (Fig. 6.3). Respondents were also presented with a five point Likert scale (Very Unconfident, Unconfident, Neither, Confident, Very Confident) to gauge perceived payment and policy consequentiality (Fig. 6.4). Policy consequentiality is the belief that responses to the survey will affect the supply of the environmental good in question and payment consequentiality is the belief that the respondent's stated WTP will affect how much they actually have to pay for the good, should it be provided (Zawojska et al., 2019). The survey concluded with sociodemographic questions (e.g., age, gender and household income), since such factors commonly influence WTP (Whitehead, 2006).

6.3.6. Statistical analysis

All statistical analysis was carried out in Stata (version 15.1). A logistic regression model or logit model was used to analyse whether a respondent was willing to pay (WTP > £0) or not (WTP = £0). The determinants of WTP were analysed using an interval regression model. The payment card approach adopted in this study allows WTP responses to be elicited as a range. The highest payment value that a respondent is definitely willing to pay is the most conservative estimate, otherwise known as lower-bound WTP. The lowest payment value that a respondent is definitely not willing to pay is classified as upper-bound WTP – this is the least conservative estimate. However, the true WTP value may fall between lower-bound and upper-bound WTP and selecting either for analysis may result in underestimating or overestimating WTP (Cameron and Huppert, 1989). Interval regression uses the lower-bound and upper-bound responses on the payment card as the dependent variables, minimising the potential of over or underestimating WTP.

The final modelling approach to identify the determinants of whether a respondent was willing to pay or not and the amount a respondent was willing to pay (Eq. (1)) consisted of multiple explanatory variables (Table 6.1). The stated preference literature suggests that the valuation of an environmental good is impacted by a variety of sociodemographic factors and the relationship between the respondent and the good in question. Economic theory and a wide range of stated preference studies indicate that WTP increases with rising income (Barbier et al., 2017). Several studies have also indicated that membership of an environmental group is a significant determinant of WTP (Needham and Hanley, 2019a; Dahal et al., 2018). Respondents who directly use the environmental good in question tend to value changes higher than those who do not use the good and as distance between the site in question and the residence of the respondent increases, WTP tends to decrease, particularly in the case of users (Bateman et al., 2006).

$$WTPi = \beta_0 + \beta_1\ INCOME + \beta_2 ENVGROUP + \beta_3\ DISTANCE + \beta_4\ USER + \beta_5 DURATION + \beta_6\ POLICY\_CON + \beta_7\ PAY\_CON + \beta_8 TOURISM + \beta_9 IDENTITY + \varepsilon i \quad (1)$$

Value may also arise from beliefs and behaviours that are not directly related to the good in question as, familiarity with a topic or environmental good (e.g., blue spaces in general) may make valuing a good at a specific site more informed (Kniivilä, 2006). Perceived payment and outcome consequentiality were included in the interval regression explaining WTP variation, since from Zawojska et al. (2019) it was expected that WTP would increase with policy consequentiality and decrease with payment consequentiality. Explanatory variables related to attitudinal responses and blue space usage and engagement were also tested to identify the best fitting model. Additional explanatory variables were selected based on an evaluation of Akaike information criterion (AIC) and Bayesian information criterion (BIC) (Šebo et al., 2019). Variance inflation factors (VIF) were analysed during the development of each final model to test for multicollinearity among explanatory variables.

In previous contingent valuation literature, the valuation gap (VG) or uncertainty range is defined as the difference between upper and lower-bound WTP (Smith et al., 2019; Hanley et al., 2009). Given that the values in the payment card used in this study are not equally spaced, taking an absolute value of the valuation gap carries some assumption as the size of the gap may be overestimated in the higher end of the payment card, where there are larger intervals between payment values. To account for any overestimation in the valuation gap as a result of the payment card format, the valuation gap was taken as a percentage of upper-bound willingness to pay (Voltaire et al., 2013) and can be denoted as stated in Eq. (2):

$$VGi = \left(\frac{UWTPi - LWTPi}{UWTPi}\right) * 100 \quad (2)$$

where VGi is the valuation gap and UWTPi and LWTPi are the upper and lower-bound WTP responses indicated by the respondent. This approach provides a valuation gap that is relative to the payment card choices of uncertainty faced by the respondent. Respondents who did not select “Unsure” to any values on the payment card were excluded from the analysis as any differences between upper and lower-bound WTP may have occurred as a result of the payment card format, rather than preference uncertainty.

An OLS regression model was developed to understand the determinants of the valuation gap (Hanley et al., 2009). Independent variables (Eq. (3)) were selected for the modelling process based on the stated preference literature. Previous research has indicated that the age and income of a respondent can affect uncertainty regarding the valuation of environmental goods (Voltaire et al., 2013). Based on previous work, it was anticipated that respondents who have used each site in the last year and those who reside closer to each site will report a lower valuation gap as they are likely to be more familiar with the environmental good in question (Hanley et al., 2009). There were no priors on the direction or significance of any effect of perceived consequentiality on the valuation gap, but this seemed to be an interesting effect to investigate empirically.

$$VGi = \beta_0 + \beta_1\ INCOME + \beta_2 USER + \beta_3\ AGE + \beta_4\ DISTANCE + \beta_5 PAY\_CON + \beta_6\ POLICY\_CON + \varepsilon i \quad (3)$$

Table 6.1. Description of independent variables used in the modelling process.

Variable	Description
INCOME	Household income ranging from <£15 k– >£100 k per annum: (9 categories, midpoint of each category used in regression)
AGE	Age categories ranging from 18 – >65: (6 categories, midpoint of each category used in regression)
ENVGROUP	Member of an environmental group (0 = no/1 = yes)
DISTANCE	Natural log of distance to site ranging from 0 to 5 miles to > 200 miles: (10 categories, midpoint of each category used in regression)
USER	Has visited the lake in last year (0 = no/1 = yes)
DURATION	Duration of time spent when visiting any BS from 0 min to >480 min (8 h): (10 categories, midpoint of each category used in regression)
POLICY_CON	"How confident are you that the new Lochside Management Plan for Loch X will be carried out?" (0 = strongly disagree, disagree or neither/1 = agree or strongly agree)
PAY_CON	"How confident are you, that if the new Lochside Management Plan for Loch X goes ahead, that your income

Variable	Description
	tax would rise to help pay for it?” (0 = strongly disagree, disagree or neither/1 = agree or strongly agree)
TOURISM	“I believe that lochs (lakes) are important for attracting tourists to Scotland.” (0 = strongly disagree, disagree, neither or agree/1 = strongly agree)
IDENTITY	“I believe that lochs are important elements of Scotland's national identity.” (0 = strongly disagree, disagree, neither or agree/1 = strongly agree)

6.4 Results

6.4.1. Descriptive statistics

In total, 1108 survey responses were received from the online panel. After reviewing all initial responses, 24 were removed due to missing information and 28 were removed due to illogical payment card responses (e.g., where a respondent was willing to pay a higher value on the payment card but not a lower value) resulting in a final sample of 1056 for the econometric analysis. A subsample for each lake was created based on the version of the survey completed by the respondent. The final sample was made up of 534 responses to the Loch Lomond version of the survey and 522 responses to the Loch Leven version. On average, respondents took 13 minutes to complete the Loch Lomond version and 15 minutes to complete the Loch Leven survey. The sociodemographic characteristics of both subsamples (Table 6.2) were representative of the adult population in Scotland according to important measured characteristics. The modal household income category for each subsample was £20,000–£30,000 per annum, which aligns with the median household income in Scotland – £23,000 (Scottish Government, 2019). The population of Scotland has a slight majority of females (52%) (National Records of Scotland, 2019), the Loch Leven subsample was highly representative (52%) and the Loch Lomond subsample was less representative (54%) but reflected the gender balance in the population. The modal age category of each subsample was 40–45 which is highly representative of the median age for males (42) and females (41) in Scotland (National Records of Scotland, 2019).

Table 6.3 provides summary statistics related to usage of Loch Lomond and Loch Leven, and how respondents engage with blue spaces in general. During the last year (since August 2018) over half (53%) of the Loch Lomond subsample had visited the site. The national importance of Loch Lomond as recreational site is highlighted by the majority of the sample – which is drawn from all Scottish households, not just those that are located near Loch Lomond - having visited the lake in the last year. The number of respondents who had visited the site in the last year was lower in the Loch Leven subsample (31%). A small portion of each subsample lived within 10 miles each the site, approximately 9% for Loch Lomond and 5% for Loch Leven. The modal distance category (i.e. how far a respondent lived from the lake they were questioned on) was 30–50 miles for both subsamples. The majority (approximately 90%) of respondents in both subsamples had visited a blue space in the last year, with most visits lasting between 30 minutes and an hour.

Table 6.2. Descriptive statistics for sociodemographic information: Loch Lomond (n = 534) and Loch Leven (n = 522).

	% of sample (Lomond)	**% of sample (Leven)**
Income		
Under £15,000	21.05	19.54
£15,000–£20,000	14.66	13.41
£20,000–£30,000	25.19	20.88
£30,000–£40,000	15.79	19.16
£40,000–£50,000	10.53	11.11
£50,000–£60,000	4.32	6.51
£60,000–£80,000	5.26	5.94
£80,000–£100,000	2.26	1.92
Over £100,000	0.94	1.53
Gender		
Male	45.76	47.69
Female	54.24	52.31
Environmental group		
No	89.70	88.31

	% of sample (Lomond)	% of sample (Leven)
Yes	10.30	11.69
Age		
18–25	10.15	11.88
26–34	18.23	12.84
35–44	23.12	22.61
45–54	18.61	21.84
55–64	15.31	20.50
65 or older	14.47	10.34
Highest education level		
Secondary school	37.78	27.20
College	27.44	32.76
University (undergraduate)	24.81	28.93
University (postgraduate)	9.96	11.11
Relationship status		
Divorced	11.24	11.11
Married	52.25	55.75
Single (never married)	33.71	29.50
Widowed	2.81	3.64

Table 6.3. Descriptive statistics for additional variables: Loch Lomond (n = 534) and Loch Leven (n = 522).

	% of sample (Lomond)	% of sample (Leven)
Visited site in last year		
Yes	52.62	31.03
No	47.38	68.97
Distance to site from residence		
<5 miles	4.49	2.11
5 miles–10 miles	4.87	3.26
10 miles–20 miles	9.74	7.09

	% of sample (Lomond)	% of sample (Leven)
20 miles–30 miles	11.99	11.30
30 miles–50 miles	18.35	20.88
50 miles–70 miles	13.11	16.86
70 miles–100 miles	15.73	16.09
100 miles–150 miles	7.68	10.15
150 miles–200 miles	8.43	5.56
>200 miles	5.62	6.70
BS view from household		
Yes	26.40	28.16
No	73.60	71.84
Average duration of BS visits		
Never visit	10.11	11.11
<30 min	10.49	12.45
30 min–1 h	24.72	24.14
1 h–1.5 h	16.85	18.39
1.5 h–2 h	14.23	10.34
2 h–3 h	9.55	10.92
3 h–4 h	4.49	7.47
4 h–5 h	5.24	2.30
5 h–8 h	2.62	1.72
>8 h	1.69	1.15
Visits BS to socialise		
Yes	23.78	17.05
No	76.22	82.95
Visits BS to interact with nature		
Yes	30.15	28.54
No	69.85	71.46

6.4.2 Attitudinal responses

Regarding lochs specifically, the majority of respondents of each subsample strongly agreed that conserving lochs was important for wildlife in Scotland, that lochs were important for attracting tourists to Scotland and that lochs were an important part of Scotland's national identity (Fig. 6.3). Collectively, the strong positive responses suggested possible rationales for non-use and existence values among respondents. Around half of respondents in the Loch Lomond (47%) and Loch Leven (44%) subsample agreed that blue space could play an important role in improving health and well-being.

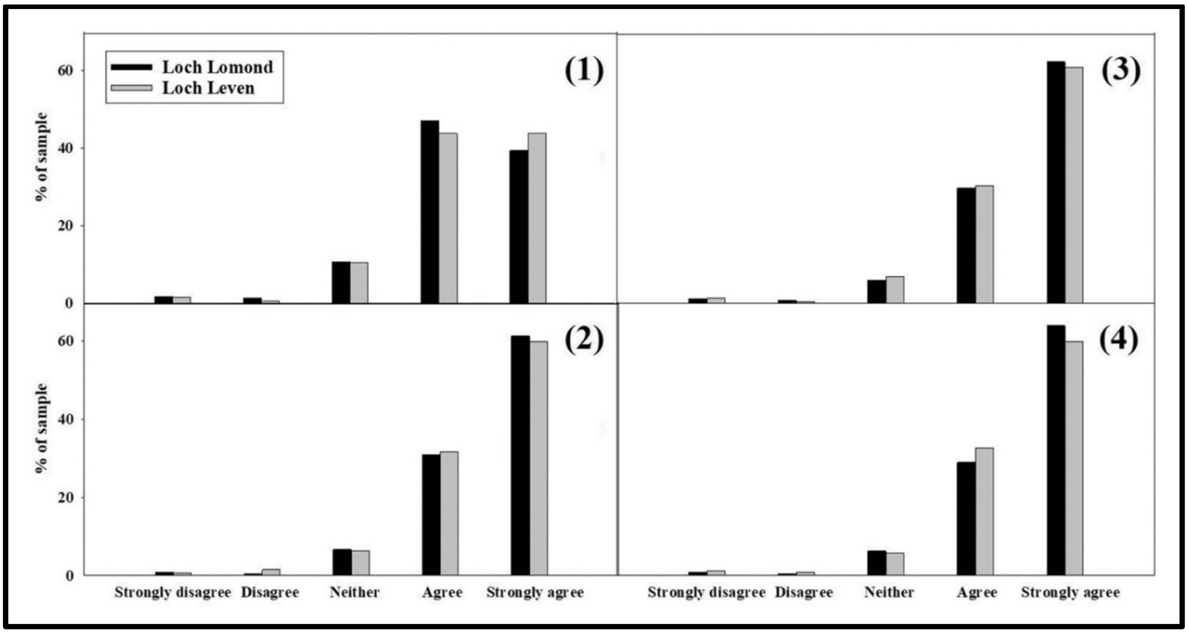

Figure 6.3. Responses to statement based questions: (1) Spending time near water such as the sea, coasts, rivers lochs, lakes, canals etc. can play an important role in improving health and well-being; (2) I believe that the conservation and protection of lochs is important for wildlife in Scotland; (3) I believe that lochs are important for attracting tourists to Scotland; and (4) I believe that lochs are important elements of Scotland's national identity.

6.4.3 Policy and payment consequentiality

The majority of respondents from the Loch Leven and Loch Lomond subsample elicited positive (confident or very confident) responses to perceived outcome consequentiality (Fig. 6.4). Most respondents in both subsamples believed that the management plan proposed in the contingent valuation scenario would go ahead. Only a small portion of respondents in each subsample - Loch Lomond (15%) and Loch Leven (14%) – selected “unconfident” or “very unconfident” to the policy consequentiality question. For payment consequentiality at Loch Lomond, most respondents (42%) in the subsample were confident that their income tax would increase to help fund the management plan. This trend was not present in the Loch Leven subsample as “neither” was the modal category (39%). However, more respondents elicited positive responses (confident or very confident – 42%) than negative responses (unconfident or very unconfident - 19%) for payment consequentiality in the Loch Leven subsample.

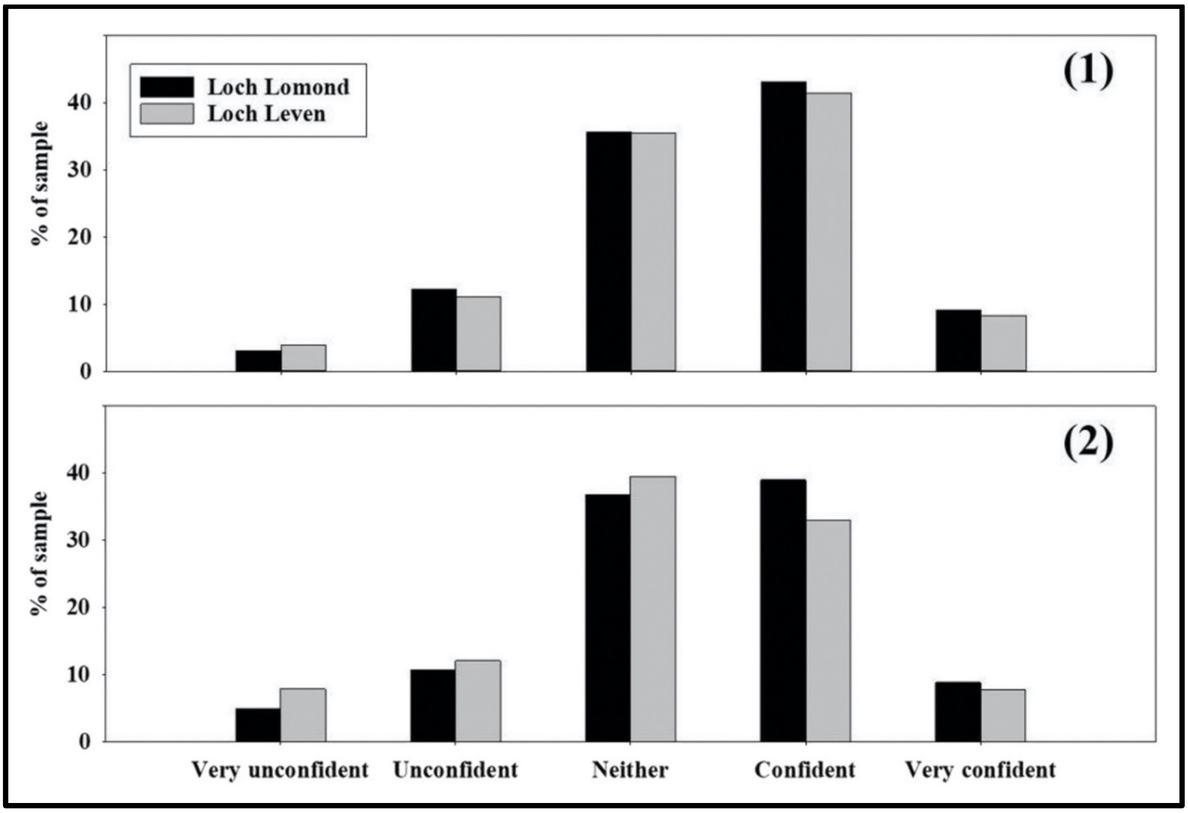

Figure 6.4. Responses to policy (1) and payment (2) consequentiality questions: (1) How confident are you that the new Lochside Management Plan for Loch Leven will be carried out? (2) How confident are you, that if the new Lochside Management Plan for Loch Leven goes ahead, that your income tax would rise to help pay for it?

6.4.4 Public willingness-to-pay

The majority of respondents in both subsamples were willing to contribute a positive amount towards the preservation of lakeside quality at Loch Leven and Loch Lomond (see Fig. 6.5). For Loch Lomond 76% had a WTP > 0 and for Loch Leven 65% had a WTP > 0. Respondents' reasons for not being willing to pay are summarised in Table 6.4 and were divided into protest (coded P) and true-zero responses (coded TZ). Protest responses suggest a respondent has rejected part of the valuation exercise, such as the choice of payment vehicle, whereas true zero responses indicate the respondent accepts the valuation scenario but has no effective demand for the good (Meyerhoff and Liebe, 2006). The main reasons for not being prepared to pay towards the protection of lakeside quality at Loch Lomond and Loch Leven were not being able to afford to pay (55% and 47%, respectively), the belief that it was not their responsibility to pay for the management of Loch Lomond/Loch Leven (21% and 16%, respectively) and preferring to spend household income on other things (8% and 15%, respectively). Protest responses accounted for approximately 20% of zero responses in both subsamples and were removed for further analysis since these responses do not tell us whether or how much people cared about the environmental changes being valued (Jones et al., 2008).

Table 6.4. Summary of true zero and protest responses.

	Summary of zero bids TZ = true-zero response P = protest response	**% of sample (Lomond) *n* = 163**	**% of sample (Leven) *n* = 215**
TZ	I am not concerned about these changes at Loch Leven/Lomond	1.23	2.33
TZ	I do not believe we need to invest in the management of lochs.	3.07	1.40
TZ	I would like to contribute but cannot afford to.	54.60	46.51
TZ	I would prefer to spend my income on other things.	7.98	14.88

	Summary of zero bids TZ = true-zero response P = protest response	% of sample (Lomond) n = 163	% of sample (Leven) n = 215
P	I do not want the management plan to go ahead.	1.84	0.47
P	I would need to know more about the plan to make a decision.	6.75	6.98
P	It is not my responsibility to invest in Loch Lomond.	21.47	16.28
	Other reason.	3.07	11.16

A summary of lower-bound, midpoint and median WTP for each subsample is included in Table 6.5. Based upon lower-bound WTP, which is the maximum amount each respondent stated they were definitely willing to pay, mean WTP was £12.06 (SE = 1.03) per household per annum for protecting lakeside quality at Loch Lomond. Mean-lower bound WTP for the protection of lakeside quality at Loch Leven (based on lower-bound WTP) was £8.44 (SE = 0.79) per household per annum. Midpoint WTP (the midpoint between lower and upper-bound WTP as reflected in the payment ladder) for Loch Lomond was £21.76 (SE = 1.33) and £15.62 (SE = 1.09) for Loch Leven.

Table 6.5. Summary of WTP for the protection of lakeside quality.

Willingness to pay summary	Loch Lomond	Loch Leven
Mean WTP (lower bound) (£)	12.06	8.44
SE	1.03	0.79
95% CI	10.04–14.08	6.90–9.99
Median WTP (lower bound) (£)	5.00	2.00
Mean WTP (mid-point) (£)	21.76	15.62
SE	1.33	1.09
95% CI	19.14–24.37	13.48–17.77
Median WTP (mid-point) (£)	10.00	6.00
Predicted WTP (interval regression) (£)	18.72	12.77
SE	0.42	0.38
95% CI	17.90–19.56	12.01–13.52
Sample size (protest responses removed)	483	471
Number of true zero bids	114	164

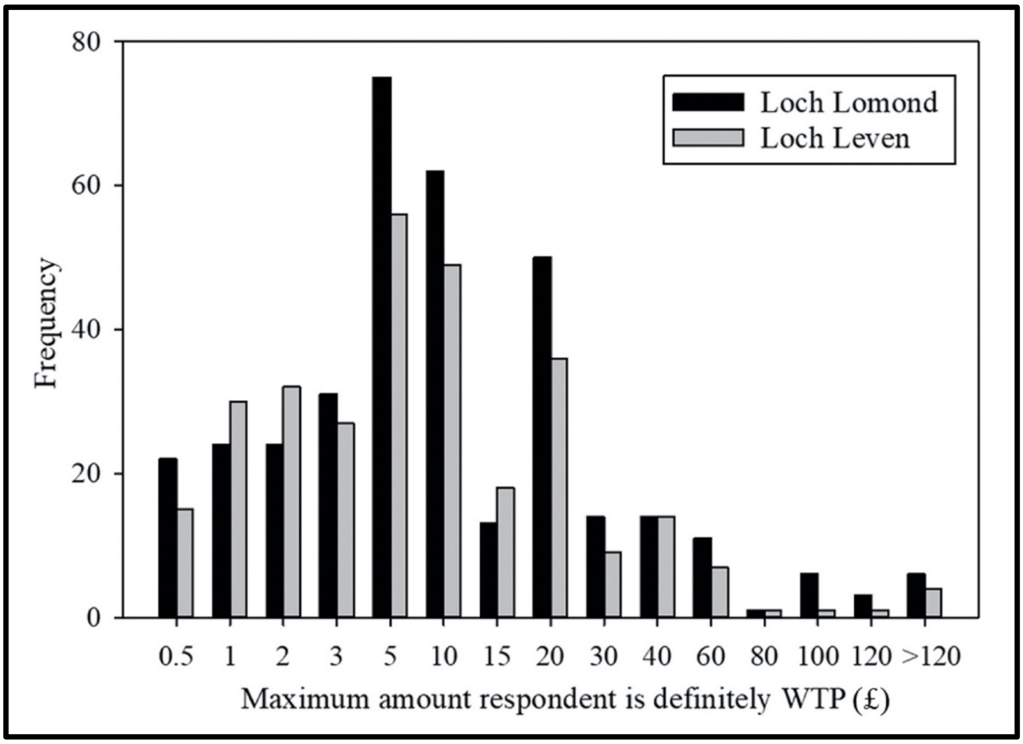

Figure 6.5. Highest payment value that respondent would definitely be willing to pay (lower-bound WTP).

6.4.5 Determinants of willingness-to-pay

A logistic regression (Table 6.6) was carried out to identify what independent variables influenced whether a respondent was willing to pay (WTP > £0) for the protection of lakeside quality at either site or not (WTP = £0). Household income was significantly associated with being willing to pay for Loch Leven ($p < 0.1$) and Loch Lomond ($p < 0.01$), with a stronger effect being found for the Loch Lomond subsample. A significant negative association was present between being willing to pay and distance ($p < 0.01$) in the Loch Leven subsample, suggesting those living further from the site were more likely to elicit a zero WTP response. A significant positive association was identified between both consequentiality questions for each subsample. For the Loch Lomond subsample, a highly significantly positive association was identified for both policy ($p < 0.01$) and payment consequentiality ($p < 0.01$). The effect of policy consequentiality ($p < 0.01$) was stronger in the Loch Leven subsample, however, the effect of payment consequentiality ($p < 0.1$) was weaker.

Interval regression models were developed to identify how each of the selected independent variables influenced stated WTP in the Loch Lomond and Loch Leven subsamples (Table 6.7). The selected sociodemographic variables had similar effects on WTP for both subsamples. A significant positive association was identified between household income and WTP for Loch Leven ($p < 0.01$) and Loch Lomond ($p < 0.01$), with a stronger effect being found for Loch Lomond. For the Loch Leven subsample, a significant positive association was present between membership of environmental group and WTP, with - all else being equal - environmental group members willing to pay £6.33 more than non-members ($p < 0.05$). The “distance decay effect” suggests that as the distance between a respondent and an environmental good increases, WTP decreases (Lee, 2016). A small but significant distance decay was present in the Loch Lomond subsample with WTP decreasing as the distance a respondent lived from the site increased ($p < 0.01$), but no such effect was found for Loch Leven. In the case of Loch Leven, a significant positive correlation between site usage in the last year and WTP was identified. Respondents who had visited Loch Leven in the last year were, all else being equal, willing to pay £3.93 more than respondents who had not visited ($p < 0.05$). In contrast, a significant negative association was identified for the Loch Lomond subsample, with users - all else being equal - willing to pay £4.71 less than respondents who had not visited the site in the last year ($p < 0.1$). The average duration of a respondents' visits to blue spaces was positively associated ($p < 0.01$) with WTP for both subsamples.

A significant positive correlation was identified between WTP and perceived payment consequentiality in both Loch Lomond ($p < 0.1$) and Loch Leven ($p < 0.05$) subsamples. All else being equal, respondents who elicited positive responses (confident or very confident) to the payment consequentiality question were willing to pay more at Loch Lomond (£4.34) and Loch Leven (£3.88) than those who did not elicit positive responses (neither, unconfident or very unconfident). A significant positive association was identified between policy consequentiality and WTP in the Loch Leven subsample ($p < 0.01$), with all else being equal, respondents who reported positive responses, willing to pay £7.74 more than respondents who did not select a positive policy consequentiality response. A significant positive association between respondents who strongly agreed that lochs represented an important part of Scotland's cultural identity and WTP was identified for the Loch Lomond subsample ($p < 0.1$). For the Loch Leven subsample, respondents who strongly agreed that lochs were important for attracting tourists to Scotland elicited significantly higher WTP values than those who did not strongly agree with the statement ($p < 0.05$).

Table 6.6. Logistic regression models for WTP > 0 for lakeside quality protection at Loch Lomond and Loch Leven.

Variable	Loch Lomond		Loch Leven	
INCOME	0.02***	(0.01)	0.01*	(0.01)
ENVGROUP	0.17	(0.42)	0.61	(0.38)
DISTANCE	−0.09	(0.13)	−0.43***	(0.14)
USER	0.08	(0.26)	0.08	(0.26)
DURATION	0.00	(0.00)	0.00**	(0.00)
POLICY_CON	0.81***	(0.26)	0.94***	(0.23)
PAY_CON	0.76***	(0.26)	0.46*	(0.24)
TOURISM	0.43	(0.34)	0.60*	(0.33)
IDENTITY	0.68**	(0.34)	0.57*	(0.33)
Constant	−0.54	(0.62)	0.43	(0.62)
Observations	485		471	
AIC	467.75		528.75	
BIC	509.59		570.30	
Log likelihood	−223.87		−254.37	

∗∗∗ $p < 0.01$; ∗∗ $p < 0.05$; ∗$p < 0.1$. Standard errors in parenthesis.

Table 6.7. Interval regression models for WTP for lakeside quality protection at Loch Lomond and Loch Leven.

INCOME	0.31***	(0.06)	0.11***	(0.04)
ENVGROUP	2.85	(3.79)	6.33**	(2.66)
DISTANCE	−2.50**	(1.21)	−0.98	(0.99)
USER	−4.71*	(2.59)	3.93**	(1.97)
DURATION	0.03***	(0.01)	0.03***	(0.01)
POLICY_CON	2.01	(2.53)	7.74***	(1.85)
PAY_CON	4.34*	(2.56)	3.88**	(1.86)
TOURISM	−2.93	(3.45)	6.06**	(2.59)
IDENTITY	8.94*	(3.50)	−0.06	(2.65)
Predicted WTP	18.72	(0.42)	12.76	(0.38)
Constant	10.95	(5.85)	−0.36	(4.61)
Observations	485		471	
AIC	2683.86		2722.48	
BIC	2729.84		2768.19	
Log likelihood	−1330.93		−1350.24	

∗∗∗ $p < 0.01$; ∗∗ $p < 0.05$; ∗$p < 0.1$. Standard errors in parenthesis.

6.4.6 Determinants of the valuation gap

The majority of respondents who were willing to pay for Loch Lomond (75%) and Loch Leven (70%) reported WTP as a range by selecting “Unsure” to one or more of values on the payment card. The valuation gap data was similarly distributed for both subsamples (Fig. 6.6). The mean valuation gap was 70.4% (SE = 0.94) for the Loch Lomond subsample and 71.0% (SE = 1.05) for the Loch Leven subsample (see Fig. 6.6). An OLS regression was carried out to identify what independent variables influenced the size of the valuation gap; that is, why some people are more uncertain about the value they place on protecting lakeside quality (Table 6.8). The results of the regression analysis suggest different factors influenced the size of the valuation gap in the two subsamples. For the Loch Lomond subsample, a negative and significant association ($p < 0.05$) was present between age and the size of the valuation gap, suggesting older respondents were more certain about their preferences. Usage of either lake was positively associated with the size of the valuation gap for both subsamples; however, neither result was significant. Payment consequentiality was significantly negatively associated ($p < 0.05$) with the valuation gap in the Loch Leven subsample. All else being equal, respondents who believed their responses to be consequential were 4% more certain than those who did not believe their responses were consequential. In the Loch Leven subsample, a positive and significant association ($p < 0.05$) was identified between distance to the lake and the valuation gap, suggesting respondents who lived further away from the lake were more uncertain in their responses.

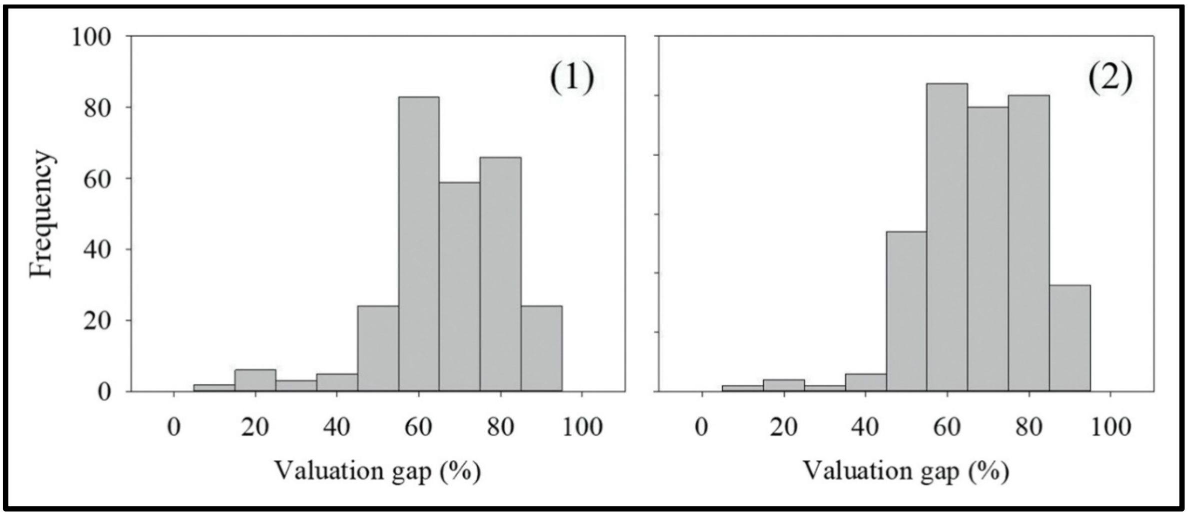

Figure 6.6. Distribution of valuation gap for (1) Loch Lomond and (2) Loch Leven.

Table 6.8. OLS regression models for identifying determinants of the valuation gap.

Variable	Loch Lomond		Loch Leven	
INCOME	0.03	(0.05)	−0.06	(0.05)
DISTANCE	1.65	(1.06)	2.64**	(1.17)
USER	0.98	(2.20)	2.22	(2.23)
AGE	−1.29**	(0.64)	0.08	(0.71)
POLICY_CON	−2.95	(2.19)	−3.23	(2.32)
PAY_CON	−0.90	(2.22)	−4.11**	(2.27)
Constant	68.03	(5.40)	65.70	(5.44)
Observations	266		211	
AIC	2230.96		1745.26	
BIC	2256.05		1768.73	
Log likelihood	−1108.48		−865.63	

∗∗∗ $p < 0.01$; ∗∗ $p < 0.05$; ∗$p < 0.1$. Standard errors in parenthesis.

6.5 Discussion

As noted at the outset of this paper, previous valuation studies of lakes have mainly focused on the economic impact of improving water quality (Huang et al., 2013; Cooper et al., 2004; Moore et al., 2011) or increasing water based recreation opportunities (Meyerhoff et al., 2019; Rolfe and Prayaga, 2007). However, with growing understanding of how humans interact with water bodies or blue spaces, it has become apparent that the majority of visits to water bodies do not involve direct water contact and that benefits are often accrued from engagement with water from terrestrial locations e.g. observing views of water (Nutsford et al., 2016) or undertaking non-water based physical activity such as walking or cycling by the waterside (Vert et al., 2019). Consequently, improving water quality may not be the highest value investment in terms of enhancing the ecosystem services offered by inland waters (Ziv et al., 2016). From a health and well-being perspective, the importance of lakeside space is well documented; however, it is often overlooked in research concerned with the valuation of ecosystem services offered by lakes. The present study thus investigated public preferences for protecting current lakeside quality, in terms of lakeside access, lake views and path quality, at two large destination lakes in Scotland.

The values obtained in this study provide novel contributions to a growing database of economic values related to the ecosystem services provided by lakes (Reynaud and Lanzanova, 2017). Based on the most conservative estimates obtained, mean WTP per household per annum for the protection of lakeside quality at Loch Lomond and Loch Leven was £12.06 (SE = 1.03) and £8.44 (SE = 0.79), respectively. These findings are comparable to recent CV studies focusing on improving water quality at lakes in Europe. For example, Šebo et al. (2019) reported a mean WTP of £9.50 per annum for improvements in water quality at an urban lake in Slovakia. A more direct comparison is offered by the work of Hunter et al. (2012) who estimate local residents are WTP between £9.99 and £12.23 per annum to reduce the number of days per year that water quality (in terms of cyanobacteria) poses a human health risk at Loch Leven. Whilst the comparison of welfare estimates obtained in CV studies is difficult due to differing elicitation methods, payment vehicles and the framing of the environmental good in question, these comparisons contextualise the findings of the present study by showing similarities to welfare estimates obtained for improving water quality. The findings can assist the decision-making processes at water bodies by demonstrating that changes to waterside space have an important non-market economic impact, relative to improving water quality and that both users and non-users derive welfare benefits from the protection of lakeside space. Economic analysis that focuses solely on water quality and excludes changes to waterside space, may neglect the effects of a policy on the provision of cultural ecosystem services that do not require direct water contact and consequently, result in uneconomical and suboptimal water resource management policies.

Kuhfuss et al. (2016) used the CV method to estimate the value of maintaining access to a variety of publicly funded historic monuments in Scotland, which like the two lakes in this study, are also valued by individuals who do not routinely visit the sites. Their study found that 48% of the sample were willing to contribute towards maintaining public access to a variety of historic monuments and mean WTP was £2.79 per annum. The proportion of responses willing to contribute, and mean WTP, were greater for both nationally important lakes in this study than those reported for maintaining public access to historic sites. Using Scotland as a case study, the observed preferences among users and non-users of two large samples may inform future debates on the allocation of public funding between nationally important built and natural environmental resources.

Contingent valuation studies obtain an economic value from a sample of individuals and these values need to be aggregated to the relevant population to obtain the total value of the good in question (Mitchell and Carson, 1989). In this study, both subsamples were representative of the adult population in Scotland based on a number of observable characteristics, so a coarse aggregation of WTP across the 2.45 million households in Scotland was performed. Per year the aggregate value for protecting lakeside quality at Loch Lomond based on mean lower-bound WTP was £29,547,000 and £53,312,000 based on mean midpoint WTP. Per year the aggregate WTP value for Loch Leven was £20,678,000 based on mean lower-bound WTP and £38,269,000 based on mean midpoint WTP. These substantial aggregate values demonstrate the significant economic benefit of protecting lakeside quality at large freshwater lakes. These values should better inform decision-makers at large freshwater lakes in Scotland and further afield via benefits transfer approaches, mainly in terms of providing robust economic data that was not available prior to this study.

As expected, respondents with higher household income were significantly more likely to be willing to pay and willing to pay significantly more for the protection of lakeside quality than those with lower household income, reinforcing a well-established trend in stated preference literature and economic theory (Barbier et al., 2017). Indeed, a recent meta-analysis of CV studies on improving the ecological status of water bodies suggests income to be a frequently significant driver of WTP (Tyllianakis and Skuras, 2016). The identification of a distance decay effect in the Loch Lomond subsample has been replicated in a wide variety of CV studies including for rivers (Jørgensen et al., 2013). This finding is contrary to a recent study demonstrating a positive distance decay effect in relation to WTP for water quality improvements at an urban lake in Slovakia (Šebo et al., 2019). Understanding the distance decay effect at large destination water bodies can assist debates between key stakeholders, national government and local authorities, by helping to answer critical questions such as who gets the benefits from investing in blue spaces, and who should bear the cost of managing these spaces. Investigating distance decay effects can also assist in gauging the extent of the market i.e. the group of people whose welfare could be affected by the changes at each lake (Smith, 1993). The findings of this study suggest that although welfare benefits decrease with greater distance to Loch Lomond, the welfare benefits obtained from nationally important freshwater lakes span far wider than the local scale adopted in previous valuation studies (Šebo et al., 2019; Hunter et al., 2012).

The interval regression models suggest that people who spend longer periods of time at blue spaces when they visit are willing to pay greater amounts for the protection of lakeside quality. It may be the case that respondents who visit for longer periods of time feel more familiar with the lakeside settings in question due to greater familiarity with similar site characteristics at other blue spaces (Kniivilä, 2006). In both subsamples, respondents who were confident or very confident that their survey response would affect how much they actually have to pay for the protection of lakeside quality at Loch Leven or Loch Lomond, should it be provided were WTP more than those that were not confident. This is contrary to the result reported in Zawojska et al. (2019) and it may be the case that respondents used their responses to perceived consequentiality as another way to express their positive preferences for the management plan (Needham and Hanley, 2019b). In the Loch Leven subsample, respondents who reported positive policy consequentiality responses, reported higher WTP than those who did not select a positive policy consequentiality response, which is in accord with the findings of Zawojska et al. (2019).

Respondents who had visited Loch Leven in the last year (users) were willing to pay significantly more than those who had not visited (non-users). This result is in line with previous studies that have identified higher WTP among users of the environmental good in question (Bateman et al., 2006). Contradictorily, users of Loch Lomond were willing to pay significantly less than non-users. This result was unexpected, however, the high non-use value of Loch Lomond is supported by the positive responses to statement-based questions regarding the preservation of lakes in Scotland as this is seen to support tourism and protect wildlife. There are a number of other reasons as to why the protection of lakeside quality at Loch Lomond may be valued among non-users. Firstly, people who have not visited the site in the last year may value the option to visit the site in its current state in the future. Secondly, non-use value may be induced by altruism, where value is motivated by safeguarding usage for others, such as one's own children or future generations. Thirdly, non-use value may be motivated purely by knowing that an environmental good exists in a certain state, irrespective of potential future use (Nijkamp et al., 2008). Existence value is often associated with environmental goods with unique characteristics or cultural importance (Hanley et al., 2019) and Loch Lomond falls within these categories. The negative association observed between visiting Loch Lomond in the last year and WTP may also suggest that usage is not an effective indicator of WTP for protecting nationally important natural resources. Furthermore, it may be the case that lower WTP among users of Loch Lomond comes as they already make a financial contribution towards the management of the site (Rodella et al., 2019) e.g. through car park charges or investing in services offered by current land managers.

Economic values for environmental goods often exhibit a degree of uncertainty (Butler and Loomes, 2007) and when given the option, many people favour reporting a range of economic values rather than a specific value (Mahieu et al., 2017). The present study also found that the majority of respondents preferred to report WTP as a range of values. The findings contribute to a small but growing body of research dedicated to understanding what determines the size of this range or valuation gap. In the Loch Leven subsample, distance between the household and lake was significantly associated with the size of valuation gap. This finding is in alignment with previous research showing location relative to the site influences the size of the valuation gap (Hanley et al., 2009). In both subsamples, no significant association was observed between using the site in the last year and the size of the valuation gap. These findings are in contrast to results obtained by Hanley et al. (2009) for beach quality improvements in Scotland, and cast doubt over the assumption that familiarity with the environmental good in question is associated with higher payment certainty and that usage is a good proxy for familiarity. Respondents who believed their income tax would be increased if the management plan at Loch Leven went ahead reported significantly lower valuation gaps than respondents who were unconfident that their income tax would be increased. The negative relationship identified between payment consequentiality and the size of the valuation gap represents a novel finding, although it is not clear what the behavioural mechanism behind such a relationship might be.

6.6 Conclusion

Bodies of freshwater offer valuable ecosystem services; however, there remains significant and ongoing debate on their economic value and how this value is impacted by water resource management policies. Economic valuations of water policies and their impact on lake ecosystem services often focus on water quality or changes to water-based recreation opportunities. The emerging blue space, health and well-being research agenda has highlighted the importance of waterside space in facilitating cultural ecosystem services at inland water bodies and yet waterside space is overlooked in the economic valuation literature. Findings from this CV study of two large freshwater lakes have important and internationally relevant implications. Firstly, the findings suggest that changes to lakeside space have important non-market economic impacts and, therefore, greater consideration of these changes can improve and refine decision-making processes at large water bodies. Secondly, by determining the non-market value of protecting lakeside quality, valuable economic data is provided that can inform decision making at large lakes across Scotland and further afield. Thirdly, by determining how the benefits of protecting lakeside quality are shared across a sample of users and non-users, the findings can inform decisions related to resource allocation and debates around who benefits from and, therefore, who should fund the management of nationally important water bodies. Fourthly, the study provides insight on the determinants of the valuation gap, by highlighting the complex role that consequentiality has on preference uncertainty. The present study classifies lakeside quality as a package of goods due to lack of previous research on the economic impact of changes to lakeside space. Consequently, the study does not provide an understanding of preferences between path quality, lake views and lakeside access, which may further inform management processes. Future research using the choice experiment (CE) method is needed to understand how attributes of lakeside quality interact with one another.

Chapter 7 - Synthesis and conclusion

The overarching aim of this thesis was to use multiscale and multidisciplinary approaches to quantify the health and well-being impact of proximity and exposure to freshwater blue space in Scotland.

7.1. Key scientific implications

By addressing the aim, objectives and key knowledge gaps outlined in C1, this thesis makes several original contributions to our understanding of the relationship between exposure to freshwater blue space and human health and well-being. The key thesis findings suggest spending time in and around freshwater blue space can benefit mental health and well-being. Although some physical / general health benefits were also observed, these were significantly outweighed by mental health and well-being benefits.

The findings of this thesis add to a growing evidence base that suggests freshwater blue space exposure can benefit mental health and well-being (de Vries et al., 2021; de Bell et al., 2017; Chen and Yuan, 2020). For example, a study of blue space visitation across 18 countries (including the UK) suggests visiting freshwater blue spaces is associated with higher mental well-being and reduced mental distress (White et al., 2021). Similarly, research conducted in the Netherlands found that people tend to be happier when in or near freshwater blue spaces (de Vries et al., 2021). The potential of freshwater blue space, like green space and coastal blue space, to promote health and well-being, is particularly relevant amid growing concerns surrounding mental ill-health globally (Campion et al., 2022; Steel et al., 2014). Indeed, improving mental well-being and reducing mental illness is a major public health objective of the Scottish Government (Scottish Government, 2022).

Adopting multiscale and multidisciplinary methods throughout this thesis offered a number of significant advantages. The blue space, health and well-being literature is broad and diverse (White et al., 2020) and the adoption of a wide variety of methods allowed contributions to different knowledge gaps across this varied research landscape, including in areas of environmental economics (C6), environmental epidemiology (C3 and C4) and human geography (C5). Despite each chapter addressing different research questions, the methods adopted in each chapter are complementary and add value to the evidence generated in the thesis. For example, C2 adopts an ecological approach and provides a national scale overview of the well-being impact of proximity to freshwater for older adults, but it was unable to provide the individual-level context or likely mechanisms of this relationship. However, C5 adopted a qualitative approach and was able to provide a more in-depth overview of some of the more nuanced elements of freshwater interactions which lead to improved mental well-being. The combination of differing spatial scales and methodological approaches, spanning the quantitative and qualitative research spectrum, is a key strength of this thesis and adds substantial value to the evidence generated throughout.

It is well established that the availability of freshwater ecosystem services is critical for human life. As such, freshwater resources are often viewed from a pathogenic health perspective (focusing on the causes of disease and ill-health), e.g., the health risks of poor access to clean and safe drinking water (Ray and Smith, 2021). When freshwater environments are considered in relation to well-being, studies often focus on scenarios which lead to negative mental well-being impacts, such as flooding (Fernandez et al., 2015) or drought (Vins et al., 2015). However, the findings of this thesis highlight that freshwater blue spaces can play an important role in the promotion of well-being, rather than solely facilitating survival and avoiding ill-health. A conceptual shift is, therefore, required whereby exposure to freshwater blue space is now considered from both a salutogenic (focusing on the cause of health promotion and wellness) (Antonovsky, 1979) and pathogenic health perspective.

Collectively, the empirical findings in this thesis reinforce a key argument proposed in C2, which suggested that freshwater blue space requires increased consideration as a health-promoting asset in alignment with levels of consideration of coastal blue space and green space. As discussed throughout this thesis, green space is now an established component of global urban planning and public health policy (Shanahan et al., 2015) and recognition of the public health benefits of coastal blue space exposure is also growing rapidly. However, freshwater blue spaces offer different physical characteristics and opportunities for recreation than green space and coastal blue space. Freshwater environments also offer a range of distinct ecosystem services and their management often involves dedicated stakeholders (e.g., Scottish Canals and Scottish Water). Consequently, in order to maximise the unique health and well-being benefits offered by freshwater blue space, distinct consideration of freshwater in public health and planning policy is required.

When this thesis is considered alongside other recent studies demonstrating the potential of freshwater and coastal blue space to promote health and well-being, shifts in conceptual thinking within nature-health research over the last decade begin to emerge. Figure 7.1 depicts the development of freshwater blue space within the nature-health research and situates the contribution of this thesis within the wider development of the literature. Historically (Stage 1), blue space was often classified within definitions of green space or excluded from study designs and somewhat overlooked in nature-health research. In 2011, Völker and Kistemann described blue space and health and well-being research as '…*at best a by-product of environmental psychology and environmental health research*'. In the last decade (Stage 2) there has been an increased interest in the relationship between blue space and human health, predominately focusing on coastal blue space (Gascon et al., 2017). A focus on coastal blue space may be explained due to historical recognition of oceans as sites of healing (Bell et al., 2015) and the ease of quantifying access to the coast relative to freshwater environments (McDougall et al., 2020a) Furthermore, highly cited publications (e.g., Wheeler et al., 2012 and White et al., 2013), which have advanced the blue space and health field, have focused predominately on coastal environments.

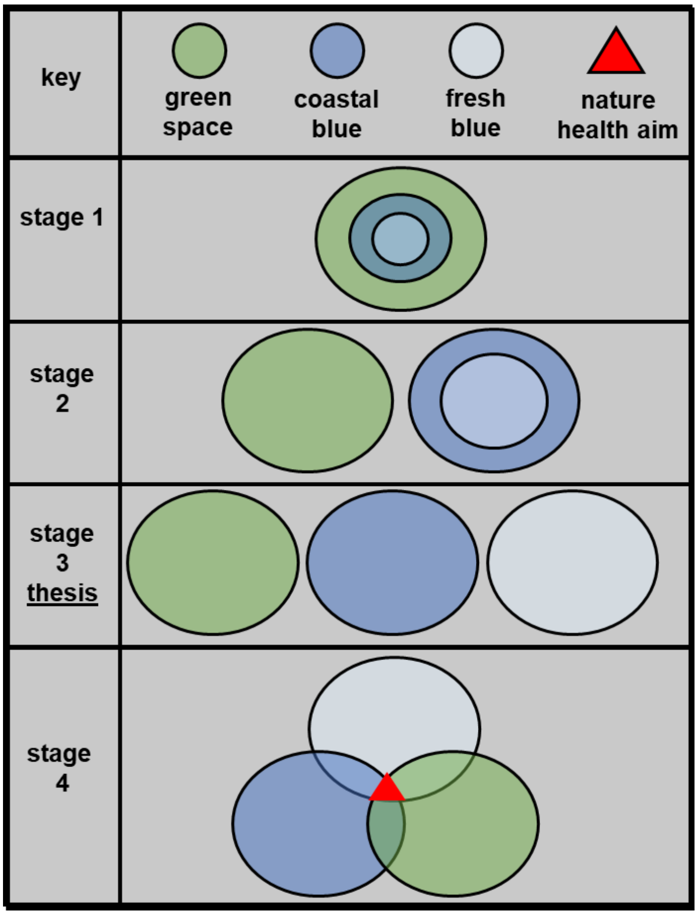

Figure 7.1. Development of nature-health and freshwater blue space research.

In recent research (de Bell et al., 2017; Poulsen et al., 2022; Pearson et al., 2019; White et al., 2021; Völker et al., 2018) freshwater blue space has been increasingly studied and has gained recognition as a health-promoting environment (Stage 3). The findings of this thesis, in particular C3, C4 and C5 have also contributed to the growing evidence base of freshwater blue space exposure enhancing health and in particular mental health and well-being. Independent consideration of different environments, as described in stage 3, is a key step in understanding which elements of nature impact health and advancing the nature-health evidence base (Frumkin et al., 2017).

Some evidence, including C3 and C4, suggests that exposure to coastal and freshwater blue space and green space may have varying impacts on health and well-being (Nutsford et al., 2016, Pasanen et al., 2019, de Vries et al., 2016). However, these environments are highly connected and are often indistinguishable in landscapes. Despite the importance of understanding the health-promoting potential of different natural environments, conducting or acting upon such research may not always be feasible or practical for policymakers. Nature-health researchers, therefore, face the challenge of combining emerging evidence of the health-promoting benefits of freshwater and coastal blue space and green space to determine how the health and well-being benefits offered by nature can be maximised (Stage 4). However, effective integration of the blue space and green space and health evidence base, requires the health-promoting potential of each environment, both in isolation and in different combinations, to be understood.

Although freshwater environments are becoming more frequently recognised as health-promoting assets, freshwater ecosystems are increasingly threatened and this could potentially be catalysed by increasing human usage (Chen et al., 2020). Key threats to freshwater ecosystems such as climate change, extreme weather and biodiversity loss threaten the potential of these environments to promote health and well-being. Similarly, water pollution and resulting impacts, such as algal blooms can threaten public health. Moving forward, there is scope to frame the protection and enhancement of freshwater ecosystems as not only an environmental issue, but an economic and public health issue, given the public health benefits that freshwater blue spaces can offer. Indeed, promoting awareness of the health and well-being benefits of freshwater blue space may provide a potentially charismatic rationale for protecting freshwater ecosystems.

7.2 Addressing research objectives

7.2.1. Objective 1: To quantify the health and well-being impact of proximity and exposure to different freshwater blue space types

Objective 1 was addressed extensively in C4 and partially in C3 and C5. In C4, a nationwide survey of adults in Scotland was conducted to determine the health and well-being impact of proximity and exposure to lochs, canals and rivers. To best knowledge, this is the first empirical study to simultaneously quantify the relationship between proximity and exposure to multiple freshwater types and health and well-being. Living within a ten-minute walking distance of lakes, rivers or canals was not associated with greater general health or mental well-being. However, frequently visiting rivers and canals but not lakes, in the last month, was associated with greater mental well-being. Taken together, our findings suggest that freshwater blue space exposure can provide mental well-being benefits. However, the provision of these benefits may vary among different freshwater blue space types. Similarly, C3 found that people who live within 1km of large freshwater lakes in Scotland have lower antidepressant medication uptake, a proxy for mental ill-health, compared to individuals who live further than 1km from large lakes. This result contributes to a small body of evidence that suggests large freshwater lakes may be a blue space type particularly beneficial for mental health promotion (Pearson et al., 2019). Although focusing specifically on experiences wild swimming, C5 provided further insight into the unique place-related elements of lochs, which appear to be connected with improved mental well-being. For example, the stillness and tranquillity of lochs was highlighted as being particularly important in the provision of mental well-being benefits.

Collectively, C3, C4 and C5 addressed objective 1 to advance our understanding of the health and well-being impact of proximity and exposure to different freshwater blue space types. These chapters build upon C2, which provides a theoretical overview of how different freshwater blue space types may engage with key pathways to improved health and well-being. For example, in terms of reducing environmental harms, flowing water bodies may provide more effective buffering of urban noise than stagnant water (Wysocki et al., 2007). Larger water bodies are likely to provide greater effects on surrounding temperatures (Wu et al., 2018) and the microclimate cooling effect of lakes tends to be higher than that of rivers (Du et al., 2016). Although urban microclimate cooling is often overlooked in the UK, this issue is of growing importance, particularly as the Met Office recently issued the first ever red weather warning due to the public health risk of extreme heat (Met Office, 2022).

Although consideration of different freshwater blue space types is merited and can provide greater detailed and more actionable evidence of the health and well-being benefits provided by freshwaters, the approach is not optimal. Ideally, individual blue spaces would be evaluated for their health promoting potential (or quality) regardless of type. However, despite the development of blue space quality indicators, such as the BlueHealth Environmental Assessment Tool (BEAT) (Mishra et al., 2020), there remains a dearth in suitable quality indicators which can be practically applied at a population scale. Consequently, the approaches developed in this thesis offer practical solutions to the overgeneralisation of freshwater environments in blue space and health research.

7.2.2. Objective 2: To identify the health-promoting potential of freshwater blue space exposure for different demographic groups

Objective 2 was challenging to address for a number of reasons. Firstly, attaining sufficient sample sizes of different demographic groups who visited freshwater blue spaces was difficult and stratifying samples would reduce the statistical power of the analyses conducted in this thesis. Secondly, planned qualitative research engaging with ethnic minority and highly deprived populations was cancelled due to logistical issues of COVID-19. Consequently, this thesis does not address issues related to race (or racism) and access to freshwater blue space, which are of critical importance to ensure the equitable distribution of the public health benefits offered by blue spaces (Phoenix et al., 2020).

Despite these challenges, the research conducted has advanced understanding of the health-promoting potential of freshwater blue space exposure among different demographic groups, including older adults and females. The findings of C3 suggest older adults who live within 1km of large freshwater lochs and in neighbourhoods with high freshwater blue space availability report lower antidepressant medication uptake. These findings corroborate a number of studies from Asia which also suggest blue space exposure can benefit mental health and well-being in later life (Garrett et al., 2019a; Helbich et al., 2019; Chen and Yuan, 2020). The methodology adopted in C3 did not lend itself well to establishing causation or explaining the mediating factors in the relationship between freshwater engagement in later life and improved well-being. However, greater context was provided in C5, despite a specific focus on wild swimming which would likely only make up a small proportion of blue space engagement in the C3 sample. Older wild swimmers suggested loch swimming offered an opportunity to maintain exercise levels when other forms of high impact exercise (such as running) became more challenging with age. Indeed, the promotion of physical activity in later life is a key mechanism by which blue space exposure can promote healthy ageing (Costello et al., 2019). Some gender-specific health and well-being benefits were also observed in C5. For example, some female participants believed that regular loch swimming ‘eased’ several menopausal symptoms including hot flushes and mood swings. However, some females also experienced negative wild swimming experiences related to body image. Although this thesis was unable to address important issues related to freshwater blue space usage, race and socioeconomic status, a number of important findings related to gender and age were established.

7.2.3. Objective 3: To establish the health and well-being benefits and risks of immersion in freshwater blue space

Objective 3 was addressed directly in C5, which to best knowledge is the first study to investigate the health and well-being impact of loch swimming. The rationale for C5 was an absence of freshwater swimming experiences in wild swimming and health research, with the exception of Moles’ (2021) overview of competitive river swimming. The findings of C5 suggest participating in loch swimming provides a wide variety of physical, social and mental health and well-being benefits. Mental health and well-being benefits, such as enhancing mood, increasing mental resilience and reducing stress, were the most prominent benefits reported among the loch swimmers interviewed. In many cases, the wider social benefits that accompanied loch swimming were considered more important than the swimming experience itself and several participants appeared to use loch swimming to assist in their recovery from physical and mental ill health. Regarding risk, the participants interviewed appeared to be highly aware of the risks of wild swimming, although participants’ awareness of the risks of exposure to poor quality water was somewhat mixed. Despite generally high-risk awareness in our sample, the risk of illness and fatality as a result of wild swimming remains a growing public health concern as wild swimming becomes increasingly popular in Scotland.

7.2.4. Objective 4: To contextualise the health and well-being impacts of freshwater blue space exposure relative to coastal blue space and green space exposure and variety of demographic and socioeconomic indicators

The findings of C3, C4 and C5 address objective 4. In C3, neighbourhood freshwater availability and living in close proximity to large freshwater lakes was associated with greater reductions in reported antidepressant medication uptake than neighbourhood green space availability. In C4, green space exposure was only associated with improved general health and was not associated with greater mental well-being, unlike freshwater and coastal blue space exposure. In both chapters proximity to the sea (C3) and sea visits were associated (C4) with a greater reduction in antidepressant medication uptake and self-reported mental well-being relative to freshwater proximity and exposure. Consequently, exposure to freshwater blue space appears to have a greater impact on mental well-being than exposure to green space and a similar, yet smaller impact than exposure to coastal blue space.

In C4 the mental well-being benefits, in terms of percentage increase in self-reported well-being, of frequent canal (9%) and river visitation (7%) were smaller, yet comparable to the well-being benefits of meeting WHO physical activity guidance (12%). In C3, living in neighbourhoods with high freshwater blue space availability was closely comparable to a 1% increase in the percentage of *'income deprived'* individuals and a 0.5% increase in the percentage of in individuals living in overcrowded housing within a neighbourhood. When compared to socioeconomic and behavioural metrics that have well established links to public health, the health and well-being impacts of freshwater blue space proximity and exposure are smaller, but still important, particularly when considered from population health perspective. The identified health and well-being potential of freshwater blue space, reinforces the need for greater consideration as freshwater environments as an important component of the public health tool-kit available to policy makers.

Although difficult to compare to the influence of other factors on health and well-being due to the qualitative research methodology adopted, C5 provides a somewhat different perspective on the health-promoting potential of freshwater blue space exposure. In C3 and C4, freshwater proximity and exposure have important public health benefits when considered at a population scale, yet small benefits when considered at the individual-level. However, C5 suggests in some cases freshwater engagement can be perceived as playing a critical role in supporting mental well-being. Numerous participants credit loch swimming with assisting them overcome mental ill-health and stress. Given these benefits, it should be noted that in C3 and C4, the health and well-being benefits are the mean benefit across a large population and within that population some individuals will rely on the health and well-being benefits of freshwater more than others. Consequently, this thesis highlights the need to consider freshwater blue space as a component of a public health tool-kit to incrementally improve health and well-being at a population level, but also to recognise that for some, freshwater blue spaces are critical resources for mental health and well-being promotion.

7.2.5. Objective 5: To establish the non-market value of preserving waterside spaces surrounding freshwater blue space

Objective 5 was addressed directly in C6, where the non-market value of preserving waterside spaces surrounding Loch Lomond and Loch Leven was established via a contingent valuation experiment. Based on the most conservative estimates obtained, mean willingness to pay (WTP) per household per annum for the protection of waterside spaces at Loch Lomond and Loch Leven was £12.06 and £8.44, respectively. These values were comparable to studies focusing on improving water quality at lakes in Europe, including Šebo et al. (2019) who reported a mean WTP of £9.50 per annum for improvements in water quality at an urban lake in Slovakia. Similarly, Hunter et al. (2012) estimated local residents are WTP between £9.99 and £12.23 per annum to reduce the number of days per year that water quality poses a risk to human health at Loch Leven. Historically, valuations of freshwater ecosystems predominantly focus on changes to water quality, however, given the economic value of preserving waterside spaces established in C6, greater consideration of waterside spaces is required to fully consider the non-market benefits offered by freshwater environments and to understand the economic impact of changes to these environments.

It should be noted that the values obtained in C6 focus specifically on two large destination lochs. Scotland has more than 30,000 lochs (NatureScot, 2020) and the methods developed in C6 for valuing the preservation of waterside spaces is transferrable to other lochs in Scotland. Adopting these methods at different locations may add value to the decision-making processes of local authorities and other organisations involved in the management of freshwater ecosystems. Furthermore, our findings focus specifically on quantifying the non-market value of preserving a selection of elements of waterside environments. Other non-market values related to health savings or recreational values were not considered and were beyond the scope of this research. These values can also have significant importance to local and national economies. For example, the enhancement of a riverside pathway in Barcelona, Spain was associated with significant health and well-being benefits and an annual health-related economic benefit of 23.4 million euros (approximately 19 million pounds) (Vert et al., 2019). Likewise, travel cost and stated preference surveys conducted across 14 EU Member States suggest the recreational value of blue space visitation is €631bn (approximately £527bn) annually (Börger et al., 2021). Although health economics research was beyond the scope of this thesis, based on the previously cited studies, the health and well-being benefits of freshwater exposure demonstrated in C3, C4 and C5 are also likely to have significant and nationally important value to Scotland's economy.

7.3. Original contributions

In addressing the aims and objectives of this thesis a number of original contributions to the freshwater blue space health evidence base have been generated. Table 7.1 summarises the original methodological, conceptual and empirical contributions of each chapter. Each data chapter included a novel empirical component and to best knowledge was the first study to execute this component.

Building upon the use of prescription data to quantify relationships between green space exposure and cardiovascular (Aerts et al., 2020) and mental health (Gidlow et al., 2016), C3 was the first study to combine national antidepressant prescribing data and freshwater and coastal blue space availability data. The methods adopted in C3 demonstrated the potential to use large prescribing datasets to focus on the impact of blue space availability on particular demographic groups. This methodology may be highly useful as conducting demographic-focused blue space and health research is often challenging due to a limited number of individuals living in close proximity to blue space.

To empirically test the theory that different freshwater blue space types may vary in their health-promoting potential (as argued in C2), C4 quantified the relationship between proximity and exposure to lakes, canals and rivers and health and well-being. In doing so, C4 is the first study to simultaneously consider exposure to multiple different types of freshwater collectively, rather than focusing on one particular freshwater type e.g. canals (Tieges et al., 2020; Smith et al., 2022) or large lakes (Pearson et al., 2019).

Most wild swimming and health research has focused on the experience of sea swimming. By contrast, experiences of freshwater wild swimming have been limited to competitive river swimming (Moles, 2021). C5 is the first study to study the experience of loch swimmers and the health and well-being impacts of loch swimming. Furthermore, C5 establishes novel perceptions of the importance of place-related characteristics and risks of loch swimming which can be used to increase the safety of wild swimming in both lochs and other blue spaces.

Numerous studies have established the non-market value of water-based recreation and improving water quality in Scotland. However, C6 was the first study to determine public preference for the protection of lochside spaces in Scotland. Consequently, the findings and methods adopted in C6 can add an additional layer of detail to economic valuations of changes to freshwater ecosystems.

Table 7.1. Summary of original contributions in each data chapter.

Chapter	Methodological / Conceptual	Empirical
C2	Novel critiques of GIS-based methods to quantify freshwater exposure Suggested conceptual shift towards individual categorisation of freshwater and coastal blue space	N/A
C3	Utilised overlapping neighbourhood buffer approach to ensure freshwater blue space was shared among census zones Established new metric (3km estuary width) to define coastal blue space in Scotland	First study to combine national antidepressant prescribing data and freshwater and coastal blue space availability
C4	Presented argument to consider the health-promoting impact of different freshwater blue space types in future health research	First study to consider exposure to multiple different types of freshwater collectively, rather than focusing on one particular freshwater type Empirically demonstrated that freshwater blue space types can (but not always) vary in their health-promoting impact
C5	Demonstrated potential of combining participatory-GIS to supplement in-depth interviewing with a focus on wild swimming and place	First study to investigate the experience of loch (lake) swimming and health and well-being
C6	Developed novel methodology to assess non-market value of preserving lochside space Established the need to consider waterside space when valuing changes to freshwater ecosystems	First study to determine public preference for the protection of lochside spaces in Scotland Generated economic data that suggest changes to waterside space at destination water bodies has nationally important economic impacts

7.4. Policy relevance and recommendations

A series of policy recommendations have been highlighted for key stakeholders related to the research carried out in this thesis. Policy recommendations related to each chapter are provided in the discussion section of each. The purpose of this section is to contextualise the research findings amongst international and national policy. International policy focuses on the United Nations Sustainable Development Goals (SDGs) and policy recommendations for five national policymakers are discussed.

7.4.1 International relevance

The findings of this thesis align closely with a number of United Nations SDGs. The SDGs are a '*call to action*' to improve public health, environments and economies globally (United Nations, 2022). Figure 7.2 provides an overview of the links between the findings of each chapter and different SDGs national stakeholders (see Section 7.4.2). The findings of each chapter align with a variety of SDGs, including SDG3, SDG10, SDG11, SDG14 and SDG15. Collectively, all chapters align strongly with SDG3 which aims to ensure healthy lives and promote well-being for all at all ages. The promotion of healthy living is considered theoretically in C2 and is studied empirically in C3, C4 and C5 and a wide variety of policy recommendations are provided in each chapter focused on promoting health living by increasing opportunities for blue space exposure. C5 aligns particularly closely to SDG3 by providing policy recommendations to ensure freshwater blue spaces can be adapted to increase access for older adults.

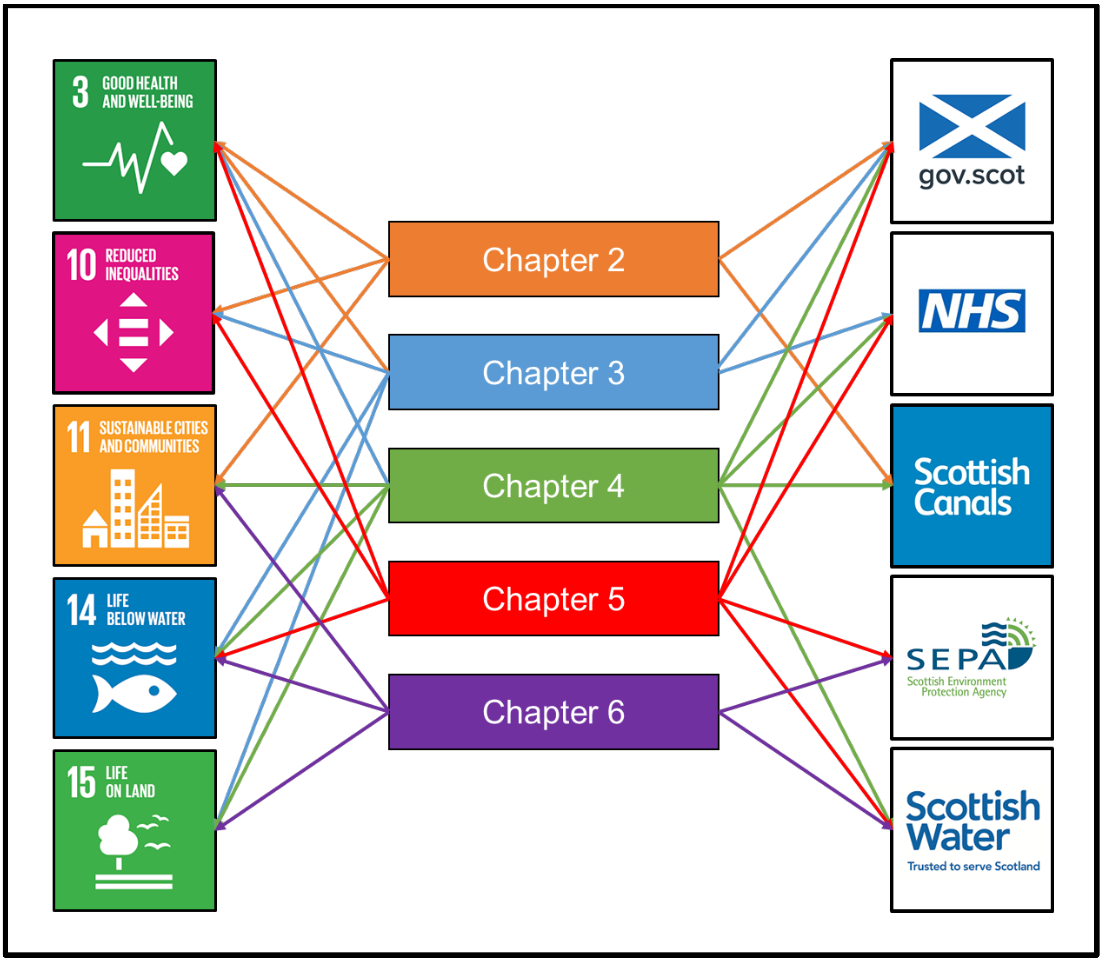

Figure 7.2. Summary of policy relevance of each data chapter.

7.4.2 National policy recommendations

7.4.2.1 Scottish Government and local authorities

Key policy recommendation: Provide increased funding for projects which aim to develop, restore and improve freshwater blue spaces in Scotland.

Several key recommendations arise from the findings of this thesis for the Scottish Government and local authorities across Scotland. In 2012, the Scottish Government (2012) published the first Hydro Nation strategy which committed to… *'…making Scotland a 'Hydro Nation' where water resources are developed so as to bring the maximum benefit to the Scottish economy'*. However, the full economic benefit of value of freshwater environments in Scotland remains somewhat unknown, particularly when freshwaters are considered as a public health resource. Building upon the contingent valuation study conducted in C6, there is a need for the Scottish Government to determine the public health benefits currently offered by water bodies in Scotland to better understand the value of these environments and to determine cost-effective and socially optimal future investments in Scotland’s freshwater resources. Although interest in the health and well-being benefits of coastal and freshwater blue space exposure in Scotland is growing, e.g., by the inclusion of blue space in national planning considerations (e.g., the National Planning Framework), many blue spaces remain underutilised as health-promoting resources. Further investment in blue spaces in Scotland will likely result in meaningful public health benefits, particularly in deprived communities as proven by reduced mortality due to the regeneration of sections of the canal systems in Glasgow (Tieges et al., 2020; Smith et al., 2022). Replicating such regeneration projects at other freshwater blue spaces across Scotland offers scope to reduce health inequalities, improve public health and stimulate local economies. As such, blue space regeneration and the of enhancement blue space quality merits substantially greater consideration by the Scottish Government and local authorities.

Although this thesis discusses the health-promoting potential of Scotland’s freshwater blue spaces, the potential risks to public health of blue space engagement should also be of critical importance to national and local governments. As a result of increasing water-related deaths in Scotland (Water Safety Scotland, 2018), several water safety campaigns have been developed by key stakeholders. In C6, the experience of loch swimmers suggested that many new ‘*swimmers*’ lack a basic understanding of the risks of loch swimming and underestimate the negative health effects of cold-water shock, suggesting the need for greater education. In England and Wales, swimming lessons are a mandatory component of the school curriculum, however, this is not the case in Scotland (Water Safety Scotland, 2018). It is strongly recommended that the Scottish Government and local authorities embed water safety and swimming lessons into the school curriculum, particularly given that socioeconomic status is often a key driver to participation in swimming lessons and swimming ability (Hastings et al., 2016). Pursuing this policy provides an opportunity to widen water safety education to a broad spectrum of swimmers and non-swimmers, which is of crucial importance given the growing number of new wild swimmers in Scotland and the associated public health risks.

7.4.2.2 National Health Service (NHS)

Key policy recommendation: Develop and fund health interventions which utilise freshwater blue spaces within the NHS estate.

Since October 2018, doctors in the Shetland Islands have been permitted to prescribe nature to their patients to reduce anxiety, stress and mental ill-health (Royal Society for the Protection of Birds, 2018). With an abundance of surrounding nature, Shetland offers a fairly unique setting to conduct nature-based prescribing, although NHS Scotland plans to offer nature-based prescribing nationwide in the coming years. In order to maximise the potential benefits of nature-based prescriptions, it is recommended that thorough audits are carried out to understand what environments are available to different patients based on where they live, work and their mobility, what environments patients feel comfortable visiting and what environments are most likely to lead to improved health outcomes. The findings of this thesis indicate that freshwater blue spaces are beneficial (even in small doses, such as two hours per month) for improving mental well-being. Given that Scotland has an abundance of freshwater resources, it is recommended that NHS Scotland consider freshwater blue space exposure distinctly in future nature-based prescribing strategies.

NHS Scotland (2020) recently published a report titled 'Unlocking the Potential of NHS Greenspace for Health and Wellbeing'. The report presents a strategy to increase the health and well-being benefits provided by NHS owned outdoor spaces for hospital patients and recreational users. Freshwater blue space received little consideration in this strategy and it is, therefore, recommended that freshwater blue spaces within NHS estates are utilised more effectively. For example, NHS-led well-being walks which are currently conducted around the Forth Valley NHS estate could be adapted to engage more directly with the loch on the site (Figure 7.3). Indeed, research in this area suggests that walking alongside freshwater blue space can result in improved mental well-being (Vert et al., 2019). It is, therefore, recommended that the potential benefits of multiple types of natural environments are considered in strategies which aim to maximise the health-promoting potential NHS estates.

Figure 7.3. NHS Forth Valley loch (NHS Scotland, 2021)

7.4.2.3 Scottish Canals

Key policy recommendation: Create a campaign to reduce negative perceptions of canals in Scotland, particularly in deprived urban communities.

Scottish Canals are responsible for managing Scotland's five main canals, which total over 220km (Scottish Canals, 2022). In C4, it was established that visiting canals in Scotland is associated with improved mental well-being. Despite their health-promoting potential, canals are often associated with antisocial behaviour and carry a negative stigma of uncleanliness due to the historic condition of these sites (Pitt, 2018). This negative stigma reduces canal visitation and consequently reduces the public health benefits that canals offer. It is recommended that Scottish Canals continue their efforts to reduce the stigma of uncleanliness associated with canals and promote the wide variety of recreational opportunities and opportunities for engagement with nature that canals in Scotland offer. Targeted campaigns to highlight opportunities for nature engagement in densely populated urban areas, where access to nature is limited, may be particularly useful. Similarly, the development of strategies to improve the inclusivity of canals in Scotland, particularly for ethnic minority communities, who often face unique barriers to blue space and active travel infrastructure (Phoenix et al., 2020), is a crucial area of policy development with far-reaching public health potential.

7.4.2.4 Scottish Environmental Protection Agency (SEPA)

Key policy recommendation: Develop environmental regulations to protect the health-promoting capacity of freshwater blue spaces and other natural environments in Scotland.

The primary role of SEPA is to help protect and maintain Scotland's environmental resources (SEPA, 2022). SEPA are responsible for environmental regulation, climate change mitigation, raising awareness of environmental matters and resolving environmental issues. Regarding blue space specifically, SEPA monitor bathing water quality across Scotland, however, the vast majority of monitored bathing sites are coastal. Given the growing popularity of loch swimming in Scotland and risks of swimming in poor loch water (as highlighted in C5), it is recommended that the number and geographic diversity of designated bathing sites is increased to account for popular loch swimming locations across the country. Incorporating popular loch swimming sites into SEPA's bathing water monitoring provides an opportunity to reduce the public health risks of swimming in lochs with poor water quality. However, it is of crucial importance that strategies to improve and monitor bathing water quality also take into account the wider impacts of bathing water improvements on the provision of other freshwater ecosystem services (Quilliam et al., 2015).

Public health plays a critical role in the regulations set by SEPA. However, almost all of SEPA's regulations are driven by pathogenic thinking e.g., the avoidance of poor health due to environmental harms, such as contaminated water. Pathogenic thinking understandably dominates environmental health research and policy given that 9 million premature deaths are related to environmental pollution annually (Fuller et al., 2022). However, moving forward there is a growing need to enhance and protect environments based on the public health benefits they provide, rather than focusing merely on the public health risks of harmful environments. It is, therefore, recommended that freshwater blue spaces and other health-promoting environments are considered by SEPA through a salutogenic health lens and environmental regulation in Scotland moves beyond focusing solely on minimising the occurrence of harmful environments towards a focus on enhancing and protecting health-promoting environments.

7.4.2.5 Scottish Water

Key policy recommendation: Design and fund a citizen science tool focused on improving water safety at freshwater and coastal blue spaces across Scotland.

Scottish Water are the sole provider of drinking water and sewerage services in Scotland. Scottish Water have a Strategic Plan to connect communities with their local environment by enabling access to Scottish Water assets for recreation and leisure purposes, including the 300 reservoirs that Scottish Water manages (Scottish Water, 2020). Reservoirs are popular sites for wild swimming in Scotland, however, they often have concealed dangers that are not immediately obvious, such as underwater machinery or tunnels (Scottish Water, 2022). Scottish Water are increasingly concerned about the risks of swimming in reservoirs, despite also attempting to increase safe access and recreation. In order to address this issue it is recommended that Scottish Water consider engaging more effectively with the wild swimming community to understand the effectiveness of current safety guidance focused on reservoir swimming and to further develop current guidance based on the experience and expertise of the wild swimming community. The development of interactive mapping tools could be particularly beneficial to highlight areas unsuitable for swimming in reservoirs, as demonstrated in C5. Such mapping tools can also incorporate citizen science techniques to capture the expertise of wild swimming community and to establish potential risks (e.g., algal blooms) in Scottish Water reservoirs in real-time.

7.5 Future research

A suite of future research needs emerge from the studies reported in this thesis. Research needs from each chapter are identified in the discussion section of each.

Broader research needs which were beyond the scope of this thesis or related to the collective findings of the thesis are classified into three themes related to the freshwater blue space exposure, health and well-being evidence base; (i) **utilising and translating** the evidence; (ii) **advancing and diversifying** the evidence; and (iii) **adapting and futureproofing** the evidence.

7.5.1 Utilising and translating

As demonstrated throughout this thesis, freshwater blue spaces can play a role in promoting health and well-being. However, freshwater environments remain underutilised as a public health resource. One potential reason for this is limited connectivity between blue space and health research and policy. Systematic reviews are often the peak of academic evidence synthesis and are used in both green space and blue space and health research to synthesise evidence (Gascon et al., 2017). However, a recent study of the use of systematic reviews in local authority decision making suggests systematic reviews often lack transferability to the needs of policy makers (South and Lorenc, 2020). As such, establishing improved pathways to connect blue space and health research to policy, without compromising methodological rigour, offers a valuable area for future research.

Regarding freshwater blue space specifically, novel areas of research exist around freshwater governance and the integration of blue-health benefits into nature-based solutions and blue infrastructure projects. Understanding the potential benefits and trade-offs of coupling environmental and public health interventions may be a particularly valuable area of future research. Environmental and health economics research to develop blue space interventions, which not only benefit public health but provide positive returns on investment can be particularly beneficial and provide opportunities to increase community and stakeholder support for such projects.

Green space governance has received increasing research interest in recent years (Huang et al., 2021). However, managing and governing both freshwater and coastal blue space involves a wider variety of stakeholders and is accompanied by a different set of environmental and urban planning challenges than managing and governing green space. Research focusing on how best to govern freshwater blue spaces to enhance their health-promoting capacity, whilst increasing a wide variety of other freshwater ecosystem services is much needed. Research in this area should consider the preferences and needs of a wide variety of stakeholders and local communities to better understand what practical and affordable opportunities exist to increase the provision of public health benefits via freshwater. Indeed, exploring and testing different methods of co-production where academics, communities and policy makers co-produce strategies to improve public health via blue space would be extremely valuable.

7.5.2 Advancing and diversifying

Although steadily growing, the freshwater blue space, health and well-being evidence base can be advanced in a number of key areas, many of which are highlighted in detail in C2. Most notably, there is a need to internationalise the evidence base to incorporate a wider variety of cultures and water landscapes. Exploring the potential of blue space in different geographies is particularly important given that seasonality and climate may impact the provision of blue-health benefits (White et al., 2021). To date, blue space research has predominantly ignored the 'global south', with some exceptions (e.g. Fisher et al., 2021). Although, more pressing water-related challenges exist in many countries in the global south, researchers should not let this undermine the potential public health value of improving well-being via freshwater engagement and further blue space and health research focusing on populations in the global-south is required.

The evidence base can also be advanced by increasing the use of longitudinal research designs (Gascon et al., 2017), which may become more possible when census data in released in Scotland in 2022. Controlled trials to reinforce findings from observational studies and natural experiments, such as the blue space types findings from C4 would also be particularly valuable. Similarrly, the development of rapidly applicable indicators of freshwater blue space quality, which can be applied at population or regional scale, offers a significant opportunity to advance current methodologies.

Unfortunately, this PhD was unable to address issues related to inequalities in blue space usage and accessibility. It has been established that inequalities in blue space usage exist regardless of access. For example, white residents are more likely to use freshwater blue spaces in Utah than Hispanic residents, despite living further away (Haeffner et al., 2017). Perhaps the most beneficial way to advance the freshwater blue space and health and well-being evidence base (and wider nature-health evidence) is to move beyond access and consider the wide variety of individual and area-level factors that influence blue space usage. At the forefront of this is the historical context of blue spaces, which can lead to racial discrimination or antisocial behaviour and can be a deterrent of usage and cause of inequalities in usage (Phoenix et al., 2020). Understanding these historical contexts, their impact on usage and developing strategies to overcome or reverse these impacts, therefore, offers an incredibly valuable area of future research. Citizen science methods to understand perceptions in and around blue space and more nuanced elements of accessibility, such as feelings of belonging and safety may be particularly valuable. However, these methods must capture the opinion and views of those who face inequalities, as failure to do so could inadvertently widen inequalities in blue space access

The study of barriers to green space usage is fairly well established and numerous transferable findings can be used to inform research on barriers to freshwater usage. However, as highlighted in this thesis, some barriers to freshwater blue space usage are distinct. Pitt (2018) suggests that fear of water is a deterrent of canal usage, whilst swimming ability and income impact wild swimming participation. Furthermore, as highlighted in C4, it is important to not only understand how to increase the usage of blue space, but ensure this usage is safe. Therefore, research establishing strategies to not only increase equitable opportunities for blue space usage, but equitable opportunities for safe blue space usage is critical.

7.5.3 Adapting and futureproofing

Finally, the freshwater blue space and health and well-being evidence base should adapt to emerging environmental, economic and societal trends. Evidence of freshwater and coastal blue space provision becoming of increasing interest from urban planning and public health perspectives is apparent both in Scotland and internationally. In Scotland, blue space was recently added to the National Planning Framework – the Scottish Government's long term planning strategy. As such and with growing evidence of the potential of blue space interventions to improve health (Britton et al., 2018; Vert et al., 2019; Smith et al., 2022), there is a high likelihood of blue space projects being accelerated in the coming years. New projects offer valuable opportunities to conduct natural experiments, which are largely absent from the current evidence base (Gascon et al., 2017). Natural experiments require adaptability and researchers to react quickly to evaluate emerging projects in real-time. As highlighted above, developing strong partnerships between research, policy and developers can aid the development of natural experiments and the collection of baseline data by integrating evaluation research into blue/green space infrastructure projects (Hunter et al., 2020).

As blue space usage increases, developing strategies to ensure safe and responsible freshwater usage may become increasingly important. Understanding the potential risks to the environment and public health of a wide variety of freshwater uses and strategies to mitigate these risks is, therefore, valuable. Increasing recognition of the value and popularity of blue space can also lead to longer term negative implications, such as environmental gentrification (Anguelovski et al., 2018). Indeed, conducting robust cost-benefit analysis is a necessary area of research to ensure blue space policies are cost-effective and socially optimal (Hanley et al., 2019).

Finally, the health and well-being benefits of freshwater blue space may be subject to a number of threats. Environmental threats such as biodiversity loss, pollution and climate change may reduce the provision of health and well-being benefits significantly. Agent-based and environmental modelling approaches that identify how different scenarios of environmental change impact the health-promoting potential of freshwater blue spaces are highly useful and can feed into mitigation strategies. The freshwater blue space and health evidence base must also adapt to wider social issues such as aging populations and mobility changes of COVID-19.

Both issues are likely to change mobility in urban environments significantly and it is critical that public health benefits of freshwater blue space exposure are safeguarded and ongoing research recognises these changing needs.

7.6 Reflection

Throughout the four years of my PhD, I believe I have developed considerably as a researcher. My writing has improved substantially and I have developed a strong foundational knowledge of a range of different disciplines. I intend to build upon the multi-disciplinary research background that I have developed during my PhD and establish my own identity as a researcher. One regret of my thesis is that I was not able to address issues related to inequity and blue space access – this will be a primary focus of my research in the coming years. Furthermore, I hope to develop a stronger connection between my research and policy, both in terms of the content and policy relevance of my work and my own ability to generate impact and connect my research to policy audiences.

In terms of quantitative research, I hope to continue to develop my knowledge of statistics and improve my confidence in data analysis. I would also like become competent in other, more flexible statistical packages (such as R). Regarding qualitative research, I would like to learn more about my own impact on my research and findings. In C5, I attempted to minimise my own personal biases and opinions by following best practice and utilising the second and third opinions of my research team. Although I received good feedback on my performance as an interviewer, it is possible that participants would be hesitant to discuss certain sensitive issues (e.g. in relation to mental well-being) with me given the short period of time we had known each other. I intend to continue to be critical of my own role in the research I conduct, particularly on sensitive topics such as mental health and well-being.

There are a number of changes I would make if I was to undertake this PhD again. Most notably, my understanding of health inequalities has improved substantially and I would attempt to adjust my methods to ensure health inequality was considered. In C3, I would adopt less restrictive categories of neighbourhood freshwater coverage. I would also adjust the criteria that I adopted to classify protest responses in C6. Although the above may seem like very technical points, on reflection, it has become apparent to me that my decisions here were driven by my lack of confidence as a researcher. I made decisions, which I over complicated, rather than relying on my own personal experience and a more common-sense based approach. I believe I now have the knowledge and confidence in my ability as a researcher to avoid making such errors again and to be more critical of some of the assumptions and methods within published research.

7.7. Conclusion

This thesis aimed to use multiscale and multidisciplinary approaches to quantify the health and well-being impact of access and exposure to freshwater blue space in Scotland. Collectively, the findings suggest exposure to freshwater blue space can benefit mental health and well-being and it was observed that these benefits can vary among different freshwater blue space types, including lakes, rivers and canals. Although some physical health benefits of freshwater blue space exposure were observed, these were significantly outweighed by mental health and well-being benefits. The population scale elements of this thesis (C3 and C4) suggest freshwater blue space exposure has smaller, yet similar, impacts on mental well-being than a range of socioeconomic and behavioural indicators with well-established links to improved public health e.g., weekly physical activity levels. However, the in-depth interview findings (C5) suggest freshwater blue space exposure can play a critical role in promoting and maintaining mental well-being. Freshwater blue space, therefore, offers valuable opportunities to promote health and well-being at multiple spatial scales. Improving freshwater blue space accessibility, therefore, merits substantially greater consideration in urban planning and public health policy, both in Scotland and internationally. However, it is of critical importance that the health and well-being benefits offered by increased freshwater blue space access and usage are available to all.

Chapter 8 - References

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Chapter 9 - Appendices

Appendix 1. Scotland's Nature and Health Survey (survey instrument)

You are invited to participate in Scotland's Nature and Health Survey. Scotland's Nature and Health Survey is being conducted by a team of researchers at the University of Stirling to understand how the natural environment impacts the health of people living in Scotland. You have been invited to participate because you are an adult residing in Scotland. The survey should take approximately 10 minutes to complete. You will be given some questions to answer about your health, background and your usage of the environment - your answers will be completely anonymous.

In which country of the UK do you currently reside?

- ○ England
- ○ Scotland
- ○ Wales
- ○ Northern Ireland

Which of the following best describes how do you identify?

- ○ Man
- ○ Woman
- ○ Other
- ○ Prefer not to say

What is your **full postcode**? This information will remain completely confidential and will be used solely to allow us to understand the amount of nature in your neighbourhood.

How old are you?

- ◯ Under 18
- ◯ 18-24
- ◯ 25-34
- ◯ 35-44
- ◯ 45-54
- ◯ 55-64
- ◯ 65-74
- ◯ 75 or older

What is your approximate annual household income (before tax)?

- ◯ Less than £15,000
- ◯ £15,000 - £19,999
- ◯ £20,000 - £29,999
- ◯ £30,000 - £39,000
- ◯ £40,000 - £49,999
- ◯ £50,000 - £59,999
- ◯ £60,000 - £69,999
- ◯ £70,000 - £79,999
- ◯ £80,000 - £89,999
- ◯ £90,000 - £99,999
- ◯ More than £100,000

Section 1: Health

How is your health in general?

- ◯ Very bad
- ◯ Bad
- ◯ Fair
- ◯ Good
- ◯ Very good

Do you have a long-term limiting illness or disability?

- ◯ Yes
- ◯ No
- ◯ Prefer not to say

Please indicate for each of the 5 statements which is the closest to how you have been feeling over the past 2 weeks.

	All of the time	Most of the time	More than half of the time	Less than half of the time	Some of the time	At no time
Over the past two weeks I have felt cheerful and in good spirits.	○	○	○	○	○	○
Over the past two weeks I have felt calm and relaxed	○	○	○	○	○	○
Over the past two weeks I have felt active and vigorous	○	○	○	○	○	○
Over the past two weeks I woke up feeling fresh and rested	○	○	○	○	○	○
Over the past two weeks my daily life has been filled with things that interest me	○	○	○	○	○	○

In the past two weeks, have you used any medicines that were prescribed to you by a doctor for any of the following conditions? Please select all that apply.

- [ ] Chronic pain
- [ ] Depression
- [ ] Anxiety disorder
- [ ] Cardiovascular disease
- [ ] No
- [ ] Prefer not to say

In the last 7 days, on how many days did you do the following types of physical activities?

Walking	▼ 0 (Not at all) ... 7 (Everyday)
Moderate - Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.	▼ 0 (Not at all) ... 7 (Everyday)
Vigorous - Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.	▼ 0 (Not at all) ... 7 (Everyday)

In the last 7 days, how much time did you spend per day on the days that you took part in these types of physical activity?

Walking	▼ Less than 20 mins ... N/A
Moderate - Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.	▼ Less than 20 mins ... N/A
Vigorous - Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.	▼ Less than 20 mins ... N/A

Have you contracted COVID-19 or self-isolated due to COVID-19 in the last 2 weeks?

- ◯ Yes
- ◯ No

Section 2: Nature + Neighbourhood

Which of the following environments are within the following walking distances of your home?

	within a 5-minute walk	within a 10-minute walk	within a 15-minute walk	None of these walking distances
Sea / beach	○	○	○	○
Canal	○	○	○	○
Lake / loch / reservoir	○	○	○	○
River	○	○	○	○
Green space (e.g. parks, woodlands and fields)	○	○	○	○

Do you have a view of any of the following from your home or garden? Select all that apply

- ☐ Sea / beach
- ☐ Canal
- ☐ Lake / loch / reservoir
- ☐ River (including streams and burns)
- ☐ Green space (e.g. parks, woodlands and fields)
- ☐ I do not have a view of any of these environments

In the past month, how many times have you visited the following environments?

Sea / beach (1)	▼ Did not visit in the past month (1) ... Everyday (32)
Canal (2)	▼ Did not visit in the past month (1) ... Everyday (32)
Lake / loch / reservoir (3)	▼ Did not visit in the past month (1) ... Everyday (32)
River (4)	▼ Did not visit in the past month (1) ... Everyday (32)
Green space (e.g. parks, woodlands and fields) (5)	▼ Did not visit in the past month (1) ... Everyday (32)

Based on the past month, how much time do you spend per trip to each of these environments when you visit?

Sea / beach	▼ 0 ... More than 12 hours
Canal	▼ 0 ... More than 12 hours
Lake / loch / reservoir	▼ 0 ... More than 12 hours
River	▼ 0 ... More than 12 hours
Green space (e.g. parks, woodlands and fields)	▼ 0 ... More than 12 hours

Which of the following best describes the body of water closest to your home?

- ◯ Sea / beach
- ◯ Canal
- ◯ Lake / loch / reservoir
- ◯ River

Thinking about the body of water closest to your home and its immediate surroundings (e.g., paths) please respond to the following statements:

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
This body of water and its surroundings are generally litter free.	○	○	○	○	○
I feel safe when I visit this body of water and its surroundings.	○	○	○	○	○
This body of water is easily accessible for me.	○	○	○	○	○
I find this body of water / its surroundings are good for walking.	○	○	○	○	○
This body of water has good facilities. Facilities could include, for example, bins, parking, footpaths or toilets.	○	○	○	○	○
The water in this body of water is clean.	○	○	○	○	○

On a typical visit to a body of water (e.g. loch, lake, sea, river or canal) which of the following activities are you likely to take part in? Please select all that apply.

- ☐ Walking
- ☐ Running
- ☐ Dog walking
- ☐ Cycling
- ☐ Fishing
- ☐ Water sports
- ☐ Socialising
- ☐ Relaxing
- ☐ Boating
- ☐ Other

Please read each statement below carefully and then ask yourself: “How much does this statement apply to my experience and relationship with nature?"

	Completely disagree	Strongly disagree	Disagree	Neither disagree or agree	Agree	Strongly agree	Completely agree
I always find beauty in nature	○	○	○	○	○	○	○
I always treat nature with respect	○	○	○	○	○	○	○
Being in nature makes me very happy	○	○	○	○	○	○	○
Spending time in nature is very important to me	○	○	○	○	○	○	○
I find being in nature really amazing	○	○	○	○	○	○	○
I feel part of nature	○	○	○	○	○	○	○

To what extent do you consider that the air in your neighbourhood is polluted?

- ○ 0 (not at all)
- ○ 1
- ○ 2
- ○ 3
- ○ 4
- ○ 5
- ○ 6
- ○ 7
- ○ 8
- ○ 9
- ○ 10 (extremely)

How much does noise from different sources in your neighbourhood (such as road traffic, construction or general noise from neighbours) bother, disturb, or annoy you?

- ◯ 0 (not at all)
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10 (extremely)

How much does the following statement apply to the outdoor places you spend time in:

The outdoor places I spend time in take me away from my everyday demands and allow me to relax and think about what interests me.

- ◯ 0 (not at all)
- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 7
- ◯ 8
- ◯ 9
- ◯ 10 (completely)

Section 3: Your Background

In the past two weeks, on how many days have you met up with friends, family or neighbours in **outdoor** places?

▼ 0 ... 14

In the past two weeks, on how many days have you met up with friends, family or neighbours in **indoor** places?

▼ 0 ... 14

Which of the following best describes your highest education qualification?

- ◯ Secondary school
- ◯ College
- ◯ University (undergraduate)
- ◯ University (postgraduate)

Which of the following best describes your current relationship status?

- ◯ Single (never married)
- ◯ Cohabiting (not married, but living with my partner)
- ◯ Married
- ◯ Separated
- ◯ Widowed

Which of the following best describes your current employment status?

- ◯ Full-time employment
- ◯ Part-time employment
- ◯ Unemployed
- ◯ Full-time education
- ◯ Retired
- ◯ Other

Do any children under the age of 18 live in your household?

- ◯ Yes
- ◯ No

Do you currently own a dog?

- ◯ Yes
- ◯ No

Do you currently have access to a garden?

- ◯ Yes (private)
- ◯ Yes (shared)
- ◯ No

Do you currently have regular access to a car?

- ○ Yes
- ○ No

How long have you lived in your current residence?

- ○ Less than a year
- ○ Between 1 and 2 years
- ○ Between 2 and 5 years
- ○ Between 5 and 10 years
- ○ More than 10 years

Has COVID-19 negatively impacted your household income?

- ○ Yes
- ○ No

Appendix 2. Summary and description of variables used in the modeling process. Categories outlined in bold.

Variable	**Description**
Proximity	Does respondent live within 10-minutes walking distance of either type of blue space or green space. **NO (ref); YES.**
Visits	Self-reported number of visits respondent made to each type of blue space and green space in the month. **ZERO (ref); OCCASIONAL (1-3 times); FREQUENTLY (>3 times)**
Contact Time	Self-reported of visits respondent made to each type of blue space and green space in the last month multiplied by average length of each visit to each type. **ZERO (ref); >0-2 hours; >2 hours**
Mental Well-being	Self-reported WH0-5 mental well-being score. **0-100**
General Health	Self-reported general health. **BAD (ref); GOOD.** BAD = Very bad, Bad and Fair. Good = Good and Very good
Ill Health	Self-reported presence of long-term health condition. **NO (ref); YES**
Gender	Self-reported gender. **FEMALE (ref); MALE**
Age	Self-reported age. Age categories ranging from **18 – >75**: (8 categories, midpoint of each category used in regression)
H.Income	Self-reported household income. Household income categories ranging from **<£15 k– >£100 k per annum**: (9 categories, midpoint of each category used in regression)
Income C-19	Self-reported negative impact of COVID-19 on household income. **NO (REF); YES**
Exercise	Compliance with WHO weekly physical activity guidance in the last seven days. Moderate and vigorous physical activity self-reported using IPAQ. **NO (ref); YES**
Relationship	Self-report of whether respondent is in a relationship. **NO (ref); YES** NO = Single, Widowed and Divorced. Yes = Married and Cohabiting
Education	Self-reported level of education. **SECONDARY (ref); HIGHER.** SECONDARY = secondary school education or lower. HIGHER = College, University (undergraduate) and University (postgraduate)
S.Interaction	Self-reported number of days respondent engaged in social interaction with friends, neighbours or family in the last 14

Variable	Description
	days. **0 – 14**
Dog Owner	Self-reported dog ownership. **NO (ref); YES**
Car Owner	Self-reported car ownership. **NO (ref); YES**
Noise	Self-reported neighbourhood noise annoyance. **0 (not at all) – 10 (extremely)**
Air	Self-reported neighbourhood air pollution. **0 (not at all) – 10 (extremely)**
Urban	Urbanicity of respondent's residence based on Scottish Government Urban Rural Classification. **URBAN (ref); RURAL.** Classification derived from respondent postcode

Appendix 3. Adjusted negative binomial regression model of perceived proximity to blue and green space and mental well-being displayed as Incidence Rate Ratios (IRR) with 95% Confidence Intervals (CI).

***** P<0.001 ** P<0.01 * P<0.05**

	IRR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Lake (No)	1	.	.	.	.	.
Lake (Yes)	1.012	.041	0.29	.773	.935	1.095
River (Yes)	1	.	.	.	.	.
River (No)	.978	.027	-0.80	.421	.926	1.032
Canal (No)	1	.	.	.	.	.
Canal (Yes)	1.072	.045	1.67	.094	.988	1.163
Sea (No)	1	.	.	.	.	.
Sea (Yes)	1.018	.04	0.44	.657	.942	1.099
G.Space (No)	1	.	.	.	.	.
G.Space Yes	1.027	.031	0.87	.385	.967	1.09
G.Health	**1.512*****	.042	14.85	0	1.432	1.597
Ill Health	**.895*****	.032	-3.13	.002	.835	.96
Gender	**1.114*****	.027	4.40	0	1.061	1.168
Age	**1.005*****	.001	6.74	0	1.004	1.007
H.Income	.999	.001	-1.25	.211	.998	1
Income C-19	**.902*****	.025	-3.81	0	.855	.951
Exercise	**1.132*****	.026	5.33	0	1.081	1.184
Relationship	1.04	.028	1.47	.143	.987	1.096
Education	1.054	.026	2.16	.031	1.005	1.105
S.Interaction	**1.017*****	.003	6.14	0	1.011	1.022
Dog Owner	**1.077****	.027	2.99	.003	1.026	1.131
Car Owner	.978	.031	-0.70	.483	.919	1.041
Noise	**.987***	.005	-2.46	.014	.976	.997
Air	.997	.006	-0.44	.662	.985	1.01
Urban	.978	.033	-0.65	.516	.916	1.045
Lake Visits	1.001	.003	0.31	.757	.995	1.007
River Visits	1.003	.003	1.24	.214	.998	1.008

	IRR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Canal Visits	**1.007***	.003	2.11	.035	1	1.013
Sea Visits	1.004	.003	1.12	.261	.997	1.01
G.Space Visits	.998	.001	-1.47	.143	.995	1.001
Constant	**28.511*****	2.105	45.38	0	24.67	32.949
Lnalpha	-1.564	.067	.B	.B	-1.695	-1.434
Mean Dependent Var	51.126	Sd Dependent Var	24.003			
Pseudo R-Squared	0.034	Number Of Obs	1392			
Chi-Square	613.064	Prob > Chi^2	0.000			
Akaike Crit. (AIC)	12671.135	Bayesian Crit. (BIC)	12812.574			

Appendix 4. Adjusted logistic regression model of perceived proximity to blue and green space and general health displayed as Odds Ratios (OR) with 95% Confidence Intervals (CI).

**** P<0.001 ** P<0.01 * P<0.05.*

	OR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Lake (No)	1	.	.	.	.	.
Lake (Yes)	.937	.223	-0.27	.784	.587	1.495
River (Yes)	1	.	.	.	.	.
River (No)	1.435	.256	2.03	.043	1.012	2.035
Canal (No)	1	.	.	.	.	.
Canal (Yes)	.798	.215	-0.84	.403	.471	1.353
Sea (No)	1	.	.	.	.	.
Sea (Yes)	.877	.186	-0.62	.534	.578	1.328
G.Space (No)	1	.	.	.	.	.
G.Space (Yes)	1.084	.196	0.44	.657	.76	1.545
Well-being	**1.053*****	.004	13.54	0	1.045	1.061
Ill Health	**.127*****	.024	-10.72	0	.087	.185
Gender	**.539*****	.086	-3.87	0	.394	.737
Age	.991	.005	-1.67	.094	.981	1.001
H.Income	**1.017*****	.004	3.95	0	1.009	1.026
Income C-19	1.17	.183	1.01	.314	.862	1.589
Exercise	**1.468***	.232	2.42	.015	1.076	2.002
Relationship	.91	.144	-0.60	.552	.668	1.24
Education	.998	.155	-0.01	.992	.736	1.355
S.Interaction	.979	.018	-1.15	.251	.944	1.015
Dog Owner	.819	.13	-1.26	.209	.6	1.118
Car Owner	**1.605****	.291	2.61	.009	1.125	2.29
Noise	.948	.031	-1.66	.097	.89	1.01
Air	.971	.036	-0.79	.43	.904	1.044
Urban	.728	.153	-1.51	.131	.482	1.099
Lake Visits	.981	.022	-0.86	.389	.938	1.025
River Visits	.998	.016	-0.14	.887	.967	1.029
Canal Visits	.983	.033	-0.49	.622	.92	1.051
Sea Visits	1.012	.021	0.59	.556	.972	1.054
G.Space Visits	**1.023***	.01	2.43	.015	1.005	1.043
Constant	.185	.086	-3.64	0	.075	.459

Mean Dependent Var	0.572	Sd Dependent Var	0.495

	OR	ST.ERR.	T-VALUE	P-VALUE	95% CI

Pseudo R-Squared	0.351	Number Of Obs	1392
Chi-Square	346.559	Prob > Chi^2	0.000
Akaike Crit. (AIC)	1286.073	Bayesian Crit. (BIC)	1422.274

Appendix 5. Adjusted negative binomial regression model of visit frequency to blue and green space and mental well-being displayed as Incidence Rate Ratios (IRR) with 95% Confidence Intervals (CI).

**** P<0.001 ** P<0.01 * P<0.05*

	IRR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Lake Visits (Zero)	1	.	.	.	.	.
Lake Visits (Occasional)	1.022	.029	0.76	.449	.967	1.079
Lake Visits (Frequent)	1.031	.037	0.85	.395	.96	1.107
River Visits (Zero)	1	.	.	.	.	.
River Visits (Occasional)	1.047	.031	1.56	.119	.988	1.11
River Visits (Frequent)	**1.065***	.033	2.05	.041	1.003	1.132
Canal Visits (Zero)	1	.	.	.	.	.
Canal Visits (Occasional)	1.063	.036	1.79	.073	.994	1.137
Canal Visits (Frequent)	**1.095***	.046	2.13	.033	1.007	1.19
Sea Visits (Zero)	1	.	.	.	.	.
Sea Visits (Occasional)	1.078**	.029	2.78	.005	1.022	1.136
Sea Visits (Frequent)	**1.06***	.03	2.05	.04	1.003	1.122
Gs Visits (Zero)	1	.	.	.	.	.
Gs Visits (Occasional)	1.032	.044	0.74	.461	.949	1.123
Gs Time (Frequent)	1.009	.04	0.23	.821	.934	1.09
G.Health	**1.505*****	.041	15.00	0	1.427	1.587
Ill Health	**.896****	.032	-3.09	.002	.836	.961
Gender	**1.113*****	.027	4.37	0	1.061	1.167
Age	**1.006*****	.001	6.99	0	1.004	1.007
H.Income	.999	.001	-1.60	.109	.998	1
Income C-19	**.898*****	.024	-3.99	0	.851	.947
Exercise	**1.121*****	.026	4.88	0	1.071	1.173
Relationship	1.039	.028	1.43	.154	.986	1.095
Education	1.042	.026	1.68	.094	.993	1.094
S.Interaction	**1.015*****	.003	5.66	0	1.01	1.02
Dog Owner	1.066	.026	2.65	.008	1.017	1.118
Car Owner	.964	.03	-1.17	.243	.906	1.025
Noise	**.986***	.005	-2.54	.011	.975	.997
Air	.997	.006	-0.43	.664	.985	1.01

	IRR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Urban	.975	.032	-0.78	.436	.914	1.039
Constant	**27.81*** **	2.103	43.98	0	23.98	32.253
Lnalpha	-1.577	.066	.B	.B	-1.707	-1.447

Mean Dependent Var	51.126	Sd Dependent Var	24.003
Pseudo R-Squared	0.036	Number Of Obs	1392
Chi-Square	644.212	Prob > Chi^2	0.000
Akaike Crit. (AIC)	12656.094	Bayesian Crit. (BIC)	12797.533

Appendix 6. Adjusted logistic regression model of visit frequency to blue and green space and general health displayed as Odds Ratios (OR) with 95% Confidence Intervals.

**** P<0.001 ** P<0.01 * P<0.05*

	OR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Lake Visits (Zero)	1	.	.	.	.	.
Lake Visits (Occasional)	1.12	.223	0.57	.569	.758	1.656
Lake Visits (Frequent)	.803	.192	-0.92	.359	.502	1.283
River Visits (Zero)	1	.	.	.	.	.
River Visits (Occasional)	.781	.144	-1.34	.181	.544	1.122
River Visits (Frequent)	.827	.177	-0.89	.373	.544	1.257
Canal Visits (Zero)	1	.	.	.	.	.
Canal Visits (Occasional)	.913	.218	-0.38	.703	.571	1.459
Canal Visits (Frequent)	.766	.253	-0.81	.42	.401	1.463
Sea Visits (Zero)	1	.	.	.	.	.
Sea Visits (Occasional)	.908	.16	-0.55	.586	.643	1.283
Sea Visits (Frequent)	1.014	.213	0.07	.947	.672	1.532
Gs Visits (Zero)	1	.	.	.	.	.
Gs Visits (Occasional)	1.499	.347	1.75	.08	.952	2.359
Gs Time (Frequent)	**2.017****	.448	3.16	.002	1.305	3.117
Well-Being	**1.054*****	.004	13.58	0	1.046	1.062
Ill Health	**.127*****	.024	-10.85	0	.088	.185
Gender	**.54*****	.086	-3.85	0	.395	.739
Age	.992	.005	-1.46	.143	.982	1.003
Income	**1.018****	.004	4.01	0	1.009	1.027
Income C-19	1.157	.18	0.94	.346	.854	1.569
Exercise	**1.499***	.236	2.57	.01	1.1	2.041
Relationship	.893	.142	-0.71	.476	.653	1.22
Education	1.016	.158	0.10	.917	.75	1.377
S.Interaction	.98	.018	-1.10	.27	.945	1.016
Dog Owner	.863	.135	-0.94	.345	.636	1.171

	OR	ST.ERR.	T-VALUE	P-VALUE	95% CI	
Car Owner	**1.606***	.295	2.58	.01	1.121	2.301
Noise	.939	.03	-1.94	.052	.881	1.001
Air	.971	.036	-0.79	.431	.903	1.045
Urban	.783	.162	-1.19	.236	.522	1.174
Constant	**.145*****	.069	-4.05	0	.057	.369

Mean Dependent Var	0.572	Sd Dependent Var	0.495
Pseudo R-Squared	0.350	Number Of Obs	1392
Chi-Square	358.701	Prob > Chi^2	0.000
Akaike Crit. (AIC)	1287.981	Bayesian Crit. (BIC)	1424.182

Appendix 7. Adjusted negative binomial regression model of contact time with blue and green space and mental well-being displayed as Incidence Rate Ratios (IRR) with 95% Confidence Intervals (CIs)

**** P<0.001 ** P<0.01 * P<0.05*

	IRR	ST.ERR	T-VALUE	P-VALUE	95% CI	
Lake Time (Zero)	1	.	.	.	.	.
Lake Time (>0 - 2 Hours)	1.049	.032	1.59	.112	.989	1.113
Lake Time (>2 Hours)	1.024	.034	0.71	.478	.96	1.092
River Time (Zero)	1	.	.	.	.	.
River Time (>0 - 2 Hours)	1.032	.03	1.09	.274	.975	1.092
River Time (>2 Hours)	1.054	.035	1.61	.106	.989	1.124
Canal Time (Zero)	1	.	.	.	.	.
Canal Time (>0 - 2 Hours)	1.037	.038	0.99	.322	.965	1.114
Canal Time (>2 Hours)	**1.099***	.045	2.31	.021	1.014	1.191
Sea Time (Zero)	1	.	.	.	.	.
Sea Time (>0 - 2 Hours)	1.052	.032	1.69	.091	.992	1.117
Sea Time (>2 Hours)	**1.058***	.029	2.08	.037	1.003	1.116
Gs Time (Zero)	1	.	.	.	.	.
Gs Time (>0 - 2 Hours)	1.047	.044	1.08	.279	.964	1.137
Gs Time (>2 Hours)	1.016	.038	0.41	.678	.944	1.093
G.Health	**1.504*****	.041	14.95	0	1.425	1.586
Ill Health	**.896****	.032	-3.11	.002	.836	.96
Gender	**1.115*****	.027	4.44	0	1.063	1.17
Age	**1.006*****	.001	6.84	0	1.004	1.007
H.Income	.999	.001	-1.56	.12	.998	1
Income C-19	**.898*****	.024	-3.95	0	.852	.947
Exercise	**1.122*****	.026	4.89	0	1.071	1.175
Relationship	1.035	.028	1.27	.203	.982	1.091
Education	1.04	.026	1.57	.117	.99	1.092
S.Interaction	**1.015*****	.003	5.80	0	1.01	1.02
Dog Owner	**1.068****	.026	2.72	.007	1.018	1.12
Car Owner	.967	.03	-1.08	.28	.909	1.028
Noise	**.986***	.005	-2.54	.011	.975	.997
Air	.998	.006	-0.34	.733	.986	1.01

	IRR	ST.ERR	T-VALUE	P-VALUE	95% CI	
Urban	.979	.032	-0.65	.514	.917	1.044
Constant	**27.821*** **	2.101	44.04	0	23.993	32.259
Lnalpha	-1.573	.066	.B	.B	-1.703	-1.443

Mean Dependent Var	51.126	Sd Dependent Var	24.003
Pseudo R-Squared	0.035	Number Of Obs	1392
Chi-Square	628.286	Prob > Chi^2	0.000
Akaike Crit. (AIC)	12660.555	Bayesian Crit. (BIC)	12801.995

Appendix 8. Adjusted logistic regression model of contact time with blue and green space and general health displayed as Odds Ratios (OR) with 95% Confidence Intervals (CIs)

**** P<0.001 ** P<0.01 * P<0.05*

	OR	ST.ERR	T-VALUE	P-VALUE	95% CI	
Lake Time (Zero)	1	.	.	.	.	.
Lake Time (>0 - 2 Hours)	1.233	.274	0.94	.348	.797	1.907
Lake Time (>2 Hours)	.862	.193	-0.67	.506	.556	1.336
River Time (Zero)	1	.	.	.	.	.
River Time (>0 - 2 Hours)	.914	.172	-0.48	.635	.632	1.323
River Time (>2 Hours)	.886	.188	-0.57	.568	.584	1.343
Canal Time (Zero)	1	.	.	.	.	.
Canal Time (>0 - 2 Hours)	1.035	.273	0.13	.896	.617	1.737
Canal Time (>2 Hours)	.666	.201	-1.35	.178	.369	1.204
Sea Time (Zero)	1	.	.	.	.	.
Sea Time (>0 - 2 Hours)	.842	.166	-0.87	.382	.573	1.238
Sea Time (>2 Hours)	1.033	.192	0.17	.861	.718	1.486
Gs Time (Zero)	1	.	.	.	.	.
Gs Time (>0 - 2 Hours)	1.319	.307	1.19	.234	.836	2.08
Gs Time (>2 Hours)	**1.572***	.333	2.13	.033	1.037	2.382
Well-being	**1.054*****	.004	13.57	0	1.046	1.062
Ill Health	**.127*****	.024	-10.74	0	.087	.185
Gender	**.542*****	.086	-3.84	0	.396	.741
Age	.992	.005	-1.47	.142	.982	1.003
H.Income	1.019***	.005	4.14	0	1.01	1.027
Income C-19	1.143	.177	0.86	.387	.844	1.549
Exercise	1.548	.246	2.75	.006	1.134	2.113
Relationship	.894	.143	-0.70	.483	.654	1.222
Education	1.01	.158	0.06	.951	.743	1.372
S.Interaction	.983	.018	-0.96	.338	.948	1.018
Dog Owner	.879	.136	-0.84	.403	.65	1.189
Car Owner	**1.578****	.29	2.49	.013	1.101	2.261
Noise	.942	.031	-1.83	.067	.883	1.004
Air	.971	.036	-0.80	.421	.903	1.044
Urban	.797	.163	-1.11	.267	.533	1.19
Constant	**.153*****	.073	-3.94	0	.06	.389

	OR	ST.ERR	T-VALUE	P-VALUE	95% CI

Mean Dependent Var	0.572	Sd Dependent Var	0.495
Pseudo R-Squared	0.348	Number Of Obs	1392
Chi-Square	352.188	Prob > Chi^2	0.000
Akaike Crit. (AIC)	1291.476	Bayesian Crit. (BIC)	1427.677

Appendix 9. Willingness to pay question and payment ladder shown to respondents

Please select yes for the amounts you are certain that you would be willing to pay and select no for those you are certain you would not be willing to pay in additional income tax **each year** to help fund the new Lochside Management Plan for Loch Lomond? Please select unsure for amounts that you are unsure whether you would be willing to pay or not.

	Yes	Unsure	No
50p	○	○	○
£1	○	○	○
£2	○	○	○
£3	○	○	○
£5	○	○	○
£10	○	○	○
£15	○	○	○
£20	○	○	○
£30	○	○	○
£40	○	○	○
£60	○	○	○
£80	○	○	○
£100	○	○	○
£120	○	○	○
More than £120	○	○	○