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Access to nature and its impact on peoples' wellbeing

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Access to nature and its impact on peoples' wellbeing

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Abstract

Ecosystems and the services they provide (termed ecosystem services; ES) are of vital importance to human survival and wellbeing, although the mechanisms by which people benefit from them are still not fully understood. Despite this, ecosystems are threatened globally through unsustainable use. To date, a large proportion of ES data have been estimated based on land cover using a process called benefit transfer. Benefit transfer may capture the capacity of a space to provide a service but it assumes ubiquitous use (i.e., that every hectare of, for example, forest holds the same value as all are equally used). Thus, at each specific location, benefit transfer methods fail to capture if the service is actually realised, how it may be realised, nor any variation in populations or between socioeconomic groups. This is particularly problematic when considering cultural ES, the non-material benefits people gain from interacting with nature. My thesis aims to unpack ES flow, to illuminate how potential cultural ES become realised by understanding where people access these services and how this impacts wellbeing, using Wales as a case study.

In Chapter 2, I review the literature on the flow of ES drawing on models from complimentary areas of literature (animal foraging, migration and landscape connectivity). I consider how different theories may be used to describe how people access ES and propose that ES flow can be broken down into 'nature to people' (movement of nature towards beneficiaries) and 'people to nature' (movement of beneficiaries towards nature). In the remainder of the thesis, I focus on the latter as the former has been relatively well-researched.

Through social surveys, I explore the distances people in Wales travel to access cultural ES, and how this varies across socio-demographic variables (Chapter 3). My results suggest that ecosystems very close to home (within ~1 km) are very important to day-to-day wellbeing. I use the same survey to explore the impact of Covid-19 restrictions on peoples' interactions with nature (Chapter 4). I find that younger people spent more time, more often in nature during the pandemic and so likely received more ES and associated wellbeing benefits. However, older people showed the opposite pattern. Those who did not have access to a natural space at their home (i.e., a garden) during the pandemic were more likely to report a negative impact on their wellbeing; emphasizing the importance of having access to nature nearby. Finally, building on theory from Chapter 2 (i.e., that some ES are realised via a journey and not only experienced at a single point), I hypothesise that, when walking, running and cycling, people may (consciously or unconsciously) preferentially choose routes that maximise their exposure to nature. By analysing big data from the social media app Strava, I support this hypothesis (Chapter 5).

My thesis enhances the field of ES research by proposing a new theory separating the flows by which ES are realised (nature to people vs people to nature). My findings have implications for policy in Wales. I suggest that all residences should have private natural space and if this is unfeasible, nature needs to be accessible as close as possible, within a maximum distance of 1 km. I show that frequent interactions with nearby nature are important to wellbeing, therefore nature should be brought into all spaces in peoples' lives such as workspaces, schools and hospitals. Finally, the influence of nature on small-scale spatial decisions when people are walking, running and cycling can be used by local government when creating and maintaining access and active travel networks, to encourage their use. This would support active, healthy lifestyles. The flow of people to nature is increasingly challenging in our modern world, therefore nature needs to become a constant thread in peoples' lives.

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My PhD has largely been a solo endeavour in self-development, of which I am incredibly proud. I have learnt a lot and an awful lot more about myself. However, I could absolutely not have done it without the support of so many important people. I would therefore like to thank…

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In loving memory of **my Aunty Myra**, who was always so supportive of my adventures and academic endeavours. Your support meant that I could give the PhD my all in the final crazy months.

Author's declaration

'I hereby declare that this thesis is the results of my own investigations, except where otherwise stated. All other sources are acknowledged by bibliographic references. This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree unless, as agreed by the University, for approved dual awards.

I confirm that I am submitting this work with the agreement of my Supervisor(s).'

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'Yr wyf drwy hyn yn datgan mai canlyniad fy ymchwil fy hun yw'r thesis hwn, ac eithrio lle nodir yn wahanol. Caiff ffynonellau eraill eu cydnabod gan droednodiadau yn rhoi cyfeiriadau eglur. Nid yw sylwedd y gwaith hwn wedi cael ei dderbyn o'r blaen ar gyfer unrhyw radd, ac nid yw'n cael ei gyflwyno ar yr un pryd mewn ymgeisiaeth am unrhyw radd oni bai ei fod, fel y cytunwyd gan y Brifysgol, am gymwysterau deuol cymeradwy.

Rwy'n cadaranhau fy nod yn cyflwyno'r gwaith hwm gyda chytundeb fy Ngoruchwyliwr (Goruchwylwyr)'

Author Contributions

Chapter 1. Introduction

This chapter is my own work and was reviewed by Simon Willcock, Julia Jones and James Bullock.

Chapter 2. The Flows of Nature to People and of People to Nature: Applying Movement Concepts to Ecosystem Services

I conceived the research questions with Simon Willcock, Julia Jones and James Bullock. I carried out the literature review and wrote the chapter which was reviewed by Simon Willcock, Julia Jones, James Bullock, Ioannis Athanasiadis and Javier Martinez-Lopez.

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Chapter 3. Relationships between distances travelled to natural spaces, impacts on wellbeing and socio-demographic predictors

I conceived the research questions and designed the survey with Simon Willcock, Julia Jones and James Bullock. The survey had input from Sophie Wynne-Jones (Bangor University) and Sian Stacey (Summit to Sea). The survey was tested with colleagues in Bangor university. I carried out the face-to-face data collection with two research assistants, Alisha Tyrrell-Liptrot and Robert Parkinson. I coordinate the online data collection with Pick my Postcode survey website after initial contact by Simon Willcock. I carried out analyses and wrote the chapter which was reviewed by Simon Willcock, Julia Jones and James Bullock.

Chapter 4. The impact of Covid-19 restrictions on access to natural spaces in Wales

I conceived the research questions and designed additions to our existing survey with Simon Willcock, Julia Jones and James Bullock. I carried out analyses and wrote the chapter which was reviewed by Simon Willcock, Julia Jones and James Bullock.

Chapter 5. The natural environment partially determines route choices of pedestrians and cyclists

I conceived the research questions and designed the analysis with Simon Willcock, Julia Jones and James Bullock. I communicated with Denbighshire County Council and Strava after initial contact by Simon Willcock. I carried out data management, coordinated analyses with Aaron Owen (Senior Research Software Engineer, Supercomputing Wales) and wrote the chapter which was reviewed by Simon Willcock, Julia Jones and James Bullock.

Chapter 6. Synthesis

This chapter is my own work and was reviewed by Simon Willcock, Julia Jones and James Bullock.

My overall contribution to the research presented is estimated to be 95%.

Table of Contents

List of Tables and Figures

Chapter 1

1. Introduction

1.1. Research Outline

Ecosystems (communities of interacting organisms and their physical environment in a geographical space (Stuart Chapin *et al.*, 2011)) are of vital importance to human survival and wellbeing. *"The conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life"* are sometimes termed ecosystem services (ES) (Daily, 1997). The concept of ES originated in the 1970's as a way to increase the public's awareness of environmental conservation by highlighting an anthropocentric viewpoint to help ensure the benefits people gain from nature were not overlooked in planning and policy decisions (Westman, 1977; Ehrlich and Ehrlich, 1981; De Groot, 1987; Gómez-Baggethun *et al.*, 2009). The concept became more mainstream into the 1990's and was sometimes used to estimate the monetary value of ES to aid comparison between services (both natural and man-made) (Costanza and Daly, 1992; Daily, 1997; Gómez-Baggethun *et al.*, 2009). The Millennium Ecosystem Assessment, in which the consequences of ecosystem change on human well-being were assessed, raised the profile of ES even further (Millennium Ecosystem Assessment, 2005).

More recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) introduced the term 'natures contributions to people' (Díaz *et al.*, 2015) originally termed 'natures benefits to people' but renamed to incorporate negative effects as well (Pascual *et al.*, 2017). Nature's contributions to people (NCP) as a conceptual framework is considered to advance that of ES in that cultural values run through the whole framework, rather than being restricted to a section of their own, as cultural ecosystem services (Kadykalo *et al.*, 2019). NCP is also felt to integrate more readily with social sciences and other research areas and to consider more diverse worldviews and indigenous knowledge (Kadykalo *et al.*, 2019). There is ongoing discussion about the frameworks; it has been acknowledged that the concepts do not differ completely (Díaz *et al.*, 2018) and the terms are sometimes used interchangeably (Willcock *et al.*, 2020).

Ecosystems and the services people benefit from are threatened locally and globally by unsustainable practices causing overexploitation and degradation. The Millennium Ecosystem Assessment found that, over the previous 50 years, humans had altered ecosystems more rapidly and extensively than in any other time in history (Millennium Ecosystem Assessment, 2005). Whilst this exploitation has resulted in short term material gain, in the long term it represents increasingly

degraded habitats and reduced quality of life for current and future generations (Albert *et al.*, 2021). Similarly, the State of Nature report (a 'health check' on nature in the UK) found that, in 2019, 13% of the 696 terrestrial and freshwater species monitored had declined in abundance significantly since 1970, with nearly half of that decline occurring in the previous 10 years (State of Nature Partnership, 2019). Overexploitation and degradation trends should be viewed with caution as the changes in ecosystems are not necessarily linear and could result in abrupt changes that are difficult to reverse should, potentially unknown, critical thresholds be reached (Willcock *et al.*, 2021).

To date, ES data has been largely derived from land cover (i.e., if an area is woodland, grassland, or urban, for example). For example, Costanza *et al.* (1997) estimated the value of global ES to be USD $33 trillion a year using economic valuations based on land cover. This method is based on matching land cover to the potential ES it can provide and has since been widely used to give an estimate of the capacity of a space to provide different ES (for example supply of timber, fish or crops) (Bastian, Haase and Grunewald, 2012; Haines-Young and Kienast, 2012).

Whilst this approach may provide data for potential services it does not account for the social element of ES and does not capture the extent to which the services are realised. There may be the capacity for a forestry block to supply, for example, 100 tons of timber but if the local population don't have the necessary machinery to harvest it, the service goes unrealised and they do not benefit. This approach also does not capture how a service might reach people or how people might reach a service i.e. the flow of ES (Dolan *et al.*, 2021).

This becomes more complex when considering cultural ES (the non-material benefits people gain from nature (Sarukhán and Whyte, 2005)), which is my focus here. For example, a park may have the capacity to engage hundreds of visitors but if there is no way to access it via public transport, or some groups feel unwelcome there, then they may not benefit from the space. Cultural ES are harder to measure because they are non-material, intangible and subjective and thus often unique to the individual (i.e. as people can value and benefit from natural spaces in different ways that are personal to them) (Chan, Satterfield and Goldstein, 2012; Satz *et al.*, 2013). Different frameworks have been proposed to disaggregate the non-material values people place on natural spaces and how they benefit from interacting with them, for example King *et al.* (2017).

I consider the flow of ecosystem services in my literature review and three data chapters. In chapter 2, I coin the term 'people to nature' to describe the movement of people to access nature and explore how other areas of the literature might be useful in describing this process. I develop this in chapter 3 by disaggregating the flow of people to nature by socio-economic factors and exploring if it varies across different groups in society. In chapter 4, I look at the flow of people to nature through the lens of the Covid-19 pandemic and associated restrictions in Wales and explore how nature to people changed over the pandemic. In chapter 5, I use Strava exercise data to consider how the flow of

people to nature interacts with movement and journeys. Finally, in chapter 6 I bring the findings from my chapters together and consider how my development of our understanding of the flow of nature to people might be useful for current work and policy in Wales.

Here, I endeavour to unpack the flow of ecosystem services and develop a spatial understanding of the interactions of people with the natural spaces that are available to them. I use Wales, part of the United Kingdom, as a case study.

1.2   Key Terms

I use several terms throughout the thesis that are subjective, which makes for great discussion but can be a challenge for research. I therefore define my use and meaning of the terms here.

Firstly, '**nature**' is a challenging notion that "…we are all familiar with as long as we're not asked to define it" (Ducarme, 2021). A review of 2020 suggests that one of the key western definitions of nature is everything that is not created by humans i.e., plants, animals and non-built landscapes. These things may be "considered as independent of human activity and history." (Ducarme and Couvet, 2020). Note, *considered* as independent from human activity but this is not actually the case, given the extent of human influence and management across the globe (Lewis and Maslin, 2015). Nature can mean different things to different people. What one person may consider to be 'nature' or 'natural' someone else may not think is natural at all. For example, someone who may live in an urban environment and have little knowledge of biodiversity may consider an intensively managed agricultural field of rye grass (*Lolium perenne,* a perennial grass species frequently sown for short term pasture in the UK) to be 'natural' because it is green and not built on, whereas someone with some ecological knowledge would consider the same field to be a monoculture with no biodiversity and highly artificial.

Here, I use the following definition for nature "environments and physical features of nonhuman origins, ranging from plants to non-built landscape" as from Capaldi *et al.*, (2015) and Hartig *et al*, (2014). In my surveys in chapters 3 and 4, I asked people to identify a 'natural space' where they had most recently spent time. By this, I meant somewhere where they had connected with nature and said that it could include but was not limited to; gardens, mountains, the coast, meadows, farmland, a commute along a green route, water bodies, nature reserves... In this I was essentially describing different habitats. I choose the term 'natural space'' rather than 'greenspace' to avoid suggesting that they **must** choose a designated or official space like a park, or a nature reserve (although they could if they wished). In chapter five, I break nature down further by using different metrics to measure the density and cover of habitats i.e., of vegetation and waterbodies. Therefore, in this thesis when I say 'nature' or 'natural', I mean habitats, vegetation species and

water bodies, rather than built areas. I acknowledge that this excludes, for example, trees in on urban streets that stand alone in an otherwise built area.

I personally feel saying somewhere or something is part of 'nature' depends on whether it is a living, growing thing, the extent to which it is manufactured, to what extent it has been made or influenced by humans and the diversity of species there. To use the example above, I would not consider a field of rye grass to be very natural, as it is an intensively managed monoculture that has been planted by humans. I would consider it to be more natural than a slab of concrete however, as rye grass is a living, growing plant, not something that has been manufactured or processed. I would consider a wildflower meadow to be more 'natural' than a rye grass field, as it is diverse, with lots of different species, even though it has been planted and managed by humans. Possibly the switch from natural to unnatural comes when management of a habitat becomes intensive. These thoughts are based on my personal definitions of the words.

Secondly, what do I mean when I talk about **access** and access to nature? Access can be considered in terms of geographical or spatial access i.e. someone's proximity to a space and the connectivity to get there (Brabyn and Sutton, 2013). It can also be considered in terms of effective access (Brabyn and Sutton, 2013). This considers other factors that affect someone spending time at space including; whether they are able to afford entry or transport, if there are physical barriers to entry, their physical ability or disability, if they feel they have time, how attractive the space is, perceived safety of the space and the extent to which they feel welcome. These factors have been found to vary based on someone's socio-economic situation (Boyd *et al.*, 2018). For example, someone may live very close to an urban park, but they may not spend time there because it is full of litter and they associate it with anti-social behaviour. They are able to get there but there are effective barriers to them spending time in the space and benefitting from this. Here, I use the term **access** in terms of geographic access, to mean proximity to available spaces. I consider spaces that people actually spend time in. I did go on to collect data relating to effective access; factors that people felt prevented them spending time in nature, but did not have the capacity to analyse this data here.

Finally, alongside nature and access, the concept of **wellbeing** is central to my thesis. There are two main approaches to wellbeing, hedonic ('feeling good') and eudaimonic ('functioning well') (Pritchard *et al.*, 2019). Hedonic wellbeing considers satisfaction with different areas of life including relationships, work and health, how much of the time or how an individual feels positive emotions and how much of the time they feel negative emotions (Ryff, Boylan and Kirsch, 2021). On the other hand, eudaimonic wellbeing takes a more zoomed out, long-term, self-reflective overview. It encompasses autonomy, how much confidence people have in their own opinions and decisions; environmental mastery, how good people are at managing their

responsibilities; personal growth, the extent to which people see opportunities, improve themselves and learn; positive relations with others, peoples' interpersonal skills, their ability to empathise, be affectionate and intimate; purpose in life, peoples' goals and sense of direction; and self-acceptance, how much people are satisfied with who they are and their qualities (Ryff, Boylan and Kirsch, 2021). Within my surveys I say that wellbeing can be '…considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, how happy you feel and how anxious you feel.' This is the definition used by the UK's Office of National Statistics (ONS, 2022). This definition describes components of hedonic wellbeing and therefore does not capture the components of eudaimonic wellbeing. However, it is in accessible language for use in surveys.

1.3.   Why Wales?

Wales has a strong policy framework that emphasises the importance of natural resources for current and future generations, the only country in the world to do so in such a comprehensive and integrated way (Owen, 2020). The Wellbeing of Future Generations Act comprises of seven Well-being Goals which all public bodies in Wales have to work towards; a resilient Wales, a healthy Wales, a more equal Wales, a globally responsible Wales, a Wales of cohesive communities, a prosperous Wales and a Wales of vibrant culture and thriving Welsh language(Welsh Government, 2015). The act can be used to support change on a local level and has been used to create local wellbeing plans (Natural Resources Wales, 2022).

The Wellbeing of Future Generations Act has been shown to have tangible effects, leading to behavioural and policy change. For example, planning has been strongly influenced by the shift towards sustainability (Welsh Government, 2018). Further, the government and public bodies are held to account by the Future Generations Commissioner for Wales, who has statutory powers and is independent of the government (Future Generations Commissioner for Wales, 2023). This role resulted in a planned motorway being rejected by Welsh government based on cost and environmental impact in 2019 (First Minister for Wales, 2019).

This research complements these goals by working to understand how people realise the benefits gained from healthy ecosystems, which contribute to our resilience and health, both physical and mental. I explore if there is variation on these based on socio-demographic variables such as income and gender, contributing to ensuring these benefits are equally accessible to all in the future.

Wales has adopted the Ecosystem Approach and has strong policy around environmental protection. The Environment (Wales) Act 2016 recognises our complete reliance on healthy ecosystems and the increasing pressures upon them. It aims to address this challenge by ensuring that our natural

resources are used sustainably and are resilient so they continue to provide services to current and future generations (Welsh Government, 2016).

As part of the Ecosystem Service Aproach, Welsh Government supports Payment for Ecosystem Services (PES) schemes throughout Wales (Welsh Government, 2019a). These schemes incentivise land managers to provide public goods (i.e., ES) which they would not previously have received financial rewards for doing. For example, the Black Mountains Land Use Partnership (BMLUP), based in the Brecon Beacons National Park in south Wales is a partnership between land owners, graziers and regulatory bodies including the National Park Authority, Natural Resources Wales, Welsh Water and Natural England (the project area crosses the border in to England), funded by Welsh Government (BMLUP, 2018). The partnership works to improve the quality of the ecosystems in the project area for those who live and work there and those who visit. By working in this way, they are providing a suite of ES including clean water, healthy soil, flood management, carbon storage and improved wellbeing through access to nature. The project is a pathfinder in understanding how PES schemes can work in practice and how land managers can be paid for providing these services to their community and beyond. PES are being applied worldwide (Ezzine-De-Blas *et al.*, 2016).

In addition to the socio-political framework, Wales makes an interesting case study to explore peoples' interactions with nature due to its varied landscape. This gives people a huge variety of habitats and ways in which to interact with nature in Wales. In terms of land cover, Wales consists of mountainous ranges including; Eryri (Snowdonia), the Cambrian mountains and the Black Mountains (Visit Wales, 2023b). Large areas of Wales are designated within its three national parks; Eryri, Bannau Brycheiniog and Pembrokeshire coast (Visit Wales, 2023c), with a fourth national park in north-east Wales currently under consultation (Natural Resources Wales, 2023a). Wales has a continual coastal path, which totals 870 miles around the whole coast line (Wales Coast Path, 2023). Over 80% of the land cover in Wales is agricultural land (Welsh Government, 2022a), with farming deeply rooted in Welsh culture. These areas vary significantly in management intensity but are criss-crossed with footpaths and Public Rights of Way (20, 750 miles across Wales (Natural Resources Wales, 2023b), providing access to the space even if the access to nature is variable. The varied landscape gives people the opportunity to be in active in nature in a huge variety of ways including surfing, mountain biking, paddleboarding, swimming and hiking (Visit Wales, 2023a).

Settlements across Wales vary significantly too, from the capital Caerdydd (Cardiff) with a population of 362,400 (Office for National Statistics, 2021a), to tiny hamlets and single

farmhouses. There are wealthier areas, for example areas of Swansea and Flintshire (Welsh Government, 2019c), but there are also areas of deprivation, for example Rhyl in Denbighshire as well as areas of Caerphilly, Rhondda Cynnon Taff and Bridgend, (Welsh Government, 2019c).

Wales is a very popular tourist destination, within the country and further afield, with 87, 300, 000 tourist day visits in 2019 (Welsh Government, 2019b). Tourism contributes significantly to the Welsh economy, with 11% of the Welsh population employed in the tourism industry (Welsh Government, 2021c). Tourists are drawn to the dynamic landscape described above but this can lead to pressure on Welsh communities and habitats, leading to on-going development of sustainable tourism models (Nicholls, Organ and Cummings, 2020).

1.4. Research Questions

The primary aim of this project is to move beyond the landcover-based approach of assuming beneficiaries have access to ES and to, instead, directly study and understand ES access – with a specific emphasis on cultural ES in Wales.

More specifically, I aim to explore:

- How do beneficiaries 'flow' to ecosystems?
- Does this vary between different socio-demographic groups? Is there a difference in the distance people cover to access nature:
    - Between those who live in urban versus rural areas?
    - Between those with higher incomes compared to lower?
    - Between gender identities?
    - Between different age groups?
- What is the relationship between the distance people cover to access nature and the importance of nature to their wellbeing?
- How did peoples' interactions with nature in Wales change over the Covid-19 pandemic? What affect did the restrictions have on the frequency and how long people spent in nature? What affect did this have on their wellbeing?
- Do the characteristics of natural environments along routes affect peoples' choices at junctions when they are cycling or travelling by foot?

1.5. Chapter Outline

This general introduction **(chapter 1)** and the final synthesis chapter (**chapter 6**) bring together the literature review and three distinct data chapters.

Chapter 2 reviews the ES literature and also literature on migration, animal foraging and landscape connectivity to introduce a new conceptual approach to ecosystem flow. I explored these areas of the literature to see if different theories could be used to describe how people access nature. Here, I highlight that ecosystem service flow can be broken down in to 'nature to people' (i.e., the movement of nature to beneficiaries) and 'people to nature' (i.e., the movement of beneficiaries to nature). Whilst the former has been relatively well researched, the latter has not and I go on to explore this further in the data chapters.

Chapter 3 explores the relationships between distances travelled from home to natural spaces, impacts on wellbeing and socio-demographic variables.

Data collection for this chapter was undertaken through Pick my Postcode, a free postcode lottery website through which people can complete questionnaires ([Pick my Postcode](#)). With every questionnaire completed members build a cash bonus, which they have a chance to collect if their postcode is selected as a winning postcode. Members of Pick My Postcode logging in to check the winning postcode on the 'survey' competition were given the chance to complete my questionnaire before the winning postcode was revealed – with £3 being added to their bonus as incentive to complete it. If the respondent's postcode was not selected as the winning postcode that day, the bonus they gained from completing my questionnaire was added on to any prize they may win via the website in the future. Working with Pick My Postcode allowed me to access a large number of respondents across the whole of Wales, quickly and economically – collecting ~1000 respondents in about 7 days each questionnaire round. In comparison, when carrying out our face-to-face questionnaire before rolling the questionnaire out online, it took myself and two research assistants a month to collect 500 questionnaire responses.

This survey was originally carried out face-to-face working Summit to Sea ([Summit to Sea](#)) a landscape-scale partnership project in mid-Wales working to best use the natural resources in their project area for people and nature. They wanted to gain an understanding of how visitors and residents in the project area were interacting with the landscape. See Appendix 1.4. for a full summary.

Through these online questionnaires I asked people about the most recent natural spaces they had spent time in, the importance of these spaces to their day-to-day wellbeing. I collected data on socio-demographic variables (household income, age, education ethnic background, rural or urban home

location). The chapter unpacks the concept of access to nature and ends with recommendations for local and national government.

Chapter 4 explores how interactions with natural spaces in Wales changed over the Covid-19 pandemic.

I reacted quickly to a call from Welsh Government for research that would deliver a significant contribution to our understanding of the impacts of the Covid-19 pandemic. I won additional funding to run further surveys through the pandemic (grant reference: ES/V004077/1). I was ideally placed to explore this with a social survey already established on a wide-reaching platform before the pandemic started.

This chapter explores how the frequency with which people spent time in natural spaces, how long they spent in natural spaces each visit and the distance they travelled to access natural spaces changed over the pandemic and how these changes affected their wellbeing. This was broken down by socio-demographic factors as in chapter 2. The chapter ends with recommendations for local and national government. Preliminary reports were reported to Welsh Government in July 2021 at the Welsh Government COVID-19 Technical Advisory Group research and development subgroup.

Chapter 5 explores the effect of nature on decision making at junctions when walking and cycling. Here I consider that accessing nature and the associated benefits does not always occur at an end destination or location, it may be part of a route or journey. Therefore, the decisions made about that journey will affect the quality of the experience people have and how much they benefit from connecting with nature that way. At each junction, people will decide which way to go based on a number of different factors. For this chapter, I accessed Strava data from Denbighshire County, Wales from 2016 – 2019. Social media exercise platforms like Strava provide unique movement data compared to other social media in that they actually show movement routes, which allows the correlation of journeys with environmental data. I collated remotely sensed datasets to represent metrics of 'greenness' and matched these to the Strava data. I then explored if greenness could predict the decisions individuals made at junctions. The findings from this chapter have implications for local planning.

I was initially contacted by Denbighshire County Council as they wanted to analyse Strava data for their county. They wanted to understand how cycling and walking in their county varied between different communities, the efficacy of their Public Rights of Way network and how Strava data compared to their cycle counter data. I met with their Highways Information Manager to understand what they wanted to find out from the data and kept him up to date with progress through the analysis.

I produced maps showing the number of on foot and cycling activities on route sections across the county. I displayed the total, weekend and weekday data for each year with the communities of

interest highlighted so the variation between the communities was clear. I produced maps for each year of cycling and on foot activities showing where activities had been carried on Public Rights of Way (PROW's) and the Cycle Path Network, and where Strava activities had been recorded in routes that did not correspond to the recognised network. In addition, I carried out further analysis to identify areas where people were potentially using motor vehicles on Public Rights of Way in the county which was a major concern for the highways team. This was a total of 43 separate maps.

This collaboration with Denbighshire County Council led to a three-month placement with the Designated Landscapes and Countryside Access team with Welsh Government. During this placement, I explored the feasibility of creating a single, digital map of access data for Wales. Currently access data, such as PROW's, are held separately by the 25 local authorities and national park authorities in Wales, which has been recognised as a disjointed, inefficient approach. I met with stakeholders to identify the benefits and challenges of bringing access data together in one space to be held by DataMapWales, an online catalogue of public sector data in Wales held by Welsh Government (DataMapWales). I produced a report at the end of the placement identifying next steps for the work.

Chapter 6 brings the three separate but linked data chapters together and considers them in relation to each other and the wider literature. It considers the extent to which I have addressed the research gap. The chapter describes the implications of the findings for ecosystem service research, for policy and for the environmental and public health sectors. The chapter acknowledges any limitations of the project and looks forward to future research coming from this work. Finally, it brings together overall conclusions.

To ensure that my work could be linked with current work in Wales, I shared my findings with contacts in Welsh Government, Local Authorities and environmental charities. I refer to their work in the chapter.

1.6. Positionality Statement

Researchers are increasingly considering their positionality within their work as it is recognised that this can influence their approach (Moon and Blackman, 2014; Darwin Holmes, 2020). Here I reflect on how I came to undertake this doctoral research project and how my positionality may have influenced my approach.

I have been enthusiastic about animals and wildlife since I was a child and as I grew up this broadened into an interest in ecology, conservation and sustainability. This led to my undergraduate degree in Animal Behaviour and Welfare and my postgraduate degree in Biodiversity and Conservation.

Following my postgraduate degree, I worked as an intern, contractor and then in a full-time post all with National Trust Wales. Through this work across different habitats and National Trust sites, I came to understand that if people aren't able to access a space or have not developed a connection with the natural world, they cannot value it or have an interest in conserving it. Therefore, I became interested in the processes of people accessing and valuing nature, nature connectedness and the trade-offs involved in providing access to natural spaces. For example, when developing routes for people to access National Trust sites the paths needed to be accessible but also designed to minimize impact on the habitats people wanted to come and appreciate.

I was interested in undertaking a PhD primarily for my own self-development, to deepen my understanding of areas of interest to me and to improve my skills in managing spatial data, statistical analysis and critical thinking. Having seen this project advertised, the spatial element of the project really appealed to me. It also appealed to me because it was based at home, at a Welsh university and the research was focused on Wales. I felt it would give me the opportunity to get to know my home country better having attended university away for four years and travelled, whilst building new skills. This project brought together my interests in how people value and access nature with the opportunity to learn and develop myself.

My project explores the importance of natural spaces to peoples' wellbeing. I consider interacting with nature in different ways to be fundamental to my wellbeing and mental health. I grew up and continue to live in a rural environment, in a family who actively encouraged interaction with the natural world. It is very important to me to be able to interact with nature in different ways such hiking, paddleboarding, gardening, wildlife watching, foraging. Given the degradation to natural environments from human activities and the climate crisis we are now living through, it is part of my daily life to consider environmental issues and to live sustainably. Therefore, I recognise that this position will have shaped my approach to designing my studies and interpreting data.

My research is on the population of Wales. I grew up on Anglesey, went to school in Gwynedd and continue to live on Anglesey. Although I speak Welsh as a second language, I am comfortable in conversational Welsh and was able to conduct face-to-face interviews in Welsh. I am therefore coming to the population as an 'insider' and recognised that this will have made my approach different to someone coming to the research as an 'outsider' (Darwin Holmes, 2020).

I came to this research from a mainly ecological background, which comes with a positivist approach that states that things can be studied objectively (Moon and Blackman, 2014). My project was a transition from natural sciences to incorporating social sciences in my approach to consider the importance of nature to peoples' wellbeing. This was a development in my position over the project.

Chapter 2

2. The Flows of Nature to People and of People to Nature: Applying Movement Concepts to Ecosystem Services

2.3. Abstract

To date, the provision of ecosystem services has largely been estimated based on spatial patterns of land cover alone, using benefit transfer analysis. Although it is increasingly being recognised that the distribution of the human population affects whether a potential service translates into a realised service, this misses key steps in the process and assumes that everyone accesses ecosystem services in the same way. Here I describe a conceptual approach to ecosystem services in terms of movement and flows. I highlight that ecosystem service flows can be broken down into 'nature to people' (the movement of nature towards beneficiaries) and 'people to nature' (the movement of beneficiaries towards nature). The former has been relatively well described. Here, I explore the latter by reviewing research on human migration, animal foraging and landscape connectivity. I assess if and how existing theories might be useful in describing how people seek out ecosystem services. I consider some of the ways in which flows of people to nature can be measured. Such measurements may reveal which movement theories best represent how people seek out and access ecosystem services. Overall, our review aims to improve the future modelling of ecosystem services by more explicitly considering how people access potential services and therefore realise them.

2.4. Introduction

Many initial assessments of ecosystem services (ESs; nature's contribution to people (Díaz *et al.*, 2018)) were based on land cover; i.e., whether an area is woodland, grassland, urban, etc.(Burkhard *et al.*, 2009; Koschke *et al.*, 2012). For example, in a highly influential paper, Costanza *et al.*, (1997) estimated the value of global ESs to be approximately USD 33 trillion a year using economic valuations based on land cover. This method consists of matching an ecosystem type with the potential ESs they provide in a lookup table (reviewed by Campagne *et al.*, (2020)), and it has been widely used. Despite the fact that ESs are an inherently socio-ecological concept (Burkhard, Pertrosillo and Costanza, 2010), the land cover approach considers only ecological variables and does not factor in the social variables. Although this approach may give an estimate of potential ESs (Haines-Young and Kienast, 2012) or the capacity of an ecosystem to supply a service (Bastian,

Haase and Grunewald, 2012) (e.g., biophysical supply of timber), it does not account for demand or how people might access the service, which is largely unknown (Willcock *et al.*, 2019).

Alternative approaches to lookup tables or ES matrices for assessing ESs include ES modelling (e.g., InVEST), monetary techniques and socio-cultural methods (Harrison *et al.*, 2018). Monetary techniques estimate the economic value of services, for example using the travel cost method to reveal preferences (Langemeyer *et al.*, 2015). Socio-cultural methods seek to understand preferences or social values for ES, for example by asking people to rank the benefits they gain from a space (Calvet-Mir, Gómez-Baggethun and Reyes-García, 2012). These methods still do not necessarily account for how people might access and realise the service.

To move beyond assessing potential ESs to assessing realised ESs, human population data can be used to estimate demand for ES's (Van Jaarsveld *et al.*, 2005; Burkhard *et al.*, 2012; Kroll *et al.*, 2012). Demand for ESs may be considered at local, regional and global scales (Vrebos *et al.*, 2015). In some situations, considering only the local population is appropriate when assessing demand for ES. For example, where fuel is gathered from a woodland by people travelling on foot, then demand can be estimated by using local population density data (Kroll *et al.*, 2012). However, the demand may also come from beyond the local area. For example, firewood may be collected and transported to another region of the same country or internationally to be sold (Ahrends *et al.*, 2010). In such situations, ecosystems may be 'telecoupled' to distant populations(Hull and Liu, 2018; Kleemann *et al.*, 2020) and so local populations are not always a useful indicator of demand (Palacios-Agundez *et al.*, 2015). Indeed, this example illustrates that demand for an ES may be manifested over more than one spatial scale. Considering demand in any way is a marked improvement on merely estimating theoretical supply using land cover (Wolff, Schulp and Verburg, 2015; Zank *et al.*, 2016). However, estimates of demand often do not consider how people access a service or how the service might reach them, i.e., the spatio-temporal process by which the service is realised (Bagstad *et al.*, 2014). For example, although every human on Earth benefits from carbon sequestration via the omni-directional dispersal of benefits throughout the atmosphere (Locatelli *et al.*, 2014), other benefits are more localised (e.g., access to a local viewpoint (Booth *et al.*, 2017)).

ES flow refers to the whole process of a potential ecosystem service becoming realised (Fischer and Eastwood, 2016), and requires an understanding of how people access the benefits of ecosystem services (Vrebos *et al.*, 2015). To better understand ES flows, they can be broken down into two processes, which here I term 'nature to people' and 'people to nature' (based on a previously developed framework; Figure 2.1 (Kolosz *et al.*, 2018; Balbi, Villa and Marquez-Torres, 2019). 'Nature to people' (N2P) is the movement of a natural good towards the point where the good is used by beneficiaries (i.e., a flow of nature to beneficiaries (the end-users)), and thus becomes an ES (Mace, Norris and Fitter, 2012). In order for a natural good to become an ES, some human input is needed, and so a 'transactor' (Figure 2.1) is needed to translate the good into a service (Mace, Norris

and Fitter, 2012; Jones *et al.*, 2016; Kolosz *et al.*, 2018; Balbi, Villa and Marquez-Torres, 2019). The transactor is the point at which a service becomes realised. For example, a river will flow down a mountain (N2P) and people will go to the river (P2N) to fish. The point at which they catch the fish is the transactor.

'People to nature' (P2N) is the movement of beneficiaries to a transactor in the search for an ecosystem service (i.e., a flow of beneficiaries to nature). For example, a view-point within a National Park is a possible transactor; from this point beneficiaries access views of the landscape. Alternatively, when considering people going to a forest to collect firewood, the point in the forest/landscape where the wood is collected would be the transactor (Mutandwa and Kanyarukiga, 2016). In some cases, people going to nature might be the realisation of the service itself; for example, going for a bike ride through a woodland (Figure 2.1). Different mechanisms for N2P and P2N are summarised in Table 2.1, and a series of each might be combined in order to encompass the overall ES flow (e.g., as part of a value chain (Kolosz *et al.*, 2018; Balbi, Villa and Marquez-Torres, 2019)). There is a wealth of literature on N2P both within the ES literature and in other areas of research, for example, the global agri-food system (Challies, 2008) and the global trade of fish from fisheries (Grilly *et al.*, 2015; Drakou, Virdin and Pendleton, 2018). However, P2N has been much less explored in the ES literature. The first step in filling this knowledge gap is to understand better how ES beneficiaries seek out and access ES—this is the aim of this chapter.

(a) Conceptual

(b) Provisioning

(c) Regulating

(d) Cultural

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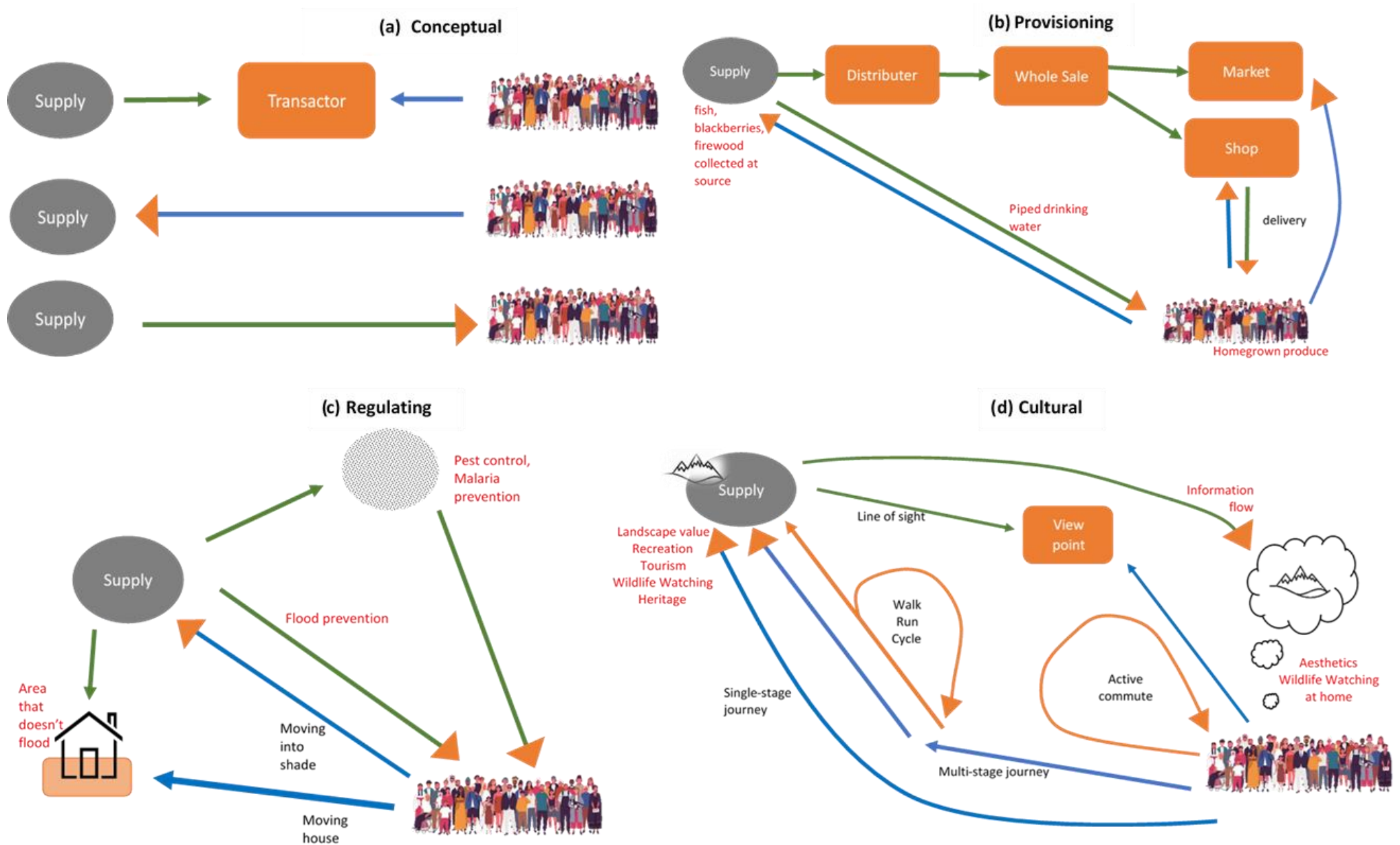
Figure 2.1. The flow of ecosystem services (ESs), conceptualised as two processes (a): nature to people (N2P; the movement of a natural good towards beneficiaries, shown in green) and people to nature (P2N; the movement of beneficiaries to a transactor in search of an ecosystem service, blue). Transactors, the point where the ES becomes realised, are shown in orange. Transactors are sometimes spatially distinct from the ecosystem and beneficiary (orange rectangles), but at other times the 'transaction' occurs in-situ (either at the ecosystem or beneficiary; orange arrowheads). Demand is shown via the group of people, with specific ES examples given in red. These processes occur across all ES categories: provisioning (b), regulating (c), and cultural (d). For example, drinking water flows down a mountain (N2P) and people go to the river to collect it (P2N). Sometimes P2N involves travelling all the way to the supply source, e.g., going to a forest to collect firewood, and sometimes N2P comes all the way to the demand, e.g., regulating services like pest control.

ES flows are known to vary across different socioeconomic groups, as people vary in their preferences, as well as in the options available to them. For example, (Cumming *et al.*, 2014) hypothesised that residents in rural areas may be more directly connected to local ecosystems, whereas those in urban areas rely more heavily on distant ecosystems. However, this hypothesis does not account for the varied experiences of individuals living within such systems. There are inevitable differences in P2N depending on people's wealth and residential location. For example, there can be a larger cost implication for urban people accessing natural spaces (Mayer and Woltering, 2018; Rodrigue, 2020), although wealthier individuals/families are more likely to have access to private or public green space (Wolch, Byrne and Newell, 2014). By contrast, many urban residents have easier access to shops than rural residents (P2N), where provisional ES can be obtained indirectly via value chains going from producers to shops (N2P) (Smith and Morton, 2009). Similarly, a number of studies have suggested gendered differences in the perception and use of urban green space, for example, in terms of the activities carried out (Sang *et al.*, 2016), reported benefits (Jefferson *et al.*, 2014) and fears about personal safety (Sreetheran and van den Bosch, 2014).

It is not the aim of this chapter to describe differences among individuals of differing socio-economic groups in terms of ES access in detail, as this has been explored elsewhere (for example, Yang *et al.* (2018) reviews ES's through a gendered lens). Instead, in this conceptual chapter, I disaggregate the flow of ES into N2P and P2N and seek to under-stand the processes by which beneficiaries seek out ES's—the movement of people to nature (P2N). I focus on large-scale, replicable theories, presenting possible approaches by which maps or models of potential ES supply can be supplemented to capture realised ES (i.e., including demand and access). I bring together insights from disciplines that might help understand how people move towards ES, by exploring the potential application of models from human migration, optimal foraging and landscape connectivity. I then

present an introduction to some of the data currently available to researchers that could represent ES flows.

Table 2.1. Mechanisms to describe ES flow, broken down into 'nature to people' (the movement of a natural good to a transactor, where it is used by beneficiaries) and 'people to nature' (the movement of beneficiaries to a transactor in search of an ecosystem service). Mechanisms are based on the work of Fisher, Turner and Morling (2009) with more recent ES examples.

Flow	Mechanism	Example of Ecosystem Service	Reference
Nature to people (N2P)	In situ Services are provided and accessed in the same area	Aesthetics—beautiful surroundings, with light flowing via the line of sight (cultural) Existence value, accessed through media (cultural)	(Booth *et al.*, 2017) (Davidson, 2013)
	Gravitational From uplands to lowlands	Flood regulation provided by forested slopes (regulating)	(Stürck, Poortinga and Verburg, 2014)
	Directional Benefits flow in one direction	Pollination—Pollinators go from habitat to crops (regulating)	(Schulp, Lautenbach and Verburg, 2014)
	Omni-directional Benefits flow in all directions	Carbon storage—global benefit (regulating)	(Locatelli *et al.*, 2014)
People to nature (P2N)	In Situ Services accessed from base, no movement needed	Gardens providing aesthetics, wildlife, sense of place (cultural)	(Cilliers *et al.*, 2018)
	Single-stage journey	To go to a park for recreation (cultural) Journey itself may be the service—recreation (cultural)	(Mollie *et al.*, 2016)
	Multi-stage journey	To go to a National Park for recreation, wildlife watching. Journey may be by train, bus or taxi, then hiking (cultural) Journey itself or one stage may be the service—recreation (cultural)	(Mayer and Woltering, 2018)
	Active Commute	Connection with nature is not the primary aim of the journey	(Vedel, Jacobsen and Skov-Petersen, 2017)

As I show in Table 2.1 and Figure 2.1, both N2P and P2N can be applied for different types of ES. For a provisioning service such as a food crop, N2P might be the movement of the product through a value chain until it reaches a shop or market. An example of the P2N part of the flow would be an individual going to the point where they can purchase the item. For a regulating service such as flood prevention, N2P is not relevant as such, but people who live in the area that does not flood benefit from this service. Individuals may move specifically to this area to benefit from the low flood risk—

an example of P2N. For a cultural service, N2P may occur through line of sight, for example, through enjoying views of mountains from one's home. Alternatively, people may travel specifically to spend time in the mountains, which would be classified as P2N.

2.5. Applying Existing Theories of Movement to 'People to Nature'

2.5.1. Migration Theory Applied to 'People to Nature'

P2N could be explored using migration models (Table 2.2). Noting that migration has a range of definitions across different disciplines, migration can be defined as "the movement of a person or a group of persons, either across an international border…, or within a state…, encompassing any kind of movement of people, whatever its length, composition and causes" (IOM, 2011). Thus, migration can be used to describe movement, from short journeys to complete relocation of someone's life, e.g., (Stockdale, 2014). In terms of ES, this could be applied to people making trips to access services such as recreation in their local area (i.e., where their place of residence does not change but they are still moving across the landscape) (Kienast *et al.*, 2012). It could also be applied to people making longer trips to access ES, for example several nights away camping (Brabyn and Sutton, 2013). It could also be applied to people moving house and basing their choice of location on the ES they can access there (Stockdale, 2014).

The push-pull-mooring (PPM) model of migration states that decisions to migrate are affected by three different groups of factors (Lee, 1966). As discussed above, migration sometimes means to relocate one's place of residence. In this case, push factors 'push' people away from one area, for example, a lack of jobs, violence, pollution and poor housing. Pull factors 'pull' people towards a different area, such as more job opportunities, better housing and better education opportunities. Mooring factors are influences that hinder the decision to migrate or the process of migrating, for example, financial cost, distance and family considerations. The push-pull-mooring model can also be applied to short-term migration (e.g., for accessing recreation opportunities). For example, a pull factor stated by visitors to parks and protected areas in Portugal was that the parks provided a space to do sports and outdoor activities (Marques *et al.*, 2017). Children can be a mooring factor when deciding where to go (Curtale, 2018).

As well as migration itself, the PPM is used to understand consumer choices and 'switching behaviour' between one service provider and another, such as social media platforms (Chang, Liu and Chen, 2014) and airline companies (Jung, Han and Oh, 2017). In these cases, push factors include high price, inconvenience, poor-quality service and a lack of trust in the company. A more attractive alternative that offers solutions to these problems pulls people away from their original service provider. Mooring factors include the financial cost and effort of switching and social factors (Jung, Han and Oh, 2017). As this theory is useful in understanding how people choose between

one economic/IT ser-vice and another, the same theory might shed light on how people choose between two different ways/locations for accessing ESs.

The inverse distance model (Rodrigue, 2020) is based on the idea that distance represents some kind of friction or cost, so that people will access opportunities closer to their starting point. The further they go, the greater the cost in terms of time and money. An in-crease in travel cost has been shown to have a negative effect on people's willingness to make a journey (Curtale, 2018; Whitehead and Wicker, 2018). Increases in the cost to ac-cess a location both in terms of time and money might be linear or the increases might be proportional jumps, such as having to switch transport modes or stay overnight because the intended location is so far away (Mayer and Woltering, 2018). These proportional jumps might represent 'cut-off points' where people are no longer able to access a service or area because it is too expensive for them.

The inverse distance model is used in health care to explore how many people can access services (Brabyn and Sutton, 2013). In health care, access can be considered based on how many people can access services within a specified distance or time limit from where they live, and on the ratio of services to the population (Gilliland Id *et al.*, 2019). This approach considers the concept of 'geographical access', i.e., literally how far away a re-source is, and the effective or perceived access, which consider other factors such as financial, social and cultural factors (Brabyn and Sutton, 2013). These concepts could be ap-plied to accessing ESs too. A recreation opportunity could be close by but may be expensive to access, thus rendering it effectively inaccessible for some groups. People may make longer journeys for longer lasting and more rewarding activities. The longer stay or better experience balances the additional cost of travelling further. For example, overnight visitors to National Parks in Germany travelled 3.5 times the distance of non-local day visitors (Mayer and Woltering, 2018). The parks that received the most overnight visitors were those in harder-to-access locations in the mountains (Mayer and Woltering, 2018). As a further example, households in Malawi were found to have a greater reliance on forest products to supplement their income the closer they lived to a forest. The further away from the forest they lived, the less rewarding the products were for the cost to obtain them (Fisher and Shively, 2005).

The gravity model is one of the longest standing in migration literature and comprises the idea that areas of higher 'mass' attract more people (Rodrigue, 2020). This higher mass can be considered in terms of attractiveness or some other factor that pulls people in. Distance is also a factor; if two areas have equal 'mass', the one that is further away will be less attractive, an effect known as distance decay. When considering ESs, areas of greater ES potential (such as National Parks) might attract more visitors (Mayer and Woltering, 2018). These areas attract high numbers of visitors because they are widely acknowledged to provide varied recreational, cultural and heritage opportunities (Plieninger *et al.*, 2013). Similarly, famous tourist attractions draw in more visitors (Bassolas *et al.*, 2016). The significance of areas (the mass) may be further increased through social media, with

people choosing locations based on what they have seen online and what they can then share themselves (Brito and Freitas, 2019). Alternatively, an area that is very rich in a desired resource such as firewood or a food item will attract more people (Willcock *et al.*, 2014).

The gravity model might be criticised in terms of the validity of using population size as a factor attracting people to the area. It also does not factor in transport networks or costs and does not consider the difference between individuals migrating, treating them as a homogenous group.

Stouffer's law of intervening opportunities considers the opportunities available at a destination (Stouffer, 1940). Migration is proportional to the opportunities at the destination and inversely proportional to those that lie between the starting point and the destination. When considering ESs, areas that provide multiple services are likely to attract lots of visitors. For example, National Parks facilitate different recreational pursuits, and they provide a place to see wildlife, to learn about culture and history, as well as an aesthetically pleasing place in which to be. However, if there was a site nearer to an individual's starting point that provided some of these opportunities, they might be more inclined to go there, as there is likely less of a cost to access it even if the site is of lower quality. Similarly, when foraging for wild food products, there might be a very rich site further from an individuals' starting point, but they may choose a poorer site closer to home.

The radiation model (Simini *et al.*, 2012) builds on the law of intervening opportunities and hypothesises that when making a decision about where to go, people go through two steps. First, they assign all opportunities that they know of a 'fitness score' based on how closely they match the experience that they want. Second, they rank the opportunities based on how far they are from their starting point. They choose the closest one that matches the experience they want. For example, people search for jobs in their field and rank them based on how closely the job matches what they want to do and how good the pay is. Then, they rank the jobs based on how far away they are from their home. They choose the closest job that best matches their requirements. The fewer opportunities there are, the further they will have to travel. Marques, Reis and Menezes (2010) explored visitors' motivations for visiting protected areas in Portugal. They identified multiple subgroups of visitors. One group's priority was to attend local sports or cultural events. Another group's priority was to see the landscape and the wildlife. The sports group travelled a shorter distance than the cultural group to access protected areas. The cultural group had to go, and were happy to go, further to see a variety of species and habitats. Thus, the visitors had ranked all possible protected areas they could access based on whether it would meet the experience they wanted, then on how far away these areas were, and then decided how far they were willing to go to gain the experience. As such, the movement of these visitors may be well described by the radiation model.

Table 2.2. Summary of migration theories and potential applications to 'people to nature' (the movement of beneficiaries to a transactor in search of an ecosystem service).

Theory	Description	Application to 'People to Nature'
Push-pull-mooring (PPM) (Lee, 1966)	• Push—negative factors that push an individual towards leaving an area • Pull—positive factors that attract people to somewhere new • Mooring—factors that may hinder or facilitate the move	• Push factors—the local area is urban (too grey and manmade) • Pull factors—fresh air, nature, birdsong • Mooring factors—too far away, too expensive, family considerations
Inverse distance law (Rodrigue, 2020)	• Most migration is over short distances • Increased distance represents greater cost. • Cost may be linear or it may be proportional and involve '*step-ups*' in cost.	• People will access services close to where they live if available. • A linear increase in friction of distance would mean accessing a service further away. • Proportional jumps might include having to stay overnight to access an area.
Gravity model (Rodrigue, 2020)	• There is greater movement between areas of greater '*mass*' i.e., attractiveness. • Distance decay means that for two sites of the same mass, there will be less movement to the further one.	• 'Mass' here corresponds to greater ES potential, attractiveness and significance. • Significance can be increased, perpetuated by social media.
Law of intervening opportunities (Stouffer, 1940)	• People will migrate to where opportunities are greatest. • The amount of migration is proportional to the opportunities at the destination and inversely proportional to opportunities between the starting point and the end destination.	• An area that offers lots of opportunities to access ES would be the most desirable. • If there are areas closer that provide some of these opportunities, people may choose to go there as the cost is lower.
Radiation Model (Simini *et al.*, 2012)	• To decide where to migrate to, people score all possible opportunities based on how closely they match their desired experience • Then, they rank them based on how far they are, and the cost to access them.	• People score all accessible locations based on how closely they provide the ES they want to access e.g., a walk in nature • Then, they rank them based on how far they are, and the cost to access them.

2.3.2. Animal Foraging Theory Applied to 'People to Nature'

Behavioural ecology models may be useful in considering ES flows, particularly through models relating to foraging (the search for wild food resources (Danchin, Giraldeau and Cézilly, 2008), Table 2.3). Behavioural ecology considers the evolutionary basis for behaviour, i.e., how a behaviour contributes to overall fitness (Danchin, Giraldeau and Cézilly, 2008). The process affects fitness because the search for resources expends energy, and accrues other costs such as risk to life, so it is a trade-off between resources gained and the cost to access them. Foraging has been explored using economic models, specifically the 'optimal model', which represents an animal foraging to

obtain the maximum reward for minimal effort (Hughes, 1989). P2N can be considered as humans 'foraging' for nature as people search the environment for resources and opportunities.

Foraging models often assume that knowledge of opportunities is based on what is learnt from the environment and from previous experience. In addition, animals may also use social information when foraging (e.g., in birds (Aplin *et al.*, 2015) and bats (Page and Bernal, 2020)). When considering how people access ES, it needs to be considered that they will use also social information learnt directly from their network and also from social media (Glover, 2009). People have the ability to research and learn about areas before they go there.

The marginal value theorem assumes that animals will use the most energy efficient method to forage (Charnov, 1976). It assumes that animals exist in an environment with patches of resources separated by areas with no resources, so they must expend energy moving from one to the other. They have to balance how long they spend at a patch with travelling between patches and how much they will gain from each patch. Resources will diminish the longer they stay at a patch. Cowie (1977) investigated whether the behaviour of foraging great tits (*Parus major*) can be predicted by the marginal value theorem (Cowie, 1977). In his experiment, great tits were allowed to forage in areas that differed in terms of the distance between resource patches and patch richness. In keeping with marginal value theorem, the birds spent longer at each patch when the patches were further apart and when they had greater resources. Birds left patches when resource levels fell below the average for the whole area, which is a more efficient way to forage, with a higher reward compared to foraging randomly (Naef-Daenzer, 2000).

There are examples of humans following the marginal value theorem. Wolfe (2013) carried out a virtual raspberry picking experiment and found that people's behaviour was in keeping with marginal value theorem. They would move on from one bush to the next when the number of berries fell below the average for the whole area, and they would stay longer when it took longer to travel from one bush to the next. Their behaviour departed from the marginal value theorem if patches varied in quality, in which case people would stay at the same bush when it would have been more beneficial to move on. When considering ES's, the resource may not necessarily run out but service quality may become degraded after repeated access; for example, the habitat may become degraded, which reduces the quality of the experience (Davenport and Davenport, 2006).

The marginal value theorem assumes 'perfect knowledge' of the environment; it does not consider individuals exploring an unfamiliar area, where they might not know how rich the resources are so will spend more time familiarising themselves (Nonacs, 2001). It also does not consider other factors affecting an individual, such as their physiological state or other individuals around them, such as their offspring, potential mates or predators that might affect their behaviour or compete with them

(Nonacs, 2001). Therefore, the marginal value theorem can be helpful in exploring how people access ESs, especially in a familiar environment, but it does not consider the whole picture.

Central place foraging theory comprises the idea that an individual will forage at a particular patch and then must return to a central place. The further they have to go from their central point, the more costly the journey, so the value of the resource they are seeking has to increase to match this. For example, beavers bring back larger saplings when they travel further from the lodge (Fryxell and Doucet, 2008). Adapting this theory for P2N, the central place might be considered as a person's residence or home area, depending on the scale of the study (Riechers *et al.*, 2019). The theory predicts that the further away an individual travels from their central point, the longer they will stay there. Central place foraging has been observed in the case of artisanal fishers setting up 'moored fish aggregating devices' in Dominica (Alvard, Carlson and Mcgaffey, 2015). As a cultural ES example, visitors to the Atlantic Coast in the United States were found to stay longer the further away they had come from (Nicolau, Zach and Tussyadiah, 2018). However, costs, the characteristics of the people travelling, transport options and time constraints are also likely to factor into these decisions (Gössling, Scott and Hall, 2018).

The ideal free distribution (IFD) also considers the way animals distribute themselves among patches of resources. The IFD considers the effect of other individuals, assuming that animals are free to move between different patches and that each patch has a value depending on how resource-rich it is and how many other individuals are also on this patch. Individuals are aware of the value of all available patches and are competitively equal, and increasing the number of individuals reduces the value of the patch (Fretwell and Lucas, 1970). Distribution should be proportional to the resources available, so if the availability of resources changes, for example, due to more individuals arriving and increasing competition, the distribution of individuals should change to rebalance the distribution. For example, free-ranging cattle in Norway were observed to graze in areas providing lower-quality grazing when the density of cattle was higher. Individuals moved away from the areas with more palatable grazing as competition increased (Tofastrud, Devineau and Zimmermann, 2019). People have also been observed to follow the IFD. Moritz *et al.* (2015) observed mobile pastoralists to follow IFD in common-pool grazing areas in Cameroon. Disma, Sokolowski and Tonneau (2011) observed children selling bottles of water to drivers at a crossroads in Istanbul, Turkey. In keeping with IFD, as the number of vehicles in each lane (the number of foraging opportunities) changed, the children redistributed themselves (Disma, Sokolowski and Tonneau, 2011).

The IFD would predict high levels of ES use in areas that provide high levels of ESs. For example, protected areas attract a lot of people seeking cultural services compared to areas that are less rich in wildlife and opportunities (Plieninger *et al.*, 2013). Similarly, Willcock *et al.* (2014) found that people in Tanzania are more likely to live in areas of high biodiversity resources that allow them to access

more ES's (Willcock *et al.*, 2014). IFD would also predict that the higher the use of ES hotspots, the more people will spread out to areas that provide fewer opportunities. Even though there are fewer opportunities to access ESs there, there may be a greater chance to do so because there are less people competing for them. For example, bird watchers can put off spending time at very popular sites because due to the amount of people there, they may actually be less likely to see species of interest (Kolstoe and Cameron, 2017). Like the marginal value theorem, the IFD does not consider individuals who are unfamiliar with an area, nor does it consider other social or internal factors that might influence their decisions (Nonacs, 2001).

The movement ecology paradigm (Nathan *et al.*, 2008) considers a wide range of factors: the internal state of the individual (why they move), how they move from one site to another, their ability to navigate and external factors that might affect them. For example, a vulture is foraging because it needs food (internal state) but it also has to conserve energy levels; therefore, as the time since it has last eaten increases, it changes its foraging strategy to save energy by using uplifts as much as possible and avoiding flapping and take-offs/landing, which require more energy (Alarcón and Lambertucci, 2018).

In applying the movement ecology paradigm to P2N, consider someone going for a run in their local woodland. The individual's internal state or drivers could be desire for exercise, to keep fit, for social interaction or to be outside in a natural space. They have to consider how they are going to get there: Do they run straight from home? Do they walk or drive to their starting point? What is their personal level of health, fitness and mobility? They need to be confident of their ability to navigate to the woodland and within it. External factors may include external pressure to exercise, the atmosphere at the woodland (maybe there are unpleasant areas covered in litter or linked with anti-social behaviour) and other individuals who may enhance or bring down the experience.

Table 2.3. Summary of foraging theories and potential applications to 'people to nature' (the movement of beneficiaries to a transactor in search of an ecosystem service).

Theory	Details	Application to 'People to Nature'
Marginal Value Theorem (Nonacs, 2001)	• Individuals use the most energy-efficient method to move around their environment • Assumes resources are patchy • Assumes perfect knowledge	• People have to access ESs, but will not necessarily use the most efficient route, especially if they do not know the area • ES provision is patchy within the landscape
Ideal Free Distribution (Fretwell and Lucas, 1970)	• Individuals will distribute themselves proportionately based on the resources available. • Assumes perfect knowledge of patch quality	• IFD might allow people to have the optimal experience • Realistically, distribution will likely be clumped around areas of easy access and high significance, especially if people are unfamiliar with the area.
Central Place Foraging (Fryxell and Doucet, 2008)	• Individuals forage and then return to a central place	• People accessing ESs from home and then returning home • Return journey has to be factored in
Movement Ecology Paradigm (Nathan *et al.*, 2008)	• Considers the internal state of the individual (why they move), how they move, their ability to navigate and external factors that might affect them.	• Internal state: why do they want to seek a particular ES? • How: walk, cycle, drive? Multi-stage or one-stage journey? Is anything limiting movement? • Ability: Knowledge of the area, confidence • External factors: external pressures, other individuals, surroundings

2.3.3. Landscape Connectivity Literature Applied to 'People to Nature'

The movement of people to access ESs can also be considered in terms of landscape connectivity, which is more traditionally applied within ecology in the area of wildlife conservation. Connectivity is described as "the degree to which the landscape facilitates or impedes movement between resources and habitats" (Taylor *et al.*, 1993). A lack of connectivity in a landscape is widely recognised as a driver of species decline as species are unable to move across the landscape and access resources that they need in order to survive, such as food, shelter and other individuals/populations (Newbold *et al.*, 2015). For wildlife, connectivity may be severed or reduced by infrastructure such as roads (Fensome and Mathews, 2016), agricultural land (Habel, Samways and Schmitt, 2019) and urban development (Elmqvist *et al.*, 2013).

While moving to access ESs, humans are also affected by landscape connectivity. Similarly, to animals, there might be areas that are unsafe to cross, such as large roads with no crossings if one is a pedestrian, for example. However, transport networks (aviation, rail, road, cycle networks, footpaths) could also increase connectivity for people. If transport networks are poor or non-existent, destinations may be relatively inaccessible (Lucas *et al.*, 2016). For example, physical access (e.g., access by car to a recreation area and then access within that area via tracks and paths) has been

demonstrated to be one of the key factors in identifying the areas chosen by people to undertake recreational activities (Westcott and Andrew, 2015; Olson *et al.*, 2017). Landscape connectivity is an important factor in transhumant pastoralism in South America, in which families and their livestock move seasonally between the lowlands and uplands in search of grazing lands (León, Bruzzone and Easdale, 2020).

Connectivity can be both structural and functional. Structural connectivity describes the physical aspects of the landscape and their configuration. Functional connectivity is the behavioural response of the organism to the landscape, the actual movement of individuals and their ability to access spaces, based on structural constraints and other factors (Tischendorf and Fahrig, 2000). In terms of accessing ESs, structural connectivity could refer to where the ES can be accessed (where the transactor is), how far away it is and the travel network options to get there. Functional connectivity could correspond to the ability of people to get there, for example, if a beach can only be accessed by car and someone does not have access to one, they cannot get there. Similarly, someone could live within walking distance of a country park but if it is a pay-for-entry site and they cannot afford the entrance fee, the space and the ESs they could access there are inaccessible to them.

Connectivity can be explored using resistance surface models (Zeller, McGarigal and Whiteley, 2012). 'Resistance' represents the reduction or facilitation of movement across a landscape (Puyravaud *et al.*, 2017). Different land cover or conditions represent different levels of resistance, such as land use, roads, slope and vegetation type (Cushman *et al.*, 2006; Spear *et al.*, 2010; Etherington, 2016). For example, (Puyravaud *et al.*, 2017) created resistant surface models to look at landscape connectivity for Asian elephants (*Elaphus maximus*) in India and to assess how accurate expert opinion was in predicting how easily the elephants could move through the landscape. They built resistance models based on land cover, slope, elevation, roads and buildings, and used these to predict least-cost pathways across the landscape (Puyravaud *et al.*, 2017). Least-cost pathway modelling identifies corridors across the landscape (Adriaensen *et al.*, 2003; Sawyer, Epps and Brashares, 2011). The 'cost' assigned to each cell represents how willing an animal is to cross the land cover type, the physiological cost of moving and the potential reduction in survival (Compton *et al.*, 2007).

Connectivity could be applied to human movement; in which case the costs would be the use of financial and time resources. One would also need to incorporate travel networks and consider the jumps represented if a change in transport is necessary (inter-modal transportation costs). Just as different species have varying abilities to travel across different landscapes, different social groups might be more or less able to make a journey. Poorer groups within a country tend to be less mobile (Titheridge *et al.*, 2014), with unaffordable transport excluding people from basic services like accessing shops, employment and healthcare (Litman, 2015). The services are there, but some are unable to access them—i.e., there is a lack of functional connectivity.

In relation to ES access, it needs to be considered not only that people might be going from one site to another to access an ES (P2N, Table 2.1, Figure 2.1), but also that the whole route might be the resource they are wanting to access (i.e., somewhere to go for a run/walk/bike ride). If their route is blocked, fragmented, non-existent (reduced structural connectivity) or they are not able to get there (lack of functional connectivity), they are unable to access that ES. Well-connected infrastructure has been found to be an important factor for recreational travel and active commuting. (Sun *et al.*, 2017) found that Strava users cycling for recreation were more likely to cycle on short streets with high connectivity to other streets and a low volume of traffic (Sun *et al.*, 2017). Similarly, connectivity was also found to be a factor for people cycling to work (Fan, Wen and Kowaleski-Jones, 2014).

A resource selection model is any model that gives values proportional to the probability of use of an area or resource (Boyce *et al.*, 2002). These functions compare use at 'known' sites (where use has been recorded) and 'available' sites (random points within the available area). For example, Squires *et al.* (2013) explored habitat selection in lynxes using radio-tracking data (Squires *et al.*, 2013). They investigated the environmental characteristics where the lynx had been recorded and extended this to identify other areas of with these desired characteristics, deeming them a high conservation priority.

Resource selection models have been applied to recreation, described as 'terrain selection models'. Olson *et al.* (2017) explored terrain selection by people pursuing motorised and non-motorised winter sports; skiing and snow-mobile use. They collected GPS data from recreationists and created a terrain selection model using remotely-sensed environmental correlates from the area where the GPS points had been recorded. They then used the model to create maps showing where the different activities may conflict with each other or may cause damage to ecologically sensitive areas (Olson *et al.*, 2017).

2.4. Mapping and Modelling 'People to Nature' Behaviours

The theories and models described above can be used to provide spatially explicit predictions of where people might travel for ESs and thus are an important step in moving from maps of potential ESs to realised ESs (Bagstad *et al.*, 2014). For example, for a given location, the inverse distance model might predict that inhabitants search for ESs in the nearest available greenspace, whereas the gravity model might suggest that they search for the greenspace with the largest 'mass' (in terms of size or popularity). The ideal free distribution approach would imply that beneficiaries should disperse across all available greenspaces based on the number of beneficiaries, and connectivity theory might suggest that the most easily accessed greenspace is the most used. By comparing these predictions to real-world observations, future work can determine which of these theories best describes P2N for different types of ES. Some of the models assume perfect knowledge of the environment, which is a strong assumption, as it neglects the fact that certain individuals/groups may

have different access to knowledge, as well as the different learning process through which new knowledge is gained, i.e., by sharing experience (Paget *et al.*, 2019) or through education.

Thus, to understand the movement of P2N, data on and from beneficiaries are required. Traditionally, these kinds of data are collected by social surveys. However, social surveys are often limited to smaller scales than those studied by natural scientists, with the exception of large data sets such as census data (e.g., Ernsten *et al.*, 2018). As a result, to understand the socio-ecological system of ESs at large scales, novel methods of data collection might be needed. Here I give an introduction to some of the data that currently may be used.

Demand for ESs and how different areas are used or valued can be measured using social media data (Minin, Tenkanen and Toivonen, 2015). Social media platforms produce huge amounts of data across time and space. The data are relatively easy to access and analyse, assuming that there is the knowledge and technology to do so (Hausmann *et al.*, 2018; Fox *et al.*, 2020). Although social media big data are hugely valuable, care should be taken to ensure that the data harvested are representative of the population (Tufekci, 2014). The use of Instagram has been found to decrease with age and income, whereas sites like Flickr are used more by professional photographers and wildlife enthusiasts (Hausmann *et al.*, 2018). Multiple platforms can and should be used to get a more complete picture of the use or value of an area.

Social media has already been used in ecosystem service research. For example, Martinez-Harms *et al.* (2018) used images from Flickr to explore who was accessing protected areas in Chile. Using the geotagged images and the home locations of visitors, they were able to establish how far people had travelled to access the protected area (Martinez-Harms *et al.*, 2018). Similarly, Martínez Pastur *et al.* (2016) used geotagged images to identify hot spots for four cultural ESs (aesthetics, existence value, recreation and local identity) in Patagonia (Martínez Pastur *et al.*, 2016). Hausmann et al. (Hausmann *et al.*, 2018) used Flickr, Instagram and surveys to explore preferences for nature experiences in Kruger National Park. They found that the preferences matched those revealed in face-to-face surveys on site, but social media offered a much larger sample size. Going a step further, InVEST ES mapping tools use social media data to estimate landscape value based on recreation and other cultural ESs.

Social media platforms that have been less exploited so far in terms of ESs are exercise platforms like Strava, wikiloc and MapMyRun, which allow users to record routes. These data are important as they show actual movement, rather than just capturing end destinations, as is the case with Flickr and other social media platforms. The use of these data could be further developed to try and understand why people choose certain routes or areas to cycle/run/walk in, as well as providing more information on how many people use an area and when they access it. The use of 'big data' such as these allows a much greater magnitude and resolution of data collection, compared to traditional

methods such as surveys. The two can be used together to create a more complete picture. Big data will show correlations between land cover and where people go, whereas surveys can provide data on the motivations for going there and the decision-making process.

Strava data have been used to explore people's preferences when cycling. Sun et al. found in 2017 that Strava users cycling for recreation were more likely to cycle on short streets with high connectivity to other streets and a low volume of traffic (Sun *et al.*, 2017). Griffin and Jiao (2015) found that when cycling for fitness, cyclists showed a preference for steep terrain, but when commuting, hills were avoided. Strava data have also been used to explore cyclists' exposure to air pollution (Sun, Moshfeghi and Liu, 2017) and to observe how cycling traffic changes in response to changes in road infrastructure (Boss *et al.*, 2018). It should be acknowledged that while Strava could be useful in exploring preferences while cycling, route choice may also be based on training or fitness outcomes, rather than a desire to access green spaces.

It is important to gain a better understanding of who uses a space to access ESs, as well as addressing the questions of how and why. However, it is also important to explore the question of who does not use the same ecosystem and the reasons behind that. For example, reasons for not using urban green space can include a perceived lack of safety, the reputation of an area, the fact that it is too crowded or perceived 'ownership' by another social group (Wolch, Byrne and Newell, 2014). For example, in England, infrequent users of urban green space were most likely to be female, older, in poor health, from a minority group and/or a poorer socio-economic background, from a deprived area with limited green space and further from the coast (Boyd *et al.*, 2018). These 'absence' data might improve the accuracy of ES models/maps similarly to way in which equivalent data are used within species distribution modelling (Liu, White and Newell, 2011). However, there are limitations to certain social media sources, which have been discussed above. Traditional, face-to-face surveys are normally done at the site of interest, and are thus not able to capture the characteristics of people who do not go there or their reasons for not going there.

2.5. Conclusions

There are extensive theories from numerous disciplines that can be adapted in order to better understand the movement of people to nature (P2N). These have the potential to increase the accuracy of ES models/maps (Willcock *et al.*, 2019), moving away from maps of ES potential by better incorporating beneficiaries. However, to date, the area of P2N is under-explored. Research is needed in order to clarify the decisions people make in searching out ESs, as well as the barriers they may face in accessing them. I suggest that by incorporating the movement of people, maps and models of ES may become more useful to decision-makers by predicting and disaggregating ES

flows (Figure 2.1) (Willcock *et al.*, 2016). This advancement in future ES maps/models is necessary to ensure the equitable and sustainable future use of our ecosystems.

Following this study, further research could include a systematic review of the data available to measure P2N obtained from social media and other sources, going beyond the limited introduction I have provided here. Future studies could include further theories from disciplines not reviewed here, using validation data to quantitatively evaluate which movement theories are most applicable to ES.

Chapter 3

3. Relationships between distances travelled to natural spaces, impacts on wellbeing and socio-demographic predictors

3.1. Abstract

Connecting with nature has widely acknowledged benefits for people's physical health and mental wellbeing. However, people's access to natural spaces in not equal, with variation across society. Here, I used questionnaires with more than 7000 respondents to explore the distance people in Wales travelled to access natural spaces and the importance of these spaces to their wellbeing, disaggregated by socio-demographic factors. I found that natural spaces closest to a person's home were the most important to their wellbeing. Importance decreased with increasing distance from home, and beyond 1 km natural spaces were unimportant for day-to-day wellbeing. People travelled further for one-off trips compared to spaces where they spent time several times a year and spent longer at spaces closer to their home. My findings emphasise the importance of natural spaces very close to people's homes and provide a tangible way to quantify nearby nature which could inform local and national government policy.

3.2. Introduction

The importance of connecting with nature can, in part, be revealed by the amount of time and money many people spend to access natural spaces (such as mountains, the coast, meadows, farmland, a green route, water bodies, nature reserves). For example, the outdoor recreation economy in the U.S. was worth US$788 billion in 2019 (NPT, 2020). Visitors to Natura 2000 sites across Europe create an estimated €50–85 billion of expenditure per year (Natura 2000, 2018). In the UK, spending time in natural spaces contributed an estimated £12 billion to the UK tourism and leisure industry in 2019 (Davies and Dutton, 2021); this included spending associated with walking, running and cycling activities (valued at £3.6 billion), with £1.7 billion linked to sightseeing and £1.6 billion with wildlife watching and visiting parks and gardens. In Wales, adults reported an average of eight visits to natural spaces every four weeks (Natural Resources Wales, 2018). Of these, 46% said that their most recent activity included an average spend of £20, indicating a large contribution of outdoor recreation to the Welsh economy (Natural Resources Wales, 2018).

However, economic proxies can only capture a small part of the importance of natural spaces for wellbeing (e.g. Sharifi *et al.*, 2021). Individuals who have greater connections to natural spaces report greater hedonic wellbeing (happiness, life satisfaction) as well as eudaimonic wellbeing (sense that life has meaning, personal development, independence and competence) (Capaldi *et al.*, 2015; Pritchard *et al.*, 2019). There is a correlation between reporting greater connection to natural spaces and reporting greater connection to friends, family and those around them (Zelenski and Nisbet, 2014). Natural spaces in urban areas in particular have been shown to benefit people's physical and mental health. For example, an Australian study found that, accounting for socio-demographic variables including measures of deprivation, the probability of hospitalisation through stroke or heart disease was 37% lower for those who lived in urban neighbourhoods with higher tree cover compared to those living in areas with very few trees (Pereira *et al.*, 2012). Spending time in urban natural spaces 4-5 times a week has been found to reduce levels of depression by up to 17% (Cox *et al.*, 2017). Natural spaces can reduce air pollution, a major health risk in cities, by up to 60% (Pugh *et al.*, 2012) and have also been shown to have a climatic cooling effect (Du *et al.*, 2017) – natural spaces only 0.1 km^2 in size can reduce the temperature up to 350 m from their boundaries.

For people to enjoy such wellbeing benefits, they need to be able to access natural spaces. 'Access', here refers to actually spending time in a space which depends on a combination of proximity, and other potential factors. Access can be considered in terms of locational/geographic access and effective access, a concept initially applied to healthcare (Joseph and Phillips, 1984) and applied to nature by Brabyn and Sutton (2013). Locational/geographic access considers physical proximity to a space and the connectivity to get there, and can be explored relatively easily using GIS (Brabyn and Sutton, 2013). Effective access considers financial, social, practical and physical factors that may affect someone accessing a space. A space may be effectively inaccessible for different reasons, for example if you are too busy with other commitments like work and family, you have poor health or you are unable to afford it (Boyd *et al.*, 2018).

However, different groups of people do not equally spend time in natural spaces. Low-income and minority groups have been found to be under-represented spending time in natural spaces in urban areas (Heynen, N., Perkins, H.A., Roy, 2006). This is partly due to proximity, areas in England with the highest deprivation scores also had the least natural space (Mullin *et al.*, 2018) i.e. the space isn't physically there to spend time in. However, there are other factors; Morris and O'Brien, (2011) evaluated a programme in England to increase involvement of under-represented groups in woodlands. Black, Asian and minority ethnic groups were under-represented in the study, as they made up a high proportion of the local population but a very low proportion of woodland visitors (Morris and O'Brien, 2011). Reasons for not spending time in the woodland varied across different groups but included a lack of confidence, lack of public transport, poor health and low income. Lack

of confidence was a key barrier for women spending time in the natural space; facilitated activities helped to overcome this.

Wealthier households are more likely to live close to natural spaces, providing easier access in terms of proximity. Those in unskilled, semi-skilled or casual work in Britain are three times more likely to be without a garden (Office for National Statistics, 2020). This results in substantial geographic divides: e.g. in central Cardiff 50-98% of households have no garden, compared to less than 7% across most of Anglesey (Office for National Statistics, 2020). For those with gardens or in rural areas, there are few to no travel costs associated with spending time in a natural space, providing greater opportunity to engage regularly in practices such as gardening, feeding the birds and wildlife watching for example (Fish *et al.*, 2016). In urban areas, neighbourhoods with more natural space (both public and private) are usually more expensive (Wolch, Byrne and Newell, 2014). This excludes those who cannot afford to live there, potentially putting them further away from natural space and the associated benefits. In poorer areas, urban natural space has been shown to be associated with anti-social behaviour or to be poorly maintained (e.g. a high level of litter or with poorly maintained facilities like paths and toilets), discouraging people from spending time there (Ward Thompson *et al.*, 2016). Thus, people living near these areas may need to make a specific trip to access a more pleasant natural space that is further away (Žlender and Ward Thompson, 2017), representing a greater cost in terms of time and money (Mayer and Woltering, 2018).

Age and gender identity can influence the distances people travel to access natural space. Studies looking at age or life-stage and relationships with nature tend to look at children (McEachan *et al.*, 2018) or older adults (Van Heezik *et al.*, 2020) with less focus on intermediate age groups. Proximity to natural space has been shown to be an important factor contributing to exercise levels in younger and older people but less so for those in the middle (Sang *et al.*, 2016). Retirees have been found to have more time and greater opportunity to spend time in natural spaces (Freeman *et al.*, 2019). They can also have more time and money to invest in practices that connect them to nature at home such as gardening and wildlife watching (Fish *et al.*, 2016). Gardens have been found to be very important in ensuring that elderly adults are able to continue accessing nature (Van Heezik *et al.*, 2020); meaning poorer, older adults without their own garden can lose out. In urban areas, some studies have found that fear for personal safety resulted in older adults spending less time in natural spaces (Sreetheran and van den Bosch, 2014). Roe, Aspinall and Thompson (2017) found that younger adults used natural spaces in urban areas as a place to unwind when they felt stressed, whereas middle-aged and older adults chose to stay at home. Women are more likely to be accompanied by children when spending time in natural spaces (Kavanagh *et al.*, 2006; Garrido-Cumbrera *et al.*, 2020). When the primary motivation is for children to spend time outside, it is reasonable to assume people will seek out natural spaces more suitable for children. Women are

potentially more likely to feel unsafe in urban natural spaces, which may influence where women choose to spend their time (Sreetheran and van den Bosch, 2014).

Wales is ideally placed to explore how access to nature varies across different groups and the importance of nature to wellbeing. There is a strong policy framework in Wales that emphasises the importance of healthy ecosystems and the benefits people derive from them. The Wellbeing of Future Generations Act (2015) encompasses seven wellbeing goals for Wales which include; a resilient Wales in which natural spaces support communities, a healthier Wales in which people's mental health is supported and active lifestyles are encouraged, and a more equal Wales in which people are able to access opportunities whatever their socio-economic background (Welsh Government, 2015).

Despite a growing literature on the importance of natural spaces for well-being, and on the socio-demographic variables which can influence access, there are few systematic studies exploring how distances travelled to access natural spaces varies by socio-demographic groups, and the importance of that use for wellbeing. To date assessments of ecosystem services, including cultural ES which I focus on here, have been based on land cover and the benefits people derive from different spaces assumed based on the type of land cover and proximity. This not account for variation across socio-demographic groups, it assumes that people access specific spaces available and does not consider any limitations on them.

Therefore here, I wanted to move away from assuming where people access nature and explore where they actually do access nature, within what radius from their home base. I use social surveys to explore the distance people in Wales, in the UK (Figure 3.1) travel to access natural spaces and the importance of these spaces to their wellbeing, disaggregated by socio-demographic variables (Appendix 1.1). A measure of distance could provide tangible actions for future policy. I use an ecosystem services (ES) approach, focussing on cultural ES (the non-material benefits that people derive from ecosystems (Sarukhán and Whyte, 2005), which often require access in order to be obtained (i.e. the beneficiary typically travels to the ecosystem, rather than relying on the flow of goods to them (Dolan *et al.*, 2021)). This is discussed in the introductory chapter. I hypothesised that those in urban areas and wealthier people will travel greater distances to access nature (Hutchings *et al.*, 2022) and that individuals who frequently spend time in natural spaces close to their homes will report that these spaces are important to their day-to-day wellbeing.

3.3. Methods
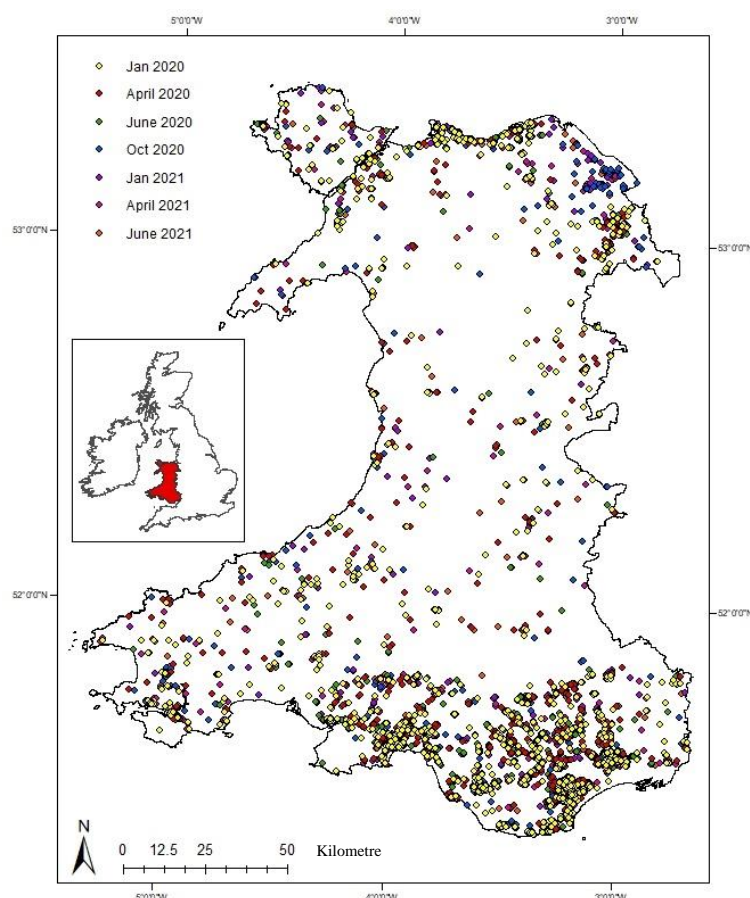
Figure 3.1. Map showing the sample points (home locations) for all seven surveys exploring the distance people travelled to natural spaces and wellbeing outcomes from January 2020 to June 2021 across Wales (see Figure 3.2). Inset map shows Wales highlighted in red within the UK and Ireland.

I designed an online survey to collect data on how far people travel to access cultural ES, how they access these services (transport taken) and the importance of cultural ES to their well-being (Appendix 1.1). My definition of wellbeing ('Wellbeing can be considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, how happy you feel and how anxious you feel') was that used by the UK's Office of National Statistics (ONS, 2022). I also collected demographic data on gender identity, age, income, education and ethnic background. Categories for demographic variables (Appendix 1.1) were based on those used for the UK Census (2011) and National Survey for Wales (National Survey for Wales, 2019). Within the survey, I asked respondents to select on a map a natural space where they had spent time most recently. Respondent were able to zoom in to maximum of 1:500 (Open Street Map). If they had done a route e.g., a bike ride, they were asked to select the point that most represented the experience for them. Natural spaces were defined as "including but not limited to: gardens (including your own garden), mountains, the coast, meadows, farmland, a commute along a green route, water bodies, nature reserves", see Appendix 1.1. I intended 'nature' or 'natural spaces' to mean habitats, vegetation

species and water bodies, rather than built areas, whilst acknowledging that these spaces may be heavily managed by humans and some people may not consider them to be 'natural'. They could select up to three spaces, starting with the most recent first, then the second most recent and third most recent, and answer follow up questions on all three. Respondents then specified if this was a one-off trip or somewhere they spent time regularly. If the latter they were asked about the time they spent there both in the summer and winter. I asked about their primary motivation for spending time at the space, with the options aligning with the cultural ecosystem benefits described by King *et al.* (2017) (Appendix 1 Table A1.2.1.). I also asked about barriers that people felt prevented them spending time in natural spaces, how often they spent time in nature and what activities they did in natural spaces. See S1-1 for an example of the full survey questions. Ethical approval was obtained via Bangor University (Ethics approval numbers: COESE2020RD01, COESE2020RD01cov19, Appendix 1.3.). The survey was initially developed for an in-person study which was carried out in person with 510 respondents in mid-Wales in 2019. This acted as an extensive development and pilot phase for the online survey (Appendix 1.4.).

The survey was distributed to residents within Wales aged 18 or over in seven survey rounds over 2020 and 2021 (Table 3.1). This period spanned the Covid-19 pandemic and so, in the surveys that ran over the pandemic, participants were asked if they had spent time in the natural space before, during or since any restrictions associated with the pandemic – this is not the focus of this study (the impacts of restrictions associated with the pandemic are investigated in Chapter 4), but allows us to statistically control for any impacts (see Data Analysis). The surveys were distributed using Pick My Postcode – a free, postcode lottery website through which people can complete surveys (https://pickmypostcode.com/survey-draw/). Pick my Postcode was used as a platform for longitudinal data collection throughout the pandemic (Covid-19 Social Study) and is also used by businesses to survey their customers (e.g. HelloFresh). With every survey completed members build a cash bonus, which they have a chance to collect (alongside other prizes) if their postcode is selected as a winning postcode. Members of Pick My Postcode logging in to check the winning postcode on the 'survey' competition were given the chance to complete my survey before the winning postcode was revealed – with £3 being added to their bonus as incentive to complete it. If the respondent's postcode was not selected as the winning postcode that day, the bonus they gained from completing my survey is added on to any prize they may win via the website in the future. Pick my Postcode membership is broadly representative of the UK population as a whole, although slightly skewed towards female members, aged 35-54, in work ranging from supervisory, junior managerial, professional, skilled, semi-skilled and unskilled manual occupations (Pick my Postcode, 2019). Working with Pick My Postcode allowed us to access a large number of respondents across the whole of Wales, quickly and economically – collecting ~1000 respondents in about 7 days each survey round. In total, I surveyed 7581 respondents (i.e., before data cleaning). As a result of using this method, each of the seven surveys was completed by self-selecting sets of respondents. It is

possible that respondents filled in surveys for more than one time period but there was no way to know this. Their representativeness of the Welsh adult population is examined in the Results section.

Table 3.1. Survey dates, number of responses and links to my surveys exploring distance travelled to natural spaces in Wales.

Survey	Dates Live	Responses*	Link
January 2020	16th – 23rd	1002	January 2020 survey
April 2020	22nd – 29th	1178	April 2020 survey
June 2020	2nd – 9th	1066	June 2020 survey
October 2020	30th – 17th November	1101	October 2020 survey
January 2021	14th – 1st Feb	1184	January 2021 survey
April 2021	14th – 29th	1019	April 2021 survey
June 2021	2nd – 23rd	1031	June 2021 survey

*Total responses before data cleaning
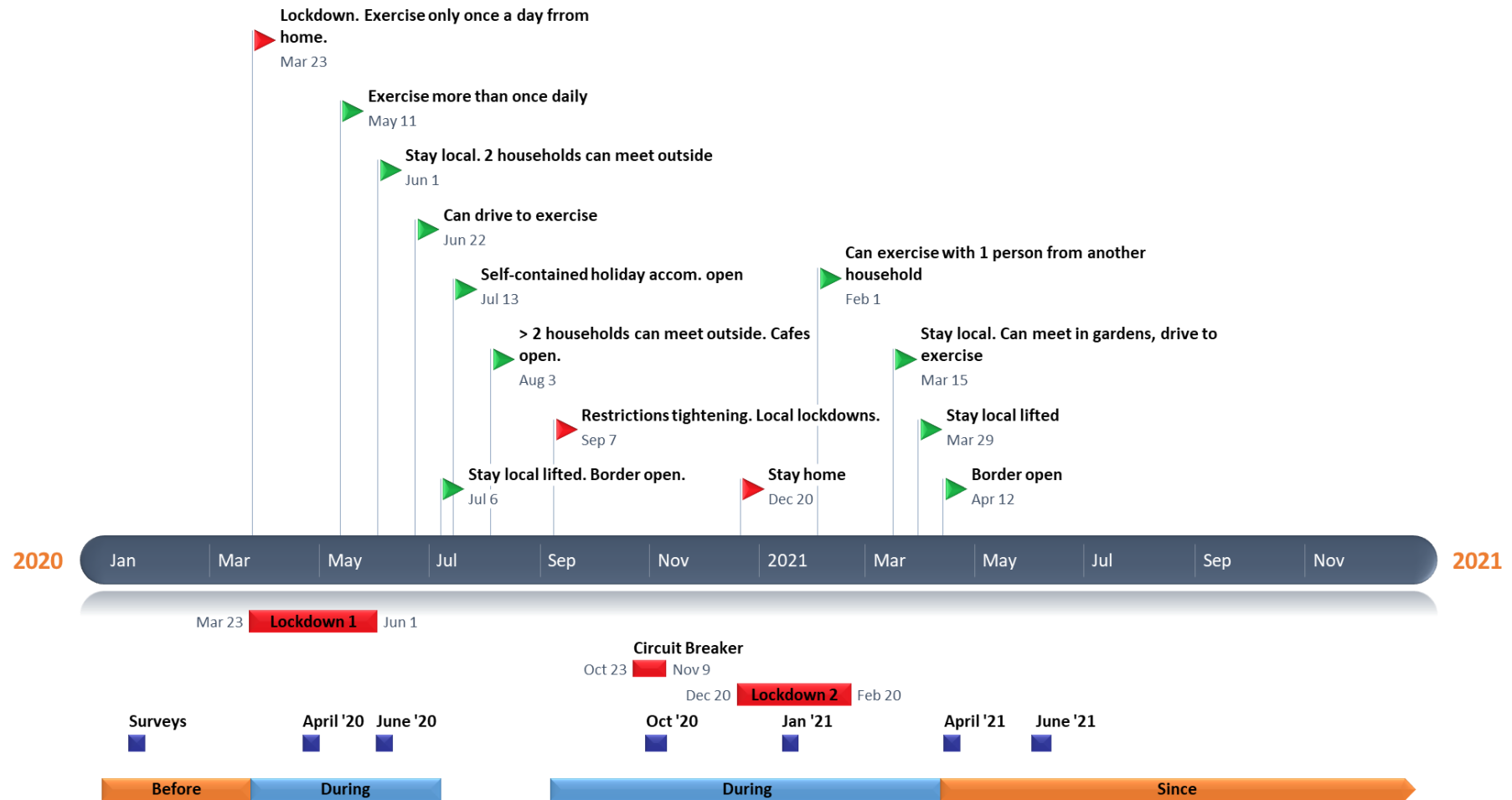
Figure 3.2. Timeline showing lockdowns and Covid-19 restrictions in Wales over 2020 and 2021. My surveys exploring the distance people travelled to access natural spaces are shown below the lockdowns, with colours corresponding to the same survey points in Figure 3.1. 'Before', 'During' and 'Since' refers to periods before, during or since any restrictions associated with the pandemic.

3.3.1. Data Processing

The dataset was arranged so that each row held the data for only one natural space that a respondent had chosen. The vast majority of the respondents (90%) provided data on only one space so, to simplify the analysis and avoid any risk of pseudoreplication, I created a subset of just the first spaces selected by each respondent. Participants had been asked to provide their home postcode (zipcode). These were batch converted to latitude and longitude grid references using UK Grid Reference Finder (Grid Reference Finder, 2023) and included in the matrix. For postcodes that did not convert to latitude and longitude in this way, the full postcode was entered into Google Maps and then one letter at a time was removed until an area was identified and the coordinates of the centre of this area were used – this step was required for less than 1% of the dataset. These grid references were used as the participants' start points. Straight-line distances were calculated from each respondents' start point (i.e. their home) to the natural space they chose, using the distgeo function in the geosphere package (Karney, 2013) in R (v4.1.2; R Core Team 2021).

To establish if it was appropriate to use straight-line distances for my analysis, I carried out a sensitivity analysis to compare these calculated distances against distance by road. I randomly selected 1000 datapoints from the final dataset (using the sample function in R (v4.1.2; R Core Team 2021)). I excluded any space selected to which the respondent would have flown or travelled by boat because these included multiple stages some of which respondents were not travelling by road. I worked out the distance by road from the start point to the end point on Google maps. I ran a linear regression model to establish to what extent straight-line distance predicted road distance. The model fitted was; road distance in km ~ straight-line distance in km. The overall regression was statistically significant, R^2= 0.75, p <0.001, intercept = 3.66, gradient = 1.08. The intercept was not statistically significantly different from 0 (p>0.05) and the gradient is very close to 1. Therefore, road distance was significantly predicted by straight-line distance. It must be acknowledged that Google maps is not a perfect method for calculating road distance travelled; it may have suggested routes that were not feasible and I have no way of knowing the exact route that each participant took to the natural space they selected. I also had to exclude from the random sample any space selected to which the respondent would have flown or travelled by boat, as a road distance to these spaces could not be calculated on Google maps.

Next, the land cover at each start point grid reference was obtained using the CEH Land Cover Map 2015 (Rowland *et al.*, 2017) in ArcGIS. This is vector data based on data from Landsat-8 (30 m resolution) and AWIFS data (60 m resolution). The polygons represent real-world boundaries. Each start point was attributed the land cover of the polygon it fell inside. These were then grouped into "Rural", "Suburban" and "Urban" as shown in Appendix 1.2. Table A1.2.2. In the CEH Land Cover Map, 'urban' was defined as dense town and city centre areas where there is little vegetation, also including docks, industrial areas and car parks. 'Suburban' included areas with a mix of urban and

vegetation. These two classifications had previously been grouped together as 'built up areas and gardens'.

Respondents provided answers to the questions *"How often do you spend time in this space?"* and *"How long did you spend at this space?"*. Variables with numerical values rather than categories for these answers were created by converting the variable categories into numbers; how long in hours and how often per month (Appendix 1.2. Tables A1.2.3. & A1.2.4.). For example, if someone selected that they had spent 'Less than 30 minutes' at a space '1-2 times a week' this was recast numerically as 0.25 hours, 6 times a month. For this chapter, I focus on the data covering the most recent visit to a natural space from when the respondent filled in the survey), minimising any recall bias. So, if, for example, a respondent had filled in the survey in January 2020 (winter) and said that they spent time at the space multiple times throughout the year, spending 2 hours at the space in the winter and 6 hours in the summer, the data for 'time spent at site' would be '2 hours' (as the survey was conducted in winter).

I checked whether my categorical explanatory variables were correlated using the polychoric function (Olsson, 1979; Drasgow, 1986) in R (v4.1.2; R Core Team 2021) (not including the Age variable, which was converted to a continuous variable). None of the variables showed greater correlation than 0.7 (Appendix 1.2 Table A1.2.5), and so I concluded that collinearity issues in the analyses were unlikely. Ordinal variables were created for all variables that could be ordered, including: household income, highest level of education, how often a space was visited, how long people spent time in a space, and importance to wellbeing. Finally, I removed any data points with incomplete observations using na.omit. This resulted in a final total of 6489 observations, where an observation is a single person visiting a single natural space. All data cleaning and organisation was carried out in Microsoft Excel, R (v4.1.2; R Core Team 2021) and ArcGIS (version 10.7.1).

3.3.2. Data Analysis

I conducted a descriptive analysis by aggregating distance travelled to natural spaces by the different socio-demographic factors, the motivation for spending time in the space and importance to wellbeing (Appendix 1.2. Table A1.2.6). A similar descriptive analysis was performed for wellbeing. I then ran a general linear model to investigate the impact of socioeconomic variables on the distance people travel to access nature (Equation 1). In order to conform with the assumptions of a general linear model, the distance data were logged. Furthermore, the 'primary reason' variable was releveled so that the reason 'for mental and physical health' became the default to which the other variables were compared as the majority of respondents (53%) chose this reason. Recognising the Covid-19 restrictions (Figure 3.2) may impact, but are not the focus of, this analysis (see Chapter 4), it was necessary to factor them in to the analysis via statistical blocking. To this end, I included variables for the month the survey took place and whether the survey took place before, during or

since Covid-19 restrictions on accessing natural spaces. Forward and backwards stepwise regression was used to determine the best-fit model.

Log$_{10}$ Distance from start point to natural space = PR + TimeSpent + HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + Month + BDS + VisitFrequency

(Equation 1)

In which, PR is the categorical Primary Reason for spending time in that space, TimeSpent is a continuous variable representing how long the respondent spent at the space in hours, HHIncome is the ordinal household income category (either Less than £15,838, £15,838 - £44,125, More than £44,125), Gender is the gender identity of the respondent identified as (categorised into female, male, prefer not to say, prefer to use own words), Education is the highest level of education of the respondent (ordinal from secondary school, GCSE, apprenticeship, A level, Higher Education), EthnicGroup is the ethnicity of the respondent (categorised as either White or Black, Asian and minority ethnic [BAME] due to high prevalence of white respondents in the area), LandCover is the land cover at start point (categorised into Rural, Suburban, Urban), Wellbeing is the importance of the space to day-to-day wellbeing (ordinal from 1 unimportant to 5, very important), Month is the month the survey was carried out (categorical: January, April, June, October), BDS is a categorical variable representing whether the survey was carried out before, during or since restrictions to accessing nature in response to Covid-19 (Figure 3.2), and VisitFrequency is a categorical variable whether the respondent spent time at the space as a one-off trip or multiple times throughout the year.

3.4. Results

The final dataset used to run my models contained 6489 observations (each from an individual respondent). Across this total, more women (58±1.2%; ± 95% Confidence Interval, dCode, 2023) than men (41±1.2 %) responded to my survey, and the vast majority of my respondents identified as white (98±0.3 %). These patterns largely reflect the wider Welsh population: 49% male and 51% female (Welsh Government, 2021b); and 95% white (Welsh Government, 2022b). The majority of respondents lived in suburban areas (69±1.1 %). In the 2011 national census, 63% of people lived in wider urban areas in Wales, based on built up areas of more than 20 ha (Office for National Statistics, 2021b). The most frequently selected reason for spending time in the identified natural space was *"for physical and mental health"* (53±1.2 %), with *"other"* as the second most common reason (21±1.0 %). The majority of respondents spent time in the spaces they selected *"multiple times throughout the year"* (94±0.6 %; Appendix 1.2. Table A1.2.6).

The relationship between wellbeing and distance travelled to access natural spaces was one of my main hypotheses, so here I break down the respondents who selected that spaces were *"very*

important" to their wellbeing compared to those who said they were *"unimportant".* Over half of all respondents (52±1.2%) said that the space they selected was *"very important"* to their day-to-day wellbeing. Breaking this subset down by the socio-demographic explanatory variables in my model, 63±1.6 % of these respondents (n=3384), identified as female and 37±1.6 % as male. As with the overall dataset, the majority, 51±1.7 %, chose *"for mental and physical health"* as their reason for spending time in the space. The next most common reason was *"other"* at 22 (±1.4) % and *"to feel connected to the natural world"* at 18±1.3 %. Examples of 'other' were varied and included; to walk the dog, fresh air, to decompress, close to home. 55±1.7 % were in the middle income group (£15, 838 - £44, 125), with 27±1.5% in the lower group (< £15, 838) and 18±1.3% in the upper (> £44, 125). The majority (67±1.6 %) lived in a suburban area. 46±1.7% of these respondents were highly educated to degree level and higher. The modal age of respondents in this group was 62 (age category 60-64), with 14±1.2% of respondents in this bracket. The respondents in this subset split equally between spending 0.75 hours, 2.5 hours or more than 24 hours at their chosen space, with 27±1.5% of respondents in each group.

By contrast, only 5±0.5% of my respondents said that the space they chose was unimportant or relatively unimportant to their day-to-day wellbeing. Of these (n=324), 51±5.4% identified as female and 44±5.7 % as male. 42±5.6% chose *"for mental and physical health"* as their reason for spending time in the space*,* with 30±5.2% selecting *"other",* and 15±4.1% selecting *"to feel connected to the natural world"*. 52±5.7% were in the middle income group (£15, 838 - £44, 125), with 23±4.8% in the lower group (< £15, 838) and 24±4.9% in the upper (> £44, 125). Again, the majority, 70±5.2% lived in suburban areas. 50±5.7% of these respondents were highly educated to degree level and higher. The most frequent age of respondents in this group was lower at 32, with 14±3.0% of respondents in this bracket. These respondents mostly spent shorter times at their space; 0.75 hours (29±5.2%), 0.25 hours (26±5.0%) or 2.5 hrs (22±4.7%). Only 5±2.5% spent more than 48 hours at the natural space.
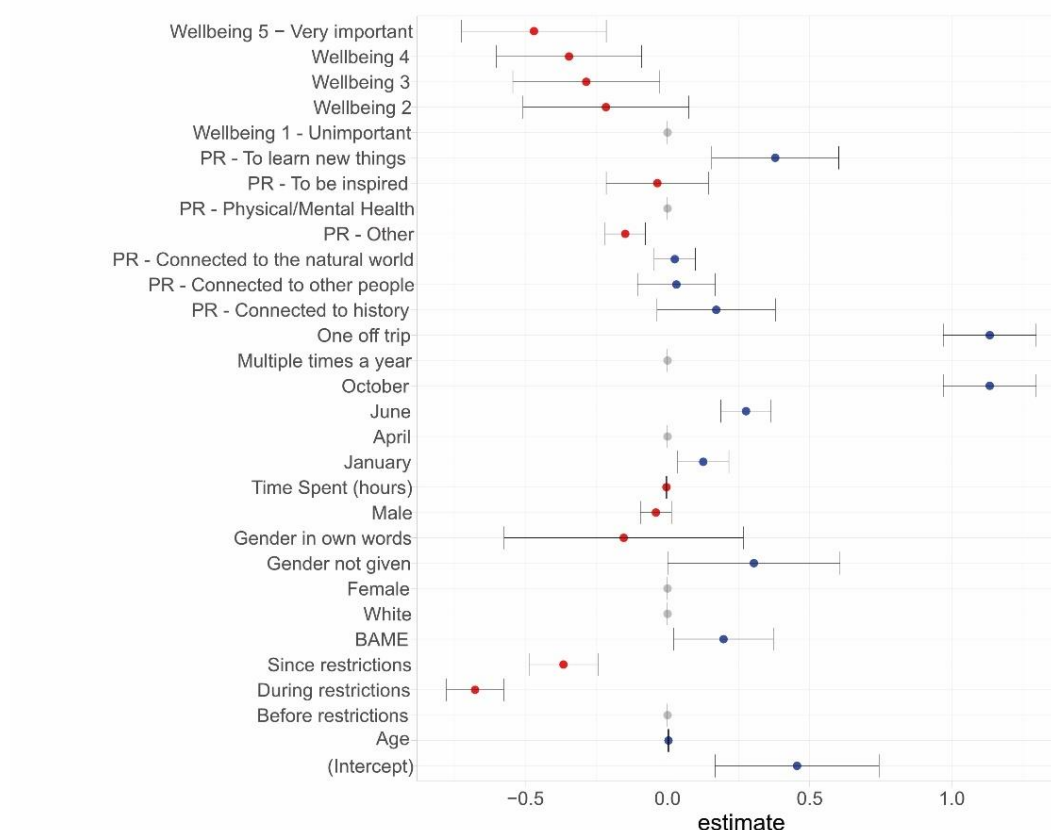
Figure 3.3. Coefficient plot from my general linear model, modelling the straight-line distance survey respondents travelled to spend time in natural spaces (in km) broken down by explanatory variables, which are: Wellbeing is the importance of the space to day-to-day wellbeing (from 1 unimportant to 5, very important), PR is the Primary Reason for spending time in that space, One off trip or multiple times a year are the Visit Frequency, October, June, April January are the months the survey was carried out, TimeSpent represents how long the respondent spent at the space in hours, Male, Gender in own words, gender not given, Female is the gender identity the respondent identified as, White or BAME is the Ethnic Group of the respondent and Since, During or Before restrictions is when the survey was carried out in relation to Covid-19 restrictions on access natural spaces. Variables are those remaining following forwards and backwards stepwise regression. Grey points are the reference level for the variable i.e., the most common response chosen, blue points show the estimate was positive, whereas red show the estimate was negative.

My general linear model shows a number of significant correlations with the distance travelled to access the selected natural space. For example, the distance travelled varied with the respondent's primary reason for accessing the natural space (Figure 3.3). The majority of respondents (53±1.2%) selected 'for physical and mental health' as a reason for access but, compared to this, those who chose 'other' (i.e., they did not identify with the options in the survey and chose to use their own

words) travelled significantly less distance (p < 0.001) and those who chose 'to learn new things' travelled significantly further (p < 0.001). Respondents travelled significantly less distance the more important the selected natural space was to their day-to-day wellbeing, with those selecting *"5 – very important"* travelling significantly less distance than those who chose *"1 – unimportant"* (p < 0.001; Figure 3.4.). Respondents travelled significantly further for spaces that they spend time in as a one-off trip compared to spaces they accessed multiple times throughout the year (p < 0.001). The closer a space was to peoples' homes, the more time they spent there (p < 0.001; Figure 3.4). There was no significant effect of gender identity, income, education, land cover at start point or ethnic group (p > 0.05; see Appendix 1.2. Table A1.2.7 for full results).

The unit differences in distances can be understood by considering an example respondent and looking at the impact of each variable in turn. For example, consider the most common respondent; identifying as female, aged 60-64, in the middle-income group, white, educated to at least undergraduate level, from a suburban area, who spent 30 mins to an hour at their chosen space and went there multiple times throughout the year for their physical and mental health and said the space was very important to their day-to-day wellbeing, having completed the survey in April 2020, during covid restrictions. With these characteristics, my general linear model estimated they travelled 240 (95% CI: 200-290) m to the natural space they selected. Using this as a default, I can highlight the impact on the variables highlighted as significant above by changing each in isolation. For example, if the reason for visit changed "to learn new things" the distance travelled increased to 580 (340-990) m. If the space was very important to their wellbeing, then the respondent likely travelled 240 (95% CI: 200-290), compared to 720 (390-1320) m for areas unimportant for wellbeing.
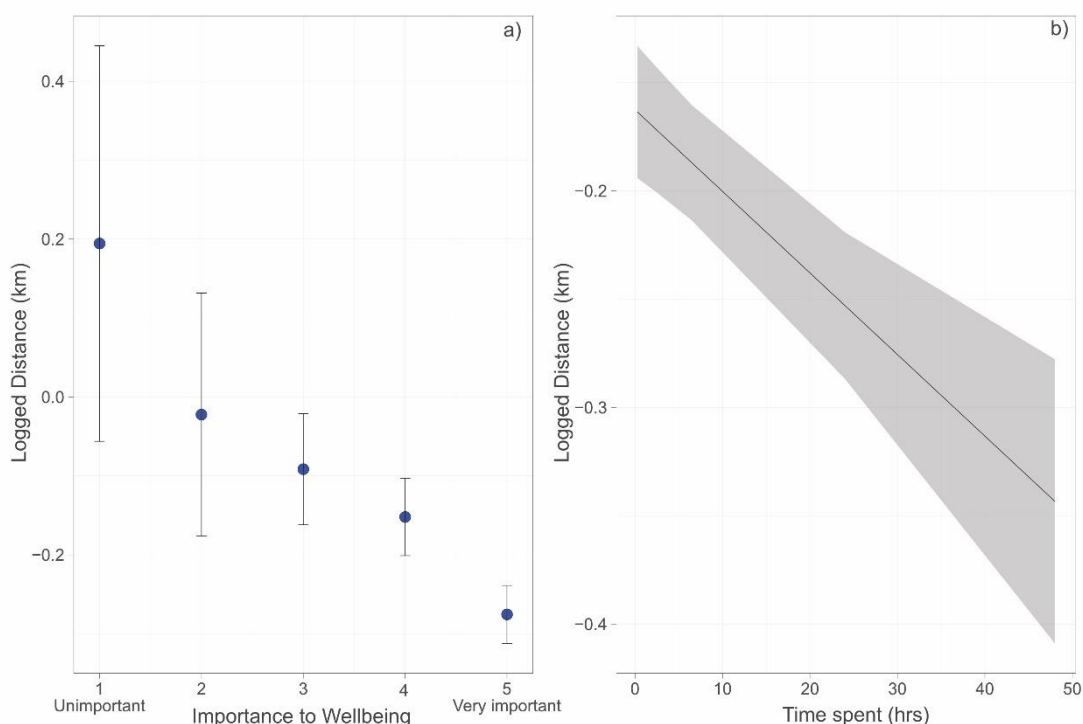
Figure 3.4. Effects plot from overall general linear model exploring distance travelled to natural spaces in Wales showing a) that distance travelled to natural spaces decreased with increasing importance to day-to-day wellbeing, and b) that the less distance respondents travelled, the longer they spent at the natural space they selected.

3.5. Discussion

My findings present a novel way to quantify access to nature and the importance of natural spaces to peoples' wellbeing. In particular, I show that, in Wales, if a natural space is over 1 km away from their place of residence, then it is unlikely to be important to their day-to-day wellbeing. The more important a natural space was to an individual's day-to-day wellbeing, the less distance they travelled to access it but the higher the frequencies of the visits and the longer they spent within it. This suggests because the space is nearby, it is easily accessible in terms of geography/location, so people go there a lot and frequent time spent there builds the importance to wellbeing. This quantification may be more informative for policy and decision makers than studies which describe, for example, 'nearby nature' but do not give a figure for what 'nearby' means (e.g. Freeman *et al.*, 2019). Some studies have used travel time to quantify this threshold, for example natural spaces within a five-minute walk from home (Hadavi, Kaplan and Hunter, 2018). Within a five-minute walk has also used as a measure of 'nearness' in other areas to explore accessibility of supermarkets

(Raja, Ma and Yadav, 2008) and amenities (Davis *et al.*, 2011). However, different people can walk (or travel by other means) different distances in 5 minutes.

Individuals spent significantly longer at natural spaces closer to their home. Given that I explored movement at a very localised scale, this is likely to be influenced by people spending time in their own gardens. Gardens are perhaps the closest natural space for many and have been shown to be beneficial to people's mental health (Freeman *et al.*, 2012). Gardens encourage people to be active through the physical work of gardening (Wood, Pretty and Griffin, 2015), encourage better diets through eating fresh produce produced from the garden (Heim, Stang and Ireland, 2009), and boost self-esteem and life satisfaction, especially among older people (Van Den Berg *et al.*, 2010) – people are able to see progress and feel achievement in what they have grown.

However, not everyone has access to a garden. Over half the world's population now live in cities, with this expected to rise to 68% by 2050 (United Nations, 2018). 12% of households in Wales, England and Scotland have no access to a private garden with BAME households being less likely to have access than white (Office for National Statistics, 2020). Areas in Great Britain where people are least likely to have a garden are most likely to have parks nearby (Office for National Statistics, 2020). However, living near a park does not necessarily mean people will use it. Fear of crime and anti-social behaviour can put people off using parks, especially among women, older adults and those living in deprived areas (Sreetheran and van den Bosch, 2014; Pérez-Tejera *et al.*, 2022). This can potential spark a self-reinforcing cycle; i.e., as people do not spend time in a park very often, they are less familiar with it and less comfortable there, so do not go back (Sreetheran and van den Bosch, 2014). It has also been reported that when people see other people in a space (especially when women see other women) they are more likely to feel it is safe but if the space is littered and unkept this will have the opposite effect (Sreetheran and van den Bosch, 2014; Pérez-Tejera *et al.*, 2022). Further, Lin *et al.* (2014) highlighted that people's level of connection to nature was a more important factor in predicting their use of parks than their general proximity. (Dobson, 2018) found that ensuring parks had toilets, minimum standards of maintenance, supported community activities and had staff to facilitate access encouraged use of parks. These interventions may not directly improve people's wellbeing themselves but may facilitate them spending time in nature, which likely benefits their wellbeing.

Individuals travelled significantly further to spend time at natural spaces as part of a one-off trip, compared to spaces at which they spent time multiple times throughout the year. This pattern has been found in studies over a bigger scale, for example visitors to a National Park in Germany intending to stay overnight were found to come from significantly further away than those who lived locally and could visit regularly (Mayer and Woltering, 2018). Similarly, tourists spending time on the Atlantic Coast of the United States were found to stay longer the further away they had travelled from and if it was the first time they had been to that space (Nicolau, Zach and Tussyadiah, 2018).

This also supports my finding that people travelled significantly further to access spaces when their motivation was 'to learn new things' compared to those who accessed spaces for their physical or mental health – novelty was a factor in predicting distance travelled.

Further work could explore how the distance people travel to access natural spaces, the time they spend there, and the frequency they visit is affected by how connected they feel with the space and wider nature. How close do you need to live to a natural space in order to feel connected to it? How often do you need to spend time there? How do the activities you engage in there affect this?

There may be a difference between passively being in the presence of natural spaces (e.g., living in a greener area) and actively connecting with them. Living in a greener neighbourhood may not result in greater wellbeing but actively deciding to spend time in natural spaces and engage with nature likely does (Martin *et al.*, 2020). Nature connectedness and engaging with nature through simple activities such as smelling flowers or watching wildlife had a greater association with positive wellbeing compared to time spent in nature (Richardson *et al.*, 2021). Those with a greater connection to nature spend time in multiple spaces (e.g. both their gardens and public parks) when it is available to them (Lin *et al.*, 2014). Thus, I suggest there is potential for targeted city planning policies to nurture a reinforcing feedback loop (i.e., that increasing access to diverse natural spaces will increase connectedness to nature which, in turn, further increases the natural spaces accessed). Worryingly, there is evidence that nature connectedness is decreasing, termed 'extinction of experience' (Soga and Gaston, 2016; Price *et al.*, 2022) which given its established link with positive wellbeing could put further pressure on, already strained, health services (Kruize *et al.*, 2019).

My findings fit well within policy framework in Wales which under the Wellbeing of Future Generations Act (2015) has committed to long term decisions both environmentally and socially for the benefits of current and future generations (Welsh Government, 2015). In Wales, the cost of physical inactivity and mental ill health to the Welsh economy is estimated to be £314 million and £7.2 billion respectively (Public Health Wales, 2016). World-wide, the cost of days lost to work-related stress has been estimated to be up to US$187 billion; in the UK it is estimated to be the £19.7 billion (Hassard *et al.*, 2017). Natural spaces have been rated as more restorative spaces to exercise (Hug *et al.*, 2009) and provide additional benefits compared to exercise indoors like the opportunity to see wildlife (Kajosaari and Pasanen, 2021). In showing the importance of natural spaces within 1 km of peoples' home, I provide a clear, tangible action to reduce these burdens and work towards the objectives of the Wellbeing of Future Generations Act (2015).

My data collection was carried out through online surveys, which has some limitations. For example, the second most common reason to visit a natural space selected was '*other*'. This may suggest that respondents didn't feel their reasons fitted into the survey categories (Appendix 1.1.). Sometimes when providing their owns words people gave the activity (e.g., walking the dog, painting,

photography) they did in the space rather than their motivations for spending time there and how they felt that activity benefitted them. Other studies have also found that people sometimes have difficulty describing their interactions with nature in terms of benefits or values (Stålhammar and Pedersen, 2017). Whilst the ES framework is useful for practitioners, it is perhaps abstract and confusing to the general public. This is why I modified the descriptions of cultural benefits from the framework by King *et al.* (2017) to use more accessible language, e.g., instead of saying 'a regenerative cultural ES pathway' I said 'a natural space where you go to benefit your physical or mental health'. The way people value cultural ES benefits and the natural spaces where they gain them has been found to be varied and nuanced, especially around spaces used for physical activity (Maund *et al.*, 2020). Physical activity is considered only one category of cultural ES benefit under some frameworks (e.g. CICES, Haines-Young and Potschin, 2018) but different people may spend time at a natural space for physical activity and benefit in different ways (Moseley *et al.*, 2018). Variation in the values people describe has also been found to be associated with ethnicity, for example white people are less likely to report spiritual values associated with woodlands (Maund *et al.*, 2020). Therefore, broad categories within a framework may not resonate with people and it is important to change frameworks into more accessible language or give people the opportunity to use their own words. Furthermore, as my survey came with an associated cash incentive, there was some potential for some respondents to fill in the survey quickly without giving much thought to their answers to gain the bonus (Chandler, Sisso and Shapiro, 2019; Singh and Sagar, 2021). This is maybe less likely with the platform I worked with as the survey came with the potential of a cash prize rather than a certain reward.

3.6. Conclusions

My findings emphasise the importance of natural spaces to peoples' day-to-day wellbeing, especially natural spaces very close to home (i.e., < 1km). This provides a tangible measure for resources need to be allocated. Resources need to be directed towards ensuring there are accessible natural spaces close to peoples' home with facilities and support to help people access it, especially in areas where access to gardens is low. Such changes would allow the benefits of nature connection to be realised for individuals and wider society.

Chapter 4

4. The impacts of Covid-19 restrictions on access to natural spaces in Wales

4.1. Abstract

In response to the Covid-19 pandemic, Governments across the world introduced restrictions on movement and activities on a massive scale. These restrictions potentially limited some people's access to natural spaces, with potentially detrimental outcomes as connection with nature has benefits for people's physical and mental health. I use social surveys to explore what affect the restrictions in Wales had on the frequencies and lengths of time people spent time in nature, the distance they travelled to spend time in nature and their day-to-day well-being. My results show that younger people were more likely to say there had been an increase in the frequency, time spent and distance they travelled to natural spaces, with the opposite pattern observed for older people. Those who did not have access to a garden were more likely to say that there had been a decrease in the frequency and time spent in natural spaces, and that the restrictions had a negative effect on their wellbeing. The more important natural spaces were to a person's wellbeing, the more likely they were to have said there was an increase in frequency and time spent in natural spaces during Covid-19 restrictions, despite the limitations in movement. Existing inequalities in access to nature were exacerbated and highlighted by the Covid-19 restrictions, therefore my findings here can potentially lead to broader conclusions about access. My results suggest that central and local governments should focus efforts on ensuring that natural spaces are provided in locations where accommodation does not provide garden access (e.g., flats); maintaining the levels of nature access for young adults (who spent more time in nature during the pandemic), and increasing the levels of greenspace access for older (who spent less time in nature during the pandemic). By increasing access to nature in this way, the wellbeing of the UK public would likely increase.

4.2. Introduction

In response to the Covid-19 pandemic, Governments across the world introduced restrictions on movement and activities, sometimes known as 'lockdowns' or 'stay-at-home' orders. These restrictions happened on a massive scale. For example, the first lockdown was in China's Hubei province on 23rd January 2020, in which all public transport was suspended and movement out of the city was controlled (Pan, Cui and Qian, 2020). By April 2020, the closure of schools, universities and colleges affected over 1.5 billion students across 194 countries (Aristovnik *et al.*, 2020). In the USA, 'stay-at-home' orders varied across states with most enforcing variations on remote working, curfews, limited travel and the closure of non-essential businesses (Fowler *et al.*, 2021). The first country to lockdown nationwide (and the first European country to lockdown) was Italy from 9th March to 18th May 2020; this included banning non-essential travel, limiting free movement, shutting non-essential businesses, closing schools and universities and banning events (Tondo, 2020). In the UK, a nationwide lockdown was announced on the 23rd March 2020 in which the public were ordered to stay at home, only leaving their homes for essential reasons and, a maximum of once per day, to exercise (UK Government, 2020). Health care is devolved in the UK, therefore each of the four nations (England, Scotland, Wales and Northern Ireland) followed their own timeline (Figure 4.2). Initially as restrictions eased in Wales, people were asked to 'stay local' and only go five miles from home to meet other households outside (Welsh Government, 2020b).

Whilst restrictions were introduced to control the spread of the virus, and were found to be effective in reducing transmission (Flaxman *et al.*, 2020), they also restricted some people's access to natural spaces. For example, beaches across the world were closed to avoid people gathering in popular spots (Surfline, 2020). Under strict lockdowns such as those in Spain, Italy and China, people were only allowed to leave their homes for essential activities such as getting food or medicine, not for exercise (Pouso *et al.*, 2020). In Wales, following the lockdown announcement on the 23rd March 2020, popular natural spaces that would normally attract many visitors (such as Yr Wyddfa; Wales's highest mountain), were closed to avoid people gathering there (Natural Resources Wales, 2020). It is highly likely that restrictions such as these would have had a large impact on peoples' ability to access natural spaces. For example, in the UK, 1 in 8 people do not have access to a garden at home (Office for National Statistics, 2020), so when lockdown restrictions were at their strictest a substantial portion of society would likely have had minimal access to natural spaces.

Reduced access to natural spaces is potentially detrimental to wellbeing as access to and connection with nature has acknowledged benefits for people's physical and mental health. Those who access natural spaces more often are more likely to achieve recommended amounts of physical activity (Hillsdon, Jones and Coombes, 2011). Furthermore, exposure to natural spaces is associated with decreases in indicators of cardiovascular disease and mortality (Kondo *et al.*, 2018). In terms of

mental health, individuals who have greater connections to natural spaces report greater hedonic wellbeing (happiness, life satisfaction) as well as eudaimonic wellbeing (sense that life has meaning, personal development, independence and competence) (Capaldi *et al.*, 2015; Pritchard *et al.*, 2019). Those living within 3 km of natural spaces in Auckland, NZ were less likely to be receiving treatment for anxiety or depression (Nutsford, Pearson and Kingham, 2013). Further, those who report greater nature connectedness also report greater connection to friends, family and those around them (Zelenski and Nisbet, 2014). Following the Covid-19 restrictions, it is therefore reasonable to hypothesise that many people lost out on many of the benefits they would normally gain from access to natural spaces.

This loss of access would likely have been unequal. Inequality in access to nature existed before Covid-19, and may have been heightened by the pandemic. For example, areas in England with the highest deprivation scores have been found to have the least natural space (Mullin *et al.*, 2018) and the more deprived areas in New York have lower cover of urban trees (Nyelele and Kroll, 2020). The natural spaces in more deprived urban areas may also be more likely to be perceived as inaccessible and unsafe and so are not used as frequently as in less deprived areas (Jones, Hillsdon and Coombes, 2009). In the UK, those in professional, managerial or administrative jobs (i.e., those with a higher salary) are almost 3 times less likely to be without access to private natural space than those without work or those in semi-skilled or casual work (Office for National Statistics, 2020). Private spaces like gardens were likely to have been important over the pandemic when people could not travel away from home or beyond the local area to access nature (Welsh Government, 2020). Black, Asian and minority ethnic (BAME) groups in the UK have been found to be under-represented in programmes promoting connection with natural spaces (Morris and O'Brien, 2011). Those from BAME backgrounds are also more likely to live in deprived areas in many majority white countries like the UK (Otu *et al.*, 2020) and the USA (Barber *et al.*, 2016). Therefore, minority groups, those living in deprived areas, and those on lower incomes were in a worse position in terms of access to natural spaces before the pandemic and Covid-19 restrictions may have limited access even further.

The Covid-19 pandemic and associated restrictions provided an opportunity to explore how the restrictions changed access to natural spaces and how this affected wellbeing. I was fortuitously placed to explore this having undertaken data collection exploring how access to nature varies across socio-demographic groups in Wales immediately before the pandemic. In response to the initial Covid-19 restrictions, I modified the survey to explore what affect the restrictions had on the frequency people spent time in nature, how long people spent in nature, the distance people travelled to spend time in nature and people's day to day well-being. Here I report these modified methods and their findings.

4.3.   Methods

This chapter used data collected in the surveys described in chapter 3 (section 3.3.), with additional questions to explore the effect of the Covid-19 restrictions. In the surveys that ran over the pandemic, respondents were asked if they had spent time in the natural space they selected before, during or since Covid-19 restrictions. To specifically explore the effect of Covid-19 restrictions on people's access to nature I added the following questions; 'On a scale from -2 (a large decrease) to +2 (a large increase) how large an effect has the Coronavirus/Covid-19 pandemic had on the frequency with which you spend time in natural spaces?', '…on how long you spend in natural spaces?', '…on the distance you travel to spend time in natural spaces?' and 'On a scale from -2 (very negative) to +2 (very positive) what affect have the lockdown restrictions on access to natural spaces had on your day-to-day wellbeing?'. In the surveys that ran in October 2020, January, April and June 2021, I asked how much people felt they had adapted their behaviour relative to the general population to avoid catching Covid-19, where they could answer 'more than most people, equivalent to most people, less than most people'. This variable was not included in the models as it was not part of every survey. For survey questions, see Appendix 2.1. Ethical approval was obtained via Bangor University (Ethics approval number: COESE2020RD01cov19), with the survey being distributed online (see Appendix 2.2. Table A2.2.1. for details).
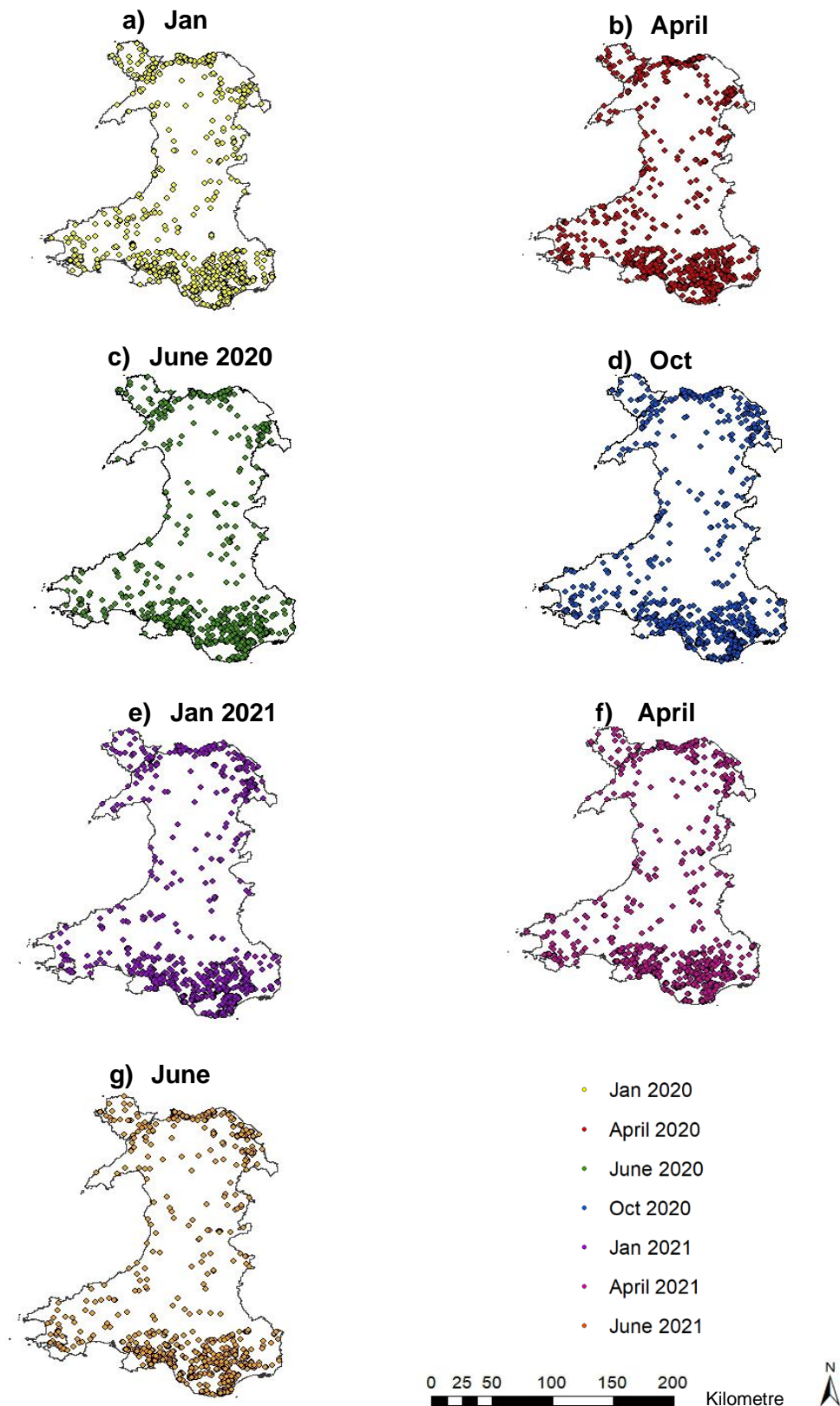
Figure 4.1. – Maps showing the sample points (i.e., home locations) for all seven surveys exploring the distance people travelled to access natural spaces from January 2020 to June 2021 across Wales.
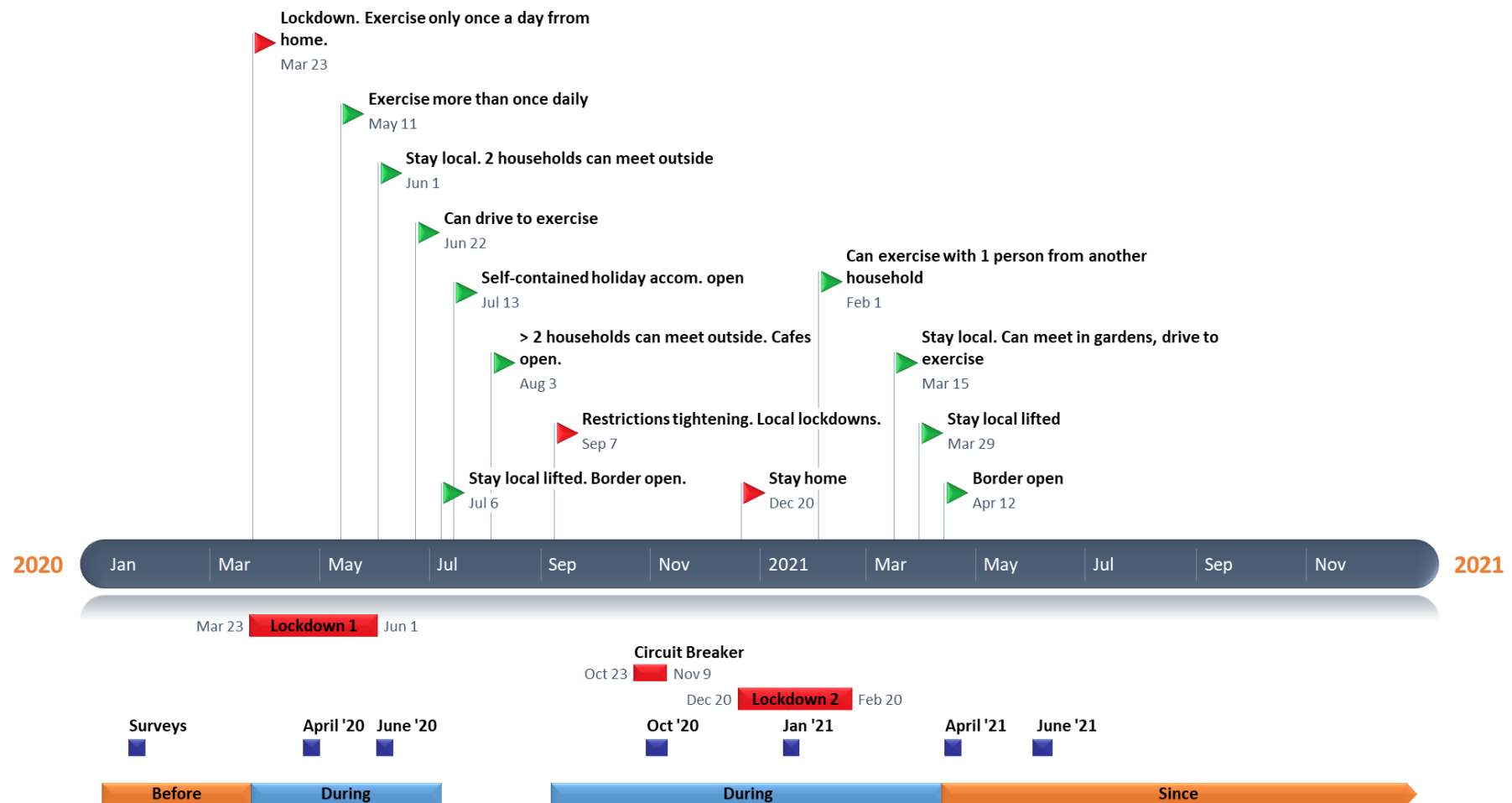
Figure 4.2. Timeline showing lockdowns and covid 19 restrictions in Wales over 2020 and 2021. The surveys are shown below the lockdowns, with colours corresponding to the same survey points in the map (Figure 4.1). Before, During and Since refers to restrictions around accessing nature.

The methods of survey distribution and data processing are described in section 3.3.1.

4.3.1. Data Analysis

I ran ordinal regression models to investigate the effect of Covid-19 restrictions on the frequency, how much time spent and distance travelled to nature, and the effect on people's day-to-day wellbeing (Equation 1-4). I also ran an ordinal regression model to see if the change in wellbeing was predicted by the change in frequency, time spent and distance travelled (Equation 5).

Change in frequency of time spent in nature = HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + BDS + Garden **(Eq. 1)**

Change in how much time spent in nature = HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + BDS + Garden **(Eq. 2)**

Change in distance travelled to nature = HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + BDS + Garden **(Eq. 3)**

Effect on day-to-day wellbeing = HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + BDS + Garden **(Eq. 4)**

Effect of change in frequency, how much time spent and distance travelled on wellbeing = Change in frequency + Change in how much time spent + Change in distance + HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + BDS + Garden **(Eq. 5)**

In which, *HHIncome* is the ordinal household income category (either Less than £15,838, £15,838 - £44,125, More than £44,125), *Gender* is the self-identified gender of the respondent (categorised into female, male, prefer not to say, prefer to use own words), *Education* is the highest level of education of the respondent (from secondary school, GCSE, apprenticeship, A level, Higher Education), *EthnicGroup* is the ethnicity of the respondent (categorised as either White or Black, Asian and minority ethnic [BAME] due to high prevalence of white respondents in the area), *LandCover* is the land cover at start point (categorised into Rural, Suburban, Urban), *Wellbeing* is the importance of the space chosen to day-to-day wellbeing (from 1 unimportant to 5, very important), *BDS* is whether the survey was carried out before, during or since restrictions to accessing nature in response to Covid-19, and *Garden* is whether the respondent had access to a garden or not (yes/no).

In a separate analysis using this dataset, I explored the distance people travelled to spend time in natural spaces and how this varied with socio-demographic variables. I controlled for whether they spent time at the space before, during or since restrictions on accessing natural spaces. I have included this analysis, with before, during, and since restrictions as the variable of interest in Appendix 2.3.

4.4. Results

My final dataset had 5783 observations (each representative an individual respondent). Across this total, 58±1% (± 95% Confidence Interval, dCode, 2023) of respondents were female and 41±1% male. The majority of respondents (54±1%) in this dataset were within the middle income group (£15,838 - £44,125), with 26±1% in the lower income group (less than £15, 838) and 20±1% in the higher income group (more than £44,125). 46±1% of respondents were educated to at least degree level. 98±0.4% of respondents were white. 93±0.7% of respondents said they had access to a garden. The majority (69±1%) of respondents lived in suburban areas, compared to 20±1% in rural areas and 11±0.8% in urban areas. These patterns largely reflect the wider Welsh population: 49% male and 51% female (Welsh Government, 2021b); and 95% white (Welsh Government, 2022). The majority of respondents lived in suburban areas (69±1.1 %). In the 2011 national census, 63% of people lived in wider urban areas in Wales, based on built up areas of more than 20 ha (Office for National Statistics, 2021b).

The majority (54±1%) of people said that the space they had chosen was very important to their wellbeing, compared to only 1±0.3% saying that the space was unimportant (from a choice of responses ranging from 5 - very important to 1- unimportant. 30±1% of people reported a decrease in the frequency with which they accessed nature due to Covid-19 restrictions, compared to 25±1% stating no change and 45±1% reporting an increase. 29±1% of people reported a decrease in how long they spent in nature, compared to 28±1% who reported no change and 43±1% reporting an increase. 41±1% of people reported a decrease in the distance they travelled to access nature compared to 28±1% reported was no change and 31±1% who reported an increase. 45±1% of respondents said covid restrictions had a negative effect on their day-to-day wellbeing, compared to 33±1% who said there had been no change and 22±1% who reported a positive effect. Of the 3773 respondents who answered the question on how much they felt they had modified their behaviour to avoid catching covid, 5±0.7% answered 'less than most people', 48±2% answered 'equivalent to most people' and 46±2% answered 'more than most people'. See Appendix 2.2. Table A2.2.4 for a breakdown of respondents for each variable.

How did change in frequency of visits to, time spent in and distance travelled to natural spaces affect day-to-day wellbeing?

As a result of Covid-19 restrictions on access to natural spaces, those who said there was a large decrease in frequency with which they spent time in nature were more likely to say there was a negative effect on their wellbeing ($p<0.001$; Figure 4.3; Equation 5). Similarly, those who said there was a large decrease in the amount of time they spent in nature were more likely to report a negative effect on their wellbeing ($p<0.001$). Both those who reported a large increase and a large decrease in distance travelled to access nature were more likely to report a very negative effect on their wellbeing ($p<0.001$).

Controlling for these changes in frequency of time spent, how much time spent and distance travelled, those in the lower income category (<£15,838) and those in the higher income category (>£44,125) were more likely to report a very negative effect on their day-to-day wellbeing ($p<0.001$ and $p<0.05$ respectively) than the middle income group (£15,838 - £44,125). Those in rural areas were less likely to report a very negative effect on their wellbeing ($p<0.05$), Figure 4.4. See Appendix 2.2. Tables A2.2.5 for model summary.
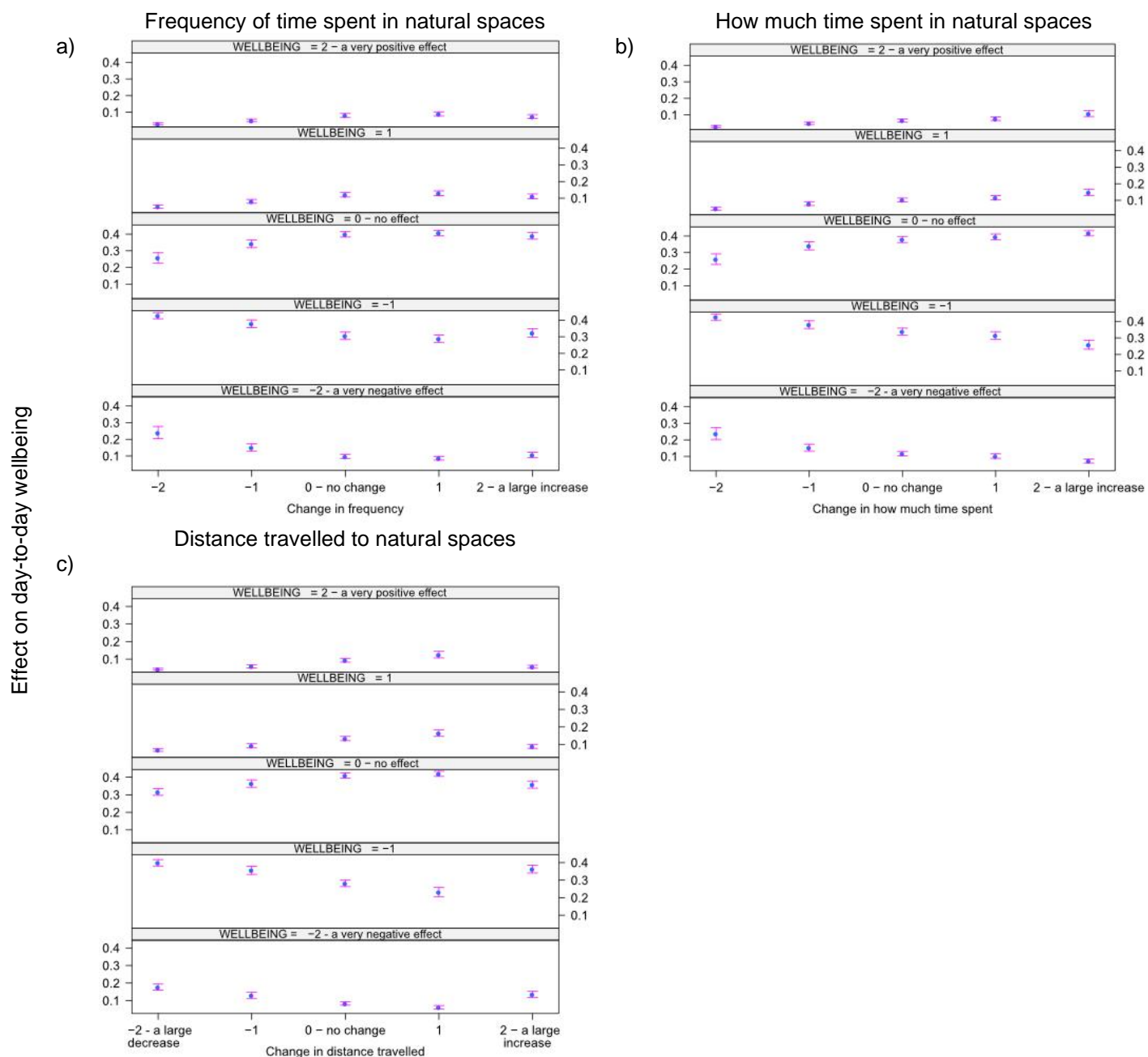
Figure 4.3. The effect of change in a) frequency of time spent, b) how much time spent and c) distance travelled to natural spaces on day-to-day wellbeing during Covid-19 restrictions in Wales.
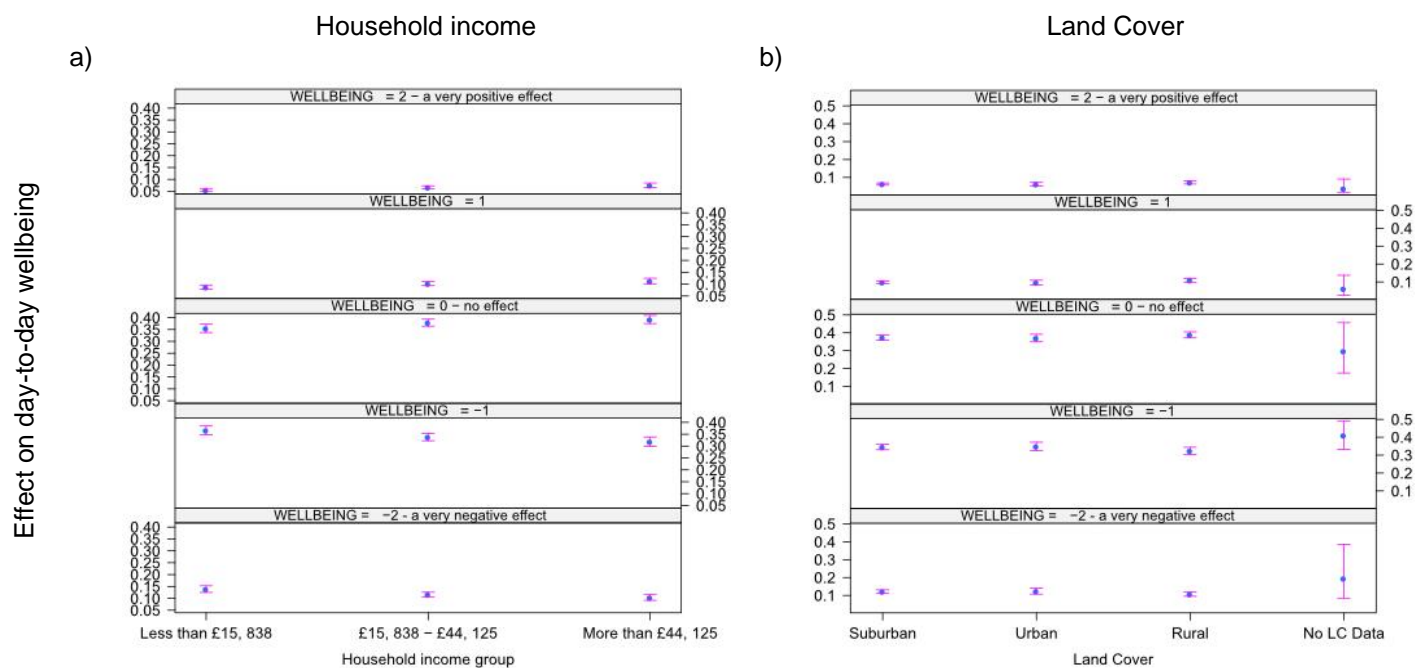
Figure 4.4. With change in frequency of time spent, how much time spent and distance travelled to natural spaces variables controlled for, a) household income and b) land cover where the respondent lived were also found to influence what effect the restrictions on access to natural spaces beyond the home had on day-to-day wellbeing.

Relationship between gender identity and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Those who identified as male were less likely to say there had been a large increase and more likely to say there had been a decrease in the frequency of time spent ($p<0.05$) and how long they spent ($p<0.01$), in natural spaces during Covid-19 restrictions compared to those who identified as female. They were more likely to say there'd been a positive effect on their wellbeing over the whole period compared to females ($p<0.05$), Figure 4.5. There was no relationship identified with distance travelled to natural spaces.
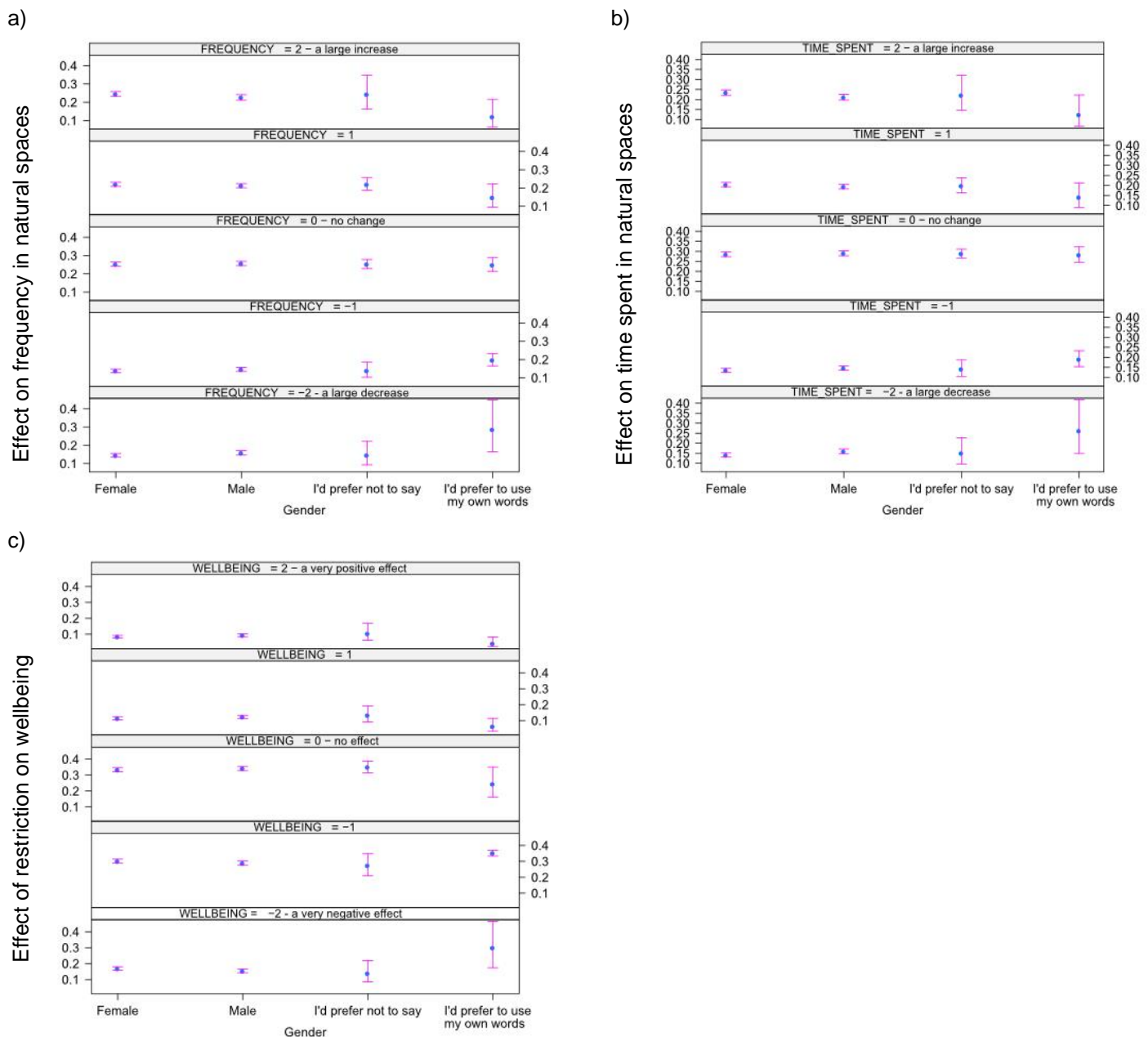
Figure 4.5. The relationship between gender identity and a) change in frequency of time spent in natural spaces, b) how much time spent and c) effect of the restrictions on wellbeing over the pandemic.

Relationship between household income and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

During Covid-19 restrictions, those in the lower income category (<£15,838) were more likely to say there'd been an increase in distance travelled to access nature and less likely to say there'd been a decrease (p<0.01) compared to the middle-income category (£15,383 - £44,125). Those in the higher income category (>£44,125) were less likely to say there had been an increase in distance travelled to access nature (p<0.01), Figure 4.6. No relationship was identified with frequency of time spent, how long spent in natural spaces or wellbeing.
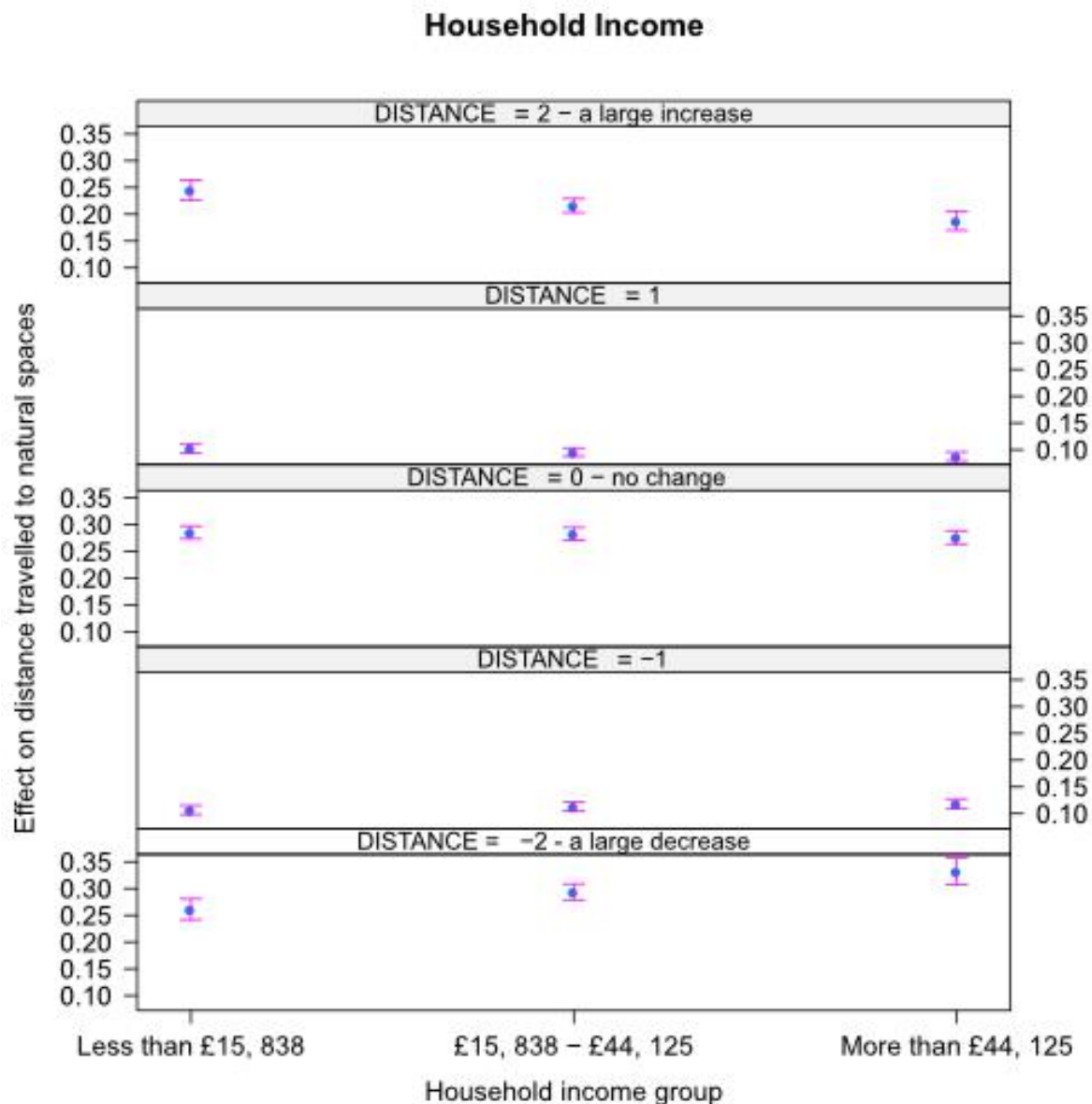
Figure 4.6. The relationship between household income and distance travelled to natural spaces over the pandemic in Wales.

Relationship between age and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Younger people were more likely to say there had been a large increase in frequency of time spent (p<0.001), how long they spent in natural spaces (p<0.001) and distance travelled to natural spaces (p<0.05) whereas older people more likely to say there had been a decrease in these three factors. Older people were more likely they were to say that there had been a very negative effect on their wellbeing than younger people (p<0.05), Figure 4.7.
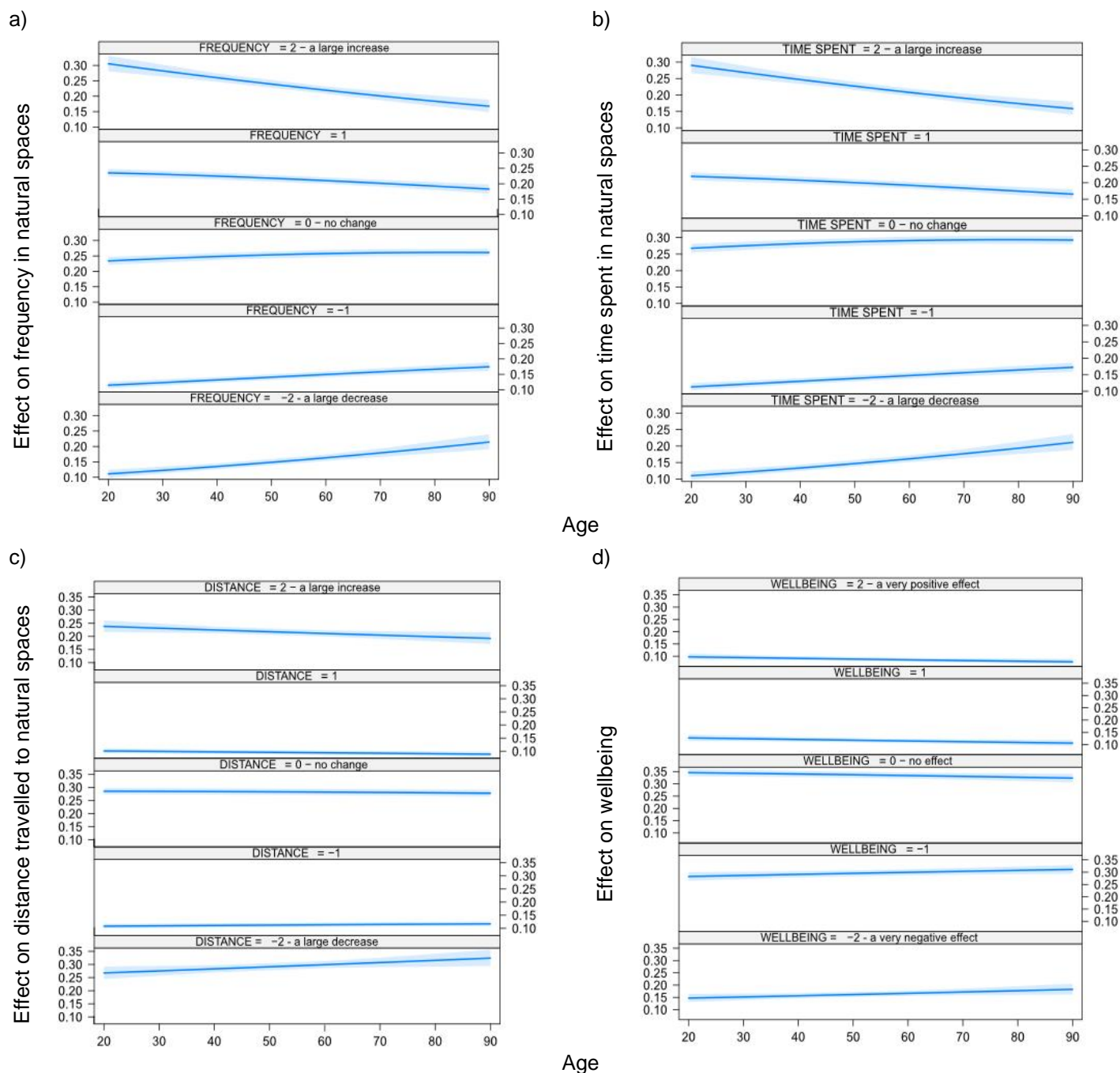
Figure 4.7. The relationship between age and change in frequency of time spent in natural spaces, how long spent in natural spaces, distance travelled to natural spaces and effect on wellbeing over the pandemic in Wales.

Relationship between ethnic group and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Those who identified as BAME ($2\pm0.4\%$ of dataset) were more likely to say there was an increase in frequency of time spent in nature compared to those who identified as White ($p<0.05$). They were also more likely to say there had been a positive effect on their wellbeing and less likely to say there had been negative effect ($p<0.05$), Figure 4.8. No relationship was identified with how much time spent or distance travelled to natural spaces.

a)   b)
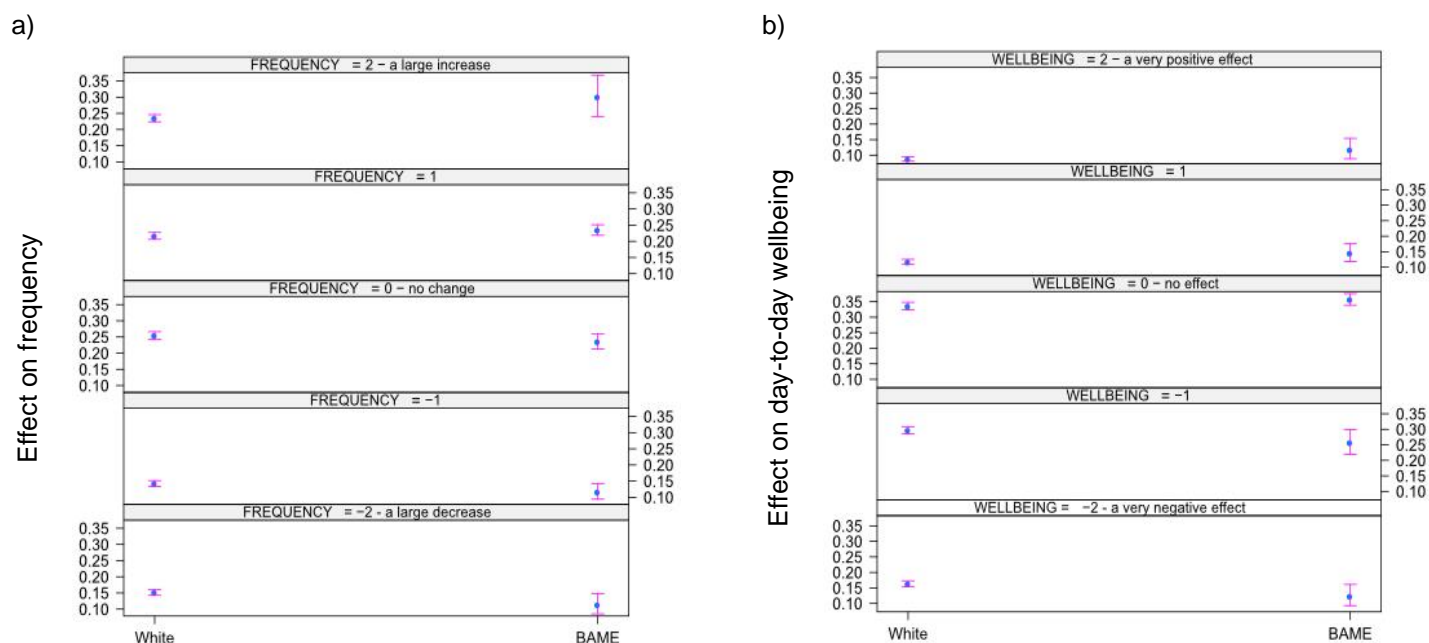
Figure 4.8. Relationship between ethnic background and change in frequency of time spent in natural spaces and effect of restrictions on day-to-day wellbeing over the pandemic in Wales.

Relationship between education and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Those whose highest level of education was secondary school ($11\pm1\%$) were more likely to say there had been an increase in frequency ($p<0.05$) and time spent ($p<0.05$) in natural spaces compared to those whose highest level was higher education.

Those educated to Secondary school, GCSE and Apprenticeship level were more likely to say there'd been an increase in distance travelled and less likely to report a decrease ($p<0.001$, $p<0.001$, $p<0.05$ respectively) compared to those educated to higher education level.

Those educated to Secondary school and A level were more likely to say there'd been a positive effect on their wellbeing ($p<0.001$, $p<0.01$ respectively) compared to those educated to higher education level. See Figure 4.9.
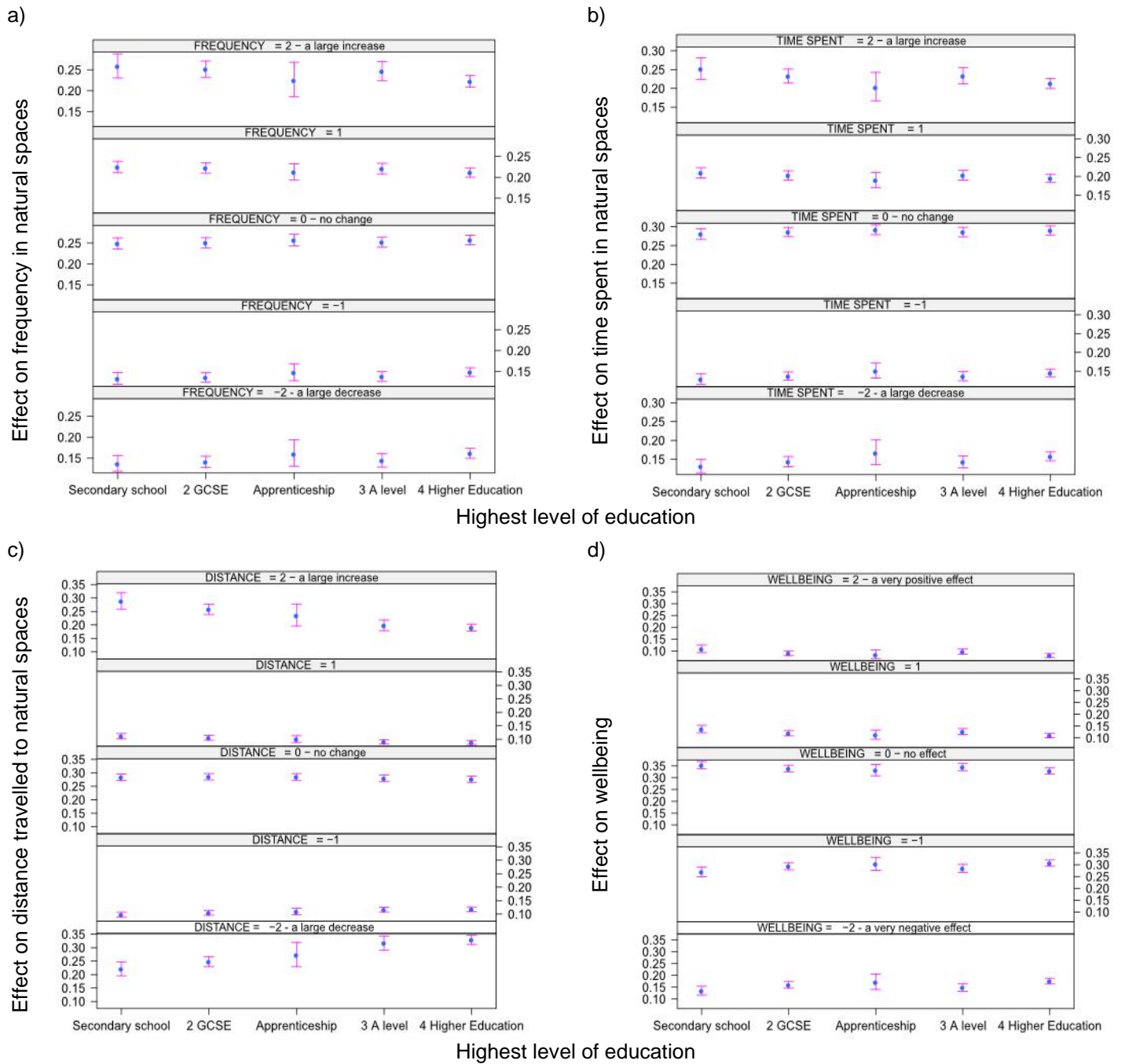
Figure 4.9. Relationship between highest level of education and change in a) frequency of time spent in natural spaces, b) how much time spent in natural spaces, c) distance travelled to natural spaces and d) effect of restrictions on wellbeing over the pandemic in Wales.

Relationship between land cover at home location and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Those who lived in rural areas were more likely to say there had been a positive effect on their wellbeing and less likely to say there had been a negative effect compared to those living in suburban areas (p<0.001), Figure 4.10. No relationship was identified with frequency of time spent, how long spent or distance travelled to natural spaces.
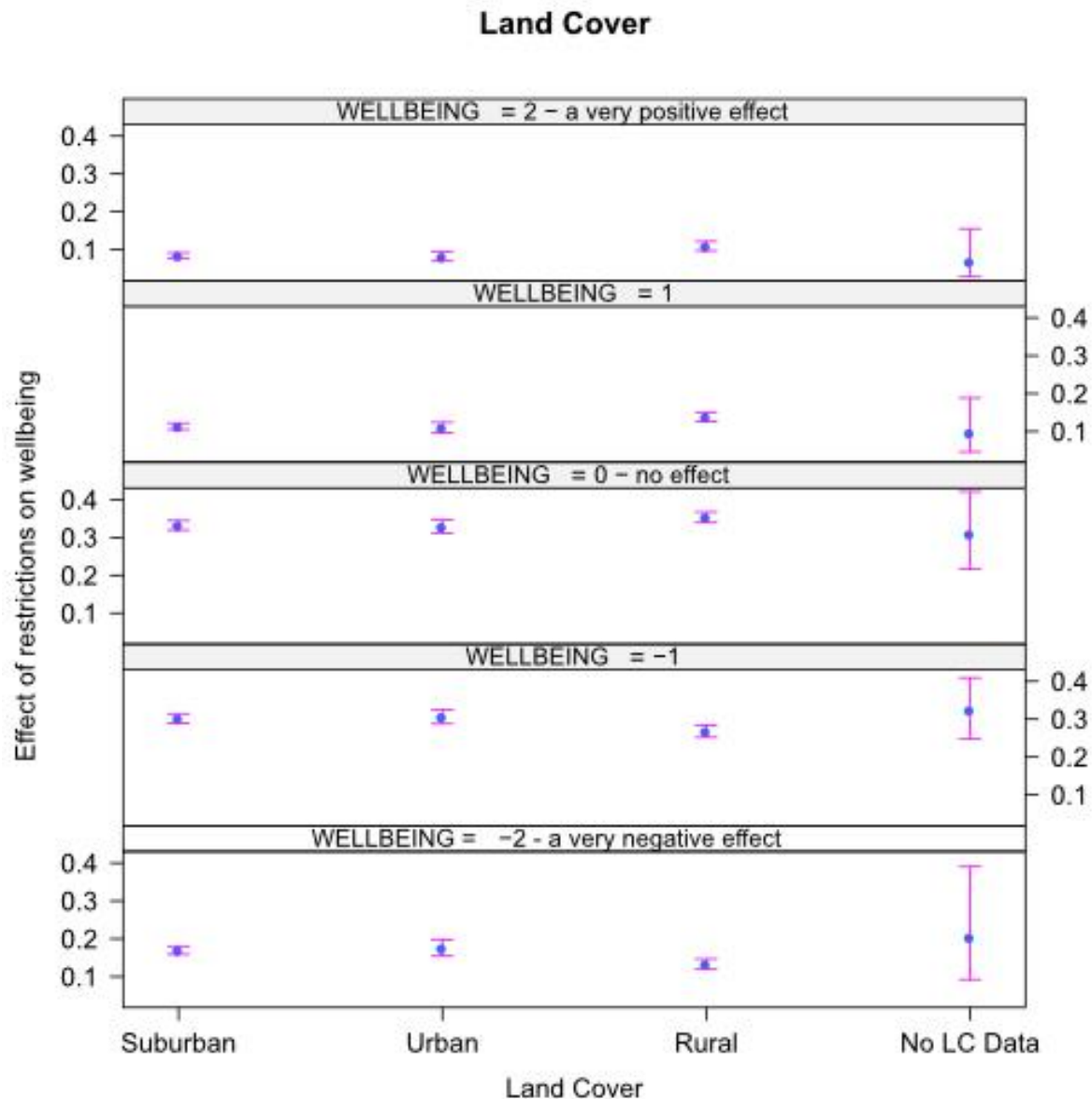
Figure 4.10. Relationship between land cover at home location and effect on wellbeing of restrictions during the pandemic in Wales.

Relationship between garden access and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Respondents who didn't have a garden (7±1%) were significantly less likely to report an increased in frequency of time spent(p<0.001) and how long spent (p<0.001) in natural spaces and were more likely to report a decrease. They were more likely to report that restrictions had a very negative effect on their wellbeing (p<0.05), Figure 4.11. No relationship was identified with distance travelled to natural spaces.

a)

b)

c)
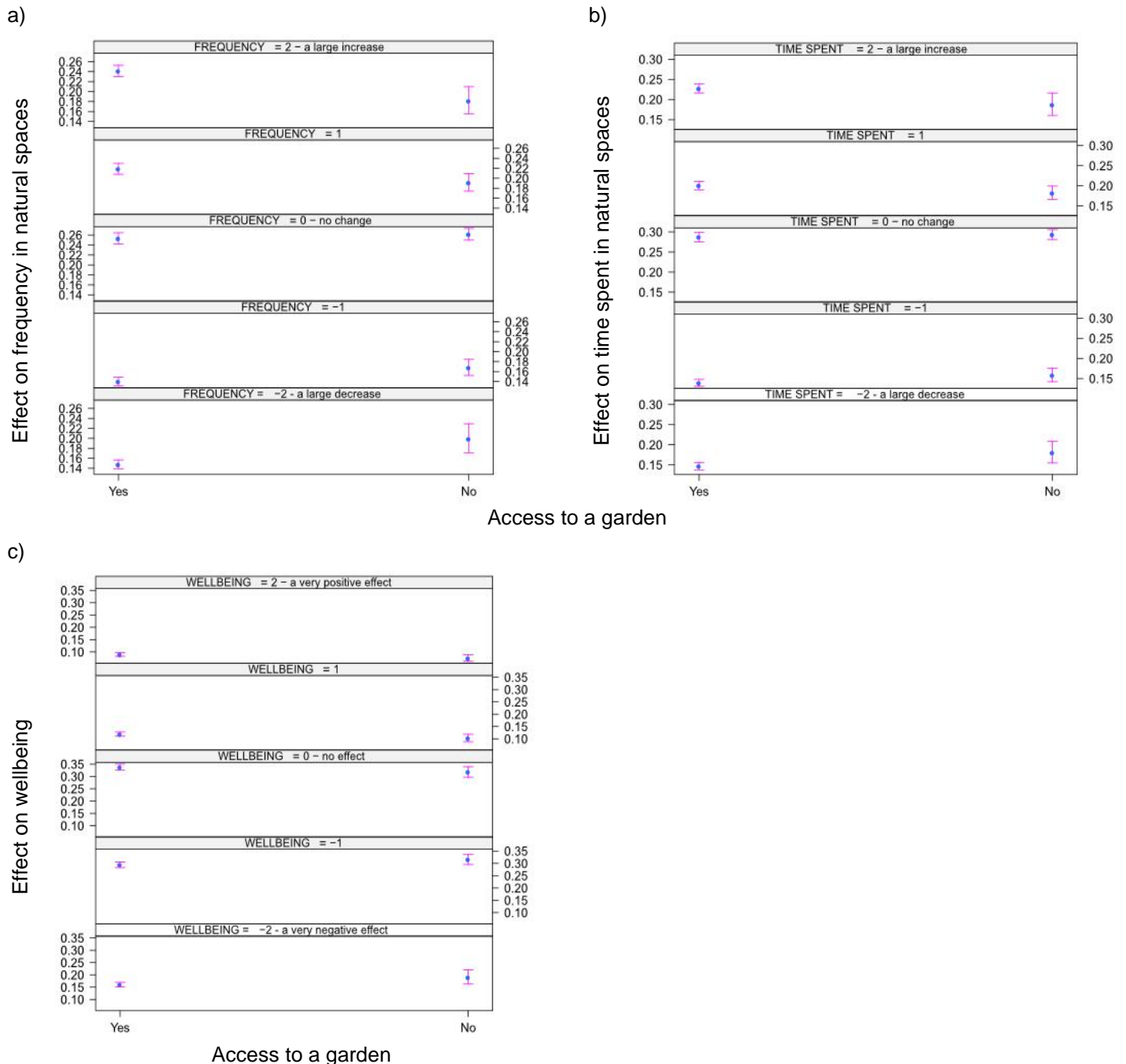
Figure 4.11. Relationship between garden access and a) change in frequency of time spent in natural spaces, b) how much time spent, and c) effect of restrictions on wellbeing over the pandemic in Wales.

Relationship between the importance of natural spaces to wellbeing and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

The more important natural spaces were to people's wellbeing, the more likely people were to say that there had been a large increase in frequency of time spent (p<0.001), how long they spent at a time (p<0.001) in nature and distance travelled (p<0.001) and the less likely they were to say there had been a decrease, Figure 4.12.
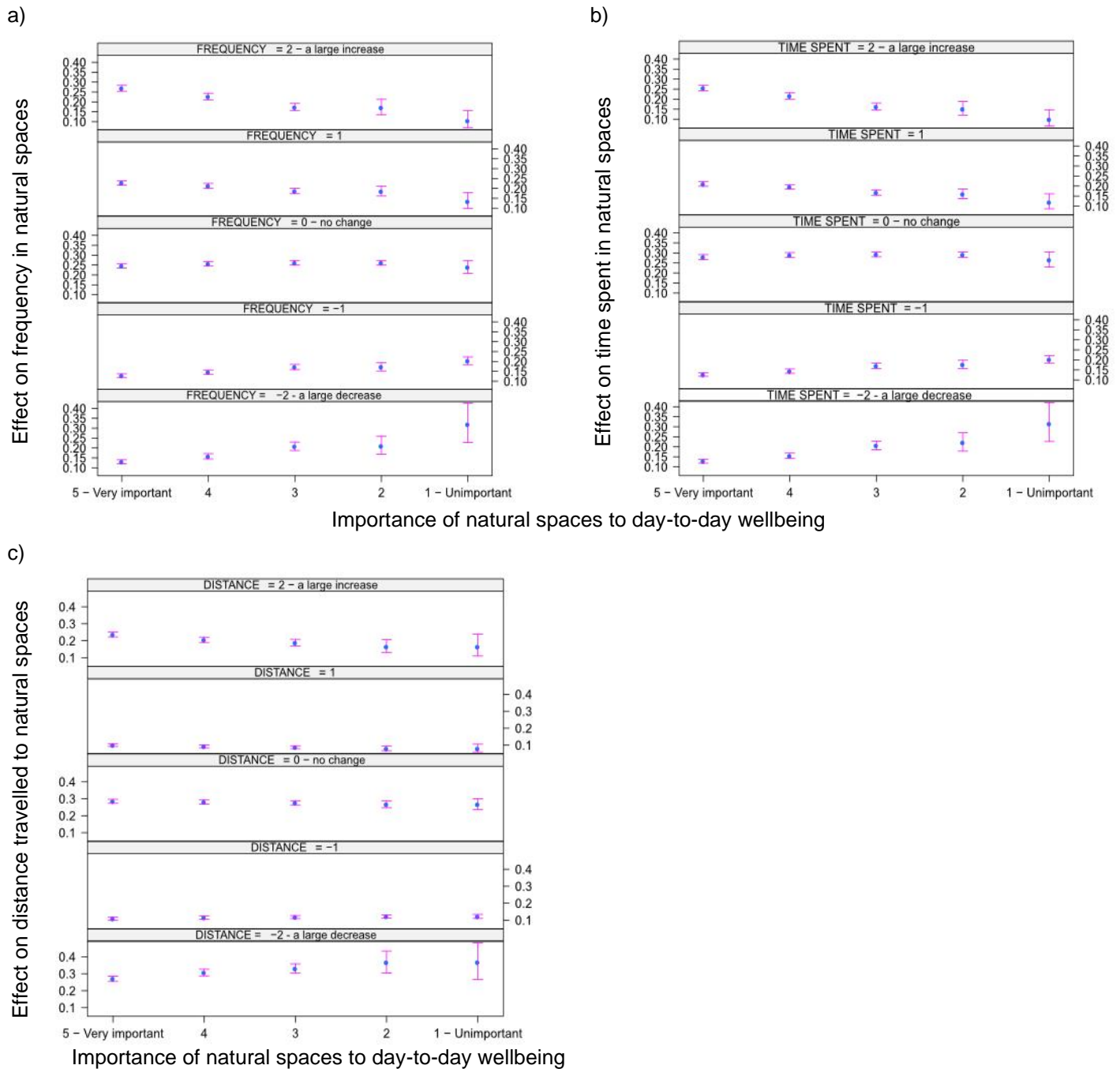
Figure 4.12. Relationship between the importance of natural spaces to wellbeing and a) change in frequency of time spent in natural spaces, b) how much time spent, and c) distance travelled to natural spaces over the pandemic in Wales.

Relationship between spending time in natural space during or since restrictions and change in frequency of time spent, how long spent and distance travelled to natural spaces and day-to-day wellbeing over Covid-19 restrictions

Those who completed the survey since restrictions on access to natural spaces had ended were more likely to say that there had been a positive effect on their wellbeing during the pandemic ($p<0.001$), Figure 4.13. No relationship was identified with frequency of time spent, how much time spent or distance travelled to natural spaces.
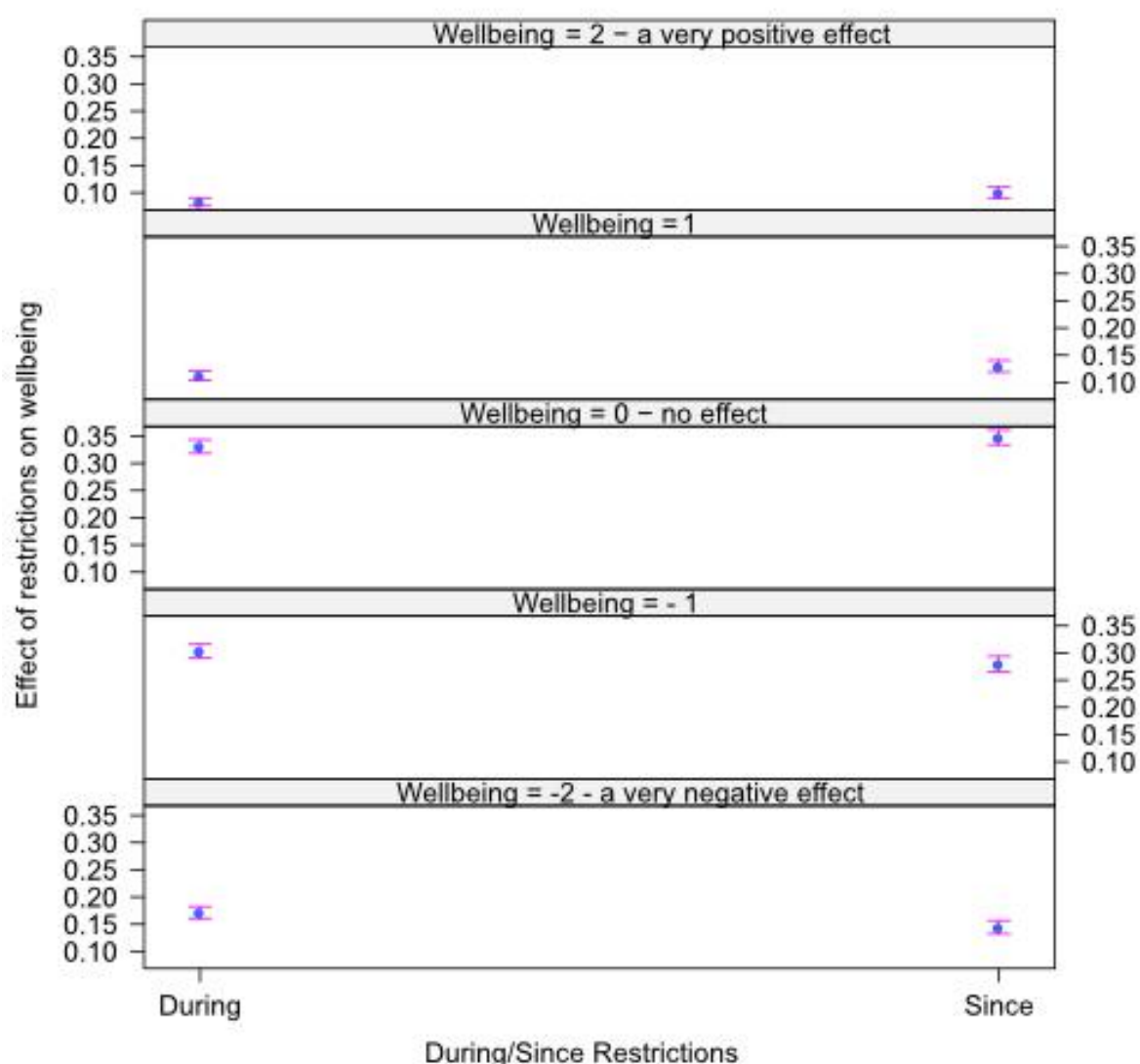
Figure 4.13. Relationship between reporting on experience over the pandemic during or since restrictions and reported effect of the restrictions on wellbeing in Wales.

4.5. Discussion

The more important natural spaces were to people's wellbeing, the more likely they were to report an increase in frequency, time spent and distance travelled to natural spaces over the pandemic. This suggests that people were using time spent in natural spaces as a way to look after themselves during a challenging time; they knew it would help them and make them feel better (Hansmann, Hug and Seeland, 2007; Kajosaari and Pasanen, 2021). This may become circular; the more important somewhere is to wellbeing, the more often someone will go there and the more important it will become, especially during difficult times.

Some groups reported that they distance they travelled to access natural spaces over the pandemic increased, which seems counter intuitive given the movement restrictions. These could have been changes on a small, local scale for example people who before the pandemic normally only spent time in their own garden, but now, furloughed from work or working from home, had more opportunity to take a walk from home or spend time in a local park. They spent more time in natural spaces because other options were closed to them. Conversely, people who more regularly spent time in a variety of natural spaces further from home would see the distance they travelled to access nature decrease.

When asked about the impact of the restrictions on access to natural spaces on their wellbeing, those who said there had been a decrease in the frequency and time spent in natural spaces over the pandemic were more likely to say that there had been a negative effect. Poor mental health including depressive, anxiety and insomnia symptoms were found to be significantly higher in UK during lockdown restrictions compared to beforehand (Pieh *et al.*, 2021). These were more severe in women, those under 35, those out of work and those with low income. Poor mental health could then have been exacerbated further for those who valued spending time in natural spaces but were then less able to do so under restrictions. A study by Natural England found that 26% of adults had not spent any time in a natural space in April 2020 (one month into restrictions) (Natural England, 2020). Whilst the restrictions on movement were intended to reduce the spread of Covid-19 and were successful in doing so (Flaxman *et al.*, 2020), the unintended consequences on people's mental health may have been substantial and should be considered in the event of future health crises, as well as again highlighting the importance of private natural spaces.

I found that younger people were more likely to say there had been an increase in the frequency, time spent and distance they travelled to natural spaces during the pandemic, with the opposite pattern observed for older people. This pattern has been observed in other research. For example, a Norwegian study found an increase in use of urban green space during the pandemic and sustained afterwards, most pronounced in younger age groups (Venter *et al.*, 2021). Similarly, a US study found that natural spaces had a more protective effect on the mental health on their second

youngest age group (31-38) during restrictions (Wang *et al.*, 2019). This could be because this group were most affected by additional stressors relating to work and childcare so were more in need of mental health support. Alternatively, this finding could in part be due to younger working adults being furloughed from work or working from home which gave them more flexibility to spend time in natural spaces (compared to pre-Covid-19 when they were too busy). Older people were more likely to say there had been a decrease in frequency and time spent in natural spaces. Older people were also at greater risk from Covid and more likely to have other health conditions which could have made them more anxious about spending time in public natural spaces. Spending time in natural spaces and especially being active there has been found to be beneficial for middle-aged and older adults; an Australian study found that pre-Covid those who lived in the greenest neighbourhoods were most active and at least risk of poor mental health (Astell-Burt, Feng and Kolt, 2013). Given these benefits, it is important to ensure that this pattern of decreased time in natural spaces does not continue for older adults as society moves away from the pandemic.

Those who did not have access to a garden were more likely to report a decrease in the frequency and time spent in natural spaces, and that the restrictions had a negative effect on their wellbeing. Gardens have been found to have been very important over the pandemic, possibly even more important than public natural spaces (Marques *et al.*, 2021), as they allowed people to connect with nature whilst still remaining isolated from others (Labib *et al.*, 2022). Higher levels of garden use during the pandemic were associated with better self-rated physical health, mental health and sleep quality in a Scottish study of over 70's (Corley *et al.*, 2021). Private natural spaces like gardens allow for moments of nature connection, like smelling flowers you have grown, which have been shown to be key to boosting our wellbeing, above and beyond just time spent in natural spaces (Richardson *et al.*, 2021). Community gardens were also found to have positive effect over the pandemic as people were able to attend to their own plot but with others socially distanced around them, allowing them to be 'physically apart but socially connected' (Joshi and Wende, 2022). This effect was observed in parallel gardens with neighbours able to see each other and talk over fences but remain socially distanced (Jones *et al.*, 2020). A Natural England study in April 2020 found that 86% of respondents with access to a private garden or allotments said that natural spaces were 'very important' to them, with 87% agreeing that 'being in nature makes me happy' (Natural England, 2020). This shows the importance of access to private natural spaces, especially during times when there may be anxiety about accessing public spaces and that it is important to ensure dwellings that do not have private gardens have access to some kind of natural space, even plants on a balcony.

Similarly, those who lived in rural areas were less likely to say the restrictions had a negative effect on their day-to-day wellbeing. This could be because they were more likely to have access to a garden, had natural spaces very close by or were at least able to see greenery and trees from home. A US study found that during restrictions, 'outdoor enthusiasts' (especially those who liked to spend time in 'backcountry' natural spaces beyond road access) living in rural areas were less affected than

those in urban areas (Rice *et al.*, 2020). They had to make less adjustments in terms of finding different natural spaces to access whereas those in urban areas had to substitute desired spaces for closer, less preferable ones (Rice *et al.*, 2020). This could have had an unintended benefit of allowing people to find new natural spaces closer to home and getting to know their local area better (Salama, 2020) but in the short term, negatively impacted people's mental health as they could not access their preferred spaces. This supports the idea of making our urban areas greener (Cilliers, 2021) so people are able to connect with nature wherever they live.

With changes in frequency, time spent and distance travelled controlled for, those in the lowest income group (less than £15,838) were more likely to say the restrictions on access to natural spaces had a negative effect on their wellbeing. Higher social deprivation was found to be a risk factor for death from Covid-19 with the most disadvantaged found to be 20% more likely to die than the least (Woodward *et al.*, 2021). Those out of work and with low incomes also suffered disproportionately with poor mental health during the pandemic compared to before (Pieh *et al.*, 2021). In addition, less wealthy individuals are less likely to have access to private natural spaces (Office for National Statistics, 2020). Therefore, those in the lowest income group had more stressors to contend with over the pandemic, but were also less likely to be able to access natural spaces to help them cope.

Those who completed the survey since restrictions on access to natural spaces had ended were more likely to say that there had been a positive effect on their wellbeing during the pandemic, compared to those who completed the survey during restrictions. No statistically significant relationship was identified between whether the survey was completed during or since restrictions and frequency of time spent, how much time spent or distance travelled to natural spaces. This is despite my findings that the more important natural spaces were to people's wellbeing, the more likely they were to report an increase in frequency, time spent and distance travelled to natural spaces over the pandemic. Potentially those who were completing the survey once restrictions had lifted, and maybe now had to return to work or spend more time working, were finding the transition and new rules stressful and uncertain. There is evidence to suggest that peoples' anxiety levels did not return to pre-lockdown levels as restrictions eased, they continued to feel there were more stressors in their life and they were more anxious compared to before the pandemic (Shiba *et al.*, 2022). Therefore, they reported a positive impact during the restrictions, despite the impact of the restrictions themselves. A potential limitation to my study is the meanings attached to the language that become commonly used during the Covid-19 pandemic. Whilst in my surveys, I specified that I was exploring the impact of restrictions on access to natural spaces, respondents may still have thought of 'restrictions' as all restrictions imposed during the pandemic period including access to shops, cafes, spending time with others and in others' houses.

4.6. Conclusions

In combination, these results emphasise the importance of spending time in natural spaces, especially during times of stress, which people continue to experience as society moves out of the Covid-19 pandemic and as other global and national challenges affect people, such as the cost-of-living and climate crises. The restrictions during the Covid-19 pandemic highlighted existing inequalities in access to nature and the restrictions themselves affected people unequally.

I suggest there is potential for targeted planning policies to nurture a reinforcing feedback loop (i.e., that increasing access to diverse natural spaces will increase connectedness to nature which, in turn, further increases the natural spaces accessed). Increasing awareness and dialogue on the benefits of spending time in natural spaces could help people to support themselves, actively spending time in natural spaces to take care of themselves, rather than relying on medication or other options. This could reduce pressure on health and social services. This is growing already through the 'social prescribing' movement (Bickerdike *et al.*, 2017) in which doctors and other health professionals direct their patients to activities (e.g. Parkrun, 2019) rather than relying on medical interventions.

I suggest that central and local governments should focus efforts on ensuring that greenspaces are provided in locations where accommodation tends not to provide garden access (e.g., flats); maintaining the levels of greenspace access for young adults (which increased during the pandemic), and increasing the levels of greenspace access for older (which decreased during the pandemic). This could include providing and maintaining communal, diverse natural spaces for flats, work places and universities and encouraging use of balconies as mini-gardens or having indoor plants, especially in urban areas. Work spaces should emphasise the importance of taking breaks outside in natural spaces. Emphasising the importance of spending time in natural spaces and facilitating this needs to be completely interwoven into our health and social care systems, work and daily lives. By increasing access to greenspace in this way, the wellbeing of the UK public would likely increase.

Chapter 5

5. The natural environment partially determines route choices of pedestrians and cyclists

5.1. Abstract

There is substantial interest in cultural ecosystem services, the non-material benefits that people gain through connecting with nature. Such ecosystem services are difficult to value but the choices people make with respect to where they chose to spend their time are often used to reveal such values. Less research has explored the cultural ecosystem services people gain from nature on journeys they make. If a journey is the mechanism by which people connect with nature, then the choices made at junctions may reveal the extent to which they value travelling through nature (even if connection with nature was not the primary reason for the journey). Here, I use data from the biggest exercise social media platform, Strava, to explore if the characteristics of natural environments along roads/paths (i.e., how much vegetation and natural habitats are nearby) affects choices people make when faced with a junction. I analysed pedestrian and cycling data from Denbighshire County in North Wales, UK, from 2016 – 2019, and explored the extent to which four different nature metrics were associated with choices individuals make at a junction using generalised linear mixed effect models. The difference in the nature metric was a significant positive predictor in the direction people chose at junctions (regardless of the metric of nature used). This affect was found to be slightly stronger on the weekend, when people are more likely to be travelling for leisure than commuting. This study represents a novel use of Strava data to explore revealed preferences for 'greener' directions among people walking, running and cycling. An important caveat is that my findings show correlation between nature and the choice of direction at junctions but not causation - nature may be a proxy for a quieter, safer path. However, my findings support work on 'greening up' active travel routes, public rights of way and other routes to encourage use and to support active lifestyles.

5.2. Introduction

Cultural ecosystem services (ES) are the non-material benefits that people gain through accessing nature (Sarukhán and Whyte, 2005). Benefits include improving physical and mental health, feeling connected with the wider world, feeling connected to the past, family and community, and aesthetic appreciation (King *et al.*, 2017). The effort people make to access and spend time in nature is often used as an approach to demonstrate how valuable these cultural ES's are to people, for example the 'travel cost model' explores how much people are will to spend in terms of time and money to access a space (e.g. a National Park (Mayer and Woltering, 2018). Social media data can be used to explore what people value, the locations, habitats and features that they have chosen to visit and share images of (Hausmann *et al.*, 2018). Finally, people have been shown to be willing to spend more on houses close to green space (McCord *et al.*, 2014).

However, sometimes people do not only connect with nature at one particular space or destination – instead, the connection may be gained through movement or a journey (Venter *et al.*, 2020). For example, an individual going for a bike ride may be benefitting from the nature around them throughout the whole journey, with no single point where the ES is realised (Dolan *et al.*, 2021). Similarly, people may benefit from cultural ES even when that is not the main purpose of the journey. For example, people may be able to benefit from connecting with nature throughout their commute to and from work (Zijlema *et al.*, 2018).

If an entire journey is the mechanism by which someone connects with nature, the choices they make along their route can be used to evaluate the extent to which they value travelling through nature (Figure 5.1). Previous studies have shown that a multitude of factors can affect the routes people choose to take. For example, when walking for leisure in urban areas, noise, traffic levels, air pollution and greenspace have been found to be factors affecting route choice (Bunds *et al.*, 2019). Typically, a combination of these factors comes together to determine the final route individuals take and their choices at junctions. The relative importance of these factors can vary depending on socio-demographic group, environmental factors (both built and natural environment) and trip characteristics (e.g. destination, whether the trip is for leisure or work) (Basu *et al.*, 2022). Pedestrians often prefer to take the shortest route but will sometimes take a longer option if there is less traffic or if the route takes them past shops or parks (Basu *et al.*, 2022). Unsurprisingly, many of these factors also impact route choices for other modes of transport. For example, safety is a key factor that affects route choice when cycling, with cyclists shown to avoid areas of high traffic and to prefer cycle lanes where available (Broach, Dill and Gliebe, 2012) – a preference that is stronger in female cyclists than male (Misra and Watkins, 2018). Distance, how often they have to turn, slope and traffic controls have also been found to influence cyclists' route choices (Broach, Dill and Gliebe, 2012). Therefore, at each junction, an individual may be deciding which way to go based on multiple

factors. However, if cultural ES are important to decision making then I hypothesise that the characteristics of ecosystems along each route would be an important determinant of route choice.

Social media platforms, which provide huge amounts of data across space and time (Minin, Tenkanen and Toivonen, 2015), could be used to investigate this hypothesis – i.e. whether nature factors into route-based choices. Social media has already been used in ES research. For example, Martinez-Harms *et al.* (2018) used images from Flickr to explore who was accessing protected areas in Chile. Flickr is an online platform intended for amateur photographers to share images. Using the geotagged images and the home locations of visitors, they were able to establish how far people had travelled to access the protected area. Similarly, Martínez Pastur *et al.* (2016) used geotagged images to identify hot spots for four cultural ES's (aesthetics, existence value, recreation and local identity) in Patagonia. However, exercise social media platforms, which allow users to record routes (e.g. Strava [www.strava.com] and MapMyRun [www.mapmyrun.com]), have been little used to understand how and where people connect with nature. These platforms provide additional information in terms of the movements people make, and how they make them (walking, cycling, running etc) rather than just providing information at a single point. Strava, for example, is one of the biggest exercise social media platforms, with 76 million users in 2021 (Haden, 2021). It attracts ~1 million new users a month and more than 10 million activities are uploaded every week (George, 2020).

Within the Strava app, each activity produces a mapped route which can allow users to compare their times on specific segments to other users. Researchers and bodies that manage transport and planning can access data through Strava Metro (Strava 2022, metro.strava.com/). Through this, data can be viewed and whole datasets downloaded to analyse further. Through the dashboard, data can be aggregated by gender identity and other socio-demographic factors, allowing researchers to investigate differences in behaviours between these groups.

Strava data have been used previously to explore people's preferences when cycling. For example, Sun *et al.* (2017) found that Strava users cycling for recreation in Glasgow, Scotland were more likely to cycle on short streets with high connectivity to other streets and low volume of traffic. Griffin and Jiao (2015) found that when cycling for fitness, cyclists in Texas USA showed a preference for steep terrain, but when commuting, hills were avoided. Strava data have also been used to explore cyclists' exposure to air pollution (in Glasgow, Scotland, Sun, Moshfeghi and Liu, 2017) and to observe how cycling traffic changes in response to changes in road infrastructure (in Canada, Boss *et al.*, 2018).

Here, I use Strava data to explore if the characteristics of natural environments along routes (i.e., how much vegetation and/or water bodies are nearby) affects choices made when faced with a junction during a journey. I hypothesise that:

1. When travelling, people (consciously or subconsciously) prefer routes with more vegetation and waterbodies (Figure 5.1).
2. People will be more likely to choose routes with more nature on the weekend when they have less time pressures compared to during the week
3. People will be more likely to choose routes with more nature in the Spring and Summer compared to Autumn and Winter when the contrast in the directions with more vegetation will be greater compared to those with less.

Additionally, I predict that slope will be an important factor in peoples' choices and account for this in my models.

Throughout, I contrast the difference in route choices when compared to chance alone (i.e., the difference between the observed route choices and those that would have occurred if people had chosen a direction randomly given the possible route options available). For simplicity, this will be referred to as the 'difference in choices' henceforth. Similar differences in nature metrics (i.e., differences in the characteristics of the natural environment between possible route options and those taken) and slope were also calculated.

I use the terms 'nature' and 'natural environment' to describe vegetation and features such as water bodies along the routes that people are travelling. I acknowledge that these features and spaces will not be entirely 'natural' in that they will be heavily influenced by human activity. However, I chose these terms to represent components of nature along routes rather than 'greenspace' to avoid suggesting I mean only designated or official greenspace.

Figure 5.1. When faced with a junction, the characteristics of local natural environments may factor into the choice of which route is taken. For example, if 100 people enter a junction with two possible outbound routes, the null hypothesis would expect 50 people to choose outbound direction A and 50 people to choose outbound direction B (i.e., by chance), a split of 0.5 each way. However, if local natural environment is a key factor for direction-based choices, then less people than expected by chance might choose Direction A which is more built up, and more people chose Direction B which has more nature (as shown in the figure). Having expected a proportion of 0.5 of the people to go each way, if 0.1 (10 people) are actually observed to go in Direction A and 0.9 (90 people) go in Direction B, then this gives a difference in people of -0.4 in Direction A and 0.4 in Direction B.

5.3. Methods

5.3.1. Data Collection

I obtained pedestrian (walking, running and hiking) and cycling Strava data for Denbighshire County, North Wales (Figure 5.2) for 2016 – 2019. This time span of the previous four years was standard availability from Strava at the time when providing data for research purposes. Pedestrian and cycling data were considered separately in the analysis. Strava data are divided into sections of road or path between each possible junction (termed 'edges'), using OpenStreetMap (OpenStreetMap, 2022). For Denbighshire, this (GIS shapefile dataset consisted of 26,853 edges (Figure 5.2). To this edge dataset it is possible to join datasets giving the number of people (users, termed 'athletes') on each edge for different time spans; for example, the whole of 2016, or all the weekends in 2016. The number of people is rounded to the nearest 5 to prevent identification of individuals, therefore any

count less than 5 does not appear in the dataset. These data are summarised as totals for weekdays, weekends and commutes per month and per year.

Denbighshire covers an area of 326 square miles (844km^2) and has a population of approx. 95, 800 people (Office for National Statistics, 2022), of which 49% are men and 51% are women (Varbes, 2023). The median age of the population in 2019 was 47 years (Varbes, 2023). The largest towns are Rhyl and Prestatyn on the north coast. Denbighshire has a varied landscape with the Clwydian Range mountains to the east of the county, the Berwyn Range mountains (with the highest point at 827 m) to the south, Denbigh moors to the west and the river Clwyd running from north to south through the centre of the county (Denbighshire Countryside Service, 2023).

Strava users are unlikely to be representative of the population as a whole (Griffin and Jiao, 2019; Lee and Sener, 2021). To check how representative Strava data was of cyclists, I used data from 29 cycle counters in Denbighshire County for the same time span as the Strava data (each month in 2016 – 2019). Cycle counter data was provided by Denbighshire County Council. The data gave counts of cyclists in both directions and total at counter points throughout the county for every month in 2016 - 2019. I compared the counter data and corresponding Strava activity cycling data for the edge the counter lay on. I computed a Pearson correlation coefficient to explore the relationship between cycling Strava data and cycle counter data for the same edges, which showed there was positive relationship between the two samples (r = 0.36, p<0.001) whereby Strava users made up on average 15% of the total activities each month compared to cycle counter data (e.g. compared to 7% found by Fischer, Nelson and Winters (2022) for Vancouver and Victoria in Canada). Pedestrian counter data were unavailable to compare. I therefore concluded that the Strava data were moderately representative of population of cyclists.
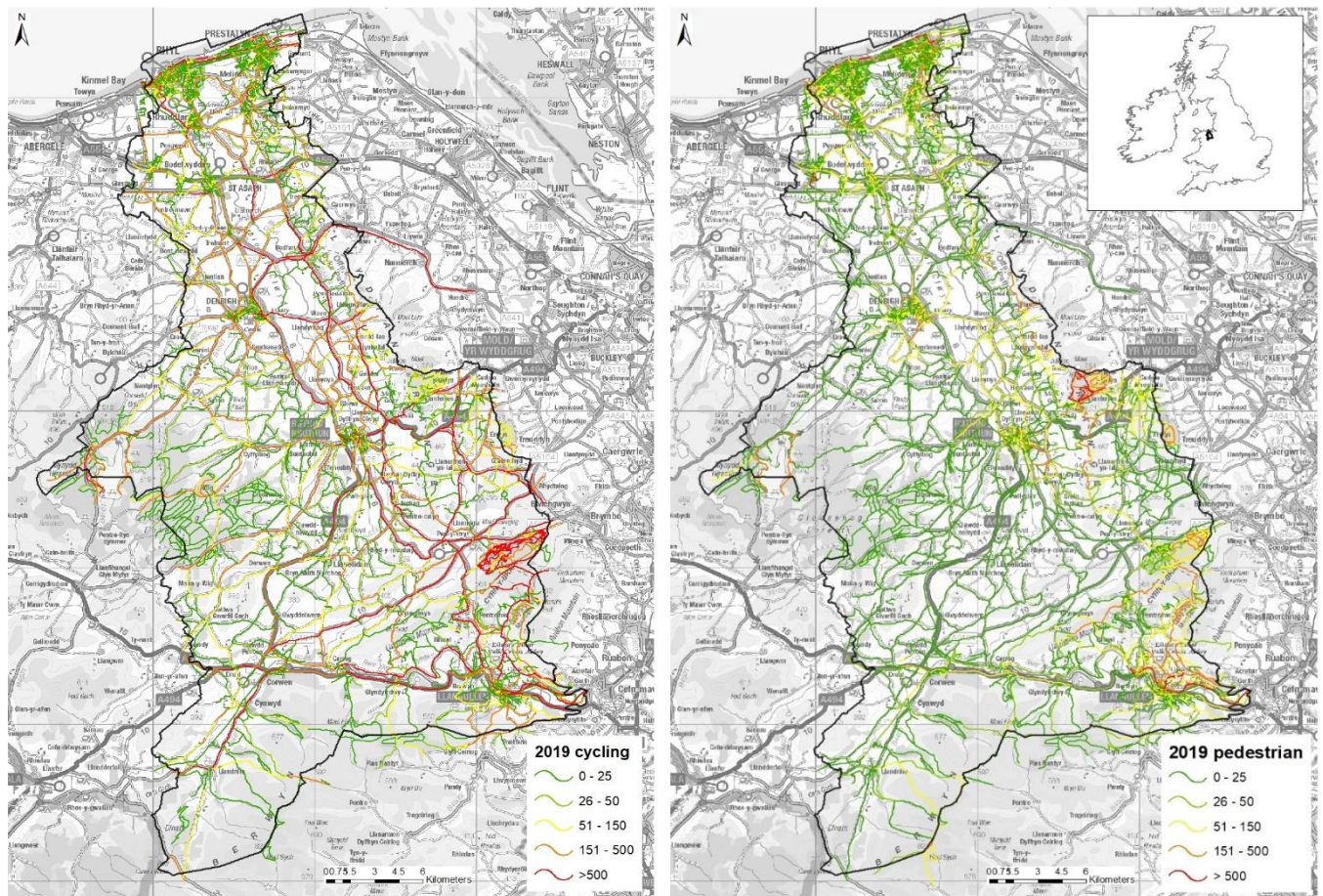
Figure 5.2. Strava data overlaid on an Ordinance Survey basemap for Denbighshire County (black outline), North Wales. The sections of roads and paths, 'termed edges' are based on OpenStreetMap (OpenStreetMap, 2022). Data for the number of people recorded cycling (left) and walking, running or hiking (right) on each edge over the whole of 2019 has been joined to these spatial data as an example, with the number of people shown ranging from 0-25 (dark green) to more than 500 (red). © Crown Copyright and database right 2022 Ordnance Survey 100021874

I collated remotely sensed data to provide different metrics to quantify the characteristics of natural ecosystems across the Strava edges (Table 5.1). Specifically, I used two different 'nature metrics', which were: tree canopy cover (Hansen *et al.*, 2022) and land cover (Morton *et al.*, 2020). I categorised land cover in two different ways: i) urban and suburban as 0 and all other land covers as 1, to equate to 'not nature/nature'; and ii) urban and suburban as 0, intensively managed habitats such as improved grassland, arable and forestry as 0.5 and semi-natural habitats such as broadleaf woodland and species-rich grassland as 1. I sourced slope data at a resolution of 25m to factor in the effect of slope on athletes' choices (Copernicus Land Monitoring Service, 2016). This gave a value for overall gradient for each cell. In R Statistical Software (v4.1.2; R Core Team 2021). I used the extract function from raster package (Hijmans, 2021) to extract the nature metric values from these raster layers corresponding to the Strava edges (ensuring zero-value cells were included)

(Figure 5.2). I extracted the nature metric of each edge in the Strava data using four extraction protocols:

- **The whole edge** – representing individuals who may have knowledge of the whole edge
- **100 m along the edge from the junction** representing the natural characteristics that might be within sight of the junction (i.e., no knowledge of the characteristics of the rest of the edge)
- **A 20 m buffer around each edge** – representing the natural characteristics that might be within sight of the edge whilst they travelled along it, with knowledge of the full edge
- **100 m along the edge from junction including 20 m buffer either side** – as above, but representing the natural characteristics that might be within sight of the junction (i.e., no knowledge of the viewshed across much of the edge).

Table 5.1. – Remotely sensed layers from which greenness values were extracted corresponding to Strava edges for Denbighshire, North Wales.

Layer	Description	Reference/Source
Land cover 2019 This layer allowed the inclusion of blue space as well as green space and gave the option to extract greenness in different ways.	Values were extracted from this layer in two different ways; 0/1 in which urban and suburban were categorised as 0 and all other land covers as 1, to equate to 'not green/green' (land cover 1). 0/0.5/1 in which urban and suburban were categorised as 0, agricultural land cover categories were categorised as 0.5 and natural categories were categorised as 1 to equate to 'urban/semi-natural/natural' (land cover 2). Resolution: 25 m Source: CEH Raster data	(Morton *et al.*, 2020)
Canopy cover Hansen	Percentage canopy cover calculated from a time-series analysis of Landsat images	(Hansen *et al.*, 2013)

This layer is just tree cover rather than all vegetation so allowed the exploration of the effect of canopy cover and larger, more obvious features in the landscape.	showing forest extent and change from 2000 – 2019. Resolution: 30 m Raster data	
Slope	An additional variable to account for factors other than greenness that may affect peoples' decisions at junctions. Resolution: 25 m Source: Copernicus Raster data	(Copernicus Land Monitoring Service, 2016)

5.3.2. Data Processing

I extracted datasets for weekends and weekdays for each month in each year and joined these to the nature metrics of the four different types. I used the spatial coordinates of each edge to identify edges that meet at a junction (i.e., at the same point). I identified the total number of people entering the junction. To minimise spatial autocorrelation and to account for some directions being more popular (i.e., having more people) than others, I calculated the proportion of people that selected each possible direction at that junction rather than use absolute numbers. I then calculated the difference in the proportions of people, difference in proportion of nature metrics and difference in proportion of slope (i.e., observed proportion minus expected proportion, the latter derived by random choice given the direction options available) for each of the outbound edges available at a junction (Figure 5.1). As slope can indicated a gradient up or down, I also included overall slope in the analysis to account for this. This process was repeated for all possible inbound directions at all junctions (Figure 5.2). All differences in choices, nature metrics and slope were rescaled between 0 and 1, enabling a binomial distribution to be used in the analysis. This was necessary as I was analysing proportional data. The final dataset used to run the model was 1,719,264 observations, in which each observation was the difference in choices at a junction at a point in time with associated difference in nature metric and slope.

To partition the data more meaningfully, I created two different subsets of the main datasets. I separated out rural and urban edges by joining the edges to the Land Cover raster (25 m resolution) that I had reclassified to show 'not natural' (built) and 'natural' (not built) areas in ArcGIS. This gave a dataset of edges in which each edge a value of 1 for rural and 0 for urban. I merged this dataset in R with the final datasets for each greenness metric, and then created a Rural and Urban subset for each.

I also separated out times when people were likely to be commuting and times when they would be more likely to be travelling for leisure. I did this by following the data processing steps described above but instead of using the total number of people entering the junction, I only used the people who had recorded on Strava in time segments that matched the morning and evening commute. Strava breaks the day into 5 segments; 0 – early morning, 1 – morning commute, 2 – over midday, 3 – evening commute, 4 – late night. I used slots 1 and 3, summed, to create the commute data set. I then repeated the processes for time slots outside the morning and evening commute (0, 2 and 4, summed). This gave me Commute and NonCommute datasets for each nature metric. I used only weekday data to create these datasets.

I ran the models described below on the full data sets and these subsets.

5.3.3. Data Analysis

I ran the following generalised linear mixed effect models:

Difference in choices ~ Difference in nature metric*WkendWkday*Season + Difference in Slope + Slope + (1|Year) + (1|JuncationCat)

(Equation 1)

In which: 'Difference in choices' is the difference in observed proportion of people choosing that direction compared to the proportion that would be expected if the choice at the junction was taken by chance; Difference in nature metric' is the difference in observed proportion of the nature metrics on the exiting edges from the junction compared to if they were all equal (hypothesis 1); 'WkendWkday' is whether the activity was recorded on a weekday or weekend (hypothesis 2); 'Season' is Spring, Summer, Autumn, Winter (hypothesis 3); ''Difference in slope' (gradient) is difference in observed slope on the exiting edges from the junction compared to if they were all equal (hypothesis 4); 'Slope' is overall gradient of the edge; Year is 2016-2019 respectively as a random factor; and the 'junction' variable (which gave an identifier to each junction analysed) was converted to categorical variable ('JunctionCat') and also considered a random factor. * indicates an interaction between variables (including the main effects). Interaction terms were included because it was hypothesised that nature may be more important to choices on the weekend when people may be

more likely to be travelling for leisure (hypothesis 2) and in Spring and Summer when the contrast between directions with more vegetation cover compared to those with less would be greater (hypothesis 3).

Due to the large size of the datasets, data processing and modelling was carried out with Supercomputing Wales. Supercomputing Wales is the national supercomputing research facility for Wales and its two computing hubs allow researchers to undertake large analyses significantly faster than would be possible with standard computing. A highly parallel and efficient workflow was developed to process the models on the Supercomputing Wales service. The models had been configured to request 1 core (Intel(R) Xeon(R) Gold 6148 CPU @ 2.40GHz) with 8GB of memory and a maximum of 7 days runtime of computing resources.

With a total of 8 data preparation workflows and 8 data model workflows for each nature metric for the overall dataset, the sum of the requested computing resources was as follows:

- Cores: (8 models) * (4 cores) * (2 workflows) = 64 cores
- Memory: (8 models) * (32 GB) * (2 workflows) = 512 GB
- Runtime: (8 models) * (7 days) * (2 workflows) = 112 days

The models were developed to recover from any failures in code or hardware with periodic checkpointing to save the workflow's state to disk. Access to the Supercomputing Wales service and its ability to run multiple workflows in parallel reduced the average runtime to obtain all the results to 3 days.

5.4. Results

Results were broadly consistent across all nature metrics. Here, I present the results for pedestrian data using the nature metric whereby land cover was classified into 'natural' or 'not natural' (i.e., urban and suburban land cover compared to land that is not built on; Figure 5.3), and highlight any differences to the other nature metrics (whose results are presented in Appendices 3.1. and 3.2.).

Figure 5.3. Coefficient plots showing effect of coefficients and interactions on difference in pedestrians based on Strava data choosing junction exits in Denbighshire, Wales in 2016-2019. In which: 'Wkend' is whether the activity was undertaken on the weekend or a weekday, with weekday as the reference level, 'Spring/Summer/Winter' are the season the activity was undertaken with 'Autumn' as the reference level, 'Diff. Nature' is the difference in the nature metric on each exiting edge from junctions compared to all being equal, 'Diff. Slope' is the difference in slope (gradient) on each exiting edge compared to all being equal, 'Slope' is overall Slope on the edge and * indicates an interaction between the variables. Red indicates that the estimate of the coefficient is negative, blue indicates that the estimate is positive. 'Diff. Nature' and 'Diff. Slope' are statistically significant.

For the pedestrian data using the natural/not natural land cover nature metric, all four extraction protocols (the whole edge, the first 100m of the edge, the whole edge plus a 20m buffer and the first 100m plus a 20m buffer) showed that difference in nature metric was a significant predictor of the difference in choices – the more natural the direction, the more people chose that direction (p<0.001; Figure 5.3, Figure 5.4). Differences in nature metric explained ~15% of the direction -based choice,

rising to 17% when considering the whole edge plus a 20m buffer (the largest area of the four different extraction protocols; Figure 5.4). These results are consistent across all nature metrics (Appendices 3.1. and 3.2.), suggesting this is not a chance outcome.

Figure 5.4. The difference in nature metric showed a positive relationship on pedestrians' choices using Strava data at junctions, with more people likely to choose directions with higher proportions of nature. Data shown here uses land cover classified into 'nature/not nature' as a nature metric, in Denbighshire, Wales, 2016-2019.

The pedestrian data using the natural/not natural land cover nature metric also highlight some patterns that were less well supported by the other analyses (e.g., other nature metrics and/or using data from cyclists). For example, regarding hypothesis 2, when considering difference in nature metric for the first 100m of the edge with a 20m buffer, the effect of the difference in nature metric on the direction chosen was found to be stronger (i.e., more positive) on the weekend – when people potentially have fewer time pressures (p<0.01; Figure 5.5). This pattern was also found for cycling data using the natural/not natural land cover nature metric for the first 100m of the edge, but was not found using land cover categorised into urban/intensively-managed/semi-natural, canopy cover for pedestrian or cycling data. For hypothesis 3, no relationship was found between season and the

difference in people choosing directions with more nature using canopy cover or either land cover nature metric.
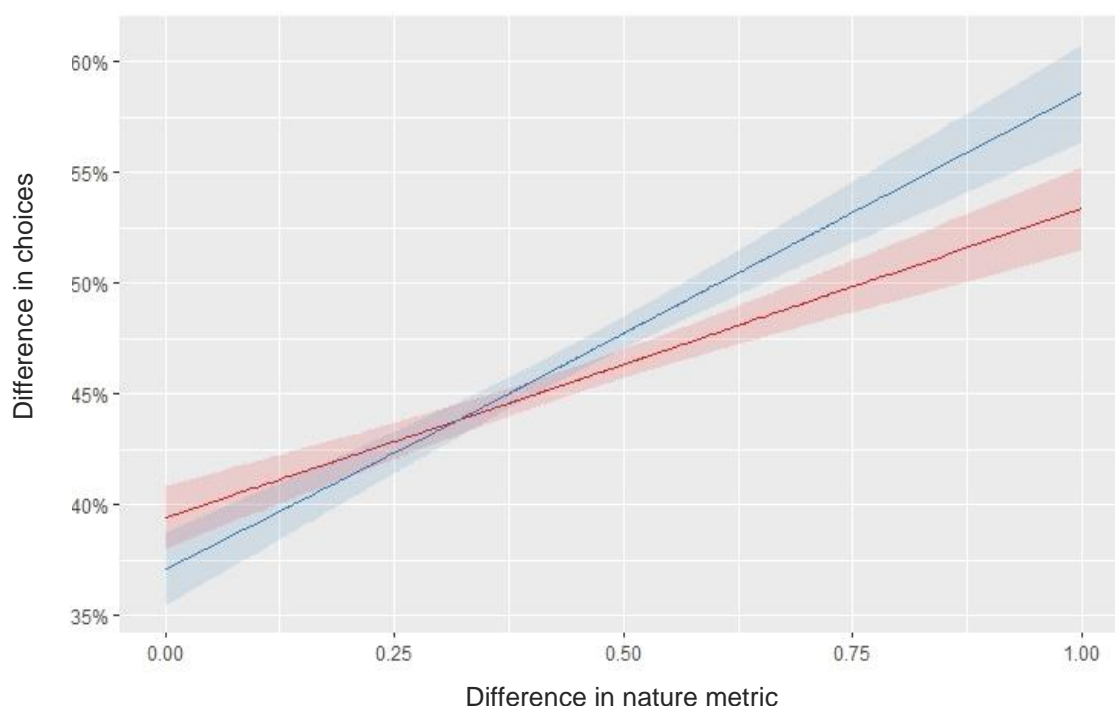
Figure 5.5. The positive effect of difference in nature metric on pedestrians' choices using Strava data at junctions was stronger at weekends (blue) than weekdays (red) when using land classified into 'natural' and 'not natural' as a nature metric and using the extraction protocol that focussed on the first 100m of the edge with a 20m buffer in 2016-19 in Denbighshire, Wales. Due to the variables being rescaled, 0/0 is at 0.5/50 on the axis.

For the data subsets broken down into rural and urban edges, all four extraction protocols for the **rural** subset showed the opposite pattern to the overall dataset; the difference in the nature metric was a significant predictor of the difference in choices but the **more** natural the direction, the **fewer** people chose that direction (nature for the whole edge - $p<0.001$, first 100 m of the edge - $p<0.01$, whole edge plus 20m buffer - $p<0.001$, nature for first 100m of the edge plus 20m buffer – $p<0.05$, Figure 5.6, Figure 5.7). This could be due to the rural nature of the study area; if people chose a direction where the edge had one house compared to no houses this edge would have comparatively less nature compared to the other even if was still largely vegetated.

For the **urban** subset, all four extraction protocols showed the same pattern as the overall dataset, in that the difference in nature metric was a significant predictor of the difference in choices – the **more** natural the direction, the **more** people chose that direction ($p<0.001$; Figure 5.8, Figure 5.9). This effect was found to be stronger on the weekend when considering nature for the first 100 of the edge ($p<0.05$) as was found with the overall dataset. When looking at nature for the first 100 m of the edge and the first 100 m plus a 20 m buffer, the season had an influence, with effect of nature

on peoples' choices being less strong in the Summer. This could be due the contrast between different directions being less in the summer when the vegetation is at its greenest.

When considering the other greenness metrics, land cover split into semi-natural/intensively managed/built showed the same pattern as land cover split into built/not built discussed here. When looking at Hansen tree canopy cover however, in rural and urban areas the greater the tree cover, the more people chose that direction. This could be because trees specifically are larger, more obvious features in the landscape that can be seen from junctions.

When looking at the data subsets broken down in to commuting and non-commuting times on weekdays, there was no significant effect of difference in nature on peoples' choices for all extraction protocols (p>0.05). This is likely to be because, when considering the overall dataset, the effect of nature on peoples' choices was found to be stronger on the weekend. Therefore, no effect was found considering the weekdays only. This subset was created looking at weekdays only because that is primarily when people commute.
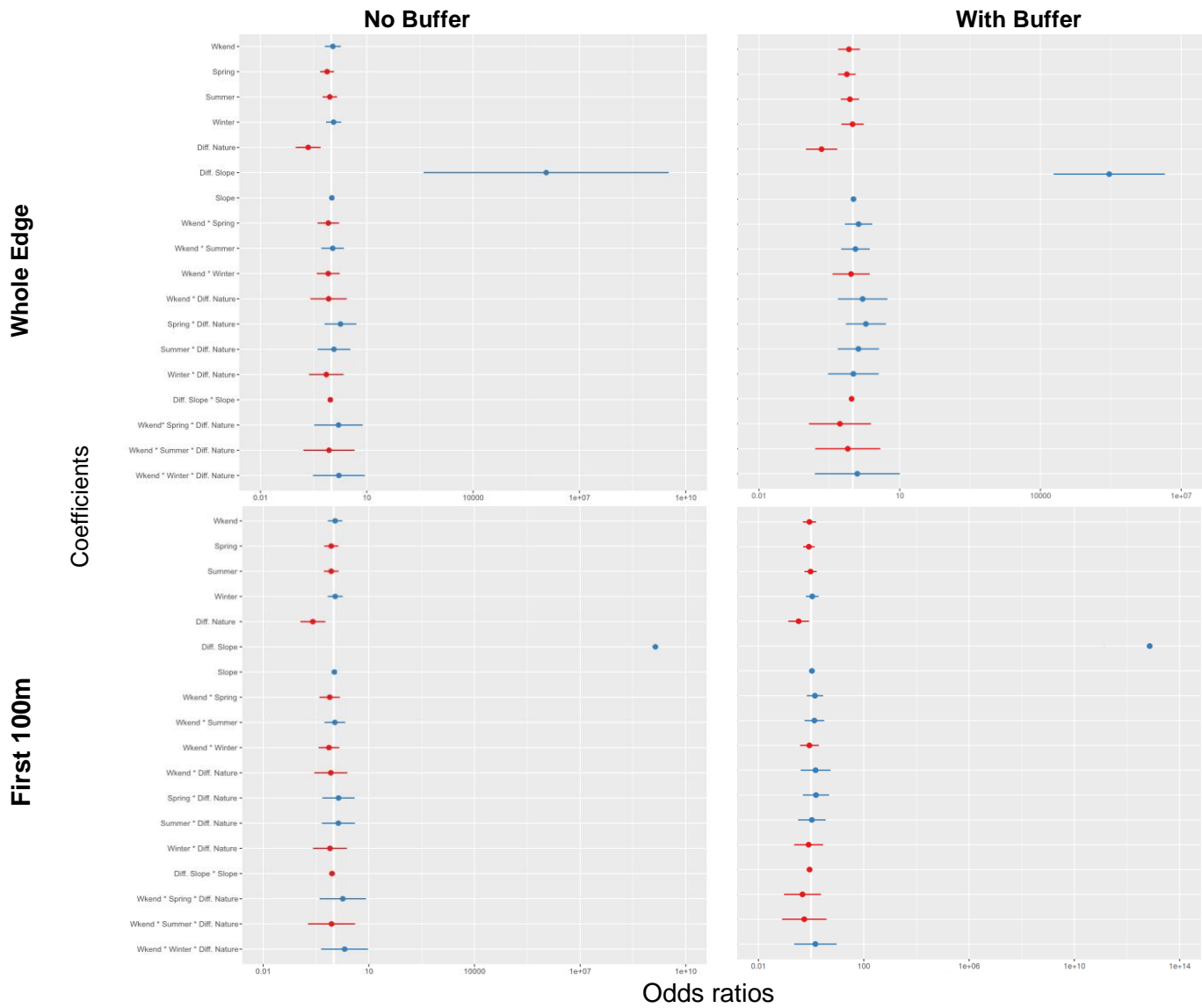
Figure 5.6. Coefficient plots showing effect of coefficients and interactions on difference in pedestrians in **rural** areas based on Strava data choosing junction exits in Denbighshire, Wales in 2016-2019. In which: 'Wkend' is whether the activity was undertaken on the weekend or a weekday, with weekday as the reference level, 'Spring/Summer/Winter' are the season the activity was undertaken with 'Autumn' as the reference level, 'Diff. Nature' is the difference in the nature metric on each exiting edge from junctions compared to all being equal, 'Diff. Slope' is the difference in slope (gradient) on each exiting edge compared to all being equal, 'Slope' is overall Slope on the edge and * indicates an interaction between the variables. Red indicates that the estimate of the coefficient is negative, blue indicates that the estimate is positive.

Figure 5.7. The difference in nature metric showed a positive relationship on pedestrians' choices in **rural** areas using Strava data at junctions, with **less** people likely to choose directions with higher proportions of nature. Data shown here uses land cover classified into 'nature/not nature' as a nature metric, in Denbighshire, Wales, 2016-2019.
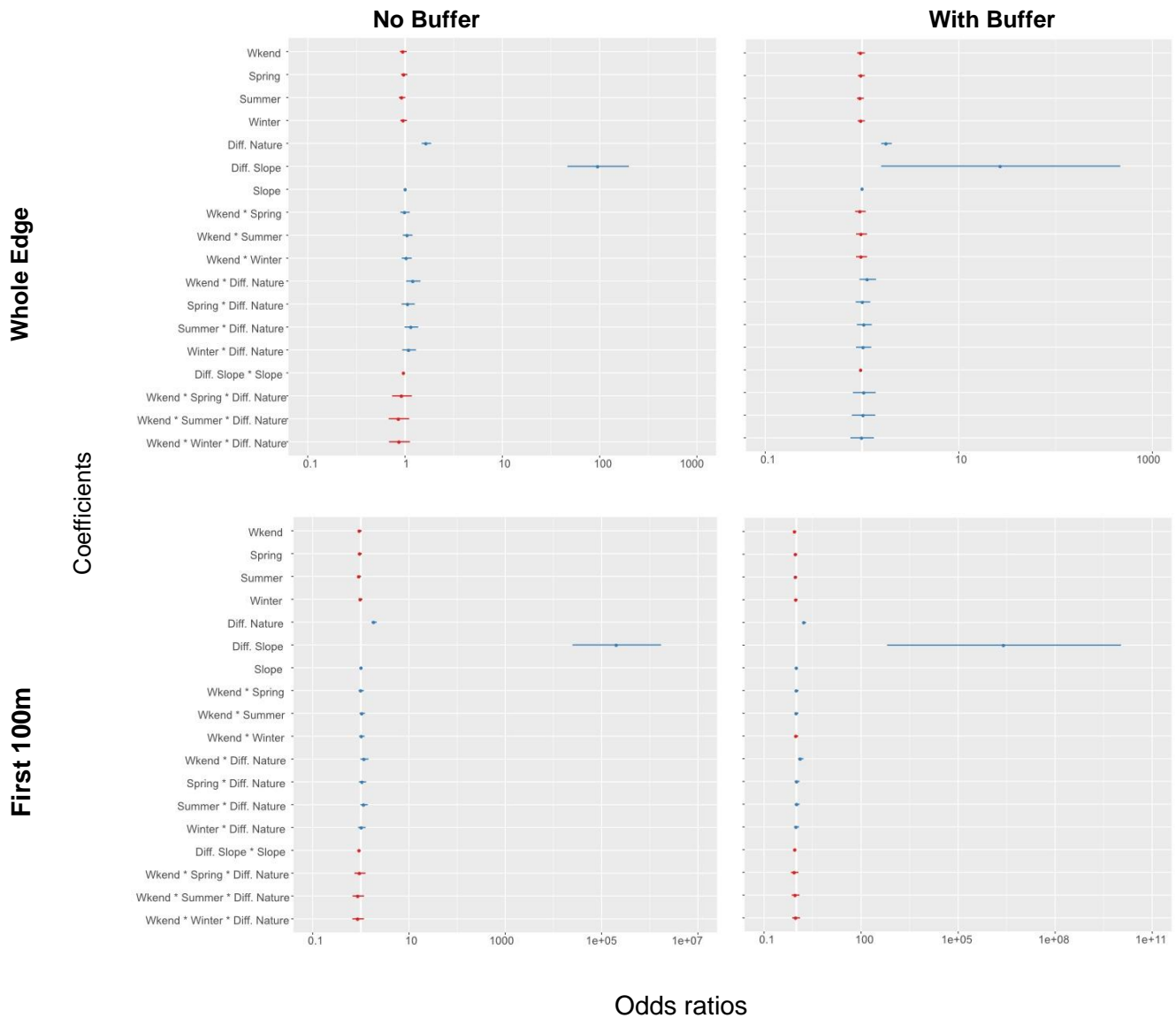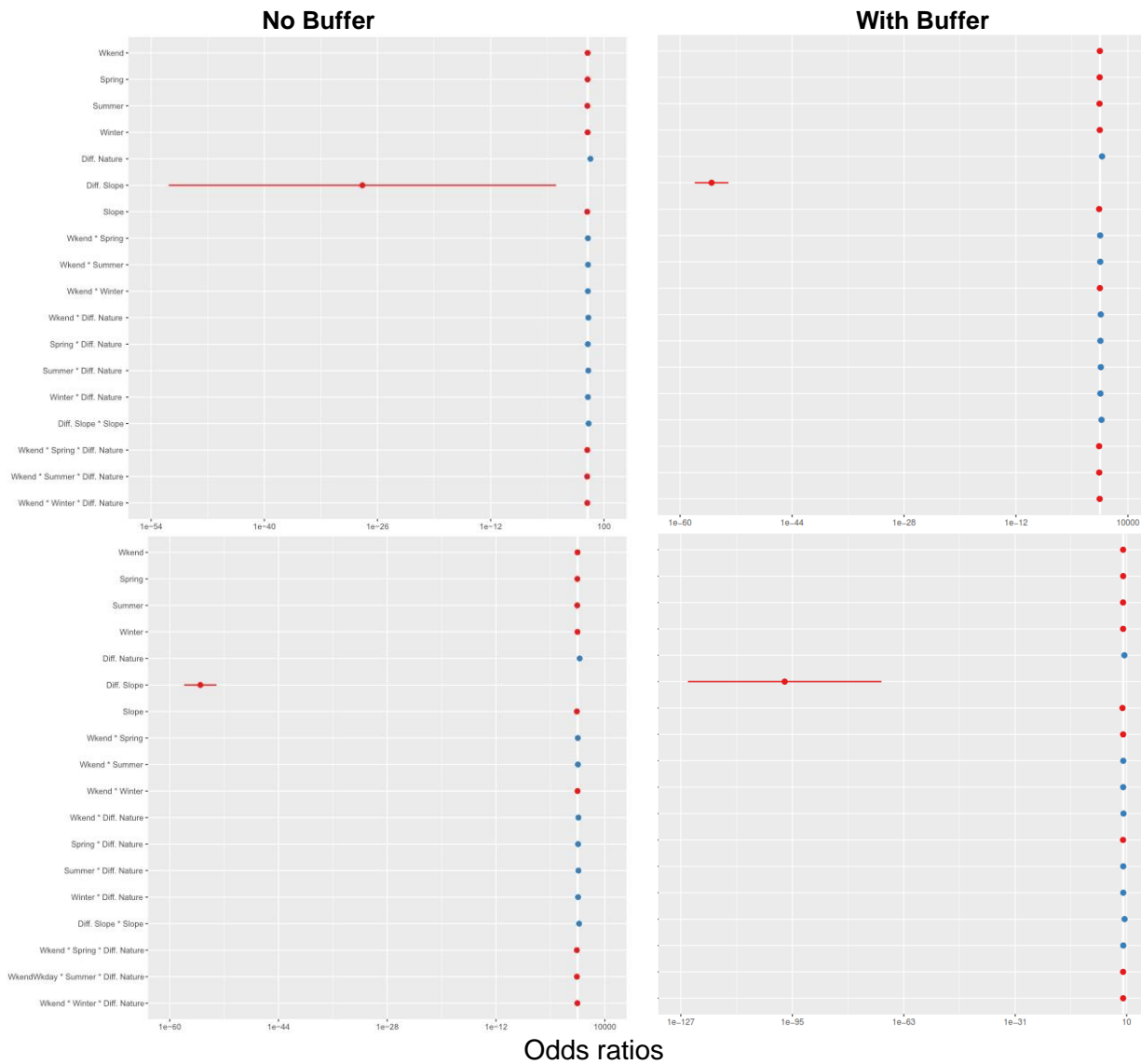
Figure 5.8. Coefficient plots showing effect of coefficients and interactions on difference in pedestrians in **urban** areas based on Strava data choosing junction exits in Denbighshire, Wales in 2016-2019. In which: 'Wkend' is whether the activity was undertaken on the weekend or a weekday, with weekday as the reference level, 'Spring/Summer/Winter' are the season the activity was undertaken with 'Autumn' as the reference level, 'Diff. Nature' is the difference in the nature metric on each exiting edge from junctions compared to all being equal, 'Diff. Slope' is the difference in slope (gradient) on each exiting edge compared to all being equal, 'Slope' is overall Slope on the edge and * indicates an interaction between the variables. Red indicates that the estimate of the coefficient is negative, blue indicates that the estimate is positive.
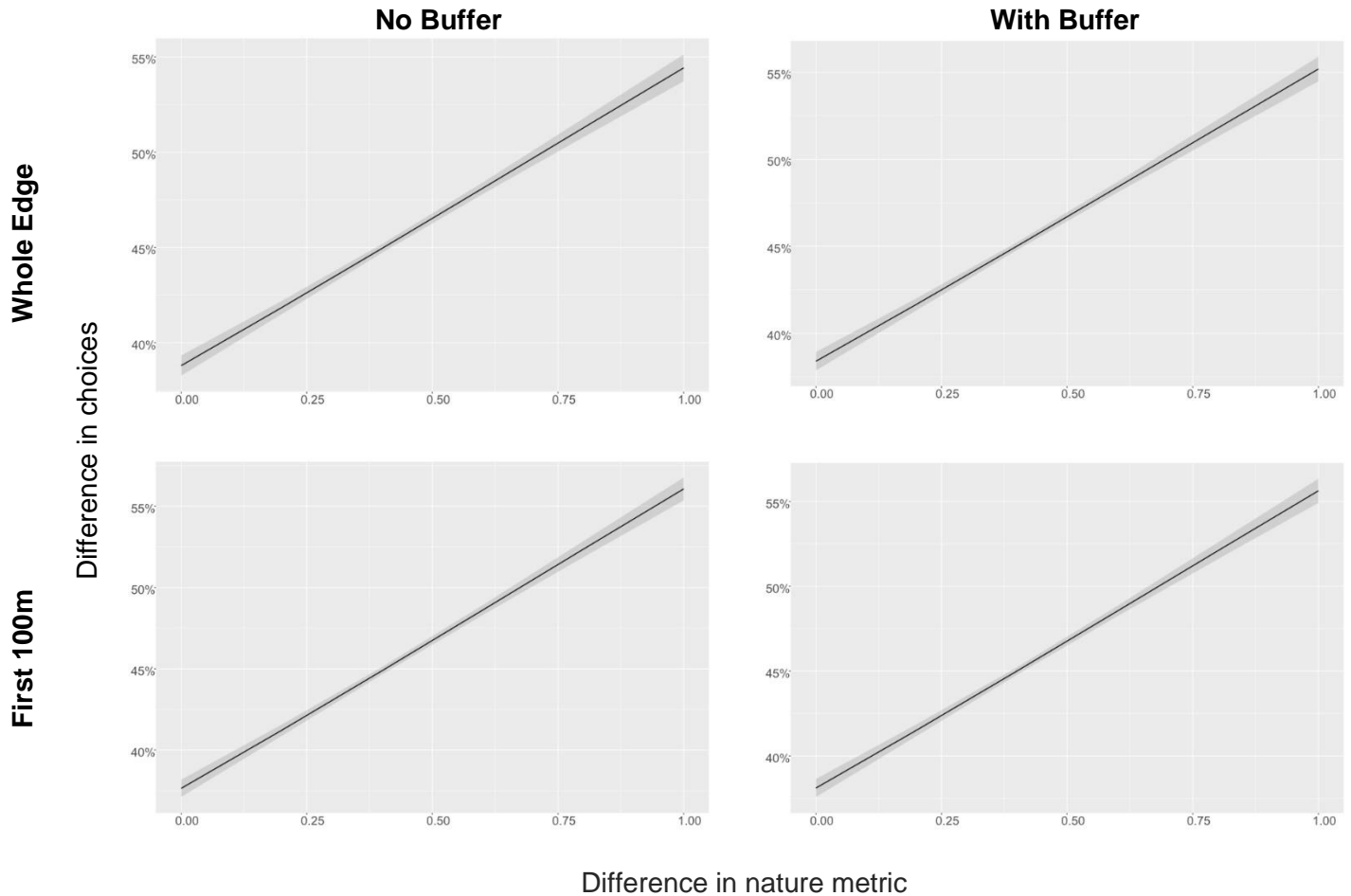
Figure 5.9. The difference in nature metric showed a positive relationship on pedestrians' choices in **urban** areas using Strava data at junctions, with **more** people likely to choose directions with higher proportions of nature. Data shown here uses land cover classified into 'nature/not nature' as a nature metric, in Denbighshire, Wales, 2016-2019.

5.5. Discussion

My study represents a novel use of Strava data looking at the difference in the number of people walking, running and cycling choosing a direction at junctions based on surrounding landcover compared to what would be expected by chance.

My findings suggest that, when faced with a junction, pedestrians and cyclists choose directions with higher proportions of nature than would be expected by chance (Figures 5.3 and 5.4; Appendix 3). This result is consistent across all nature metrics investigated in this analysis, which provides strong evidence of a real-world relationship. My study develops previous findings that suggest that frequency of pedestrian and cycling activity correlates with nature. For example, parks and greenery add to the attractiveness of a road/path and increase the likelihood of pedestrians and cyclists selecting it (Wang *et al.*, 2020; López-Lambas, Sánchez and Alonso, 2021). Natural spaces may encourage people to take longer routes to walk through or adjacent to them (Basu *et al.*, 2022). My study builds on this by considering behavioural choices rather than just looking at the absolute number of people taking different directions.

Simply spending time in nature has been found to be important for wellbeing (White *et al.*, 2019; Meredith *et al.*, 2020). There is evidence to support the mental health benefits of direct connection and engagement with nature such as through simple actions like smelling flowers and noticing seasonal changes (Capaldi *et al.*, 2015; Richardson *et al.*, 2021). Greater diversity of plant species and enhanced natural spaces with additional planting have been found to be stimulating and considered more attractive, whereas more subtle greenery creating a 'green background', was found to be more calming and restorative (Hoyle, Hitchmough and Jorgensen, 2017). Here I am capturing time spent and exposure to nature through movement; running, walking and cycling, either as leisure or to commute, rather than in one space. The fact that people are choosing the directions with more nature implies they value what the direction provides to them.

5.5.1. Limitations

My analysis uses observed choices at junctions using data from Strava. However, it could be confounded if the natural metrics were correlated with other factors not included in the analysis (like level of traffic – a road with more nature may have less cars). The volume of vehicle traffic alongside a walking route has been found to be an influential factor in choices, with people preferring routes with less traffic (Riggs and Gross, 2017; Sevtsuk *et al.*, 2021). Thus, whilst it might appear that people are favouring more natural routes, they may in fact be choosing other factors that are correlated with my natural metrics, like quietness or less air pollution. Roads with greater vegetation cover along the sides could be smaller roads where the traffic is slower so people are therefore at less risk of traffic collisions with high-speed traffic, which is especially a consideration if someone is

cycling, running or walking directly on the road. Van Treese *et al.* (2017) found that tree cover along roads was correlated with reduced driving speeds and also reduced stress and frustration in drivers, resulting in safer driving and a safer experience for cyclists and pedestrians on the road.

In some circumstance, people might be expected **not** to choose directions with greater vegetation cover. For example, areas with greater vegetation cover, especially tree cover may have poor visibility especially later in the day or early in the morning when it is dark and so deem them to be unsafe (Sreetheran and van den Bosch, 2014; Pérez-Tejera *et al.*, 2022). When considering the whole dataset, I did not find any difference in the winter compared to summer when visibility could be more of a consideration in direction choice due to reduced daylight hours. However, season did have an effect when considering rural and urban, and commute and non-commute subsets. For urban subsets, the effect of nature on peoples' choices being less strong in the Summer. This could be due the contrast between different directions being less in the summer when the vegetation is at its greenest. Further study could explore if there is a difference in peoples' direction choices based on time of day. Additionally, further study could also consider including the type of road/path in the analysis; e.g., whether it is a road with heavy traffic, with less traffic, a cycle path or a footpath.

For the data subsets broken down into rural and urban edges, all four extraction protocols for the **rural** subset showed the opposite pattern to the overall dataset; the difference in the nature metric was a significant predictor of the difference in choices but the **more** natural the direction, the **fewer** people chose that direction. This could be due to the rural nature of the study area; if people chose a direction where the edge had one house compared to no houses this edge would have comparatively less nature compared to the other even if was still largely vegetated. When looking at Hansen tree canopy cover however, in **rural** and **urban** areas the greater the tree cover, the more people chose that direction. This could be because trees specifically are larger, more obvious features in the landscape that can be seen from junctions.

My analysis assumes that the destinations people are moving towards and randomly distributed with respect to possible directions. Realistically, this will not be the case, people will be following routes and the destinations that people could be aiming for like workplaces, shops and residences will be grouped. Strava data were only available as numbers of people on each 'edge' within different time segments. While people obviously follow routes, there is no way of reconstructing these routes because individuals cannot be identified. To minimise spatial autocorrelation and to account for some directions being more popular (i.e., having more people) than others, the proportion of people that selected each possible direction at that junction was calculated rather than using absolute numbers. I might have expected that people heading to these destinations would choose directions with less nature, and would therefore mask those choosing the directions with more nature. As this was not the case, and people choosing directions with more nature came out as a strong pattern across all nature metrics, this suggests that it is strong evidence of a real-world effect.

As it was not possible to identify routes, my analysis focused on junctions to overcome this issue. Rather than consider absolute numbers of people on an edge, the analysis focussed the realised decisions people make at each junction between edges. It assessed the proportions of people arriving at any junction that chose each of all possible edges, and whether that proportion was related to the relative greenness of the edges available. As such, the absolute numbers of people arriving at a junction do not affect the response variable, but the choices they make do. This captures choices between edges based on the differences in nature between those specific edges rather than assuming people distribute themselves over the whole area based on the relative naturalness of all edges. The null hypothesis is therefore that people choose randomly among edges at any particular junction.

In real life, this is unlikely as the choices will be driven by the start and end point of each individual. There will certainly be variation among individuals in their start and end points, which is most simply represented by assuming random choices. However, our approach considers every possible junction from every possible direction, and so captures the decisions made in every possible journey. If no effect of nature had been found, it is likely that straightforward choices as to the easiest route to the destination were dominating the choices made at junctions, even if that could not be included in the analysis (i.e., it was a source or error). The fact that greenness was found to be a significant factor suggests this is a strong effect that emerges despite other potential sources of variation in the choices made at junctions.

Whilst this research provides strong evidence that the quality/quantity of the natural environment available may impact route-based choices for both pedestrians and cyclists, the choice-making processes at junctions are complex. Choices at individual junctions are part of a whole route choice and so people may make counter-intuitive choices (e.g., picking the least natural route at one junction, because they know that several junctions later it leads to cumulatively high levels of nature and associated cultural ES). The direction with the most vegetation may not take people to their desired destination, such as their workplace or shops. Similarly, at each junction, the local natural environment is likely one of many metrics that are factored into the choice. For example, people prefer simpler routes with as few direction changes as possible (Shatu, Yigitcanlar and Bunker, 2019), so they may not choose a direction with more nature if it makes the whole route more complicated. Basu and Sevtsuk (2022) explored how different attributes affect 'willingness to walk' in Boston and San Francisco using routes from smart phone apps. In addition to nature, they found journey length, the ability to connect to other forms of transport, exposure to traffic, path/pavement design and access to shops all affected willingness to walk.

Although social media data can be valuable and informative, care needs to be taken to ensure that the data harvested are representative of the population (Tufekci, 2014). The use of Instagram has been found to decrease with age and income, whereas sites like Flickr are used more by professional

photographers and wildlife enthusiasts (Hausmann *et al.*, 2018). Strava data is not representative of the population as a whole in terms of age, gender and reasons for cycling/walking. More men than women use Strava, more younger people than older and users tend to be training and fitness focused (Griffin and Jiao, 2019; Lee and Sener, 2021; Fischer, Nelson and Winters, 2022). That said, the cycling Strava data accessed for Denbighshire was found to be a moderately good proxy of the cycle counter data for the county, which suggests the cycling data from Strava is probably at least representative of cyclists in Denbighshire as a whole (i.e., Strava users plus non-users). However, while Strava is useful in exploring preferences while walking and other forms of exercise, direction choice of Strava users may also be based on training or fitness outcomes, rather than a desire to obtain ES from natural ecosystems. In future, multiple platforms or data sources should be used to get a more complete picture of the use or value of an area.

5.5.2. Policy Implications

By walking, running or cycling along vegetated routes and/or routes with less and slower traffic, people are experiencing less exposure to air pollution. Air pollution is a major cause of ill health in the UK, linked to around 40,000 premature deaths each year (Brand and Hunt, 2018). Vegetation barriers have been found to reduce the load of particle pollutants from cars in the air and reduce particle dispersal – and thus people maybe (consciously or unconsciously) drawn towards this regulating ES to minimise negative health effects of air pollution (Morakinyo and Lam, 2015). If people are able to choose a direction that puts vegetation between themselves and a road, they experience less noise pollution, which has been identified as a stressor. That said, it was not possible to tell in my analysis on which edges vegetation was a barrier between people and roads. Tree cover and other vegetation has been found to reduce noise pollution from roads (Samara and Tsitsoni, 2011) and areas with greater vegetation cover are perceived to be calmer and less noisy (Van Renterghem, 2019). Whatever an individuals' primary reason might be for choosing a direction with more nature, they are also experiencing secondary benefits. However, given the rural nature of Denbighshire county, neither traffic nor air pollution are present at high levels (Welsh Government, 2017; Department for Transport, 2021). That said, I caution that my results show correlation and not causation. Further study should investigate this, as well as studying rural locations and locations where there is greater contrast between rural and urban areas. Enhancing nature along routes has the potential to benefit both peoples' physical and mental health.

An average personal travel journey in Wales is 8 miles, ranging from 1 mile when walking to 9 miles when driving (Welsh Government, 2013). A more recent statistic for England suggests that 60% of car journeys are under 5 miles (Department for Transport, 2020). Given the short distance of the majority of peoples' journeys, exploring and promoting active travel (e.g., walking, cycling) seems highly feasible and achievable. As the local natural environment appears to be an important factor influencing the route-based choices, initiatives to establish/maintain natural components (e.g.,

planting trees) along roads and paths could be used as a way to manipulate the flows of people. For example, people could be encouraged to take a longer, but more natural route, towards retail areas in order to avoid an accident hotspot thereby reducing the risk of injuries (Basu *et al.*, 2022).

5.6. Conclusions

My study represents a novel use of Strava data to explore the extent to which people's choices while travelling, by bicycle or on foot, is affected by nature around them. I use this to obtain insights in the extent to which nature matters to people undertaking these activities. Across multiple nature metrics, I found that nature is a significant predictor in the direction people choose to take at junctions when travelling by foot and cycling in that the more nature present in that direction, the more likely people are to take it. Thus, people may be consciously choosing directions to connect with nature or choosing routes with more nature for different reasons. Whatever their reasons, these choices are likely to be beneficial to them and wider society. Nature therefore needs to be considered as one of the many factors that contribute to decision making at junctions when walking, running and cycling for leisure and commute. This finding has implications for planning and policy when considering development of walking and cycling networks and promoting active travel.

Chapter 6

6. Synthesis

In this thesis, I aimed to better understand the flow of ecosystem services, i.e., how a service might reach people or people might reach a service (Dolan *et al.*, 2021). I sought to develop a spatial understanding of the interactions of people with the natural spaces that are available to them. I wanted to move beyond simple assumptions (e.g., assuming that beneficiaries definitely have access to ecosystem services produced and that they and will go to wherever the services are) by directly studying ecosystem service access – with an emphasis on cultural ecosystem services in Wales. Cultural ecosystem services are the "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Sarukhán and Whyte, 2005). Through this, I have established my key findings; that nearby nature accessed frequently is very important to peoples' wellbeing and that nature influences small-scale spatial decisions when people are moving.

I considered the flow of ecosystem services throughout my thesis; in my literature review and three data chapters. In chapter 2, I coined the term 'people to nature' to describe the movement of people to access nature, and explored how the literature on movement concepts might be useful in describing this process. I developed this people to nature approach in chapter 3 by disaggregating the flow of people to nature in terms of socio-economic factors and exploring if this flow of people to nature varies across different groups in society. In chapter 4, I looked at the flow of people to nature through the lens of the Covid-19 pandemic and associated restrictions on movement in Wales. I explored how people to nature movements changed over the pandemic. In chapter 5, I used Strava exercise data to explore how the flow of people to nature interacts with movement and journeys. Here in my synthesis chapter, I bring the findings from my previous chapters together and consider how developing understanding of the flow of nature to people might be useful for research and policy in Wales.

My findings emphasise the importance of nature to people's wellbeing. In my surveys (Chapters 3 and 4), the majority of people said that the natural space they had identified was 'very important' to their day-to-day wellbeing. This builds on previous work (predominantly done in the global north) showing that spending time in nature and experiencing moments of connection with nature is beneficial to people (Pritchard *et al.*, 2019; White *et al.*, 2019; Martin *et al.*, 2020; Richardson *et al.*, 2021). I found that spaces visited frequently had the greatest importance to peoples' wellbeing.

Further, my findings emphasise the importance of nearby nature, nature close to peoples' homes (i.e., within 1km), and provide a novel, tangible way to consider what 'nearby' actually means. Given the importance of nature to peoples' wellbeing, the Covid-19 pandemic highlighted and exacerbated existing inequity in access to nature across Wales (chapter 4). Those who did not have access to nature by having their own garden during the pandemic were significantly more likely to say that there had been a negative effect on their wellbeing. This builds on previous work showing that it is important for people to have nature close to where they live (Cox *et al.*, 2017; Richardson *et al.*, 2021) and that proximity is an important factor (although not the only factor) in accessing nature.

As highlighted in my literature review (Chapter 2), cultural ecosystem services can be obtained from specific spaces (e.g., Chapters 3 & 4), but also encountered when undertaking journeys and through movement which do not have the aim of ending up at natural spaces. I studied this further using exercise data from Strava, the most widely used exercise social media platform (Chapter 5). I identified that nature plays a significant role in the decisions people make when moving (walking, running and cycling), in that people will preferentially choose directions with more nature. This finding could inform and support the work of local and national governments, businesses and workplaces in encouraging active travel and active lifestyles, while promoting wellbeing associated with being in natural spaces. Chapter 5 presents a novel analysis of Strava exercise data and this analysis also demonstrates the utility of big data in exploring how people interact with nature.

Overall, my findings suggest that the majority of peoples' regular interactions with nature in Wales are very close to home. Frequent interaction with nearby nature is important to peoples' wellbeing, and nature influences small-scale spatial decisions.

6.1. Specific Contributions to Knowledge

Below, I highlight the contributions to knowledge of each chapter, summarised in infographic 6.1.

In the literature review (Chapter 2), I broke down ES flow into 'nature to people' and 'people to nature'. I demonstrated that cultural ES are dominated by the flow of people to nature; people seeking out the benefits from connecting with nature. I considered that this could occur *in situ* or that people travel to access a natural space, or they may access ES incidentally as part of another activity such as commuting. I considered that peoples' ability to travel to connect with nature or to be close to nature where they lived would depend on socio-demographic factors. This is published as: Dolan R,; Bullock, J. M.; Jones, J. P. G.; Athanasiadis, I.N.; Martinez-Lopez, J.; Willcock, S. The Flows of Nature to People and of People to Nature: Applying Movement Concepts to Ecosystem Services. *Land* **2021**, *10*, 576. https://doi.org/10.3390/land10060576.

In chapter 3, I wanted to explore if the movement of people to nature varies between different socio-demographic groups. Specifically, I looked at the difference between; those who live in urban versus

rural areas, those with higher incomes compared to lower, gender identities and different age groups. Whilst one might have expected that, for example, wealthier people may have better access to nature (Wolch, Byrne and Newell, 2014), I did not find this pattern. Nor did I find any effect of gender identity on the distance people travelled to natural spaces. I found that older people travel slightly further than younger to access natural spaces. However, this was a very small effect. This finding could potentially be because older, retired people have more time and money to spend time in nature and accessing different spaces (Freeman *et al.*, 2019).

In chapter 3, I also wanted to explore the relationship between the distance people cover to access nature and the importance of nature to their wellbeing. I found that the closer spaces were to peoples' homes, i.e., the less distance they travelled to spend time there, the more important they were to their day-to-day wellbeing. However, the exact cause of this is unclear e.g., one explanation is that the spaces closer to home are accessed more often and therefore become important to wellbeing, and are therefore accessed more. Intuitively, given limited time available to people, it makes sense, that spaces in close proximity are accessed more often and therefore make a greater contribution to wellbeing.

In chapter 4, I wanted to find out how peoples' interactions with nature in Wales changed over the Covid-19 pandemic. What effect did the restrictions have on how often and how long people spent in nature? What effect did this have on their wellbeing? I found that some people reported an increase in the frequency, time spent and distance travelled whilst others reported a decrease. This potentially reflects differences between those who had access to their own natural spaces or spaces very nearby compared to those who did not. My findings show that interactions with nature did change over the pandemic and that people had varied experiences, not everyone was affected in the same way. The effect on wellbeing was also varied, with different groups more likely than others to say there had been a negative effect on their wellbeing. The pandemic and associated restrictions exacerbated existing inequalities in access to nature and differences in peoples' wellbeing.

Finally in chapter 5, I explored if the natural environment along routes affects peoples' decisions at junctions when they are cycling or travelling by foot. My findings suggest that nature along routes does make a significant contribution to peoples' decision at junction when they are cycling, running or walking. The greater the proportion of nature on the exit from the junction, the more likely people are to choose that direction. This incorporates people benefitting from nature as part of a journey or part of an activity that they are doing anyway, rather than nature connection and the associated benefits being the main aim of their activity.

(A)
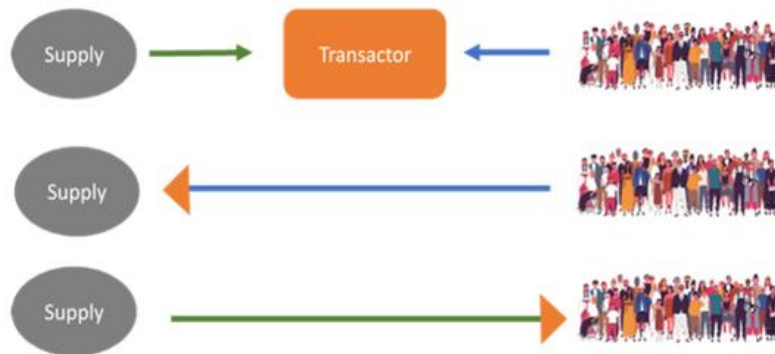
ES flow is a combination of the movement of **nature to people** and **people to nature**, meeting at the point where the **benefit is realised**. Cultural ES are predominately the movement of **people to nature**.

(B)

Frequent access to nearby nature is better for maintaining wellbeing than infrequent trips to distant nature.

1 km

10 km
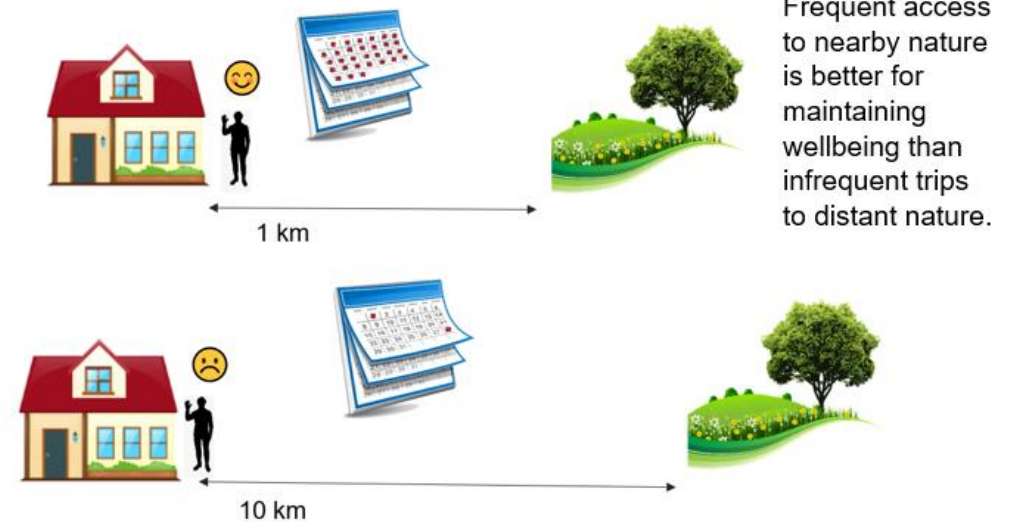
(C)
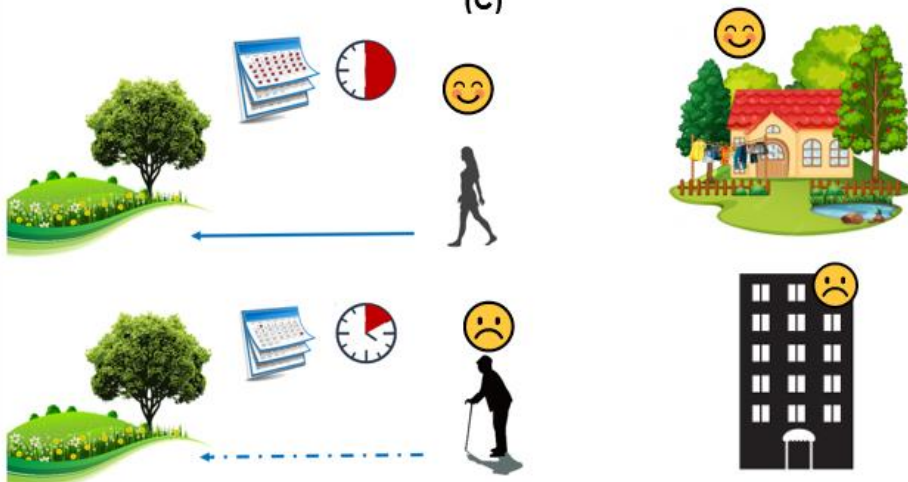
During lockdown, younger people spent time in natural spaces more frequently, for longer periods of time, which was beneficial for their wellbeing. Older people showed the opposite pattern, which was detrimental for their wellbeing. Those without a garden were more likely to report a negative impact on their wellbeing.

(D)

Nature has an effect on peoples' decisions when they are walking and cycling; on reaching a junction, people are more likely to choose directions with a higher proportion of nature.

Inforgraphic 6.1. Summary inforgraphic bringing together the key findings from my thesis.

6.2. Research Implications

Having identified my key findings, that nature is important to peoples' wellbeing especially nearby spaces accessed frequently, and the influence of nature on peoples' decisions when they are moving, here I consider their implications for policy and wider work in Wales and beyond.

6.2.1. The importance of nature

Society faces significant environmental challenges including the climate crisis, loss of biodiversity and pollution. Creating, expanding and maintaining areas of biodiverse, natural habitat including grassland and woodland helps us combat these challenges. Firstly, natural habitats store carbon (Ostle *et al.*, 2009; Hungate *et al.*, 2017). They also support more biodiversity than dense urban areas and intensively managed agricultural land (Walker *et al.*, 2004; State of Nature Partnership, 2019). Here, I have demonstrated that nature is important to the wellbeing of people in Wales. But that fact that it is important to us is in turn important to nature. It becomes circular, nature needs to be protected to support human wellbeing, which leads to more nature.

Given that the samples of people that I considered in my thesis stated and revealed through their behaviours that they value nature, and that more broadly the importance of nature to peoples' survival and wellbeing is increasingly understood, the ongoing habitat destruction and unsustainable practices throughout the global community seem completely non-sensical. This is likely largely driven by short-term economic gain, a reluctance to shift away from existing models and priorities and a disconnection from the natural world (De Groot, 1987; Nisbet, Zelenski and Murphy, 2009; Bazerman and Hoffman, 2017). Whilst my population sample in Wales revealed these values potentially these are not held elsewhere in the world or are not expressed in the same way. Whilst in Wales, and the global north, there is maybe the flexibility to consider wellbeing, think longer-term and factor in the impacts of biodiversity loss and disconnection from nature, there may not be this flexibility in other parts of the world.

Through boosting peoples' wellbeing, nature contributes to wider societal benefits. People who are exposed to nature are more likely to show pro-social, cooperative behaviours (Zhang *et al.*, 2014; Zelenski, Dopko and Capaldi, 2015), suggesting that nature may help to support a more cohesive society of people who are more likely to help each other, reducing pressures on already overburdened services. Mental ill health is estimated to cost the UK economy £118 billion (£4.2 billion in Wales) (Mcdaid *et al.*, 2022). The majority of this is through lost work days from those with mental health conditions and those who are obliged to take on unpaid caring responsibilities. In

maintaining nature, a more supportive environment for those with mental health conditions is created. To maintain peoples' wellbeing, existing nature needs to be maintained and new natural spaces created close to peoples' homes, which will save money in the long term.

6.2.2. Nature during the Covid-19 pandemic

Furthermore, my findings highlight the importance of nature that is close to peoples' homes, especially during the Covid-19 pandemic. The pandemic highlighted inequalities in access to nature at a time when nature increased in importance to many people. At the start of the first lockdown, 9% of households in Wales did not have access to a private, outdoor space (Office for National Statistics, 2020). 36% of people living in flats had no access to a private outdoor space, a higher figure than England and Scotland (Office for National Statistics, 2020). 13.5% of the vulnerable people who had been told to shield (i.e., to not leave their homes at all) had no access to outdoor space (Welsh Government, 2020a). Given how important nature is to peoples' wellbeing, as shown by my findings, this deprivation likely had a significant negative effect on individuals. Based on the findings of my thesis, I would recommend that it is ensured that the majority of people have access to some private, outdoor space and in residences where this isn't possible, such as blocks of flats, there is communal green space or nature accessible very nearby. Those who do not have nature within 1 km, the distance within which natural spaces were considered to be 'very important' to wellbeing, need this access. The Wales Index of Multiple Deprivation identifies the small areas of Wales that are most deprived, based on income, employment, health, education, access to service, housing, community safety and physical environment (Welsh Government, 2022c). My findings on the importance of nearby nature could potentially support the development of the physical environment aspect of this work when it is next reviewed (personal communication, Social Justice Statistician, Welsh Government).

Nature and access to outdoor spaces became increasingly important to many people over the pandemic This could partly have been due to the restrictions placed on other activities such as shopping and access to cafes (UK Government, 2020) and because access to nature beyond the home was limited so people became more aware of what they were missing (Helm, 2020; Natural Resources Wales, 2020). This ties in with increasing media attention given to the climate and biodiversity crisis and the idea that access to nature could be lost forever (Helm, 2020). The greater importance and connection some people attached to nature also have been linked to people taking the time to consider their lives and priorities in the unprecedented circumstances they found themselves in, especially for those who had lost loved ones or been very ill. Nature was found to help people cope during the pandemic and help them feel less isolated (Vimal, 2022).

Recognising the importance of nature to people and that a significant proportion of the population was unable to access nature during the Covid restrictions, the Future Generations Commissioner for

Wales has pushed for everyone in Wales to be no more than a 4-minute walk from nature (The Future Generations Commissioner for Wales, 2020). Welsh Government provided grant funding through 'Local Places for Nature'; a scheme intended to help deprived areas enhance nature in their local area (Wales Council for Voluntary Action, 2021). Following behaviour changes over the Covid-19 pandemic in which more people began walking, cycling and wanting to access nature close to their home, Welsh Government announced funding to improve walking and cycling facilities (BBC News, 2020). Similarly in England, a new UK Government Environmental Improvement Plan brought out in January 2023 announced that everyone in England will live with 15 minutes from green or blue space, under new plans to restore nature (Department for Environment Food and Rural Affairs, 2023). My findings support these initiatives and suggest they will be worthwhile; people need to be able to access nature easily close to their homes.

6.2.3. Everyday access to nearby nature

My findings also demonstrate that everyday access to nature is important, rather than big, one-off trips to novel locations. Research suggests that when people feel they are time poor, especially when time with partners or other significant people is limited, they may prioritise 'extraordinary experiences' rather than smaller scale or local experiences (Garcia-Rada and Kim, 2021). Whilst these experiences can be amazing and memorable, my findings (supported by previous research (Richardson, Hallam and Lumber, 2015)) suggest that it is nearby, regularly accessed nature that is important to human wellbeing.

In modern society, where busyness can be seen as a status symbol (Bellezza, Paharia and Keinan, 2017) and the idea of busyness and time scarcity is further perpetuated by social media and constant digital connection (Reinecke *et al.*, 2017) people may feel that they do not have the option to make time for connecting with nature. 'Lack of time' is a reason given for not spending time in nature (Boyd *et al.*, 2018). Therefore, for many people interaction with nature as part of an activity that they are doing already (such as their commute, walking the dog or taking their children to school) may be their main 'dose' of nature for the day or week. This suggests nature should be supported everywhere, nearby to where people live so that people are able to benefit no matter what they are doing and they have greater opportunity for moments of genuine connection. In my literature review, I break down of the flow of ecosystem services, in which I unpacked ES flow into 'nature to people' and 'people to nature'. I chose to focus on cultural ES because these are dominated by the movement of people to nature, which had previously been less studied. However, my findings might suggest that, due to the structure of the busy, modern world, nature needs to be brought to people, otherwise they may not interact with it at all. Ecosystem services that people previously sought out may now need to be brought to where people are.

Bringing nature to people has been recognised as important by Natur am Byth (Nature Forever) project in Wales (Natural Resources Wales, 2021). Part of the project focuses on the conservation of highly endangered plant and invertebrate species in Wales. They are planning to create an alpine garden in Ysbyty Gwynedd (Gwynedd Hospital) in Bangor, North Wales to bring some of the endangered species to people, recognising that the majority of people will not be hiking to remote areas of the mountains to see them. Creating this space in what otherwise would have just been a utilitarian space and allowing people to see these species, in their workplace or potentially at emotional points in their lives, could allow them to benefit from spending time in nature and create connections that they may never have had the chance to.

6.2.4. Nature and movement

People connect with nature not just in specific spaces but also whilst moving. Considering active lifestyles and active travel, my findings demonstrate that nature along travel routes makes people more likely to use them. This gives greater impetus and justification for local authorities to work to 'green up' their access networks (Denbighshire County Council, 2017). This supports and validates the work of local government including Denbighshire County Council (Denbighshire County Council, 2017) with whom I worked closely during my project. Under the Active Travel (Wales) Act 2013 local authorities in Wales are obligated to continuously improve their access network and to identify opportunities to expand walking and cycling routes.

Additionally, under the Active Travel (Wales) Act 2013 (Welsh Government, 2021a), there is a push to increase the number of school children who walk to school. For primary schools under 2 miles from a child's home and secondary schools under 3 miles, the local authority does not need to provide transport to school (unless there are safety concerns or a child has additional needs) (Children's Legal Centre Wales, 2019). Despite this, the number of children walking or cycling to school in the UK is now below 50% (Children's Legal Centre Wales, 2019). My findings suggest that route options with more nature may encourage more people to walk or cycle with their children to school. Routes with more nature may be perceived to be more attractive (Hoyle, Hitchmough and Jorgensen, 2017) and safer due to less/slower traffic and less exposure to air pollution (Morakinyo and Lam, 2015; Van Treese *et al.*, 2017).

Similarly, many businesses and organisations take part in the Cycle to Work scheme whereby employees are able to purchase a bike and cycling equipment tax free as an incentive to commute actively. For example, Bangor University, offer employees the option to participate in the scheme and provides information on local routes and facilities at the university (Bangor University, 2020). The scheme was first launched by the UK government in 1999 to encourage people to commute actively for their health and to reduce the impact of car travel on the environment (Department for Transport, 2019). Research into the scheme suggests that the majority of people who take

advantage of it cycled already, so it has not necessarily converted new people to cycling to work (Swift *et al.*, 2016). Reasons given for not cycling include; it's easier/quicker to go by car, lack of time/too busy and there's too much traffic or the traffic is too fast (Swift *et al.*, 2016). These barriers could partly be combatted by following my findings that routes with more nature are more attractive. Businesses could recommend attractive routes to their workplace to employees and support the creation and maintenance of natural spaces around their workplace and key routes to it.

My findings suggest that by establishing more natural and semi-natural ecosystems along routes (e.g., urban trees) the routes can be made more attractive to people which will encourage people to use them, helping people to be healthier mentally and physically. My findings support the maintenance and expansion of green and biodiverse areas, even in spaces where this is not the primary objective such as the surrounding of businesses, office blocks and work spaces. If people are able to move through these spaces, the presence of nature will encourage people to use them, maybe helping them avoid busier areas. An example of an organisation leading the way on this in Wales is M-Sparc, Wales first science park based on Anglesey in North Wales (M-Sparc, 2022). M-Sparc works with partners and businesses to develop new, innovate, sustainable technology and ways of working. At their 20-acre site they have created woodland and grassland habitat around the buildings. Cutting through their site allows cyclists to avoid the main road including a busy roundabout, as well as providing a more attractive option with more nature as discussed in Chapter 5. By providing this they are encouraging active travel and active leisure in the area. They are also providing an opportunity to connect with nature where people already spend time; at a workplace, where people come to enjoy the café and commute/travel through.

6.3. Research limitations

The language used in the field of ecosystem services can be subjective and sometimes hard to grasp, and each study is bound by the language it uses. In my surveys, I used the term 'natural space' to ask people to identify space where they felt they connected with nature. This term was chosen after much consideration. I did not want to use the term 'green space' as this suggested somewhere official or designated like a park in an urban area or a nature reserve owned by a particular body. It suggested somewhere distinct with a clear boundary, whereas I wanted it to be clear to respondents that they could choose somewhere less distinct if they wanted, for example a countryside lane bordered with trees. The words 'nature', 'natural' and 'natural space' can mean different things to different people, as discussed in my introduction. One person may consider something natural whereas someone else may not at all; it would depend on a combination of factors including their life experiences. If I were approaching this choice again, I might avoid a specific term for the space all together and simply ask people where they most recently connected with nature. It

is possible to connect with nature in spaces that would not be considered very 'natural' for example enjoying the shade of a beautiful tree in a city centre.

As discussed in the introductory chapter, several terms used throughout the thesis, specifically nature, wellbeing and access, are subjective and complex. Whilst care was taken to define these terms to ensure they were clear to survey participants, people bring their own meanings to terms and there is always the potential for confusion to arise. Whilst the subjectivity makes for nuanced and complex discussion it can be a challenge when developing policy. Here I defined **nature** as "environments and physical features of nonhuman origins, ranging from plants to non-built landscape" (Hartig *et al.*, 2014; Capaldi *et al.*, 2015); **access** in terms of geographic access, someone's proximity to a space and connectivity to get there (Brabyn and Sutton, 2013) and finally **wellbeing** in terms of hedonic wellbeing using the definition used by the Office of National Statistics, "wellbeing can be considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, how happy you feel and how anxious you feel." (ONS, 2022).

I did not consider the value people attached to natural spaces in terms of monetary value. Instead, respondents to my surveys were asked to say how important the space was to their day-to-day wellbeing from '1 – unimportant' to '5 – very important'. Exploring the monetary cost of nature, or peoples' willingness to pay to access or preserve somewhere is a useful way to measure value as it is quantifiable and comparable, hence its extensive use in other studies (for example, de Groot *et al.*, 2012; García-Llorente *et al.*, 2012). However, this can become clouded when considering cultural ecosystem services which are "non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Sarukhán and Whyte, 2005). I did not have the capacity within this study to incorporate the monetary value of spaces, alongside the wellbeing metric that I used.

I approached this project using the ecosystem services framework. This is an anthropocentric approach in that it considers nature in terms of the good and services (and disservices) it provides to people, and how these services support human survival and wellbeing (McCauley, 2006; Victor, 2020). This does not always consider what options may be best when looking through a different lens, for example considering what might be the optimal outcome for biodiversity (e.g., potentially creating an area that people do not access, so with no immediate wellbeing benefits to people) or reducing carbon outputs as much as possible. These must also be considered when making policy decisions. Therefore, in terms of its utility to policy, my project would need to be considered alongside other work.

Methodologically, whilst I endeavoured to ensure that my samples were as representative as possible of the Welsh population, they are likely to actually be slightly biased. The membership of

Pick my Postcode is skewed towards female members, aged 35-54, in work ranging from supervisory, junior managerial, professional, skilled, semi-skilled and unskilled manual occupations (Pick my Postcode, 2019). Overall, the most common respondent was female, aged 60-64, in the middle-income group, white, educated to at least undergraduate level, from a suburban area. Similarly, the membership of Strava is known to be skewed towards younger males, with a focus on training rather than leisure (Griffin and Jiao, 2019; Lee and Sener, 2021; Fischer, Nelson and Winters, 2022). That said, the cycling Strava data accessed for my study area Denbighshire was found to be a moderately good proxy of the cycle counter data for the county, which suggests the cycling data from Strava is probably at least representative of cyclists in Denbighshire as a whole (i.e., Strava users plus non-users). Biases in population samples are impossible to avoid (Hill and Kleinbaum, 2014).

I used Wales as a case study for my thesis. My results are likely to be safely generalisable to the rest of Britain and other relatively wealthy, global north nations. However, they are less likely to be generalisable to less wealthy, global south nations. Further, within the thesis, the findings from the chapter 5 using Strava data may be safely generalisable to other similar areas. However, the findings from chapter 4 looking at the impact of Covid-19 pandemic may not be as healthcare in Wales is devolved, therefore Welsh Covid-19 restrictions were completely unique. Despite this, I collected a significant sample of 7000 respondents covering the whole of Wales, with a good geographical range across the rural to urban spectrum.

6.4. Potential Future Directions

My work here could be built on by refining the process of understanding where people connect with nature in relation to their home. Here, I used straight-line distances to see how far people travelled. This could be refined using actual distances based on the mode of transport used. However, this potentially represents more labour-intensive analysis and care would have to be taken to ensure that individual identities and address could not be identified.

Additionally, in chapter three, I considered the distances people travelled to access nature and how this might vary based on different factors. I was therefore considering people who, in selecting a space on the map, were saying that they **did** and **could** spend time connecting with nature. I was not considering people who could **not** access nature and how this might vary across socio-demographic factors. Had I considered people who could not or did not access nature, I may have found variation based on the socio-demographic factors in my analysis. My surveys did include questions on barriers to access and spaces people could not access or not as much as they would like, but I chose to focus on other parts of the surveys for the analysis. This additional data could form part of future research.

I used quantitative, rather than qualitative, data from the surveys in my analysis. I looked at the distances in km people travelled from home to access nature and how this varied based on socio-demographic factors and the importance of the space to wellbeing. I looked at the proportion of people who chose directions based on the proportion of nature in that direction. This analysis could be supplemented and supported by qualitative data, which would give a more complete picture as to why people choose the spaces they did and chose the directions they did. My surveys included the option for respondents to add their own words and further information about the spaces they chose. Whilst I did not have the capacity within this project to utilise this qualitative data, it is being incorporated into further work at Bangor University exploring the language people use when describing spaces that they identify with and appreciate, and also a project developing machine learning techniques to analyse free-text responses in surveys.

Zooming out, this project was based in Wales. It would be interesting to carry out the same analyses in other areas of the UK and world, especially contrasting Wales with more urban areas where the relationship and spatial interactions with nature may be quite different.

As discussed above, I set this work within the ecosystem services framework. Further work might explore the spaces where people interact with nature but through a different lens, rather than asking how someone benefits from connecting with nature in a specific space or how the space 'serves' them. This might identify nuances, values or benefits that could not be captured coming from an ES stand point.

Finally, my project has identified the importance of everyday interactions with nature, close to home. Future research could explore the effects and potential benefits of bringing nature into all areas of life, in spaces where it might not be expected such as work places, hospitals, offices and retail spaces as I suggested in my policy recommendations above.

6.5. Conclusions

Frequent connection with nature close to peoples' homes is of significant importance to wellbeing, both physical and mental and therefore the wellbeing of society as a whole. Proximity is a significant factor in people's ability to access nature and the Covid-19 pandemic highlighted and exacerbated existing inequality in the availability of nearby nature for large proportions of the Welsh population with many unable to access nature at all. People connect with nature not just within specific spaces but through journeys too, presenting them with many opportunities to benefit from nature connection.

The findings identified in this thesis support existing policy and initiatives across Wales; creating and maintaining natural spaces, working to ensure people have nature close to home and promoting healthy lifestyles including active travel. However, this work needs to come to the forefront and become more join-up in the light of the on-going climate, biodiversity and mental health crises. The

flow of people to nature is increasingly challenging in our modern world, therefore the opportunity to connect with nature needs to be brought in to all activities and spaces so it is a constant thread.

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Appendices

Appendix 1: Appendix to Chapter 3 - Relationships between distances travelled to natural spaces, impacts on wellbeing and socio-demographic predictors

Appendix 1.1. Online survey using January 2020 as an example

The survey was available in English and Welsh. Respondents could choose up to 3 spaces. Here I have included the questions relating to the spaces chosen only once to avoid repetition.

For links to the actual surveys used please see Table 3.1 in text.

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Purpose of the research
This research is part of a PhD project with Bangor University. My research aims to explore how people engage with natural spaces, the benefits people gain from engaging with these spaces and the barriers that might prevent people from engaging with them. My aim is to collect data to inform land managers, to support continued and enhanced access to natural spaces where appropriate

Voluntary participation
Your participation in the survey is voluntary. You can withdraw from the survey at any time should you wish to. Please note that if you withdraw from the survey you will not receive your bonus. Overall, this survey should take approximately 10 minutes to complete.

Use of data
The information provided by you in this survey will be used for research purposes only. It will be stored securely and remain confidential. T overall findings will become part of a PhD thesis and may be published as part of my studies so others may learn from the research. I will be collecting some demographic data; age bracket, gender, household income bracket and level of education. I will also be collecting postcodes which, when combined with the demographic data, could potentially allow identification of individuals. For this reason, postcode data will be stored for 3 years only and then deleted. Presentation of results will not enable the identification of addresses or individuals

Contact information

Should you have any questions about this research or wish to have your data removed, please contact Rachel Dolan (Postgraduate Researcher, University of Bangor) via email: rachel.dolan@bangor.ac.uk. Should you have any complaints about this research, please contact
Dr Simon Willcock (Senior Lecturer, Bangor University) via email: s.willcock@bangor.ac.uk

Are you happy to proceed with the survey?

- o Yes
- o No

Thank you very much for your time. Do you have any questions?

This research is part of a PhD project with Bangor University. Should you have any questions about this research, please contact Rachel Dolan (Postgraduate Researcher, University of Bangor) via email: rachel.dolan@bangor.ac.uk. Should you have any complaints about this research, please contact Dr Simon Willcock (Senior Lecturer, Bangor University) via email: s.willcock@bangor.ac.uk

What is your home postcode? (this information is useful to help us understand how far people are able to travel)

Please type in your postcode

Please identify the natural space you have spent time at most recently on the map. Natural spaces can include but are not limited to: gardens, mountains, the coast, meadows, farmland, a commute along a green route, water bodies, nature reserves... If you did a route, for example a bike ride, please select the point that most represents the route for you.

Zoom in to where you want to go on the map and select a point. Please try to be as precise as possible. You will see a blue marker which w save automatically. If you want to zoom straight to your local area you can input your postcode in the search bar above the map. If you are using the browser on your mobile device/tablet, you may need to tap "map" to activate the map first. Hit the black arrow to go back, do not hit the back button on your browser as this will close the survey.

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

search for place or address Q ◇

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How often do you spend time at this space?

- o Multiple times throughout the year
- o One off trip

How long did you spend at this space?

Please select one
- o Less than 30 minutes
- o 30 minutes to 1 hour
- o 1 hour to 4 hours
- o 4 hours to 8 hours
- o Overnight
- o Longer than overnight

On average, how often do you spend time at this space in the summer?
- o Multiple times a day
- o Once a day
- o 3-5 times a week
- o 1-2 times a week
- o Once a fortnight
- o Once a month

o   Less than once a month
o   Never

On average, how long do you spend at this space in the summer?

Please select one
o   Less than 30 minutes
o   30 minutes to 1 hour
o   1 hour to 4 hours
o   4 hours to 8 hours
o   Overnight
o   Longer than overnight

On average, how often do you spend time in this space in the winter?
o   Multiple times a day
o   Once a day
o   3-5 times a week
o   1-2 times a week
o   Once a fortnight
o   Once a month
o   Less than once a month
o   Never

On average, how long do you spend at this space in the winter?

Please select one

o   Less than 30 minutes
o   30 minutes to 1 hour
o   1 hour to 4 hours
o   4 hours to 8 hours
o   Overnight
o   Longer than overnight

Do you need to travel to get to this space from home?

If you spend time in this space often, please choose the mode of transport you use most often e.g., if you mostly drive but occasionally cycle, choose drive.

o   No (if the space you chose is your own garden or land)
o   Walk
o   Cycle
o   Bus
o   Drive
o   Taxi
o   Train
o   Fly
o   Part of a journey I make anyway e.g., commute
o   Other

How do you travel to get to this space?

Please specify in your own words

Why did you choose to spend time at this space? Please select your MAIN reason.

Please select one. You can add more reasons in the next section.

o   To learn new things

o   To be inspired, inspired to create, inspired to conserve

o   To feel connected to the natural world

o   To feel connected to history, to be reminded of your own past

o   For mental/physical health and fitness, to feel rejuvenated, restored, happier and healthier

o   To feel connected to other people, part of a community

o Other

Other than your main reason, please select any other reasons that you spend time in this space, if any

Please select all that apply. There is the option add more details next in the next section.

- o To learn new things
- o To be inspired, inspired to create, inspired to conserve
- o To feel connected to the natural world
- o To feel connected to history, to be reminded of your own past
- o For mental/physical health and fitness, to feel rejuvenated, restored, happier and healthier
- o To feel connected to other people, part of a community
- o Other

Would you like to explain further or tell us anything else about your reasons for spending time at this space? Please give more details if you answered "other" to the previous questions.

On a scale from 1 (unimportant) to 5 (very important), how important is this space to your day-to-day well-being?

Well-being can be considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, how happy you feel and how anxious you feel.

1 - Unimportant   2   3   4   5 - Very important

THANK YOU for answering questions about the natural space that you used most recently. Would you like to answer the same questions about another natural space that you spent time at recently, or move on to the next section?

- o Pick another space
- o Move on

Are there any natural spaces that you can't spend time in or not as often as you would like?

- o Yes
- o No

In general, what do you feel is preventing you from spending time in some natural spaces?

Select all that apply

- o Lack of money
- o Lack of time
- o Too far away
- o Disability
- o Poor health
- o Poor mobility
- o Lack of transport
- o Unsure where to go

- o Unsure where allowed to go

- o Lack of confidence

- o Feel out of place

- o Care responsibilities

- o Access to land prevented

- o Other

In general, what do you feel is preventing you from spending time in some natural spaces?

Please describe in your own words

Can you think of a specific natural space that you were recently unable to spend time in?

- o Yes

- o No

Please identify the natural space that you were unable to spend time in on the map

Please identify on the map. Zoom in to where you want to go and select a point. You will see a blue marker which will save automatically. If you want to zoom straight to your local area you can input your postcode in the search bar above the map. If you are using the browser onyour mobile device or tablet, you may need to tap "map" to activate the map first. Hit the black arrow to go back, do not hit the back button on your browser as this will close the survey.

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

search for place or address

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What is the primary reason preventing you from spending time in this natural space?

Please select one

- o Lack of money
- o Lack of time
- o Too far away
- o Disability
- o Poor health
- o Poor mobility
- o Lack of transport
- o Unsure where to go
- o Unsure where allowed to go
- o Lack of confidence
- o Feel out of place
- o Care responsibilities
- o Access to land prevented
- o Other

What do you feel is preventing you from spending time in this natural spaces?

Please describe in your own words

Information about you

In general, how often do you spend time in natural spaces?

- o Multiple times a day
  - o Once a day
  - o 3-5 times a week
  - o 1-2 times a week

- o Once a fortnight
- o Once a month
- o Less than once a month
- o Never

In general, what activities do you do in natural spaces?

Select all that apply

- o Walking
- o Dog walking
- o Picknicking
- o Taking children out to play
- o Informal games e.g., frisbee
- o Running
- o Wildlife watching
- o Road cycling
- o Outdoor swimming
- o Mountain biking or off-road cycling
- o Fishing
- o Watersports
- o Other

In general, what activities do you do in natural spaces?

In your own words

Please select your age group

- o Under 20
- o 20-24
- o 25-29
- o 30-34
- o 35-39
- o 40-44
- o 45-49
- o 50-54
- o 55-59
- o 60-64
- o 65-69
- o 70-74
- o 75-80
- o 84-89
- o 90-94

- 95-99
- 100 and over

Please select the gender you identify as

- Female
- Male
- I'd prefer not to say
- I'd prefer to use my own words

What gender do you identify as

Please use your own words

Please select your household income group

- Less than £15, 838
- £15,838 - £44, 125
- More than £44, 125

Please select your highest level of education

- Primary school
- Secondary school
- GCSE grades D-G/1-3, level 1 diploma/NVQ
- GCSE grades A*-C/4-9, level 2 diploma/NVQ
- Apprenticeship
- AS/A level, Baccalaureate, level 3 diploma/NVQ
- Level 4 and higher diploma/NVQ, access to higher education, foundation degree, bachelor's degree, master's degree,doctorate

Please select the ethnic background you identify as

You can select more than one option

- White – Welsh/English/Scottish/Northern Irish/British
- White – Irish
- White – Gypsy or Irish Traveler
- White – any other white background
- Mixed/Multiple ethnic groups – White and Black Caribbean
- Mixed/Multiple ethnic groups – Which and Black African
- Mixed/Multiple ethnic groups – White and Asian
- Any other Mixed/Multiple ethnic background
- Indian
- Pakistani
- Bangladeshi
- Chinese
- Any other Asian background

- o African

- o Caribbean

- o Any other Black/African/Caribbean background

- o Arab

- o Any other ethnic group

Thank you very much for taking part. Do you have any questions?

This research is part of a PhD project with Bangor University. The information provided by you in this survey will be used for research purposes only. It will be stored securely and remain confidential. Your data will not be used in a way that would allow identification of individual responses. The overall findings will become part of a PhD thesis and may be published as part of my studies so others may learnfrom the research. Should you have any questions about this research, please contact Rachel Dolan (Postgraduate Researcher, University of Bangor) via email: rachel.dolan@bangor.ac.uk. Should you have any complaints about this research, please contact Dr Simon Willcock (Senior Lecturer, Bangor University) via email: s.willcock@bangor.ac.uk

Appendix 1.2. Supplementary Tables

Table A1.2.1 Pathways to cultural ecosystem service benefits and associated recurring themes in research and related literature (adapted from King et al. 2017). The end column shows how I adapted this for use in my surveys exploring distance travelled to natural spaces in Wales.

Cultural ES pathways	Associated themes by example source							Benefit examples	Description in survey **Natural spaces where…**
	de Groot, Wilson & Boumans 2002	Alcamo 2003	Chiesura 2004	MA 2005	Natural England 2009	Church et al. 2011	Chan, Satterfield and Goldstein 2012		
Cognitive	Science & education	Knowledge systems Education values	Norms & values		Learning	Education & ecological knowledge	Education and research	Learn about biodiversity, abundance, rare species, functions of plants, botany, how to obtain pleasure, feel comforted	…you learn new things
Creative	Aesthetic information Artistic & cultural	Aesthetic values Inspiration	Freedom	Aesthetic appreciation Inspiration	Inspiration		Artistic	**Inspired to:** Paint, draw, take photos, be active/get out, conserve, manage, protect **Inspired by:** Beauty, colours, diversity of species, variety of flowers, shape and texture	…you feel inspired to create and/or conserve
Intuitive		Spiritual & religious value	Self-development Norms & values	Spiritual services	Spiritual escapism	Religious & spiritual	Ceremonial	Connected to nature, to God, to life, and to the area	…you feel connected to the natural world
Retrospective	Historic & Spiritual	Cultural heritage	Ideals	Heritage values	Sense of history	Heritage		Places visited, past summers, childhood, previous land-use, the origins of the species, the past and potential for habitat degradation	…you feel connected to history or you're reminded of your own past
Regenerative	Recreation	Recreation & Tourism	Recreation Psychological Health	Recreation & Tourism	Leisure & activities Calm	Leisure, recreation & tourism	Recreation Subsistence	**A sense of:** rejuvenating, upliftment, nostalgia, absorbing, interest, dreaming, getting away from it all **From:** Vibrancy, beauty, colours, sounds, smells, diversity, wildflowers, meadows, nature, blue skies, the feeling of enjoyment	…you go to benefit your mental and/or physical health
Communicative		Cultural diversity Sense of Place, Social Relations	Cultural Identity Social contact	Cultural identity	Sense of place			Connection to other people, feel part of a community e.g., farming community, volunteers for a charity	…you feel connected to other people, part of a community

Table A1.2.2: Land cover classifications from CEH Land Cover 2019 grouped into broader categories for use in my analysis. Respondents to my surveys exploring distance travelled to natural spaces in Wales provided their home postcode. I then spatially joined these start points to a GIS layer of land cover classifications (CEH Land Cover 2019) in ArcGIS to give us the land cover at people's home locations. These were grouped into broader categories in R Statistic Software v4.1.2; R Core Team 2021to allow us to explore if there was a difference in distance travelled between those living in urban compared to rural areas.

UKCEH Land Cover class	Grouping used in analysis
Deciduous woodland	Rural
Coniferous woodland	Rural
Arable	Rural
Improved grassland	Rural
Neutral grassland	Rural
Calcareous grassland	Rural
Acid grassland	Rural
Fen	Rural
Heather	Rural
Heather grassland	Rural
Bog	Rural
Inland rock	Rural
Freshwater	Rural
Supralittoral rock	Rural
Littoral sediment	Rural
Saltmarsh	Rural
Urban	Urban
Suburban	Suburban

Table A1.2.3: Response options from the survey question "How long did you spend at this space?" converted from descriptive answers as chosen by respondents to numeric values (hours) for inclusion in my analysis. This survey question was included in my surveys exploring distance travelled to natural spaces in Wales.

How long did you spend at this space	In hours
Less than 30 minutes	0.25
30 minutes to 1 hour	0.75
1 hour to 4 hours	2.5
4 hours to 8 hours	6.5
Overnight	24
Longer than overnight	48

Table A1.2.4: Response options from the survey question "How often do you spend time at this space?" converted from descriptive answers as chosen by respondents to numeric values (times per month) for inclusion in my analysis. This survey question was included in my surveys exploring distance travelled to natural spaces in Wales.

How Often	Times per month
Multiple times a day	60
Once a day	30
3 -5 times a week	16
1 – 2 times a week	6
Once a fortnight	2
Once a month	1
Less than once a month	0.5
Never	0

Table A1.2.5: Correlation values between all explanatory variables used to in my model to predict distance travelled to natural spaces in Wales. Correlation values were calculated using the polychoric function (Olsson, 1979; Drasgow, 1986) in R Stastical Software (v4.1.2; R Core Team 2021).

None of the variables showed greater correlation than 0.7, and so I concluded that collinearity issues in the analyses were unlikely.

	HHIncome	Gender	Education Group	Primary Reason	Ethnic BW	Land Cover Group	Wellbeing	Before During Since	Month	Multiple OneOff
HHIncome	1	-0.03626	0.082343	-0.0689	0.003319	-0.03659	0.0115	-0.00681	0.037694	0.998565
Gender	-0.03626	1	0.236068	0.027256	0.085262	-0.11077	0.00124	0.040837	0.003701	-0.01537
Education Group	0.082343	0.236068	1	-0.09771	-0.00295	0.002815	-0.01412	0.011325	0.046703	0.082343
Primary Reason	-0.0689	0.027256	-0.09771	1	-0.16101	0.12	-0.2035	0.041851	-0.22379	-0.0583
EthnicBW	0.003319	0.085262	-0.00295	-0.16101	1	-0.11545	0.01147	0.001479	0.075866	-0.00816
Land Cover Group	-0.03659	-0.11077	0.002815	0.12	-0.11545	1	0.121313	0.000181	-0.33626	-0.04511
Wellbeing	0.0115	-0.00124	-0.01412	-0.2035	0.01147	0.121313	1	-0.12819	0.07389	0.011688
Before During Since	-0.00681	0.040837	0.011325	0.041851	0.001479	0.000181	-0.12819	1	-0.0225	-0.00428
Month	0.037694	0.003701	0.046703	-0.22379	0.075866	-0.33626	0.07389	-0.0225	1	0.038188
Multiple OneOff	0.998565	-0.01537	0.082343	-0.0583	-0.00816	-0.04511	0.011688	-0.00428	0.038188	1

Table A1.2.6: Count and percentage of 6489 respondents and median distance travelled from home to natural spaces broken down by explanatory variables from my surveys exploring distance travelled to access natural spaces in Wales.

Variable	Level	Count	Percentage	Median distance travelled from home point to natural space (km)
Gender	Male	2636	40.62	0.49
	Female	3776	58.19	0.54
	Own words	24	0.37	0.39
	Prefer not to say	53	0.82	3.06
Household income	Less than £15, 838	1696	26.14	0.54
	£15, 838 - £44, 125	3505	54.02	0.50
	More than £44, 125	1288	19.85	0.53
Education group *numbers show the overall education level	Secondary school	688	10.60	0.42
	2* GCSE	1499	23.10	0.42
	Apprenticeship	276	4.25	0.42
	3 A level	1051	16.20	0.61
	4 Higher Education	2975	45.85	0.59
Ethnic group	BAME	154	2.37	1.12
	White	6335	97.63	0.51
Land Cover at Start Point	Urban	726	11.19	0.70
	Suburban	4480	69.04	0.53
	Rural	1252	19.29	0.40
	No LC data	31	0.48	0.61
Survey	Jan '20	945	14.56	2.39
	April '20	1047	16.14	0.24
	June '20	844	13.01	0.33
	Oct '20	939	14.47	0.45

	Jan '21	884	13.62	0.44
	April '21	910	14.02	0.58
	June '21	920	14.18	0.69
Primary Reason (PR) for spending time at the natural space chosen	For mental/physical health, to feel rejuvenated, restored, happier and healthier	3433	52.90	0.58
	To feel inspired, inspired to create, inspired to conserve	145	2.23	0.46
	To feel connected to history, to be reminded of your own past	112	1.73	1.36
	To feel connected to other people, part of a community	266	4.10	0.54
	To feel connected to the natural world	1089	16.78	0.71
	To learn new things	108	1.66	1.26
	Other	1336	20.59	0.28
Importance to day-to-day wellbeing	1 - Unimportant	84	1.29	4.20
	2	210	3.24	1.17
	3	960	14.79	0.90
	4	1851	28.53	0.71
	5 – Very important	3384	52.15	0.33
Restrictions Were there restrictions on access to nature at the time of the survey	Restrictions	3714	57.24	0.35
	No restrictions	2775	42.76	0.97
Before, During, Since (BDS) Was the survey before, during or since a lockdown.	Before	945	14.56	2.39
	During	3714	57.24	0.35
	Since	1830	28.20	0.62
Month The month the survey was carried out	January	1829	28.19	0.91
	April	1957	30.16	0.36
	June	1764	27.18	0.48
	October	939	14.47	0.45
MultipleOneOff Did the respondent spend time at the space they selected multiple times throughout the year or was it a one off trip.	Multiple times throughout the year	6073	93.59	8.97
	One off trip	416	6.41	0.47

Table A.1.2.7. Summary table from my general linear model predicting the distance travelled to natural spaces in Wales by Welsh residents, following step-wise regression.

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.455524	0.147057	3.097608	0.00196
PR1Connected to history	0.171256	0.106143	1.613438	0.1067
PR1Connected to other people	0.031108	0.069648	0.44664	0.655151
PR1Connected to the natural world	0.025613	0.037017	0.691927	0.489009
PR1Other	-0.1488	0.035968	-4.13704	3.56E-05
PR1To be inspired	-0.03593	0.091713	-0.39178	0.695231
PR1To learn new things	0.378777	0.114073	3.320481	0.000904
HowLongSpendHRS_NOW	-0.00377	0.000817	-4.60636	4.18E-06
GenderI'd prefer not to say	0.303714	0.15469	1.963366	0.049648
GenderI'd prefer to use my own words	-0.15412	0.214698	-0.71786	0.472868
GenderMale	-0.04098	0.027853	-1.47117	0.141296
AgeCont	0.003303	0.000957	3.451589	0.000561
EthnicBW1BAME	0.197014	0.089311	2.205927	0.027426
Wellbeing_Ord2	-0.21677	0.148846	-1.45636	0.145343
Wellbeing_Ord3	-0.28596	0.131941	-2.16735	0.030246
Wellbeing_Ord4	-0.34651	0.130123	-2.66295	0.007766
Wellbeing_Ord5 - Very important	-0.46998	0.129738	-3.6225	0.000294
BDSDuring	-0.67702	0.051201	-13.2229	2.19E-39
BDSSince	-0.36606	0.061846	-5.91894	3.41E-09
MonthJanuary	0.125601	0.045829	2.740671	0.006149
MonthJune	0.098582	0.034719	2.839384	0.004535
MonthOctober	0.27605	0.045058	6.126518	9.53E-10
MultipleOneOffOne off trip	1.133345	0.083441	13.58262	1.97E-41

Appendix 1.3. Ethics Consent

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RESEARCH PROJECT ETHICAL ISSUES CHECKLIST FOR STAFF AND PHD STUDENTS

Researchers (staff and PhD) should complete this ethical checklist for all research projects. If you answer 'no' in ALL of sections A B and C below, please keep this form on file as it may need to be referred to when you submit results for publication. If you answer 'yes' in ANY of sections A, B, or C below, further details will be required. Please complete sections 1, 2 or 3 as appropriate.

To assist with record keeping, please name your checklist files according to the following format: Ethics_surname_year

A. Research involving people and human biological samples	YES	NO
Does the proposed research involve people or human biological samples?	X	
B. Research on animals	**YES**	**NO**
Does the proposed research involve live vertebrates or cephalopods? (if working with live invertebrates other than cephalopods please provide a brief description of your work in section 2)		X
C. Research conducted overseas and fieldwork	**YES**	**NO**
Will the proposed research be conducted overseas or use experimental material from other countries?		**X**
Does the proposed research involve fieldwork where permission from landowners or other authorities may be required?		**X**

Project title: Beyond Land Cover: Understanding how we engage with nature in Wales (working title)	
Proposed start date: January 2020, to be repeated mid-July 2020	
Proposed end date: July 2020	
Funding body	**The Drapers' Company, CEH** **Additional funding from Bangor University School of Natural Sciences Research Committee**
Name of researcher (applicant):	**Rachel Dolan**
Email address:	**rachel.dolan@bangor.ac.uk**
For PhD students only	

	Supervisor's name:	**Dr Simon Willcock**
	Supervisor's signature	

Please note that it is your responsibility to follow the University's Research Ethics Policy and any relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data. It is also your responsibility to ensure that you have all necessary permits to conduct your research. <u>Any significant change to the project over the course of the research should be notified to Michelle Jones</u> (michelle.jones@bangor.ac.uk) and may require a new application for ethics approval.

Research involving people and human biological samples (please complete if you ticked yes in box A)

	Research that may need a full review by CNS Ethics Committee	Yes	No
1	Does the research require review by an NHS Research Ethics Committee? If Yes the research should be submitted to the NHS Ethics Committee in the first instance.		**X**
2	Does the research involve children or vulnerable adults, such as those with a learning disability or cognitive impairment, or individuals in a dependent or unequal relationship e.g., your own students?		**X**
2a	If you answered Yes to question 2, has the researcher confirmed with Human Resources if a Disclosure and Barring Service (DBS) check is required (replaces CRB check)?		
3	Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited? (e.g., students at school, members of self-help group, members of an association?).	**X**	
4	Will the research necessarily involve deception or be conducted without participants' full and informed consent at the time the study is carried out (e.g., covert observation of people in non-public places, analysis of social media data)?		**X**
5	Will the study involve discussion of sensitive topics (e.g., illegal or political behaviour-including resource use which breaks local rules, mental health, gender or ethnic status, drug use)?		**X**
6	Will the study involve intrusive interventions (e.g., administration of drugs or other substances, vigorous physical exercise)?		**X**
7	Will the study induce psychological stress, anxiety or humiliation or cause more than minimal pain?		**X**
8	Will the research involve access to records of personal or confidential information, including genetic and other biological information, concerning identifiable individuals?		**X**

9	Will the research involve collecting and storing information which identifies individuals?	X	
10	Will the research involve the collection or storage of human tissues (defined as any material containing human cells i.e., including blood, urine and saliva)?		X
11	Will the research involve collecting data through an online survey?	X	

RESEARCH OUTLINE

If the answer to any of the above questions is yes, then please fill out the box below and submit to the CNS Ethics Committee along with your supporting information (questionnaires or interview protocol, copies of your informant information sheet, consent forms and completed social survey checklist) via Michelle Jones – michelle.jones@bangor.ac.uk.

Outline of proposed research and the research questions:

This proposed period of data collection will fit into chapter 2 - "Ecosystem Service Foraging and Social Groups" of the PhD project "Beyond Land Cover; understanding how we engage with nature in Wales" (working title).

This chapter explores if cultural ecosystem service foraging (CESF), the movement of people to gain cultural benefits from interacting with ecosystems, varies between different social groups; rural/urban, wealthy/poorer, genders, age groups. We also want to explore if the well-being of some groups is more reliant on cultural benefits from ecosystems than others and what barriers might prevent people from accessing these benefits.

Our research questions within this chapter are:
- Is there a difference in CESF along the rural -urban gradient?
- Do those of higher socio-economic status forage for CES over a greater area?
- Does CESF vary depending on gender?
- Does CESF vary between age groups?
- Does CESF vary based on the primary motivation for using an area?
- Is the well-being of different social groups more/less reliant on cultural benefits from ecosystems?

Identify the target population:

Our target population is residents within Wales over the age of 18.

The survey will be live online for one week in mid-January with the aim of collecting 1000 responses. The survey will then be live again for one week in mid-July to collect a further 1000 responses. The two survey times will allow us to see if responses are different between winter and summer.

Sampling design (how will target population be sampled):

Data will be collected through online surveys accessed through Pick my Postcode (PMP) (https://pickmypostcode.com/) PMP is a free postcode lottery website through which people can also complete surveys. With every survey completed members build a cash bonus, which they have a chance to win alongside prize money that is awarded to winners randomly drawn from the postcodes. We will target all postcodes across the whole of Wales. Individuals signed up to Pick my Postcode will receive a notification informing them there is a survey available for their postcode with a bonus of £1. This £1 goes into their bonus, but the individuals do not receive it immediately and are not able to withdraw it; instead, when they are lucky enough to win the lottery, the £1 survey payment is added on top of whatever lottery prize they win".

By working with Pick my Postcode, we will be able to target surveys at all postcodes throughout Wales. This will allow us to see how CESF changes across the rural-urban gradient.

"Informed Consent" information will be presented before the survey, see above for survey questions.

Define the potential benefits of the research:

Currently, assumptions are made about the cultural benefits people gain from natural spaces, cultural ecosystem services, based on land cover. Ecosystem services are a socio-ecological system but this only considers the ecological side and does not factor in the social side. This can lead to incorrect assumptions about what a space provides as not all groups across society can necessarily access the space equally or use it in the same way. This research will consider the social side of ecosystem services. We will explore how different groups (wealthier/poorer, different genders, rural/urban, different levels of education, different ethnic backgrounds) use natural spaces and how far they go from their start points to do so.

Our findings on how different groups interact with natural spaces, the benefits they gain there and the barriers they may face could be used by land managers and decision makers to reduce unequal access to natural spaces. Our aim is to collect data to inform land managers on how people use natural spaces so they can continue to use areas that are important to them. We also hope that by identifying barriers, more people will be able to access natural spaces.

Define how data will be stored and what information will be provided to participants about data collection or storage:

Data will be collected using Kobotoolbox, an open-source data collection software. The survey will be created and held on KoBotoolbox and respondents will access it through a link on Pick my Postcode. Survey submissions will be stored within a project account on the Kobotoolbox server which is username and password protected. Additionally, data will be encrypted as soon as the survey is completed. Once encrypted, data can only be accessed with a private key.

Define any potential risks or negative impacts:
Describe how risks will be controlled:

We are not collecting highly sensitive information but we will be collecting postcodes and household income bracket. Postcodes are identifying data. UK postcodes cover on average 15 properties but in very rural areas may only cover one. Postcode data will allow us to identify where people are starting their journeys to travel to the sites they tell us about. The full postcode, rather than just part, is needed to provide the highest possible resolution. We are interested in the distance from individuals' start to endpoints. This will allow us to establish the most accurate distances people "forage" over, and therefore also the distances they don't/can't reach. We expect

the majority of distances to be small (for example from someone's home to their local park). These micro-distances are very important to our research questions.

To illustrate this further, see map 1 below. The red mark shows the point located by a full postcode. The black "doughnut" shows the area given by the first four digits of the postcode. The blue area shows the first five digits. The orange area represents the natural space where the resident spends time. If we were only able to collect the first four digits of the postcode, we would not be able to capture that they travel to the space marked in orange. From the full postcode, we still cannot identify exactly where they live.

Map 1. The red mark shows the point located by a full postcode. The black "doughnut" shows the area given by the first four digits. The blue area shows the first five digits. The orange area represents the natural space that the resident spends time in.
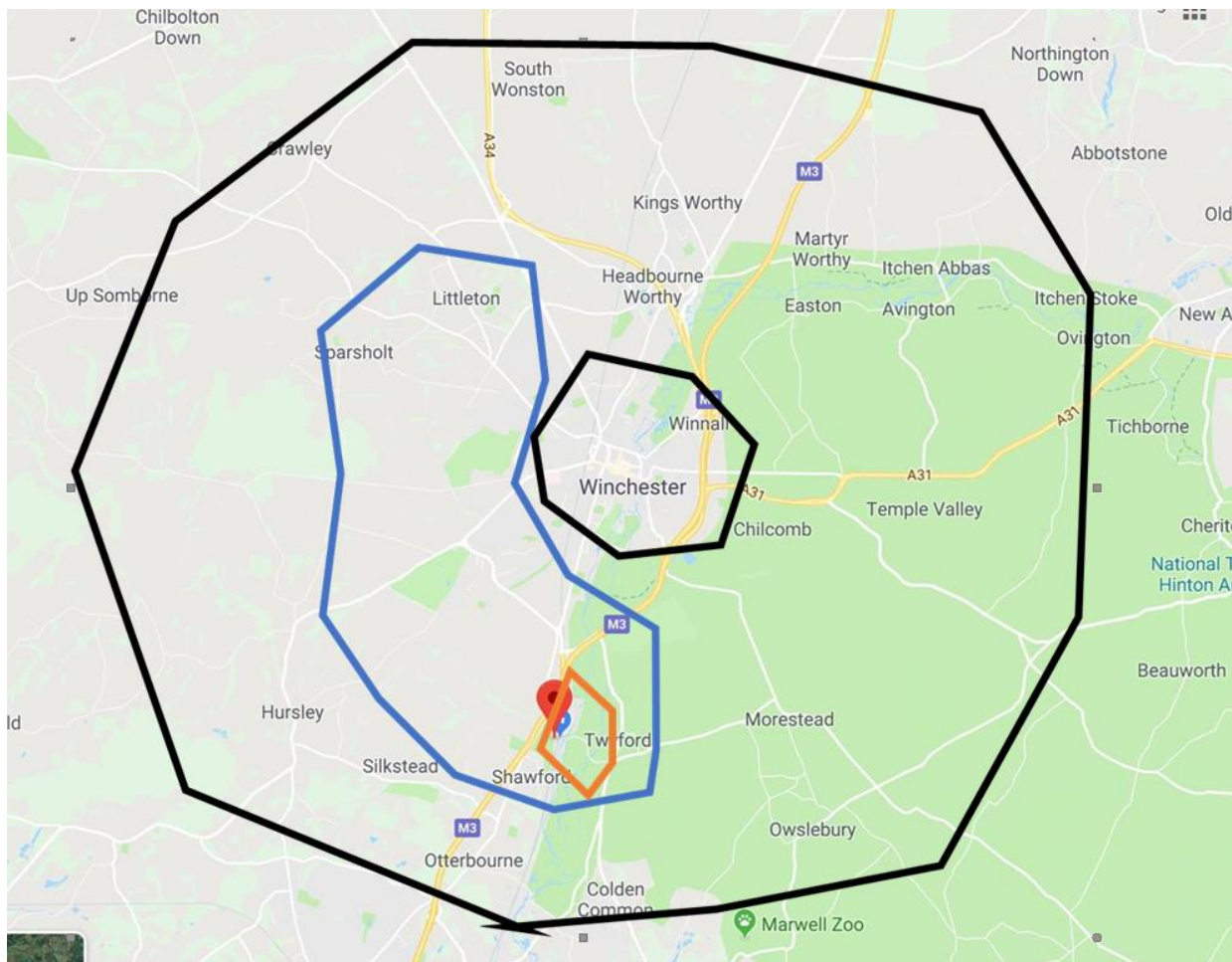
We have already received ethical clearance for the same survey questions (approval number: COESE2019RD01A). They were used in face-to-face surveys carried out in mid-Wales over August and September 2019. Here we are collecting exactly the same data, just using a different mechanism. Within one month of survey completion, we will move the postcode data into a separate file from the main dataset (linked with a code for each respondent). Therefore, it will not be possible to identify individuals (or any postcodes) from the main dataset – which will only have non-spatial information (i.e., the distance people travelled, but not where they travelled from). The separate file containing postcode data will not be shared with anyone and will be deleted once the project is completed and the manuscript has been published or within 3 years, whichever comes first.

Presentation of results will not enable the identification of individual addresses. Any results presented on maps will be at too course a resolution to identify addresses.

Participants will have the options to skip any question should they not feel comfortable answering or to withdraw from the survey at any point. This is made clear at the start of the survey. It will also be stated that if they stop the survey, they will not receive the bonus.

The data to be collected, how it will be used and stored will be explained beforehand so participants can give their full, informed consent to take part in the survey if they wish to, see informed consent document attached.

The checklist below should be completed by anyone whose social research (questionnaires, interviews, focus groups or other social survey methods) needs clearance by the CNS ethics committee.

	Tick (or added details)
Supporting documents	
A copy of the survey instrument(s) is attached.	Yes
A copy of the participant information sheet and consent forms are attached.	Yes
The research questions are laid out (in accompanying proposal or in RESEARCH OUTLINE above).	Yes
1. Fit to research questions	
The research questions are precise and answerable.	Yes
The survey questions are necessary and sufficient to answer the research questions.	Yes
The form of data to be collected (scalar, ordinal, categorical or qualitative) has been considered, and will allow appropriate analyses to be conducted.	Yes
2. Target population & sampling	
The target population is appropriate and necessary to answer the research questions.	Yes
The proposed sampling method is appropriate.	Yes
The proposed sample size is both achievable AND sufficient to answer the research questions.	Yes
4. Ethics and consent	
The participant information/covering letter clearly states:	
the purpose of the research.	Yes

the approximate duration of the survey and what is required of participants.	Yes
whether data will be anonymous/confidential (and who will see the data), how it will be stored (and any possible reuse e.g., public archiving).	Yes
how the data will be used.	Yes
the name and contact details (usually email) of the researcher.	Yes
clear and appropriate procedures for obtaining and recording Free Prior Informed Consent.	Yes
5. Piloting & proofing	
The survey instrument(s) has been piloted appropriately and amended as necessary.	Yes
Plans for further piloting are appropriate.	N/A
Survey instrument(s) and any covering letters checked for spelling, grammar and clarity.	Yes
Survey questions are clear, with appropriate response options (if applicable) and arranged in a logical order.	Yes
Jargon is minimised and any necessary terminology is clearly defined.	Yes
The survey is an appropriate length, and not overly onerous to complete.	Yes – option to extend survey or make shorted if desired

Research on animals (vertebrates and cephalopods) (please complete if you ticked yes in box B)

Research that may need review by either the CNS Ethics Committee or the University Animal Welfare and Ethical Review Body	Yes	No
1. Do you intend to perform any actions which fall under the Animals (Scientific Procedures) Act 1986? Please see http://tna.europarchive.org/20100413151426/http://www.archive.official-documents.co.uk/document/hoc/321/321.htm		
If yes, please go to question 2. If no, please complete project details section and outline of proposed research and forward to John Latchford (j.latchford@bangor.ac.uk), together with your initial research project ethical issues checklist.		
2. Will the research be carried out in the UK?		

If yes, please go to question 3. If no, please complete the research outline box below and return to John Latchford (j.latchford@bangor.ac.uk), together with your initial research project ethical issues checklist.		
3. Is this research authorised by a current Home Office project licence?		
If yes please complete the research outline box below and send the completed form, together with your initial research project ethical issues checklist, to John Latchford (j.latchford@bangor.ac.uk). If no, you must obtain a project licence before starting work. Please see *http://www.homeoffice.gov.uk/publications/science/769901/licences/project-licences/.* The completed project licence application must be submitted to and approved by the University Ethical Review Committee (Gwenan Hine, gwenan.hine@bangor.ac.uk) prior to a formal application to the Home Office. *Please also send a copy of this form, together with your initial research project ethical issues checklist, to John Latchford (j.latchford@bangor.ac.uk).*		
4. Have you got agreement of a Home Office personal licence holder that they will carry out any procedures which fall under the Act?		
If yes, please ask the appropriate licence holder to countersign this form and send it to John Latchford (j.latchford@bangor.ac.uk). If no, you will need obtain a personal Home Office licence before starting work. Please see *http://www.homeoffice.gov.uk/publications/science/769901/licences/personal-licences/?view=Standard&pubID=788367. Please also send a copy of this form, together with your initial research project ethical issues checklist, to John Latchford (j.latchford@bangor.ac.uk).*		

Home Office project licence details (*if you answered 'yes' to question 3*)
Home Office personal licence holders (*if you answered 'yes' to question 4*)
I confirm that I will carry out any procedures covered by the Animals (Scientific Procedures) Act in relation to this project.
Licence holder's name:
Licence holder's signature:
Date:

RESEARCH OUTLINE

You must complete this section for all work involving live vertebrates and cephalopods (include a brief description of the work if working with invertebrates other than Cephalopods)

Define the potential benefits of the research

List species and numbers of animals used and in which country the proposed study will take place
Describe any risks (including the potential for pain, suffering or lasting harm) to animals used in the study
Describe how the principles of the 3Rs (Replacement, Reduction, Refinement) have been applied to your study

3 Research conducted overseas and fieldwork (please complete if you ticked yes in box C)

Research that may need review by the CNS Ethics Committee	YES	NO
1. Does the proposed research involve the use of local resources from other countries (genetic, animal, plant, etc)?		
2. If the proposed research involves fieldwork, have you determined whether you have appropriate authorisation and necessary permits, including permits for importation of material to the UK if working overseas?		

If you have answered 'yes' to question 1 please complete the research outline section below and forward to Michelle Jones (michelle.jones@bangor.ac.uk)

RESEARCH OUTLINE

Outline of proposed research:

The proposed research is described above

Explain the ethical issues raised by the research and how they will be mitigated.

Ethical issues and mitigation are described above.

Explain what permits are needed for this research and confirm if they have been obtained or how they will be obtained.
Permission to share the survey will be secured though Pick my Postcode.

Appendix 1.4. A description of the initial in-person study

The questionnaire presented in this analysis was initially developed for a study to explore how the natural environment (both land and seascape) within the Summit to Sea Project area was being used and engaged with by both residents and visitors. Summit to Sea was a landscape-scale partnership project in mid-Wales that explored how best to use natural resources to benefit people and nature. In this work I interviewed 510 people (221 resident and 298 visitors). A brief report is included below. This study acted as a development phase and extensive pilot for the online survey presented in the main text.

Methodology

 A survey was designed to collect data on: how far people travel to natural spaces access to Cultural Ecosystem Services (CES), the importance of these spaces to their day-to-day wellbeing, any barriers people experience in accessing natural spaces. People were also asked about their primary motivation for spending time at a natural space. Responses were given in terms of natural spaces 'most recently visited'. Natural spaces were defined as follows: including but are not limited to gardens, the mountains, the coast, meadows, farmland, a commute along a green route, waterbodies and nature reserves. Demographic data on gender, age, income and education was also collected. Surveys were carried out face-to-face on tablets.

Within the Summit to Sea project area, I surveyed two target populations (See map 1):

a. **Visitors to nature sites** – Participants were surveyed at key locations within the project area: Bwlch Nant y Arian, Ynys Las Nature Reserve, Ynys Hir RSPB reserve, Centre for Alternative Technology. It was felt these sites were more likely to attract people with a particular interest in nature and outdoor activities, which may not necessarily have been representative of the whole area. The sites listed above are more likely to attract those specifically interested in nature and so result in a non-representative sample.

b. **Residents and visitors at more general sites within the Summit to Sea area as a whole -** Participants were surveyed at more general locations: Aberystwyth prom, Machynlleth Market, Caffi Cletwr, Borth beach, Plas Machynlleth and Aberystwyth Parkrun in Plascrug Park.
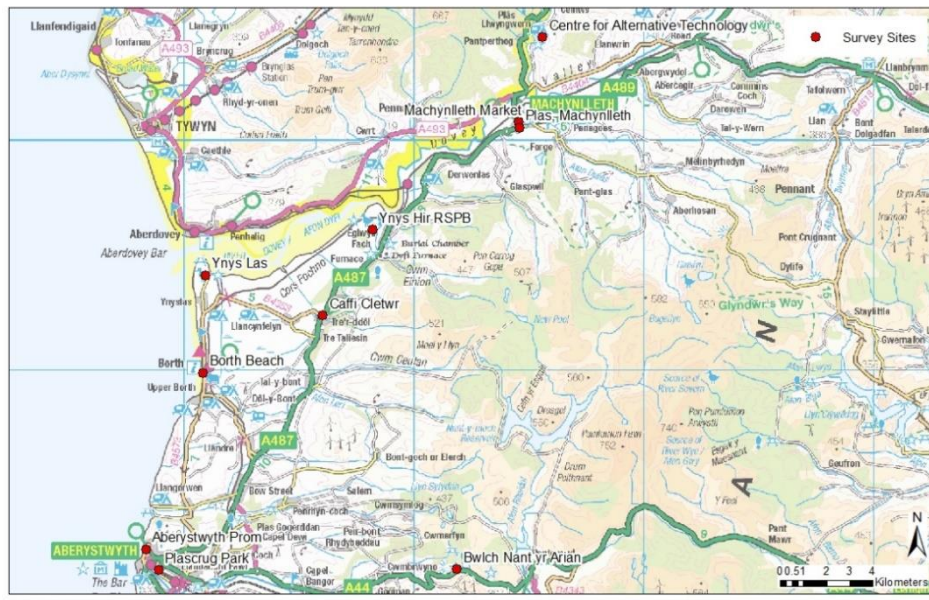
Figure A.1.4.1: Survey sites within the Summit to Sea project area.

Results

I spoke to 510 people. A total of 596 natural spaces were highlighted by these respondents, as locations they had recently visited (see map 2), of which 283 were chosen by residents and 313 were chosen by visitors. Respondents could select up to 3 spaces each. In addition to the expected representation of survey sites, a notable clustering along the coast can be observed, as well as sites that were close to areas of population, potentially showing the importance of regular access from home locations (see connections to wellbeing analysis below). Nonetheless, a wide variety of inland and more remote spaces were also being used.
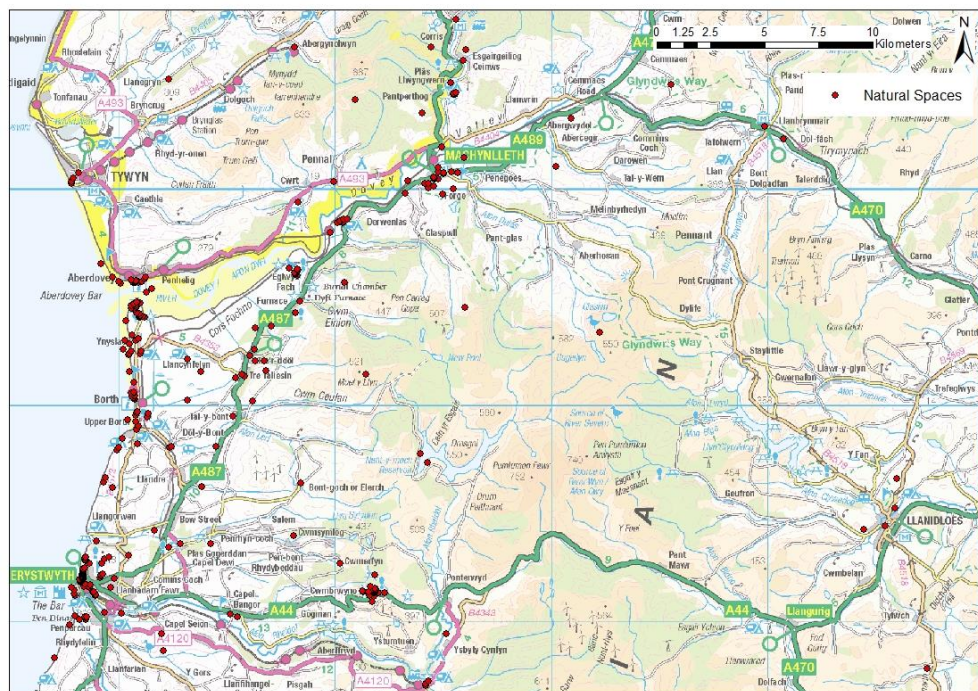
Figure A.1.4.2: Natural spaces identified by survey respondents within the S2S project area (OS map copyright: © Crown Copyright and database right 2020. Ordnance Survey 100021874)

Distances travelled: Residents in the S2S project area travelled an average of 5.59 km from their start point (home) to access the natural spaces they identified. Visitors who were staying in the area travelled an average of 25.68 km from where they were staying to the natural spaces they chose. This higher figure could be because they were specifically going to an attraction as a day trip. Visitors who were not staying in the area travelled an average of 111.74 km to access the natural spaces they chose. Several respondents talked about stopping at somewhere in the project area on the way to somewhere else, making the time part of a bigger journey.

Reasons for spending time in nature: The most selected reason for spending time in natural spaces was "for mental and physical health, to feel rejuvenated, restored, happier and healthier". A notable proportion of respondents also highlighted the importance of feeling 'connected to the natural world'.

Frequency of visits: When asked about their frequency of nature engagement more broadly, the most selected option was "once a day" with 31.95% of respondents. If residents are accessing spaces frequently, they are accessing them close to home.

Connections to Wellbeing: For all respondents it was clear that the natural spaces visited had importance for day-to-day wellbeing. For residents, the more important a space is to their wellbeing, the closer it is to their home. This pattern was less clear for visitors, probably because they do not live in the project area so the spaces they have selected there are less relevant to their everyday lives and day-to-day wellbeing.

Conclusions

These results show the importance of the natural environment within the project area to both local residents and visitors. Whilst results show the willingness of visitors to travel substantial distances to access natural spaces within the project area, they also shown the frequency of usage by local residents. This regular access to natural spaces in notably in locations close to, and easily accessible from, peoples' homes. This frequent engagement is very important to peoples' wellbeing, ensuring that they feel closer to nature, but also are rejuvenated, restored, happier and healthier.

Appendix 2: Appendix to Chapter 4 - The impacts of Covid-19 restrictions on access to natural spaces in Wales

Appendix 2.1. Online survey, using June 2021 as an example

The survey was available in English and Welsh. Respondents could choose up to three spaces. Here I have included the questions relating to the spaces chosen only once to avoid repetition. Questions relating to Covid, which were the focus of this chapter, come towards the end of the survey.

For links to the actual surveys used please see Table A2.2.1 (below).

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Purpose of the research *This research is part of a PhD project with Bangor University. Our research aims to explore how people engage with natural spaces, the benefits people gain from engaging with these spaces and the barriers that might prevent people from engaging with them. Our aim is to collect data to inform land managers, to support continued and enhanced access to natural spaces where appropriate*
Voluntary participation *Your participation in the survey is voluntary. You can withdraw from the survey at any time should you wish to. Please note that if you withdraw from the survey you will not receive your bonus. Overall, this survey should take approximately 10 minutes to complete.*
Use of data *The information provided by you in this survey will be used for research purposes only. It will be stored securely and remain confidential. T overall findings will become part of a PhD thesis and may be published as part of our studies so others may learn from the research. We will be collecting some demographic data; age bracket, gender, household income bracket and level of education. I will also be collecting postcodes which, when combined with the demographic data, could potentially allow identification of individuals. For this reason, postcode data will be stored for 3 years only and then deleted. Presentation of results will not enable the identification of addresses or individuals*
Contact information *Should you have any questions about this research or wish to have your data removed, please contact Rachel Dolan (Postgraduate Researcher, University of Bangor) via email: rachel.dolan@bangor.ac.uk. Should you have any complaints about this research, please contact Dr Simon Willcock (Senior Lecturer, Bangor University) via email: s.willcock@bangor.ac.uk*
Are you happy to proceed with the survey?

o Yes
o No

Thank you very much for your time. Do you have any questions?

This research is part of a PhD project with Bangor University. Should you have any questions about this research, please contact Rachel Dolan (Postgraduate Researcher, University of Bangor) via email: rachel.dolan@bangor.ac.uk. Should you have any complaints about this research, please contact Dr Simon Willcock (Senior Lecturer, Bangor University) via email: s.willcock@bangor.ac.uk

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What is your home postcode? (this information is useful to help us understand how far people are able to travel)

Please type in your postcode

Please identify the natural space you have spent time at most recently on the map. Natural spaces can include but are not limited to: gardens, mountains, the coast, meadows, farmland, a commute along a green route, water bodies, nature reserves... If you did a route, for example a bike ride, please select the point that most represents the route for you.

Zoom in to where you want to go on the map and select a point. Please try to be as precise as possible. You will see a blue marker which w save automatically. If you want to zoom straight to your local area you can input your postcode in the search bar above the map. If you are using the browser on your mobile device/tablet, you may need to tap "map" to activate the map first. Hit the black arrow to go back, do not hit the back button on your browser as this will close the survey.

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

search for place or address

© OpenStreetMap & Yohan Boniface & Humanitarian OpenStreetMap Team | Terms

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How often do you spend time at this space?

o Multiple times throughout the year
o One off trip

How long did you spend at this space?

Please select one

o Less than 30 minutes
   o 30 minutes to 1 hour
   o 1 hour to 4 hours
   o 4 hours to 8 hours

o   Overnight
o   Longer than overnight

On average, how often did you spend at this space during the lockdown periods?

The last lockdown ended in Wales on the 13th March, with restrictions easing gradually from this point onwards.

- o   Multiple times a day
- o   Once a day
- o   3-5 times a week
- o   1-2 times a week
- o   Once a fortnight
- o   Once a month
- o   Less than once a month
- o   Never

On average, how long did you spend at this space during the lockdown periods?

The last lockdown ended in Wales on the 13th March, with restrictions easing gradually from this point onwards.

Please select one
- o   Less than 30 minutes
- o   30 minutes to 1 hour
- o   1 hour to 4 hours
- o   4 hours to 8 hours
- o   Overnight
- o   Longer than overnight

On average, how often do you spend time in this space since lockdown restrictions eased?

The last lockdown ended in Wales on the 13th March, with restrictions easing gradually from this point onwards.

- o   Multiple times a day
- o   Once a day
- o   3-5 times a week
- o   1-2 times a week
- o   Once a fortnight
- o   Once a month
- o   Less than once a month
- o   Never

On average, how long do you spend at this space since lockdown restrictions eased?

The last lockdown ended in Wales on the 13th March, with restrictions easing gradually from this point onwards.

Please select one

o   Less than 30 minutes
- o   30 minutes to 1 hour
- o   1 hour to 4 hours
- o   4 hours to 8 hours
- o   Overnight
- o   Longer than overnight

Do you need to travel to get to this space from home?

If you spend time in this space often, please choose the mode of transport you use most often e.g., if you mostly drive but occasionally cycle, choose drive.

o   No (if the space you chose is your own garden or land)
   o   Walk
   o   Cycle
   o   Bus
   o   Drive
   o   Taxi
   o   Train
   o   Fly
   o   Part of a journey I make anyway e.g., commute
   o   Other

How do you travel to get to this space?

Please specify in your own words

Why did you choose to spend time at this space? Please select your MAIN reason.

Please select one. You can add more reasons in the next section.

   o   To learn new things

   o   To be inspired, inspired to create, inspired to conserve

   o   To feel connected to the natural world

   o   To feel connected to history, to be reminded of your own past

   o   For mental/physical health and fitness, to feel rejuvenated, restored, happier and healthier

   o   To feel connected to other people, part of a community

   o   Other

Other than your main reason, please select any other reasons that you spend time in this space, if any

Please select all that apply. There is the option add more details next in the next section.

   o   To learn new things

   o   To be inspired, inspired to create, inspired to conserve

   o   To feel connected to the natural world

   o   To feel connected to history, to be reminded of your own past

   o   For mental/physical health and fitness, to feel rejuvenated, restored, happier and healthier

   o   To feel connected to other people, part of a community

   o   Other

Would you like to explain further or tell us anything else about your reasons for spending time at this space? Please give more details if you answered "other" to the previous questions.

On a scale from 1 (unimportant) to 5 (very important), how important is this space to your day-to-daywell-being?

Well-being can be considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, hohappy you feel and how anxious you feel.

| 1 - Unimportant | 2 | 3 | 4 | 5 - Very important |

THANK YOU for answering questions about the natural space that you used most recently. Would you liketo answer the same questions about another natural space that you spent time at recently, or move on to the next section?

o Pick another space   o Move on

Are there any natural spaces that you can't spend time in or not as often as you would like?
 	
  o Yes
 	
  o No

In general, what do you feel is preventing you from spending time in some natural spaces?
Select all that apply
 	
  o Covid-19/Coronavirus restrictions
 	
  o Lack of money
 	
  o Lack of time
 	
  o Too far away
 	
  o Disability
 	
  o Poor health
 	
  o Poor mobility
 	
  o Lack of transport
 	
  o Unsure where to go
 	
  o Unsure where allowed to go
 	
  o Lack of confidence
 	
  o Feel out of place
 	
  o Care responsibilities
 	
  o Access to land prevented
 	
  o Other

In general, what do you feel is preventing you from spending time in some natural spaces? *Please describe in your own words*

Can you think of a specific natural space that you were recently unable to spend time in?
 	
  o Yes
 	
  o No

Please identify the natural space that you were unable to spend time in on the map

Please identify on the map. Zoom in to where you want to go and select a point. You will see a blue marker which will save automatically. If you want to zoom straight to your local area you can input your postcode in the search bar above the map. If you are using the browser on your mobile device or tablet, you may need to tap "map" to activate the map first. Hit the black arrow to go back, do not hit the back button on your browser as this will close the survey.

latitude (x.y °)

longitude (x.y °)

altitude (m)

accuracy (m)

search for place or address

© OpenStreetMap & Yohan Boniface & Humanitarian OpenStreetMap Team | Terms

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What is the primary reason preventing you from spending time in this natural space?

Please select one

- o Covid-19/Coronavirus restrictions
- o Lack of money
- o Lack of time
- o Too far away
- o Disability
- o Poor health
- o Poor mobility
- o Lack of transport
- o Unsure where to go
- o Unsure where allowed to go
- o Lack of confidence
- o Feel out of place
- o Care responsibilities
- o Access to land prevented
- o Other

What do you feel is preventing you from spending time in this natural spaces?

Please describe in your own words

Information about you

On a scale from -2 (a large decrease) to +2 (a large increase), how large an effect has the Covid-19/Coronavirus pandemic had on the frequency with which you spend time in natural spaces?

○	○	○	○	○
-2 - a large decrease	-1	0 - no change	1	2 - a large increase
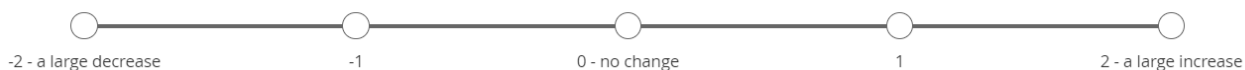
On a scale from -2 (a large decrease) to +2 (a large increase), how large an effect has the Covid-19/Coronavirus pandemic had on how long you spend time in natural spaces?
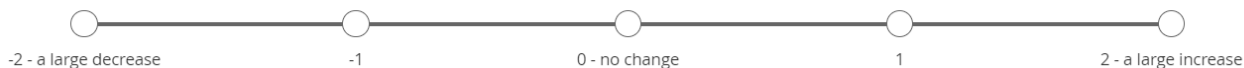
○	○	○	○	○
-2 - a large decrease	-1	0 - no change	1	2 - a large increase

On a scale from -2 (a large decrease) to +2 (a large increase), how large an effect has the Covid-19/Coronavirus pandemic had on the distance you travel to spend time in natural spaces?

○	○	○	○	○
-2 - a large decrease	-1	0 - no change	1	2 - a large increase

On a scale from -2 (a very negative effect) to +2 (a very positive effect), what effect have the lockdown restrictions on access to natural spaces had on your day-to-day wellbeing?

Well-being can be considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, how happy you feel and how anxious you feel.

○	○	○	○	○
-2 - a very negative effect	-1	0 - no effect	1	2 - a very positive effect
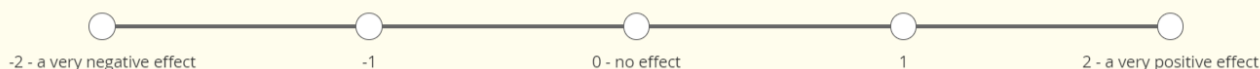
Relative to the general population in Wales, how much do you feel you have adapted your behaviour to reduce your personal risk of catching Covid-19?

- o   More than most people
- o   Equivalent to most people
- o   Less than most people

When not affected by lockdown restrictions, how often do you spend time in natural spaces?

- o   Multiple times a day
- o   Once a day
- o   3-5 times a week
- o   1-2 times a week
- o   Once a fortnight
- o   Once a month
- o   Less than once a month
- o   Never

When not affected by lockdown restrictions, what activities do you do in natural spaces?

Select all that apply

- o   Walking
- o   Dog walking
- o   Picknicking
- o   Taking children out to play
- o   Informal games e.g., frisbee
- o   Running

o   Wildlife watching
o   Road cycling
o   Outdoor swimming
o   Mountain biking or off-road cycling
o   Fishing
o   Watersports
o   Other

In general, what activities do you do in natural spaces?

In your own words

Do you have access to a garden?

     o   Yes

     o   No

Please select your age group

     o   Under 20

     o   20-24

     o   25-29

     o   30-34

     o   35-39

     o   40-44

     o   45-49

     o   50-54

     o   55-59

     o   60-64

     o   65-69

     o   70-74

     o   75-80

     o   84-89

     o   90-94

     o   95-99

     o   100 and over

Please select the gender you identify as

     o   Female

     o   Male

     o   I'd prefer not to say

     o   I'd prefer to use my own words

What gender do you identify as

Please use your own words

Please select your household income group

- o Less than £15, 838
- o £15,838 - £44, 125
- o More than £44, 125

Please select your highest level of education

- o Primary school
- o Secondary school
- o GCSE grades D-G/1-3, level 1 diploma/NVQ
- o GCSE grades A*-C/4-9, level 2 diploma/NVQ
- o Apprenticeship
- o AS/A level, Baccalaureate, level 3 diploma/NVQ
- o Level 4 and higher diploma/NVQ, access to higher education, foundation degree, bachelor's degree, master's degree,doctorate

Please select the ethnic background you identify as

You can select more than one option

- o White – Welsh/English/Scottish/Northern Irish/British
- o White – Irish
- o White – Gypsy or Irish Traveler
- o White – any other white background
- o Mixed/Multiple ethnic groups – White and Black Caribbean
- o Mixed/Multiple ethnic groups – Which and Black African
- o Mixed/Multiple ethnic groups – White and Asian
- o Any other Mixed/Multiple ethnic background
- o Indian
- o Pakistani
- o Bangladeshi
- o Chinese
- o Any other Asian background
- o African
- o Caribbean
- o Any other Black/African/Caribbean background
- o Arab
- o Any other ethnic group

Thank you very much for taking part. Do you have any questions?

This research is part of a PhD project with Bangor University. The information provided by you in this survey will be used for research purposes only. It will be stored securely and remain confidential. Your data will not be used in a way that would allow identification of individual responses. The overall findings will become part of a PhD thesis and may be published as part of

our studies so others may learnfrom the research. Should you have any questions about this research, please contact Rachel Dolan (Postgraduate Researcher, Bangor University) via email: rachel.dolan@bangor.ac.uk. Should you have any complaints about this research, please contact Dr Simon Willcock (Senior Lecturer, Bangor University) via email: s.willcock@bangor.ac.uk

Appendix 2.2. Supplementary Tables

Table A2.2.1: Survey dates, number of responses and links to my surveys exploring distance travelled to natural spaces in Wales.

Survey	Dates Live	Responses*	Link
January 2020	16th – 23rd	1002	https://ee.kobotoolbox.org/single/8IbNzXvh
April 2020	22nd – 29th	1178	https://ee.kobotoolbox.org/single/pjY6XinN
June 2020	2nd – 9th	1066	https://ee.kobotoolbox.org/single/3wKxF5FA
October 2020	30th – 17th November	1101	https://ee.kobotoolbox.org/single/Lr0XG580
January 2021	14th – 1st Feb	1184	https://ee.kobotoolbox.org/single/wKPOlvCQ
April 2021	14th – 29th	1019	https://ee.kobotoolbox.org/single/nCLTgAjb
June 2021	2nd – 23rd	1031	https://ee.kobotoolbox.org/single/BuJGvlJP

*Total responses before data cleaning

Table A2.2.2: Land cover classifications from CEH Land Cover 2019 grouped into broader categories for use in my analysis. Respondents to my surveys exploring distance travelled to natural spaces in Wales provided their home postcode. I then spatially joined these start points to a GIS layer of land cover classifications (CEH Land Cover 2019) in ArcGIS to give us the land cover at people's home locations. These were grouped into broader categories in R Statistical Software v4.1.2; R Core Team 2021 to allow us to explore if there was a difference in distance travelled between those living in urban compared to rural areas.

UKCEH Land Cover class	Grouping used in analysis
Deciduous woodland	Rural
Coniferous woodland	Rural
Arable	Rural
Improved grassland	Rural
Neutral grassland	Rural
Calcareous grassland	Rural
Acid grassland	Rural
Fen	Rural
Heather	Rural
Heather grassland	Rural
Bog	Rural
Inland rock	Rural
Freshwater	Rural
Supralittoral rock	Rural
Littoral sediment	Rural
Saltmarsh	Rural
Urban	Urban
Suburban	Suburban

Tables A2.2.3. Correlation tables. Correlation values were calculated using the polychoric function (Olsson, 1979; Drasgow, 1986) in R Statistical Software (v4.1.2; R Core Team 2021).

a. Correlation values between all explanatory variables used to in my model to predict change in frequency, time spent and distance travelled to natural spaces over Covid-19 restrictions in Wales. None of the variables showed greater correlation than 0.7, and so I concluded that collinearity issues in the analyses were unlikely.

	Household income	Gender	Education Group	Ethnic Group	Land Cover	Wellbeing	Garden	Before During Since
Household income	1	-0.02516	0.078634	-0.11429	0.000359	-0.04073	0.027873	-0.00176
Gender	-0.0251566	1	0.126166	-0.22157	0.040233	-0.10971	-0.08119	-0.02695
Education Group	0.0786341	0.126166	1	-0.1112	-0.00267	0.012032	0.006526	-0.00438
Ethnic Group	-0.1142867	-0.22157	-0.1112	1	0.14634	0.236109	0.236111	-0.01841
Land Cover	0.0003586	0.040233	-0.00267	-0.14634	1	-0.14078	-0.27572	-0.00076
Wellbeing	-0.0407346	-0.10971	0.012032	0.236109	-0.14078	1	0.214618	-0.02281
Garden	0.0278727	-0.08119	0.006526	0.236111	-0.27572	0.214618	1	0.003631
Before During Since	-0.0017569	-0.02695	-0.00438	-0.01841	-0.00076	-0.02281	0.003631	1

b. Correlation values between all explanatory variables used to in my overall model to explore if change in frequency, time spent and distance travelled to natural spaces over Covid-19 restrictions in Wales affected day-to-day wellbeing.

	Household income	Gender	Education Group	Ethnic Group	Land Cover	Wellbeing	Garden	Before During Since	Frequency	Distance	How long spend
Household income	1	-0.02516	0.078634	-0.11429	0.000359	-0.04073	0.027873	-0.00176	-0.004679	-0.04828	-0.0066919
Gender	-0.02516 57	1	0.126166	-0.22157	-0.040233	-0.10971	-0.08119	-0.02695	-0.05494	-0.0258	-0.10460131
Education Group	0.0786342	0.126166	1	-0.1112	-0.00267	0.012032	0.006526	-0.00438	-0.01108	-0.01302	-0.01084296
Ethnic Group	-0.114287	-0.22157	-0.1112	1	0.14634	0.236109	0.236111	-0.01841	-0.07036	0.00138	-0.00300426
Land Cover	0.0003587	-0.040233	-0.00267	-0.14634	1	-0.14078	-0.27572	-0.00076	-0.01636	-0.01472	-0.03123714

Wellbeing	-0.040735	-0.10971	0.012032	0.236109	-0.14078	1	0.214618	-0.02281	0.158031	0.117983	0.17243399
Garden	0.0278728	-0.08119	0.006526	0.236111	-0.27572	0.214618	1	0.003631	0.060865	0.000807	0.03004619
Before During Since	-0.001757	-0.02695	-0.00438	-0.01841	-0.00076	-0.02281	0.003631	1	-0.00199	-0.03345	-0.01343236
Frequency	-0.004679	-0.05494	-0.01108	-0.07036	-0.01636	0.158031	0.060865	-0.00199	1	0.587294	**0.83635519**
Distance	-0.04828	-0.0258	-0.01302	-0.00138	-0.01472	0.117983	0.000807	-0.03345	0.587294	1	0.6092161
How long spend	-0.006692	-0.1046	-0.01084	-0.003	-0.03124	0.172434	0.030046	-0.01343	**0.836355**	0.609216	1

Table A2.2.4. Count and percentage of 5783 respondents broken down by explanatory variables in final dataset.

Variable	Level	Count	Percentage
Gender	Male	2381	41
	Female	3328	58
	Own words	24	<1
	Prefer not to say	50	1
Household income	Less than £15, 838	1505	26
	£15, 838 - £44, 125	3120	54
	More than £44, 125	1158	20
Education group *Numbers show the overall education level	Secondary school	613	11
	2* GCSE	1350	23
	Apprenticeship	245	4
	3 A level	938	16
	4 Higher Education	2637	46
Ethnic group	BAME	140	2
	White	5643	98
Land Cover at Start Point	Urban	638	11
	Suburban	3972	69
	Rural	1157	20
	No LC data	16	<1
Before, During, Since (BDS) Was the survey before, during or since a lockdown.	Before	n/a	n/a
	During	3932	68
	Since	1851	32
Importance to day-to-day Wellbeing	1 – unimportant	60	1
	2	165	3
	3	819	14
	4	1626	28

	5 – very important	3113	54
Garden Did the respondent have access to a garden	Yes	5363	93
	No	420	7
Effect on frequency of time spent in nature	-2 - a large decrease	899	16
	-1	823	14
	0 no change	1441	25
	1	1231	21
	2 - a large increase	1389	24
Effect on how long spent in natural spaces	-2 - a large decrease	890	15
	-1	815	14
	0 no change	1632	28
	1	1129	20
	2 - a large increase	1316	23
Effect on distance travelled	-2 - a large decrease	1711	30
	-1	638	11
	0 - no change	1601	28
	1	551	10
	2 - a large increase	1282	22
Effect on day-to-day wellbeing	-2 - a very negative effect	952	16
	-1	1699	29
	0 - no effect	1928	33
	1	685	12
	2 - a very positive effect	519	9

Tables A2.2.5. Model Summary Tables

a. Summary table for my ordinal regression model predicting the change in frequency with which people spent time in natural spaces over Covid-19 restrictions in Wales, equation 1.

	Value	Std. Error	t value	p value
HHIncome_OrdLess than £15, 838	0.069832	0.057497	1.214533	0.224544388
HHIncome_OrdMore than £44, 125	0.005887	0.062942	0.093526	0.925485378
GenderI'd prefer not to say	-0.00747	0.260402	-0.02868	0.977116862
GenderI'd prefer to use my own words	-0.8622	0.358912	-2.40226	0.01629428
GenderMale	-0.10248	0.050267	-2.03877	0.04147262
AgeCont	-0.01116	0.001714	-6.51048	7.49E-11
EducationGroup_Ord12 GCSE	0.160871	0.061081	2.633733	0.00844519
EducationGroup_Ord13 A level	0.133762	0.068413	1.955208	0.05055858
EducationGroup_Ord1Apprenticeship	0.013349	0.124328	0.107372	0.914493951
EducationGroup_Ord1Secondary school	0.198274	0.083845	2.364765	0.018041531
EthnicBW1BAME	0.336269	0.156707	2.145842	0.031885566
LandCoverGroup1No LC Data	1.173957	0.462614	2.537662	0.011159564
LandCoverGroup1Rural	0.012515	0.058766	0.212957	0.83136082
LandCoverGroup1Urban	-0.009	0.077265	-0.11647	0.907276786
Wellbeing_Ord11 - Unimportant	-1.14402	0.236224	-4.84294	1.28E-06
Wellbeing_Ord12	-0.57591	0.140741	-4.09197	4.28E-05
Wellbeing_Ord13	-0.5636	0.070841	-7.95573	1.78E-15
Wellbeing_Ord14	-0.22411	0.054928	-4.07996	4.50E-05
BDSSince	0.008388	0.049463	0.169582	0.865338932
Garden1No	-0.36212	0.093688	-3.86518	0.000111008
-2|-1	-2.4314	0.110243	-22.0548	8.58E-108
-1|0 - no change	-1.58474	0.107563	-14.7331	3.95E-49
0 - no change|1	-0.51406	0.105394	-4.8775	1.07E-06
1|2 - a large increase	0.471574	0.105131	4.485582	7.27E-06

b. Summary table for my ordinal regression model predicting the change in how much time people spent in natural spaces over Covid-19 restrictions in Wales, equation 2.

	Value	Std. Error	t value	p value
HHIncome_OrdLess than £15, 838	0.020336	0.057652	0.352728	0.724292237
HHIncome_OrdMore than £44, 125	-0.04481	0.063083	-0.71028	0.477531727
GenderI'd prefer not to say	-0.0769	0.259561	-0.29628	0.767018766
GenderI'd prefer to use my own words	-0.76969	0.357351	-2.15388	0.031249632
GenderMale	-0.13883	0.050367	-2.75638	0.005844428
AgeCont	-0.01107	0.001716	-6.44959	1.12E-10
EducationGroup_Ord12 GCSE	0.11131	0.061254	1.817175	0.069190376
EducationGroup_Ord13 A level	0.114813	0.068568	1.674452	0.094041708
EducationGroup_Ord1Apprenticeship	-0.06552	0.122731	-0.53387	0.593428398

EducationGroup_Ord1Secondary school	0.215511	0.084082	2.56311	0.01037393
EthnicBW1BAME	0.115185	0.157056	0.733403	0.463312576
LandCoverGroup1No LC Data	0.77499	0.444459	1.743669	0.081216762
LandCoverGroup1Rural	0.095984	0.058842	1.631209	0.102846254
LandCoverGroup1Urban	-0.06713	0.077309	-0.86831	0.385222497
Wellbeing_Ord11 - Unimportant	-1.1406	0.232903	-4.89731	9.72E-07
Wellbeing_Ord12	-0.65941	0.14031	-4.69964	2.61E-06
Wellbeing_Ord13	-0.57159	0.070528	-8.10439	5.30E-16
Wellbeing_Ord14	-0.21801	0.055071	-3.95872	7.54E-05
BDSSince	0.036989	0.049406	0.748673	0.454054375
Garden1No	-0.24658	0.093949	-2.62464	0.008674172
-2|-1	-2.47601	0.110431	-22.4212	2.44E-111
-1|0 - no change	-1.63215	0.107794	-15.1414	8.63E-52
0 - no change|1	-0.42189	0.105564	-3.99654	6.43E-05
1|2 - a large increase	0.511054	0.105431	4.847266	1.25E-06

c. Summary table for my ordinal regression model predicting the change in how far people travelled to spend time in natural spaces over Covid-19 restrictions in Wales, equation 3.

	Value	Std. Error	t value	p value
HHIncome_OrdLess than £15, 838	0.163497	0.057826	2.827416	0.004693
HHIncome_OrdMore than £44, 125	-0.17807	0.063934	-2.78516	0.00535
GenderI'd prefer not to say	0.145347	0.255403	0.569088	0.569296
GenderI'd prefer to use my own words	-0.06277	0.371716	-0.16887	0.865897
GenderMale	-0.03053	0.050519	-0.60433	0.545623
AgeCont	-0.00389	0.001726	-2.25196	0.024325
EducationGroup_Ord12 GCSE	0.396844	0.061436	6.459433	1.05E-10
EducationGroup_Ord13 A level	0.05488	0.069859	0.785586	0.43211
EducationGroup_Ord1Apprenticeship	0.269955	0.121907	2.214438	0.026799
EducationGroup_Ord1Secondary school	0.548731	0.083578	6.565492	5.19E-11
EthnicBW1BAME	0.169681	0.155257	1.092905	0.274435
LandCoverGroup1No LC Data	0.707138	0.458516	1.542232	0.123017
LandCoverGroup1Rural	0.019746	0.059801	0.330196	0.741252
LandCoverGroup1Urban	-0.08686	0.07754	-1.12025	0.262608
Wellbeing_Ord11 - Unimportant	-0.45244	0.240285	-1.88292	0.059711
Wellbeing_Ord12	-0.44821	0.146255	-3.06455	0.00218
Wellbeing_Ord13	-0.2862	0.070745	-4.04545	5.22E-05
Wellbeing_Ord14	-0.17896	0.055622	-3.21747	0.001293
BDSSince	0.028585	0.049772	0.574319	0.565752
Garden1No	-0.08462	0.093439	-0.9056	0.365147
-2|-1	-1.02358	0.10764	-9.50925	1.92E-21
-1|0 - no change	-0.52474	0.107311	-4.88991	1.01E-06
0 - no change|1	0.649576	0.107401	6.048111	1.47E-09
1|2 - a large increase	1.144692	0.107957	10.60324	2.88E-26

d. Summary table for my ordinal regression model predicting the effect of Covid-19 restrictions on people's day-to-day wellbeing in Wales, equation 4.

	Value	Std. Error	t value	p value
HHIncome_OrdLess than £15, 838	-0.10754	0.058776	-1.82956	0.067315
HHIncome_OrdMore than £44, 125	0.10584	0.063455	1.667948	0.095326
GenderI'd prefer not to say	0.230898	0.282632	0.816956	0.413953
GenderI'd prefer to use my own words	-0.7468	0.361393	-2.06646	0.038785
GenderMale	0.113884	0.050743	2.244313	0.024812
AgeCont	-0.0037	0.001741	-2.12661	0.033452
EducationGroup_Ord12 GCSE	0.116202	0.062074	1.871999	0.061207
EducationGroup_Ord13 A level	0.198833	0.069299	2.8692	0.004115
EducationGroup_Ord1Apprenticeship	0.034729	0.121888	0.284929	0.775699
EducationGroup_Ord1Secondary school	0.317903	0.085498	3.718272	0.000201
EthnicBW1BAME	0.329017	0.159241	2.06615	0.038814
LandCoverGroup1No LC Data	-0.22375	0.469551	-0.47651	0.633708
LandCoverGroup1Rural	0.289503	0.059705	4.848874	1.24E-06
LandCoverGroup1Urban	-0.03935	0.077458	-0.50807	0.611403
Wellbeing_Ord11 - Unimportant	-0.40564	0.238087	-1.70375	0.088427
Wellbeing_Ord12	-0.21428	0.141691	-1.5123	0.130457
Wellbeing_Ord13	0.013284	0.070934	0.187271	0.851448
Wellbeing_Ord14	-0.00027	0.055596	-0.00484	0.996135
BDSSince	0.206181	0.050856	4.054244	5.03E-05
Garden1No	-0.20432	0.094996	-2.1508	0.031492
-2|-1	-1.59515	0.109126	-14.6175	2.17E-48
-1|0 - no effect	-0.12132	0.107383	-1.12974	0.258584
0 - no effect|1	1.399326	0.108998	12.83809	1.00E-37
1|2 - a very positive effect	2.385288	0.113199	21.07157	1.45E-98

e. Summary table for my overall ordinal regression model exploring if people's day-to-day wellbeing in Wales was affected by change in frequency, time spent and distance travelled to natural spaces over Covid-19 restrictions, equation 5.

	Value	Std. Error	t value	p value
CovidEffectFreq_Ord.L	0.815883	0.104195	7.830317	4.87E-15
CovidEffectFreq_Ord.Q	-0.53601	0.089551	-5.98555	2.16E-09
CovidEffectFreq_Ord.C	-0.09033	0.069651	-1.29692	0.194659914
CovidEffectFreq_Ord^4	0.048008	0.063959	0.750605	0.452890343
CovidEffectHowLongSpend_Ord.L	1.022886	0.108522	9.425652	4.27E-21
CovidEffectHowLongSpend_Ord.Q	-0.13855	0.089048	-1.55588	0.119737159
CovidEffectHowLongSpend_Ord.C	0.138073	0.071313	1.936149	0.052849448
CovidEffectHowLongSpend_Ord^4	0.033648	0.062392	0.539303	0.589677868
CovidEffectDistance_Ord.L	0.457401	0.073151	6.252842	4.03E-10

CovidEffectDistance_Ord.Q	-0.70495	0.063753	-11.0576	2.01E-28
CovidEffectDistance_Ord.C	-0.4244	0.071852	-5.9065	3.49E-09
CovidEffectDistance_Ord^4	-0.08345	0.06258	-1.33344	0.182388836
HHIncome_OrdLess than £15, 838	-0.20185	0.060073	-3.36006	0.000779247
HHIncome_OrdMore than £44, 125	0.132619	0.064502	2.056046	0.039778106
GenderI'd prefer not to say	0.221095	0.273146	0.809438	0.418263131
GenderI'd prefer to use my own words	-0.57421	0.369438	-1.55427	0.120119182
GenderMale	0.100191	0.051688	1.938382	0.052576653
AgeCont	0.001398	0.001789	0.781653	0.434418436
EducationGroup_Ord12 GCSE	-0.08099	0.063939	-1.26672	0.20525663
EducationGroup_Ord13 A level	0.133918	0.070339	1.90388	0.056925755
EducationGroup_Ord1Apprenticeship	-0.04215	0.124679	-0.3381	0.735286788
EducationGroup_Ord1Secondary school	0.14891	0.087213	1.707439	0.087740553
EthnicBW1BAME	0.291536	0.162388	1.795304	0.0726052
LandCoverGroup1No LC Data	-0.5594	0.488362	-1.14547	0.252015688
LandCoverGroup1Rural	0.144211	0.061514	2.344378	0.019058845
LandCoverGroup1Urban	-0.02101	0.078969	-0.26607	0.790184337
Wellbeing_Ord11 - Unimportant	-0.09609	0.2404	-0.39971	0.689367642
Wellbeing_Ord12	-0.05716	0.144827	-0.39467	0.693088556
Wellbeing_Ord13	0.11554	0.072395	1.595963	0.110496989
Wellbeing_Ord14	-0.01858	0.057271	-0.32442	0.745617536
BDSSince	0.053664	0.052115	1.029725	0.303139065
Garden1No	-0.13776	0.097108	-1.41866	0.155999127
-2|-1	-1.79023	0.11449	-15.6366	4.10E-55
-1|0 - no effect	0.0557	0.112149	0.496663	0.619426603
0 - no effect|1	1.843299	0.114077	16.15836	9.92E-59
1|2 - a very positive effect	2.890245	0.11832	24.42735	8.76E-132

Appendix 2.3. A separate analysis with the same dataset exploring the distance people travelled to access natural spaces in Wales and how this varied before, during and after Covid-19 restrictions.

People travelled less distance to spend time in natural spaces during and since Covid-19 restrictions compared to before

Connecting with nature has widely acknowledged benefits for people's physical health and mental wellbeing. However, access to natural spaces in not equal with variation across society, which may have been exacerbated by the Covid-19 pandemic. Here, I used social surveys to explore the distance people in Wales, UK travelled to access natural spaces, how this varied by socio-demographic factors and how this was affected by Covid-19 restrictions.

Methods

I designed an online survey to collect data on how far people travel to connect with nature. Within the survey, I asked respondents to select on a map a natural space where they had spent time most recently. They could select up to three spaces, starting with the most recent first, and answer follow up questions on all three. Respondents specified if this was a one-off trip or somewhere they spent time throughout the year. If the latter they were asked about the time they spent there before, during or since the restrictions (depending on when they survey was carried out). Specifically exploring the effects of Covid-19 restrictions, I asked how the frequency, time spent and distance travelled to natural spaces had changed and what impact there had been on people's wellbeing. I also collected demographic data on gender, age, income, education, ethnic background and wellbeing. Categories for demographic variables were based on those used for the national census and National Survey for Wales (National Survey for Wales, 2019). My definition of wellbeing ('Wellbeing can be considered in terms of how satisfied you feel with your life, to what extent you feel the things you do are worthwhile, how happy you feel and how anxious you feel') was that used by the UK's Office of National Statistics (ONS, 2022).

<u>Data Analysis</u>

I conducted a descriptive analysis by aggregating distance travelled to natural spaces by the explanatory variables including when the respondent spent time in the space chosen (table 1). I then ran a general linear model to investigate the impact of socioeconomic variables on the distance people travel to access nature (Equation 1). In order to conform with the assumptions of a general linear model, the distance data were logged prior to the model being run. Variables were releveled so the most common choice became the default to which the other levels were compared (e.g., 'for mental and physical health' was the most commonly selected reason for spending time in a space, so this became the default). Forward and backwards stepwise regression was used to determine the best-fit model.

*Log_{10} Distance from start point to natural space = PR + TimeSpent + HHIncome + Gender + Age + Education + EthnicGroup + LandCover + Wellbeing + Month + **BDS** + VisitFrequency*   (Equation 1)

In which, PR is the Primary Reason for spending time in that space, TimeSpent represents how long the respondent spent at the space in hours, HHIncome is the ordinal household income category (either Less than £15,838, £15,838 - £44,125, More than £44,125), Gender is the gender of the respondent identified as (categorised into female, male, prefer not to say, prefer to use own words), Education is the highest level of education of the respondent (from secondary school, GCSE, apprenticeship, A level, Higher Education), EthnicGroup is the ethnicity of the respondent (categorised as either White or Black, Asian and minority ethnic [BAME] due to high prevalence of white respondents in the area), LandCover is the land cover at start point (categorised into Rural, Suburban, Urban), Wellbeing is the importance of the space to day-to-day wellbeing (from 1 unimportant to 5, very important), Month is the month the survey was carried out (January, April, June, October), **BDS** is whether the survey was carried out before, during or since restrictions to accessing nature in response to Covid-19 (Figure 2), and VisitFrequency is whether the respondent spent time at the space as a one-off trip or multiple times throughout the year.

Results

The final dataset used to run my models contained 6489 observations (each from an individual respondent). More women (58±1%; ± 95% Confidence Interval) than men (41±1%) responded to my survey, and the vast majority of my respondents were white (98±0.3 %) – somewhat reflecting the wider Welsh population: 49% male and 51% female (Welsh Government, 2021); and 95% white (Welsh Government, 2022). The majority of people lived in suburban areas (69±1%). The most selected reason for spending time in the natural space selected was *"for physical and mental health"* (53±1%), with *"other"* as the second most common reason (21±1 %). The majority of respondents spent time in the spaces they selected *"multiple times throughout the year"*, 94±1%. 57±1% of respondents spent time in their chosen space during lockdown restrictions, compared to 15±1% beforehand and 28±1% afterwards (table 1).

Table A2.3.1: Count and percentage of 6489 respondents and median distance travelled from home to natural spaces broken down by explanatory variables from my surveys exploring distance travelled to access natural spaces in Wales.

Variable	Level	Count	Percentage	Median distance travelled from home point to natural space (km)
Before, During, Since (BDS) Was the survey before, during or	Before	945	15	2.39
	During	3714	57	0.35

since a lockdown.	Since	1830	28	0.62

People travelled significantly less distance to access natural spaces during (p<0.001) and since restrictions than before (p<0.001).

The unit differences in distances can be conceptualised by considering an example respondent and looking at the impact of each variable in turn. For example, consider the most common respondent; female, aged 60-64, in the middle-income group, white, educated to at least undergraduate level, from a suburban area, who spent 30 mins to an hour at their chosen space and went there multiple times throughout the year for their physical and mental health and said the space was very important to their day-to-day wellbeing, having completed the survey in April 2020, during covid restrictions. With these characteristics, my general linear model estimated they travelled 0.24 (95% CI: 0.20-0.29) km to the natural space they selected. Using this as a default, I can highlight the impact on the variables highlighted as significant above by changing each in isolation. If this example respondent made the trip during covid restrictions, they would travel an estimated 0.24 (0.20-0.29), compared to 1.16 (0.85-1.57) km before covid-19 hit and 0.49 (0.41-0.61) km after restriction had lifted.

Discussion

My findings show that restrictions intended to reduce the spread of Covid-19 also affected the distance people travelled to access natural spaces. People travelled significantly less distance to access natural spaces during and since the restrictions than they did before any restrictions were introduced. This could have meant people substituted spaces they wished to access for others closer to home, which maybe did not provide the experience they wanted (Rice *et al.*, 2020). Whilst travelling less distance during restrictions makes sense as it was prohibited, travelling less distance afterwards suggests people may have felt anxious about going further from home and potentially mixing with others despite restrictions easing. Anxiety levels increased over the pandemic and the experience of living through this period looks to have had long-term impacts on people's mental health (Taylor *et al.*, 2022). A Scottish study found in some groups that trips for outdoor exercise reduced as Covid-19 restrictions eased (Semple, Fountas and Fonzone, 2021) although this could also be due to other factors like gyms reopening. Given the benefits of spending time in natural spaces, it is important to ensure that anxiety around Covid-19 does not limit people's access completely, especially for those who do not have private natural spaces.

Conclusion

My findings suggest that resources need to be directed towards ensuring there are accessible natural spaces close to peoples' home with facilities and support to help people access them, especially in areas where access to gardens is low. Given the acknowledged benefits of connecting with nature, easily accessible natural spaces would support people in living with the after-effects of the pandemic

and any future stressors. Such changes would allow the benefits of nature connection to be realised for individuals and wider society.

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Appendix 3: Appendix to Chapter 5 - The natural environment partially determines route choices of pedestrians and cyclists

Appendix 3.1. Results - Cycling data and land cover classified as 'natural/not natural'

Here, I present the results for cycling data using land cover classified as 'natural' or 'not natural' as the nature metric. It is consistent with the equivalent pedestrian data shown in the main text. For all four extraction protocols (the whole edge, the first 100m of the edge, the whole edge plus a 20m buffer and the first 100m plus a 20m buffer), the difference in the nature metric was found to be a significant predictor in the direction people chose; with more people choosing more natural routes (p<0.001; Figures A3.1.1, A3.1.2). The nature metric predicted 13-15% of the choice (Figure A3.1.2). For one extraction protocol (when considering just the first 100m of the edge), the effect of the nature metric was found to be stronger on the weekend (p<0.05; Figure A3.1.3).
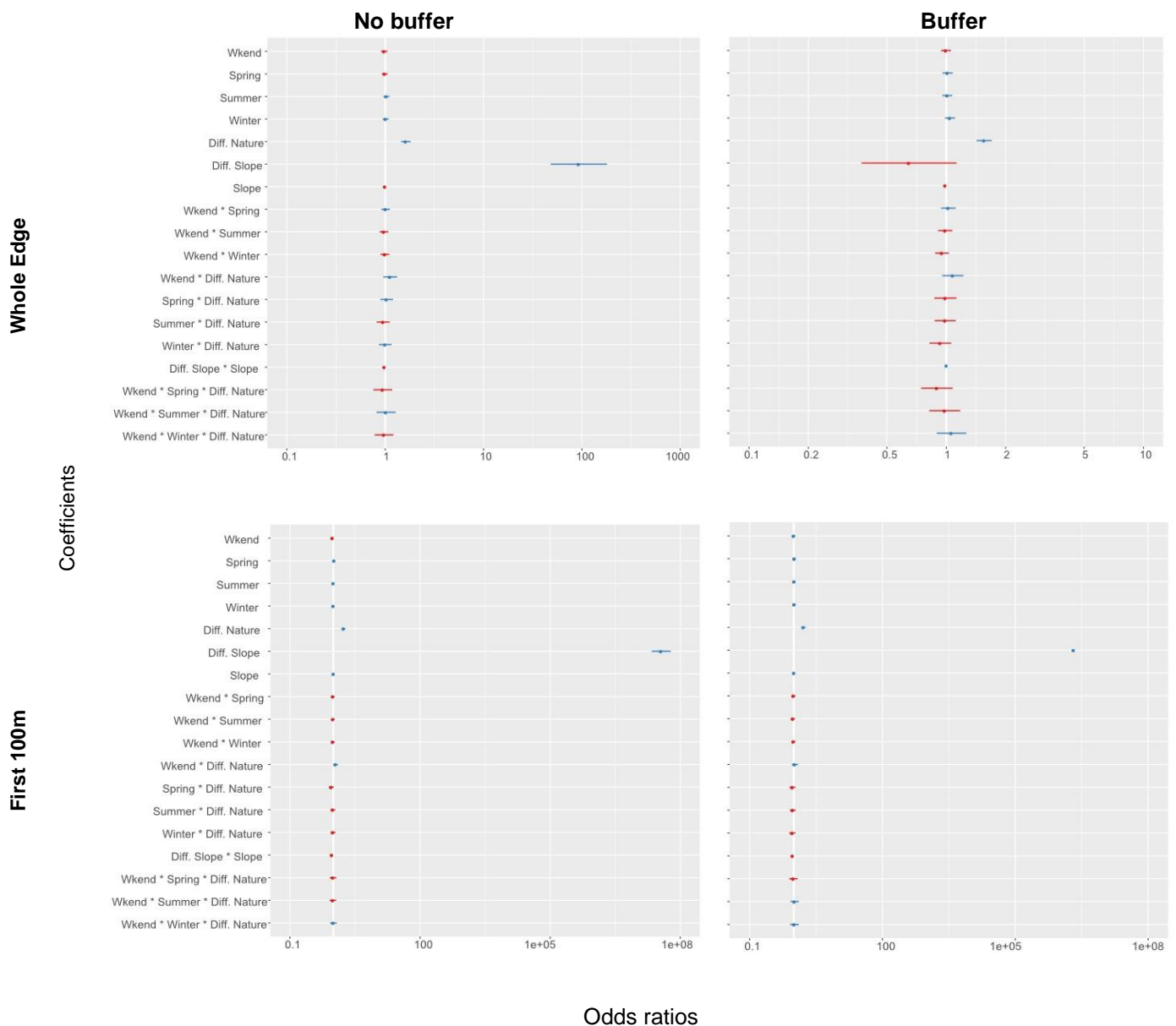
Figure A3.1.1. Coefficient plots showing effect of coefficients and interactions on difference in cyclists based on Strava data choosing junction exits in Denbighshire, Wales in 2016-2019. In which; Wkend is whether the activity was

undertaken on the weekend or a weekday, with weekday as the reference level, Spring/Summer/Winter are the season the activity was undertaken with Autumn as the reference level, Diff. Nature is the difference in nature metric on each exiting edge from junctions compared to all edges being equal, Diff. Slope is the difference in slope on each exiting edge compared to all edges being equal, Slope is overall Slope on the edge and * indicates an interaction between the variables. Red indicates that the estimate of the coefficient is negative, blue indicates that the estimate is positive.

Figure A3.1.2. The difference in nature metric showed a positive relationship on cyclists' choices at junctions using Strava data, with more people likely to choose routes with higher proportions of nature. Data shown here uses land cover classified into 'natural/not natural' as a nature metric, in Denbighshire, Wales, 2016-2019.
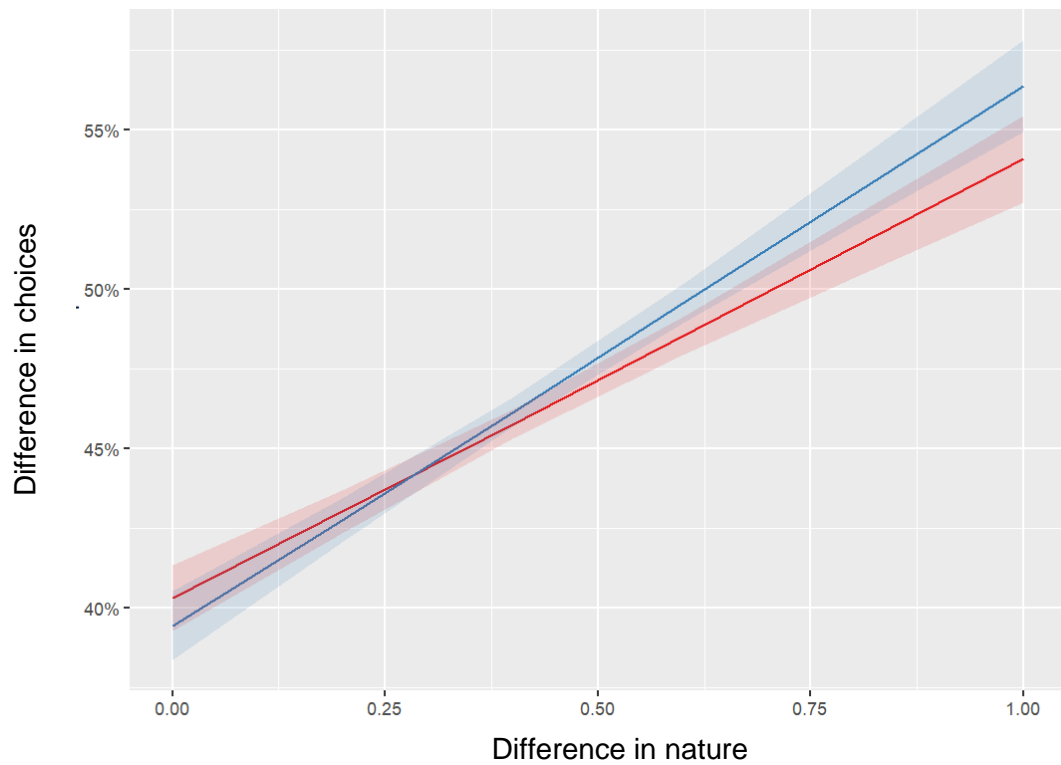
Figure A3.1.3. Effects plot showing the effect of difference in nature metric on cyclists' choices using Strava data at junctions with land cover as a nature metric classified into 'natural/not natural' and looking at natural environments for the first 100m of the edge, for weekends, blue and weekdays, red, in 2016-19 in Denbighshire, Wales. Due to the variables being rescaled, 0/0 is at 0.5/50 on the axis.

Results for data subsets (rows in grey indicate a that the variable is not statistically significant)

Table A3.1.1.								
Cycling/ Walking	**Nature variable**	**Rural/Urban**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Cycling	LCR1	Rural	1 – nature for whole edge	Difference in nature	-1.180317	0.349956	-3.373	<0.001
			2 – nature for first 100 m of edge	Difference in nature	-1.408350	0.395309	-3.563	<0.001
			3 – nature for whole edge plus 20m buffer	Difference in nature	-1.607815	0.406960	-3.951	<0.001
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-1.604e+00	2.493e-01	-1.604e+00	<0.001

Table A3.1.2								
Cycling/ Walking	**Nature variable**	**Rural/Urban**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Cycling	LCR1	Urban	1 – nature for whole edge	Difference in nature	0.607034	0.055990	0.607034	<0.001
			2 – nature for first 100 m of edge	Difference in nature	6.271e-01	5.614e-02	6.271e-01	<0.001
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.515659	0.058176	8.864	<0.001
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	5.821e-01	5.759e-02	10.108	<0.001

Table A3.1.3.

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Cycling	LCR1	Commute	1 – nature for whole edge	Difference in nature	3.91731	2.27234	1.724	>0.05
			2 – nature for first 100 m of edge	Difference in nature	2.432e+00	2.567e+00	0.947	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	4.6212	2.4004	1.925	>0.05
				Winter	3.4878	1.6328	2.136	<0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	2.20374	3.19712	0.689	>0.05

Table A3.1.4.

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Cycling	LCR1	NonCommute	1 – nature for whole edge	Difference in nature	2.61625	0.88490	2.957	<0.01
				Summer	1.84619	0.60347	3.059	<0.01
				Difference in nature:Summer	-2.39916	1.12337	-2.136	<0.05
				Difference in nature:Winter	-10.69623	3.21276	-3.329	<0.001
			2 – nature for first 100 m of edge	Difference in nature	0.6010	0.9037	0.665	>0.05
				Difference in nature:Winter	-11.7808	5.0172	-2.348	<0.05

			3 – nature for whole edge plus 20m buffer	Difference in nature	-0.43773	1.24429	-0.352	>0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	2.7378	1.1105	2.465	<0.05
				Spring	1.8653	0.7561	2.467	<0.05
				Summer	2.2462	0.7024	3.198	<0.01
				Difference in Nature:Spring	-4.5161	1.5275	-2.957	<0.01

Appendix 3.2. Results for additional nature metrics

Hansen tree canopy cover

As an alternative nature metric, I used the effect of canopy cover, as trees are large obvious features in the landscape. The dataset was percentage canopy cover calculated from a time-series analysis of Landsat images showing forest extent and change from 2000 – 2019 (Hansen *et al.*, 2022).

For walking data, for all four extraction protocols (the whole edge, the first 100m of the edge, the whole edge plus a 20m buffer and the first 100m plus a 20m buffer) canopy cover was found to be a significant predictor in the direction people chose in that the more tree cover on the route, the more people chose that direction. For the models looking at the whole edge and the first 100m of the edge, canopy cover predicted 8% of the choice p<0.001. For the models looking at the whole edge plus a 20m buffer tree cover predicted 4% of the choice. For the model looking at the first 100 m plus a 20m buffer, canopy cover predicated 5% of the choice, p<0.01. Figures A3.2.1, A3.2.2.

For cycling data, for all four extraction protocols (the whole edge, the first 100m of the edge, the whole edge plus a 20m buffer and the first 100m plus a 20m buffer) canopy cover was found to be a significant predictor in the direction people chose in that the more tree cover on the route, the more people chose that direction. For the model looking at the whole edge canopy cover predicted 5% of the choice, p<0.001. For the model looking at the first 100m of the edge, canopy cover predicted 3% of the choice, p<0.001 For the models looking at the whole edge plus a 20m buffer and first 100 m plus a 10m buffer, tree cover predicted 2% of the choice, p<0.05. Figure A3.2.1., A3.2.2.
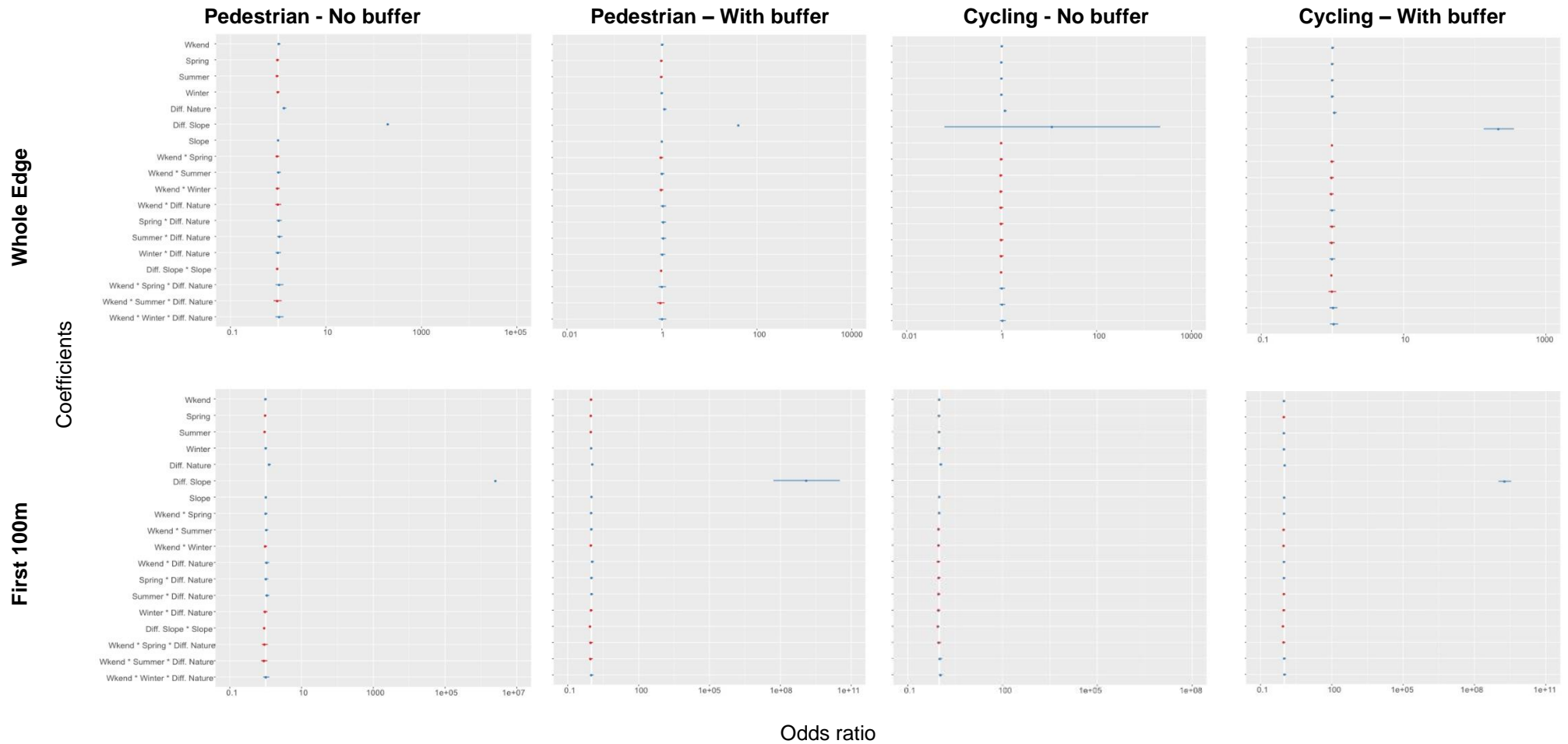
Figure A3.2.1. Coefficient plots showing effect of coefficients and interactions on difference in people based on Strava data choosing junction exits in Denbighshire, Wales in 2016-2019. In which; Wkend is whether the activity was undertaken on the weekend or a weekday, with weekday as the reference level, Spring/Summer/Winter are the season the activity was undertaken with Autumn as the reference level, Diff. Nature is the difference in nature metric (canopy cover) on each exiting edge from junctions compared to all edges being equal, Diff. Slope is the difference in slope on each exiting edge compared to all edges being equal, Slope is overall Slope on the edge and * indicates an interaction between the variables. Red indicates that the estimate of the coefficient is negative, blue indicates that the estimate is positive.
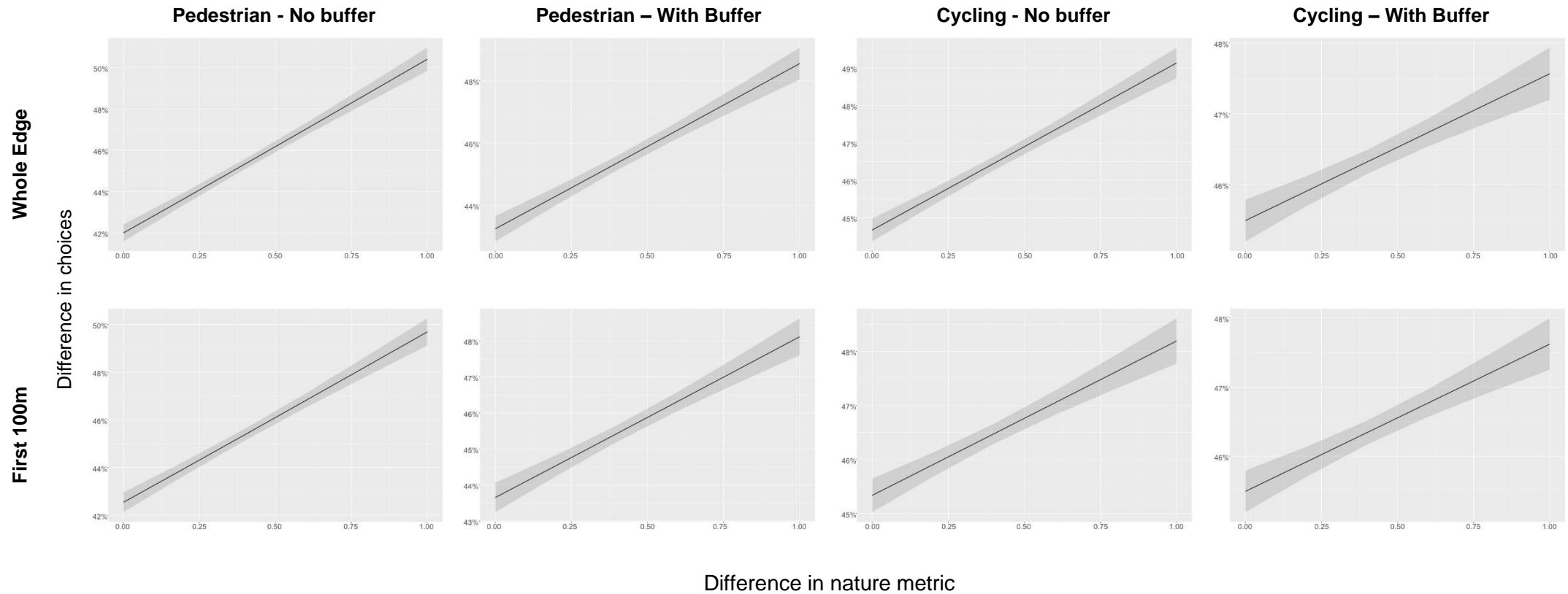
Figure A3.2.1. The difference in nature metric showed a positive relationship on peoples' choices at junctions using Strava data, with more people likely to choose routes with higher proportions of nature. Data shown here uses tree canopy cover as a nature metric, in Denbighshire, Wales, 2016-2019.

Data subsets (rows in grey indicate a that the variable is not statistically significant)

| Table A.3.2.1.								
Cycling/ Walking	**Nature variable**	**Rural/Urban**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Cycling	Hansen	Rural	1 – nature for whole edge	Difference in nature	0.353751	0.051051	6.929	<0.001
			2 – nature for first 100 m of edge	Difference in nature	0.260903	0.052367	4.982	<0.001
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.271585	0.048265	5.627	<0.001
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	0.267611	0.049653	5.390	<0.001

Table A.3.2.2.2								
Cycling/ Walking	**Nature variable**	**Rural/ Urban**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Cycling	Hansen	Urban	1 – nature for whole edge	Difference in nature	5.410e-02	5.458e-02	0.991	>0.05
			2 – nature for first 100 m of edge	Difference in nature	0.066840	0.054759	1.221	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	-6.060e-02	4.901e-02	-1.236	>0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-5.396e-02	4.868e-02	-1.108	>0.05

Table A.3.2.3.

Cycling/ Walking	Nature variable	Rural/Urban	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	Hansen	Rural	1 – nature for whole edge	Difference in nature	0.536658	0.083179	6.452	<0.001
			2 – nature for first 100 m of edge	Difference in nature	0.454555	0.083725	5.429	<0.001
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.509985	0.082741	6.164	<0.001
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	0.421577	0.083195	5.067	<0.001

Table A.3.2.4.

Cycling/ Walking	Nature variable	Rural/Urban	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	Hansen	Urban	1 – nature for whole edge	Difference in nature	0.162438	0.058092	2.796	<0.01
			2 – nature for first 100 m of edge	Difference in nature	0.159488	0.057955	2.752	<0.01
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.017248	0.052799	0.327	>0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	8.147163	1.583686	5.144	<0.001

Table A.3.2.5.

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Cycling	Hansen	Commute	1 – nature for whole edge	Difference in nature	-3.104e+00	2.731e+00	-1.137	>0.05
			2 – nature for first 100 m of edge	Difference in nature	-0.5297	5.8722	-0.090	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.7591	3.1378	0.242	>0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-5.0337	5.5843	-0.901	>0.05

Table A.3.2.6.

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Cycling	Hansen	NonCommute	1 – nature for whole edge	Difference in nature	0.60850	1.02608	0.593	>0.05
				Summer	2.03742	0.60156	3.387	<0.001
			2 – nature for first 100 m of edge	Difference in nature	-0.8950	0.7737	-1.157	>0.05
				Spring	-1.1513	0.5711	-2.016	<0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.3825	0.8917	0.429	>0.05
				Summer	1.7058	0.5399	3.160	<0.01
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-0.4382	0.8963	-0.489	>0.05
				Summer	1.1965	0.5077	2.357	<0.05

Table A.3.2.7.

Cycling/ Walking	Nature variable	Commute/Non Commute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	Hansen	Commute	1 – nature for whole edge	Difference in nature	1.59849	1.39327	1.147	>0.05
				No significant variables				
			2 – nature for first 100 m of edge	Difference in nature	0.09276	1.59408	0.058	>0.05
				No significant variables				
			3 – nature for whole edge plus 20m buffer	Difference in nature	2.6340	2.1671	1.215	>0.05
				Winter	3.1253	1.5070	2.074	<0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	1.06496	1.85866	0.573	>0.05
				No significant variables				

Table A.3.2.8.

Cycling/ Walking	Nature variable	Commute/Non Commute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	Hansen	NonCommute	1 – nature for whole edge	Difference in nature	-1.3145	5.1155	-0.257	>0.05
			2 – nature for first 100 m of edge	Difference in nature	1.0463	3.8030	0.275	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	1.281e+00	3.818e+00	0.336	>0.05
			4 – nature for first 100 m of	Difference in nature	0.4733	3.7976	0.125	>0.05

			edge plus 20m buffer				

Land cover classified into urban/intensively managed/semi-natural

As an alternative nature metric I used land cover (Morton *et al.*, 2020) classified into 0/0.5/1 in which urban and suburban were categorised as 0, intensively managed agricultural and forestry land cover categories were categorised as 0.5 and remaining semi-natural categories were categorised as 1 to equate to 'urban/intensively managed/semi-natural'. This data was at resolution of 25m.

For pedestrian data for all four extraction protocols (the whole edge, the first 100m of the edge, the whole edge plus a 20m buffer and the first 100m plus a 20m buffer) 'naturalness' was found to be a significant predictor in the direction people chose in that the more natural the route, the more people chose that direction ($p<0.001$, Figure A3.2.4, A3.2.5).). The difference in nature metric predicted 15 - 18% of the choice. For one extraction protocol (when considering the first 100m of the edge plus a 20m buffer), the effect of the nature metric was found to be stronger on the weekend ($p<0.05$; Figure A3.2.6).

For cycling data, for all four extraction protocols (the whole edge, the first 100m of the edge, the whole edge plus a 20m buffer and the first 100m plus a 20m buffer) 'naturalness' was found to be a significant predictor in the direction people chose in that the more natural the route, the more people chose that direction ($p<0.001$). The difference in nature metric predicted 8-15% of the choice (Figure A3.2.4, A3.2.5).
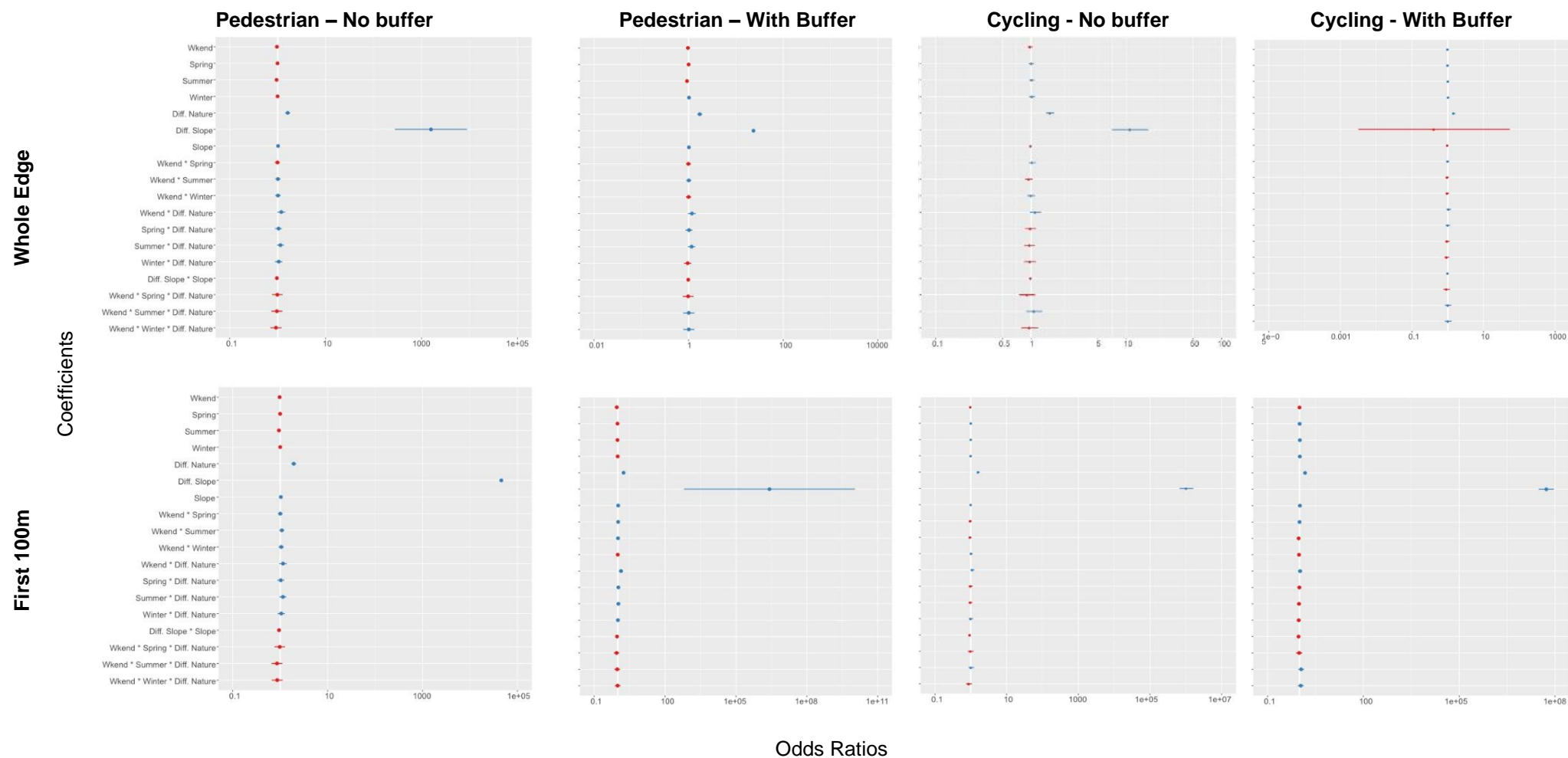
Figure A3.2.4. Coefficient plots showing effect of coefficients and interactions on difference in walking athletes based on Strava data choosing junction exits in Denbighshire, Wales in 2016-2019. In which; Wkend is whether the activity was undertaken on the weekend or a weekday, with weekday as the reference level, Spring/Summer/Winter are the season the activity was undertaken with Autumn as the reference level, Diff. Nature is the difference in nature metric on each exiting edge from junctions compared to all edges being equal, Diff. Slope is the difference in slope on each exiting edge compared to all edges being equal, Slope is overall Slope on the edge and * indicates an interaction between the variables.
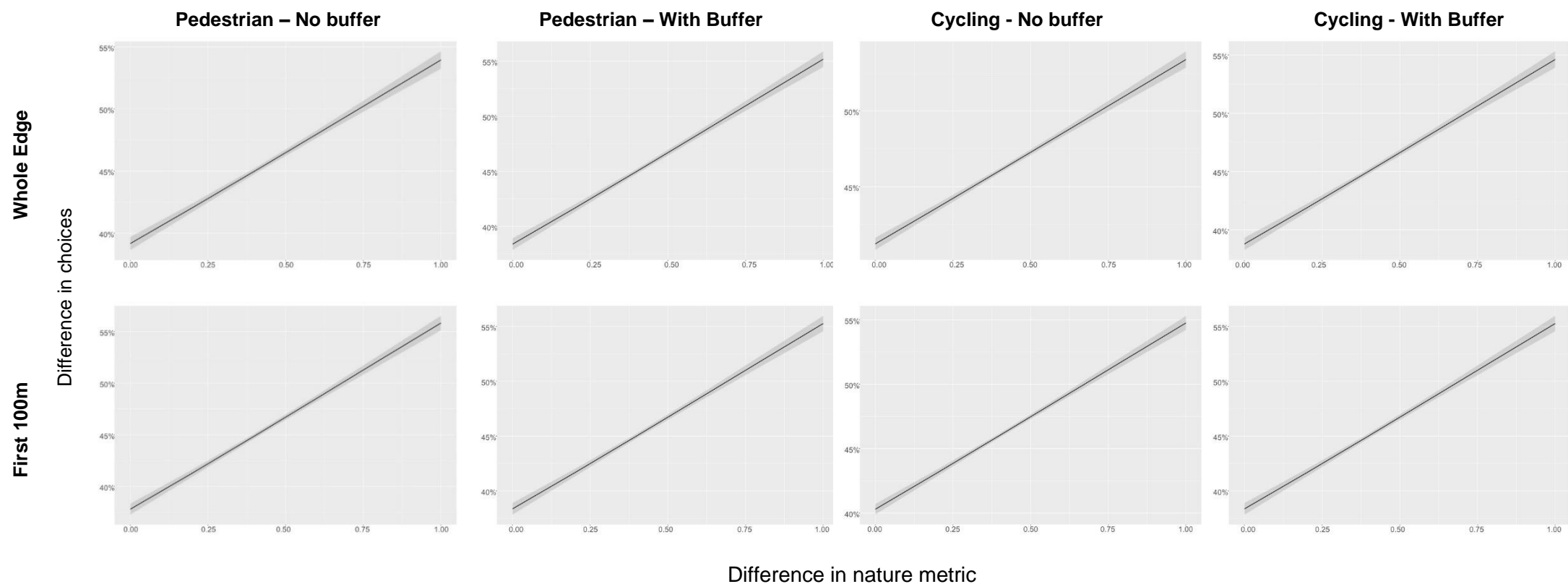
Figure A3.2.5. The difference in nature metric showed a positive relationship on peoples' choices at junctions using Strava data, with more people likely to choose route with higher proportions of nature. Data shown here uses land cover classified into urban/semi-natural/natural as a nature metric, in Denbighshire, Wales, 2016-2019.
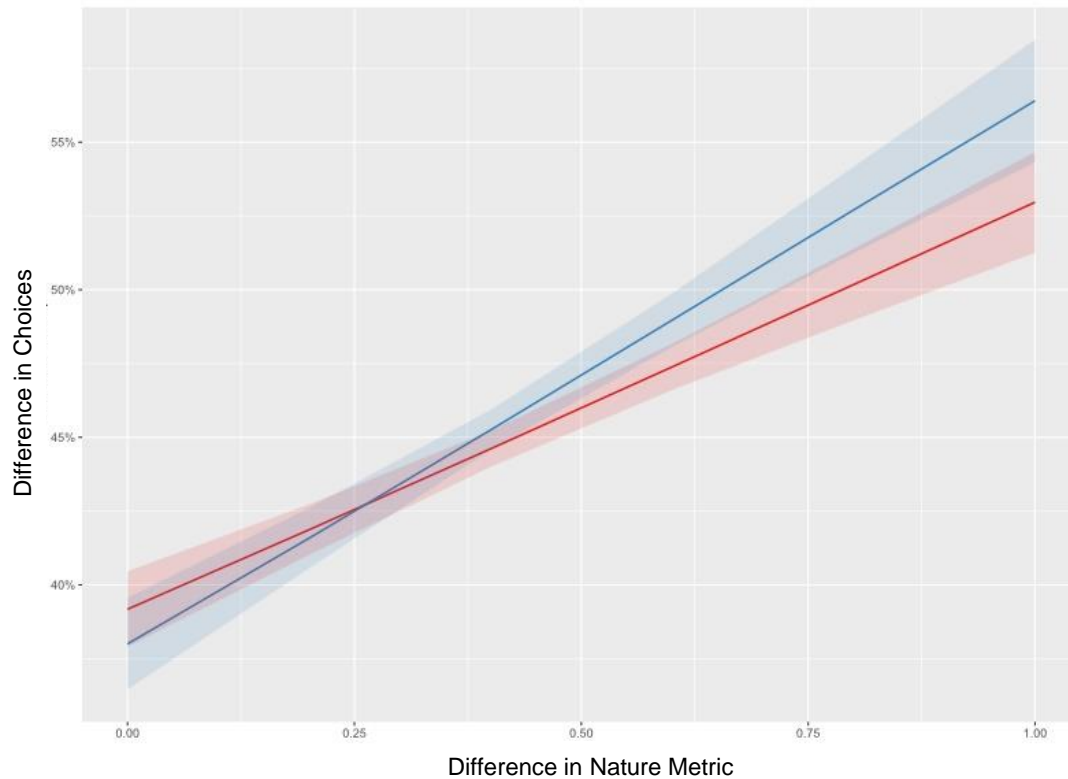
Figure A3.2.6. Effects plot showing the effect of difference in nature metric on cyclists' choices using Strava data at junctions with land cover as a nature metric classified into 'urban/intensively managed/semi-natural' and looking at natural environments for the first 100m of the edge with a 20m buffer, for weekends, blue and weekdays, red, in 2016-19 in Denbighshire, Wales. Due to the variables being rescaled, 0/0 is at 0.5/50 on the axis.

Data subsets (rows in grey indicate a that the variable is not statistically significant)

Table A.3.2.9.								
Cycling/ Walking	**Nature variable**	**Rural/Urban**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Cycling	LCR5	Rural	1 – nature for whole edge	Difference in nature	-0.6299764	0.2749961	-2.291	<0.05
			2 – nature for first 100 m of edge	Difference in nature	-0.603620	0.154028	-3.919	<0.001
			3 – nature for whole edge plus 20m buffer	Difference in nature	-1.072042	0.221492	-4.840	<0.001
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-1.555e+00	1.721e-01	-9.037	<0.001

Table A.3.2.10								
Cycling/ Walking	**Nature variable**	**Rural/Urban**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Cycling	LCR5	Urban	1 – nature for whole edge	Difference in nature	0.582909	0.055044	10.590	<0.001
			2 – nature for first 100 m of edge	Difference in nature	0.649453	0.056036	11.590	<0.001
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.540502	0.058036	9.313	<0.001
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	5.730e-01	5.830e-02	9.829	<0.001

Table A.3.2.11

Cycling/ Walking	Nature variable	Rural/Urban	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	LCR5	Rural	1 – nature for whole edge	Difference in nature	-0.672958	0.329121	-2.045	<0.05
			2 – nature for first 100 m of edge	Difference in nature	-0.331387	0.335286	-0.988	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	-0.806513	0.360488	-2.237	<0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-0.50870	0.36868	0.36868	>0.05

Table A.3.2.12

Cycling/ Walking	Nature variable	Rural/Urban	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	LCR5	Urban	1 – nature for whole edge	Difference in nature	0.69735	0.06625	10.526	<0.001
				Spring	-0.11353	0.04824	-2.353	<0.05
				Summer	-0.10219	0.04904	-2.084	<0.05
				Difference in nature:Summer	0.21040	0.09260	2.272	<0.05
				Difference in nature:Spring	0.21745	0.09108	2.387	<0.05
				Difference in nature:Weekend	0.21587	0.10311	2.094	<0.05
			2 – nature for first 100 m of edge	Difference in nature	0.82092	0.06686	12.278	<0.001
				Summer	-0.10438	0.04966	-2.102	<0.05
				Difference in nature	0.711066	0.065604	10.839	<0.001

			3 – nature for whole edge plus 20m buffer	Summer	-0.125713	0.047601	-2.641	<0.01
				Difference in nature:Summer	0.210440	0.092250	2.281	<0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	8.151e-01	6.631e-02	12.293	<0.001

Table A.3.2.13

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Cycling	LCR5	Commute	1 – nature for whole edge	Difference in nature	3.98995	2.60748	1.530	>0.05
				Winter	3.61737	1.68078	2.152	<0.05
			2 – nature for first 100 m of edge	Difference in nature	-0.76605	2.64647	-0.289	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	4.33531	2.49453	1.738	>0.05
				Winter	3.87833	1.63560	2.371	<0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	3.5673	2.5660	1.390	>0.05

Table A.3.2.14.

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Cycling	LCR5	NonCommute	1 – nature for whole edge	Difference in nature	0.5318	0.9425	0.564	>0.05
				Spring	-1.8869	0.7860	-2.401	<0.05
			2 – nature for first 100 m of edge	Difference in nature	1.83277	0.95196	1.925	>0.05
				Summer	1.73885	0.60521	2.873	<0.01
			3 – nature for whole edge plus 20m buffer	Difference in nature	0.8043	1.0421	0.772	>0.05
				Summer	1.3320	0.6046	2.203	<0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	1.471e+00	1.009e+00	1.458	>0.05
				Summer	1.687e+00	6.102e-01	2.764	<0.01

Table A.3.2.15

Cycling/ Walking	Nature variable	Commute/No nCommute	Model	Variable of interest	Estimate	Standard error	Z value	P value
Walking	LCR5	Commute	1 – nature for whole edge	Difference in nature	-1.89166	2.06286	-0.917	>0.05
			2 – nature for first 100 m of edge	Difference in nature	-1.471395	2.157841	-0.682	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	-1.2971	1.7686	-0.733	>0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	-0.1056	2.4618	-0.043	>0.05

Table A.3.2.16								
Cycling/ Walking	**Nature variable**	**Commute/No nCommute**	**Model**	**Variable of interest**	**Estimate**	**Standard error**	**Z value**	**P value**
Walking	LCR5	NonCommute	1 – nature for whole edge	Difference in nature	5.1937	5.2574	0.988	>0.05
			2 – nature for first 100 m of edge	Difference in nature	3.15503	6.43258	0.490	>0.05
			3 – nature for whole edge plus 20m buffer	Difference in nature	4.86207	5.19763	0.935	>0.05
			4 – nature for first 100 m of edge plus 20m buffer	Difference in nature	3.9545	4.9116	0.805	>0.05

Appendix 3.3. Overall Model Diagnostic Plots

Tests on a subsample of the data prior to running models with the full datasets with Supercomputing Wales showed the generalised linear mixed effect model with a binomial distribution to best conform to the model assumptions.
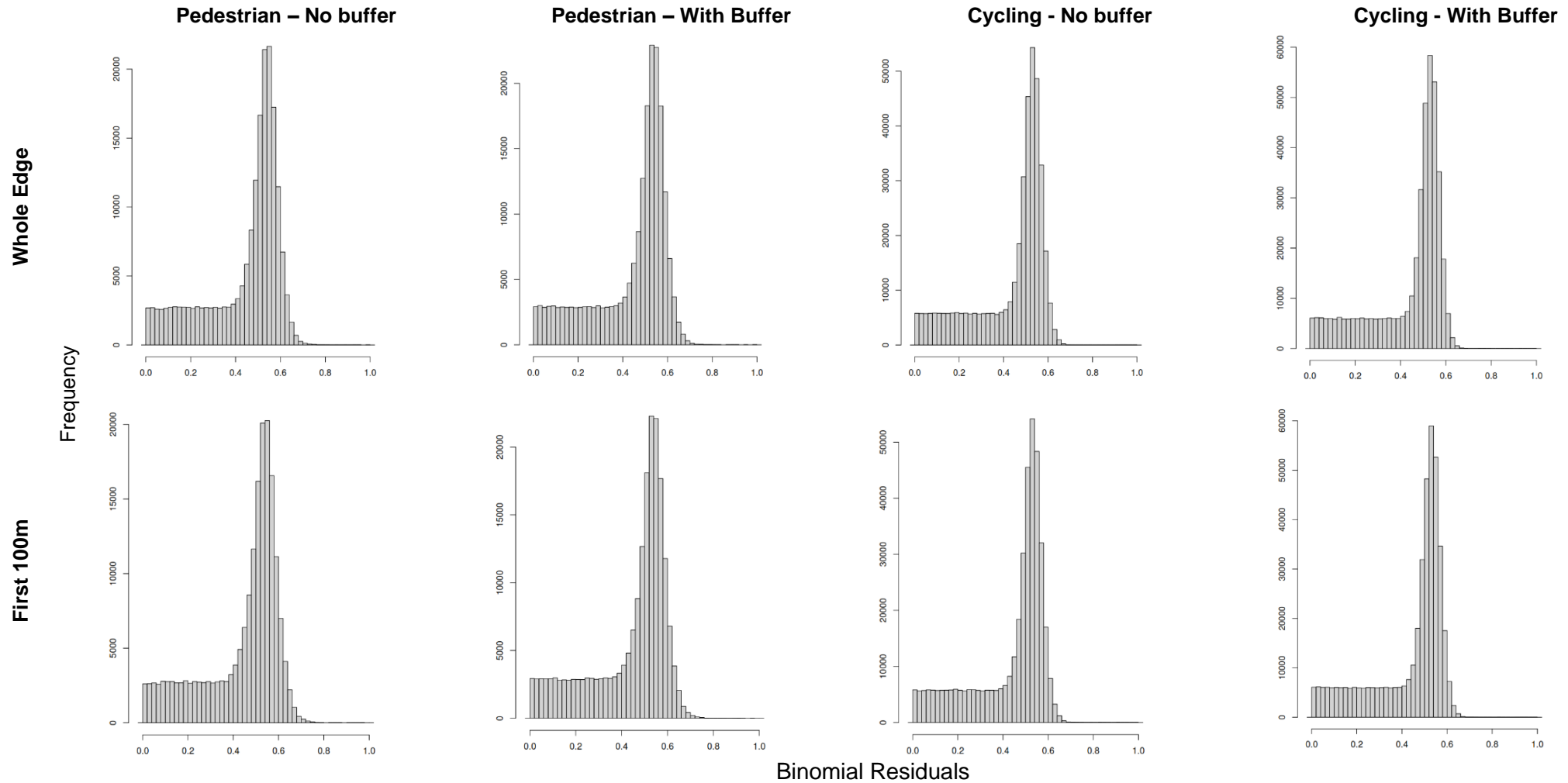
Land cover classified into 'nature/not nature'

Figure A3.3.1. Binomial residuals of models for both pedestrian and cycling Strava data land cover classified into 'nature/not nature' as a nature metric, using data for Denbighshire County, Wales from 2016 to 2019.
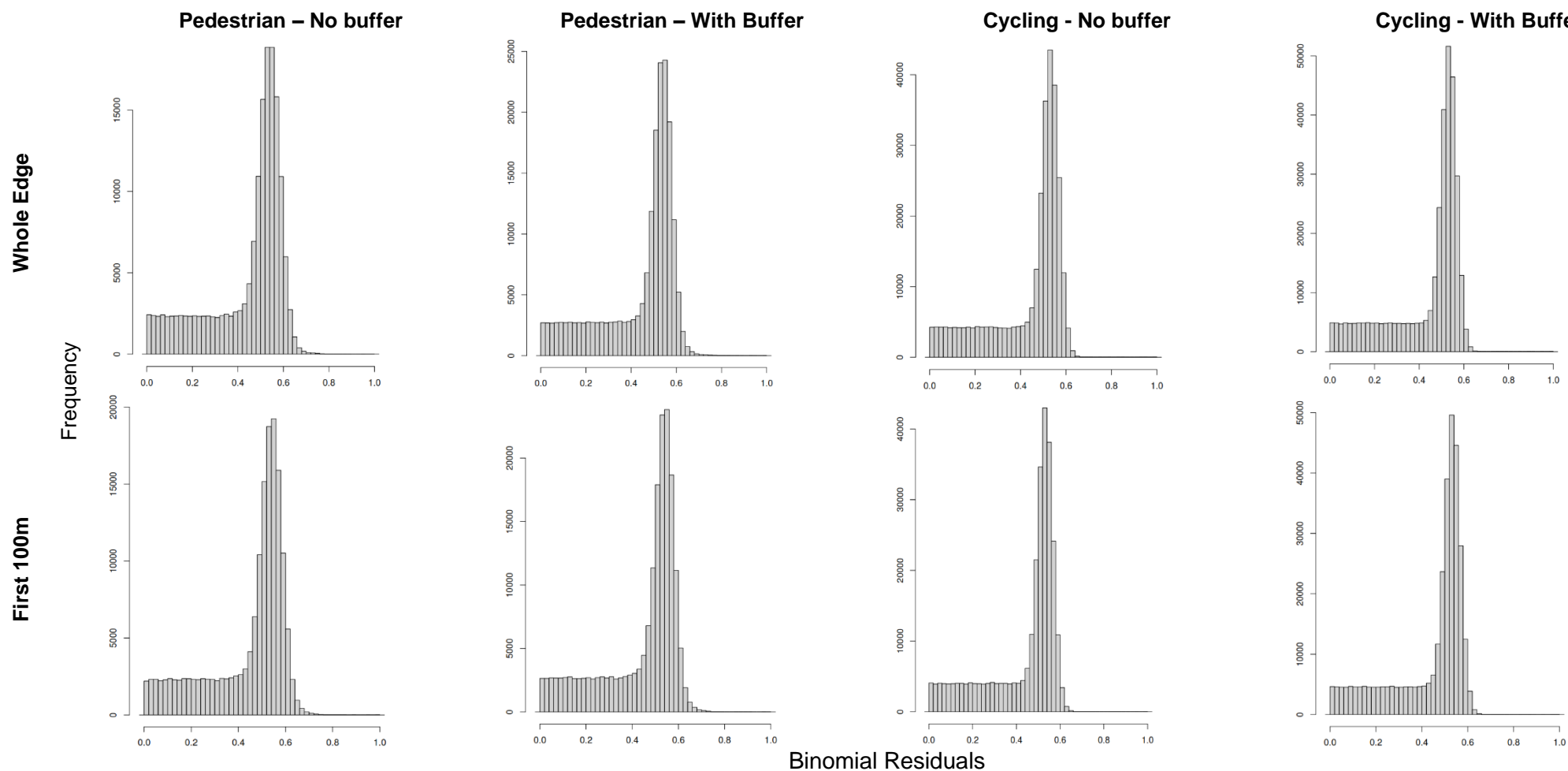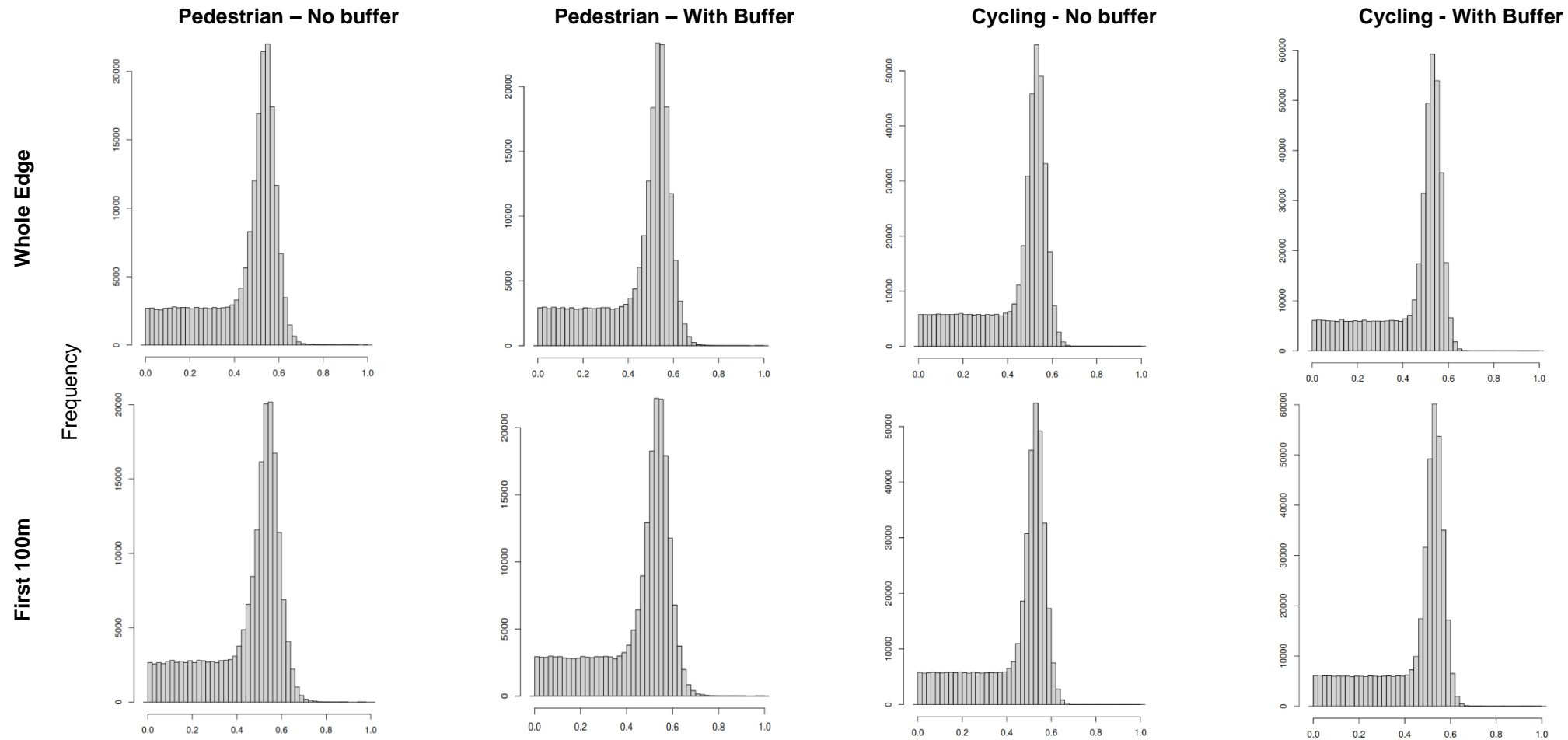
Figure A3.3.2. Binomial Residuals of models for both pedestrian and cycling Strava data show a normal distribution using tree canopy cover as a nature metric, using data for Denbighshire County, Wales from 2016 to 2019.

Binomial Residuals

Figure A3.3.3. Binomial residuals of models for both pedestrian and cycling Strava data show a normal distribution using land cover classified as urban/intensively managed/semi-natural as a nature metric, using data for Denbighshire County, Wales from 2016 to 2019