Thesis submitted for the fulfilment of the requirements for Master of Research in Environmental and Geographical Sciences

An investigation into the best management practices for mountain bike parks and trail centres threatened by tree pests or pathogens

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Declaration: "I hereby certify that this work is my own, except where otherwise acknowledged, and that it has not been submitted previously for a degree at this, or any other university."

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vi. Abstract

After the closure of two major UK bike parks, Aston Hill in the Chilterns and Revolution in North Wales, due to outbreaks of Ash Dieback and Phytophthora Ramorum, an investigation was carried out investigate the management approaches taken at each location. Additionally, this study presents findings about the scale of UK mountain biking, distribution of trails plus wider environmental issues associated such as wild/off-piste trails and social conflicts. Mountain biking is a fast-growing recreational activity that frequently takes place in forested landscapes. In the UK, these woodland environments are increasingly threatened by pests, pathogens, and conflicting land-use pressures, raising questions about access, sustainability, and trail management. A mixed-methods approach was employed, combining GIS land cover analysis, Strava heatmap data, action camera video content, online surveys, and semi-structured interviews with bike park owners and land managers. As well as Aston Hill and Revolution, two further case studies were investigated in detail, Hemlock Stone in Nottingham, and Wharncliffe Woods near Sheffield. This enabled the original case studies to be contrasted with more informal locations to see how management approaches may differ. It was determined that the extensive felling work completed at both sites was the best decision despite the various environmental and social impacts. However, it was also established that there is scope for improvement in the management of recreational spaces, especially in terms of public education and communication.

1. Introduction

1.1 General Introduction

Trees in all forms provide a range of ecosystem services including carbon sequestration, flood prevention, habitat and timber production (Boyd et al, 2013). One vital service they provide is recreation, creating areas of beauty for walking, running, horse riding, camping and many more (O'Brian et al, 2010). However, few activities are more dependent on trees that mountain biking, a growing sport that allows riders to explore the outdoors in a more adrenalin fuelled way (Thurston and Reader, 2001). Additionally, it is a significant economy in the UK and creates an alternative option for fitness, wellbeing and connecting with the outdoors (King and Church, 2019). Despite this, mountain biking is understudied in academic literature (Wheaton, 2010). Recently two major bike parks, Aston Hill in the Chilterns, and Revolution in North Wales, closed due to outbreaks of tree pests and pathogens, impacting the staff, riders and local businesses. Although both bike parks are set to reopen, the events at both locations could have easily led to permanent closure and will have lasting impacts. It is hoped that by studying the environmental issues surrounding the sport, a more informed approach to management can be taken, leading to fewer full closures in the future. However, there is a clear gap in knowledge about the scale of UK mountain biking and its dependence on forested areas.

Tree pests and pathogens pose a significant environmental threat, with many leading to mass mortality (McKinney et al, 2014). This can alter ecology and hydrology, create a health hazard for members of the public, disrupt timber production and threaten culturally significant species. Over the next century, the threat of pests and pathogens is set to increase. Climate change will alter the behaviour of species, disrupting ecosystems and allowing invasive species to interfere. In an increasingly globalised world, pathogens can easily spread (Fuente et al, 2018). Despite this, tree pests and pathogens are an understudied area, and it is vital more research is done to understand how to smartly manage the spread of pests and pathogens, as traditional methods of control are often ineffective (Potter et al, 2011). There a several new methods for managing the spread of pests and pathogens, which, with more understanding, could be very useful (Qin, et al, 2017; Green et al, 2023). Pair this with improved monitoring techniques and tree pests and pathogens could be identified early when they can be controlled. Unfortunately,

many diseases, such as Ash Dieback and *Phytophthora*, have spread widely across the country. Once this happens, control is extremely difficult (Foster and Orwig, 2006).

This investigation uses visual and GPS content to draw qualitative conclusions (Strauss and Corbin, 1998). Strava data is analysed to determine to scale of UK mountain biking and interviews were conducted to find out the views of experts. To gauge public opinion, hours of YouTube content were analysed along with a survey which was answered by 70 mountain bikers. Therefore, the conclusions of this investigation represent the views of many groups and provide positive suggestions to tackle environmental issues associated with tree pests and pathogens and outdoor recreation.

1.2 Definitions

Mountain biking: Mountain biking is a sport that involves riding bicycles off-road. The are many disciplines of mountain biking such as downhill or cross country, like skiing.

Bike Park: A designated area purely reserved for mountain biking, primarily businesses that own or lease land with the purpose of making money by charging visitors to ride

Trail Centre: Similar to walking trail centres. An area with trails is managed by usually a local authority to enable people to enjoy the outdoors. These locations have less well-defined boundaries and do not charge to ride, although there is often a parking charge and visitor centre which aims to make some money.

Downhill Mountain biking (DH): Most commonly this study will refer to downhill mountain biking although many locations that are discussed have a variety of routes for different disciplines. Downhill Mountain biking is a form of mountain biking where riders only go downhill, across extremely technical terrain or large jumps. To get back to the top riders either 'push up' or use an 'uplift' service.

Cross Country: Cross country or XC mountain biking involves riding often in a circuit including up and down hills. The terrain is usually less challenging than in downhill, and riders are more fitness focussed

Uplift: At downhill focussed sites, a service is provided that takes riders to the top of the hill as riding up a hill is not seen as enjoyable for this discipline. In the UK this is typically a van with a trailer but in Europe, ski lifts are often made use of for this purpose during the summer (non-ski) season.

Official vs Unofficial locations

A great amount of mountain biking in the UK is done outside of sanctioned areas i.e., bike parks and trail centres. These informal trails are built by locals and have varying levels of legitimacy. Some places are very well known, and others are completely secret. Many sanctioned trail networks began as unofficial locations.

Wild/Off-Piste Trails

These are unsanctioned trails and can be within bike parks/trail centres or in unofficial locations. Often some of the most steep and technical riding can be found on these trails. Riders will usually refer to them as 'off-piste', whereas landowners and forest managers prefer the term 'wild'.

1.3 Case Studies

This study was inspired by and will regularly cite two recent case studies of prominent UK mountain biking centres that have been forced to take drastic action due to the onset of tree diseases in their locations. Both are 'bike parks', which means they are businesses that have mountain biking specific trails within a privately owned area with mountain bikers paying to use them. However, this research can also be applied to mountain bike trail centres, publicly open designated mountain biking trails, often shared with other users, and unofficial 'grass roots' sites where mountain biking is popular.

The first case study is of Aston Hill Bike Park in the Chiltern Hills, which in January 2020, closed due to an outbreak of Chalara Ash dieback, which resulted in all Ash trees being removed (Aston Hill, 2022). The site was popular due to its high elevation for the area, situated on Haddington Hill in the Chilterns which reaches

267 metres, allowing for downhill tracks that are up to two minutes long, which is rare for a location so close to London. The work is still ongoing as of July 2024 with works massively altering the forest, destroying all bike trails. Although Aston Hill Bike Park and the Forestry Commission that co-run the bike park have been clear from the start that it will reopen, this date has been pushed back several times (Forestry England, 2024). Ash Dieback, caused by the fungus *Hymenoscyphus Fraxineus*, is a disease that has a high mortality rate in Ash Trees, emerging in Poland in the early 1990's (McKinney et al, 2014). Native to the UK, ash trees hold deep cultural significance, featuring prominently in folklore, mythology, (Keating, 2021) and traditional crafts due to Ash wood's strength and flexibility (Dobrowolska et al, 2011). Beyond their cultural value, they play a vital ecological role in woodland ecosystems, supporting a diverse range of wildlife. Their dense canopies provide shelter for birds, insects, and mammals, while their leaves enrich the soil, promoting biodiversity (Mitchell et al, 2014). Ash trees also contribute to the structure of woodlands, helping to sustain a balanced and thriving natural environment. (Forest Research (1)). Ash trees are potentially resilient to climate change and rarely out competes other species (Ellenberg, 2010) making it a good choice for commercial forestry.

Figure 1- *The work undertaken at Aston Hill Bike Park has left the woodland drastically changed and is still ongoing. (Source: Aston Hill Bike Park Facebook page, 2022)*

The second case study is of Revolution Bike Park in North Wales, one of the largest bike parks in the UK with global recognition. At the end of 2022 the park shut after *Phytophthora Ramorum,* affecting Japanese Larch, was identified in the forest. The disease has been prominent in North Wales over the last 15 years (Senedd Cymru, 2015). Japanese Larch comprised around two thirds of the trees at Revolution Bike Park and removal work has left the area unrecognisable (Revolution Bike Park, 2023). The monoculture forest undoubtedly heightened the park's vulnerability. Initially, the owners of the park said the closure was not permanent, but that they had little idea when it may reopen except that it will be several years at least (Revolution Bike Park, 2022). Despite being one of the largest bike parks in the UK, Revolution Bike Park is still a small business, and therefore the closure was an extreme challenge financially. The forest was vital for the park for trail design, erosion and as a wind break, which enabled all year riding.

Figure 2 – *Top, 'Vision Line' after felling work in 2023 (Revolution Bike Park, 2023), bottom 'Vision Line' in November 2022 (Original).*

As of summer 2024, Revolution has seen a very limited reopening although there is nonetheless a long way to go before the normal running of the park returns to provide the consistent revenue needed. The decision to close Revolution is a major one for the sport and has the potential to set a precedent. It is therefore important to find out if the decision was necessary. *Phytophthora Ramorum* is a pathogen affecting many species including Japanese Larch. Like Ash Dieback, *Phytophthora Ramorum* causes rapid mortality in many affected trees leading to concerns around safety and spread (Grunwald et al, 2008), potentially to other important tree species

(Forest Research). Despite the difficult position faced by the park, this year Revolution have announced many ambitious plans, including a limited opening schedule. In place of the larch forest, the owners have decided to plant 11 different tree species (Revolution Bike Park, 2023). It is hoped this will create a more varied forest which is more resistant to pests and pathogens, higher in biodiversity and more interesting for mountain biking. It will be fascinating to see how the new forest, designed for mountain biking, develops over the next few decades.

Additionally, a further two case studies have been investigated, the Hemlock Stone Trail Association in Bramcote, Nottingham, and Wharncliffe Woods near Sheffield. Neither of these sites have had significant issues with tree pests, although along with all woodland areas in the UK, there are signs of poor tree health at both locations. They have been chosen to represent the more informal places people ride, and therefore how they are managed differently. Both are free to ride with trails maintained by volunteers. Hemlock Stone is officially designated by local authorities for mountain biking, although the space is shared with other users. The council visit the site occasionally to check the safety of the work being carried out by the volunteers. The council also provide trail signage to indicate the location of bike trails and challenging obstacles. Only three trails are currently designated with every obstacle mapped out. The volunteers are only allowed to maintain what is currently there, rather than change existing parts of the trails. Recently, some additional trails in a different part of the woodland were destroyed as they were deemed too dangerous by the council.

Wharncliffe Woods is owned by the Forestry Commission. Although the Forestry Commission promotes mountain biking as a way to enjoy the woods, it deliberately avoids acknowledging the downhill trails due to their technical nature and associated risks. The trails at Wharncliffe Woods are spread out across a large area, with some trails easy to find and other well hidden. In the neighbouring Grenoside woods, there are some sanctioned trails which are extremely popular with locals. The forest has a typical range of pests and pathogens for the UK, including Ash Dieback and Oak processionary moth, although there is no suggestion that large scale felling is needed to control this.

2. Aims and Objectives

2.1 Aims

- **To suggest improved management approaches for UK bike parks and trails centres affected by tree pests and pathogens**

2.2 Objectives

- **Determine the scale of the UK mountain biking, usage patterns of various sites and associated environmental issues.**
- **Establish the distribution of mountain bike trails in terms of land use and location**
- **Investigate the importance of trees to the sport in terms of woodland types, practicality and rider experience**
- **Find out how tree diseases/pests impact bike parks**
- **Evaluate current management strategies**
- **Suggest new management approaches**
- **Evaluate methods chosen, especially the spatial and temporal detail that Strava Metro Data can offer.**

3. Literature Review

3.1 Mountain biking in environmental and geographical contexts

3.1.1 The development of Mountain biking within woodland environments.

Mountain biking emerged in the 1970s and has been gaining popularity since (Thurston and Reader, 2001; Pröbstl-Haider et al, 2018). Like other extreme sports, mountain biking enables people to engage with environments in a novel way, combing fitness, physical challenges and excitement (Melo et al, 2020) The sport involves riding bicycles off-road and ranges from cross-country, which is about endurance and speed, to downhill and freeride which is about riding challenging terrain and thrill seeking (King and Church, 2019). Along with other forms of outdoor recreation, the sport has seen a significant rise in popularity post-COVID-19, and in the UK since the Olympics (Ibid). Many are choosing mountain biking as their preferred way to engage with nature (Skår et al, 2008), bringing with it physical and mental health benefits. Many places are encouraging mountain biking due to its health benefits, public appeal and economic benefits as it is seen as a high spend activity (Brown, 2016). Mountain biking is clearly endorsed with local authorities using pictures of the sport as promotional content (ibid). Despite this, there is little academic literature focussed on mountain biking with the majority in the category of sports science looking at fitness and injuries. Globally, mountain biking is worth nine billion US$ (Palwe, 2024). Preliminary research shows that, in Britain, there are at least 33 official mountain bike parks or centres, of these 79% rely at least partly on forested areas. This is not counting the far higher number of unofficial areas used for mountain biking which are harder to quantify. A large part of the sport centres around these informal settings when investment is focussed on sanctioned trails and official clubs (King and Church, 2019). Mountain biking is a large recreational outdoor industry, dependent on forestry for its existence, however there is very limited academic research into the best management strategies.

Geographical research into mountain biking is limited, especially compared to other forms of outdoor recreation (Wheaton, 2010). Existing research tends to focus on ecological impacts, investigating its impact on flora (Thurston and Reader et al; Pickering et al, 2010), fauna (Scholten et al, 2018) and geomorphologically (Stavi, and Yizhaq, 2020; Evju et al, 2021). These articles focus on the environmental impact of mountain biking, especially regarding soil compaction, erosion, comparing mountain biking to other outdoor activities e.g., hiking, horse riding, with a goal to better inform the maintenance of trails. This research has focused on the developed world with studies based in the US, Australia and Europe, specifically Norway and Austria. Overall, this research is limited and there is disagreement as to whether mountain biking has a significant environmental impact. The main area of agreement is that mountain biking is similarly destructive to other forms of outdoor recreation such as hiking or horse riding, all of which can cause rapid destruction of vegetation, soil erosion, ground compaction, hydrological changes and disruption to animal movement. The level of damage is heavily dependent on weather conditions, and higher in more natural ecosystems.

Mountain bikers can cover a great distance compared to hikers and this range has increased recently with the popularity of electrically assisted mountain bikes (e-bikes). There are concerns that e-bikes they will allow mountain bikers to explore more remote areas that previously were less accessible to humans, therefore disrupting semi-natural ecosystems (Bayne et al, 2020; Kuwaczka, 2023). E-bikes have already enabled many people to enjoy mountain biking who previously would have found the sport inaccessible. However, along with the potential for increased ecological disruption, e-bikes have the potential to cause divisions within mountain biking culture and reduce need to engage with technical challenges usually associated with the sport (Cherrington and Black, 2023).

Existing literature points towards mountain biking typically being a low impact activity with 'single track trails' causing little geomorphic change and conforming to natural features (Kozumplíkova et al, 2018). Trails are constantly evolving with the landscape as natural and anthropogenic processes alter the direction, obstacles and surface characteristics. As a result, trails are often different year on year which is a draw for many. However, many view mountain biking as an anti-social sport, damaging the environment physically and ecologically (King and Church, 2019).

This can lead to land access issues, especially in the UK where a high percentage of land is privately owned (Cherrington, 2021), population density is high and woodland coverage is low at only 13% (Iversen et al, 2022; Forest Research, 2017). Common problems for trails systems are conflicts between riders and other users of the forest (Zajc and Berzelak, 2016). Access rights and land ownership is a prominent issue for mountain bike trails due to the perceived destruction by riders but also the high risk associated with the activity for which the landowner is responsible. Correct management of risks while maintaining the 'thrill' aspect is essential to the sport (Stavi and Yizhaq, 2020). Overall, mountain biking is a recreational activity that can be integrated easily into woodlands especially commercial forestry. Forest management trends have moved towards encouraging access and recreation due to the physical and mental health benefits (Bayne et al, 2022). The importance of trees to mountain biking cannot be overstated. The sounds, smells, and visual complexity of wooded areas are a fundamental element of the experience, beyond simply practical reasons such as trail design. With proper planning and signage, mountain biking can be integrated into commercial woodlands without an increase in pests and pathogens or other serious environmental implications (ibid). Mountain biking is a popular form of outdoor recreation for young people who are drawn to the thrill (King and Church, 2019). However, management of outdoor spaces is often not understanding of this (ibid). Most commercial forestry will incorporate mountain biking into management plans as it is usually easier to direct mountain bikers to a designated area than deal with riders using forested areas without permission (ibid; Wilkes-Allemann et al, 2022). In the UK, landowners with public bridleways must allow access to cyclists and horse riders, whilst the Forestry Commission allow public access to all their sites by default, although will oppose any activity they deem to be causing damage to their land.

3.1.2 Applications of PPGIS for mountain biking

Wolf et al (2015) explores the willingness of mountain bikers to use 'public participation GIS' (PPGIS) which could be a useful tool in woodland management. Users can submit location-based data containing information desired by the researcher. PPGIS data is inexpensive to obtain and spatially detailed. By engaging the public, management decisions are often better accepted (Raymond et al, 2009).

Compared to other forms of outdoor recreation, mountain biking requires specific features to satisfy the participants desires, such as rocks, roots, jumps and drops (Newsome and Davies, 2009; Symmonds, 2000). Therefore, user feedback is especially important. It was found that mountain bikers took well to PPGIS (Wolf et al, 2015) indicating that public reporting of signs of poor tree health could be a beneficial strategy for the future. It should be noted that the PPGIS in the study was to allow mountain bikers to suggest improvements to the trails, which they would likely take to better than tree health reporting which may lead to their favourite trails closing. This is something we see in all communities when it comes to reporting tree disease (Pocock et al, 2020). Mountain bikers are already using PPGIS widely within apps such as Strava and Trail Forks. Both have a wealth of data so if tree health reporting could be incorporated into the apps, this could have a very positive impact. Strava heatmaps have been the focus of several academic articles e.g., Yang et al, 2022; Rice 2019; Jiang et al, 2022, Yun et al 2017, although all focussing on road cycling, urban cycling or running. Compared to traditional ground survey techniques for establishing cyclists' movements, Strava is unrivalled in terms of spatial and temporal detail, with data not limited to path networks, and offering time scales from hourly to annually (Sun et al, 2017). Its main limitation is that is presents data for a clearly skewed section of society with the average Strava uploader being older and likely to be male compared to the average rider (Bordelon and Ferreira et al, 2019).

3.1.3 Geographical distribution of mountain biking

Mountain biking is often done in upland areas due to rider's desire for steep slopes. This has the potential to bring economic benefits to upland areas which can struggle for agricultural income and are typically dependent on tourism (Kozumplíkova et al, 2018; Iversen et al, 2023). The challenge is placing a value on nature-based recreation (ibid). Mountain bikers tend to be affluent and will usually visit several locations when visiting a region of the country which is also good for rural economies (Bordelon and Ferreira, 2019).

Mountain biking often takes place in areas of commercial forestry, making use of fire roads but also creating purpose-built trails (Bayne et al, 2020). Mountain biking has a low impact on the forest landscape, with many trails barely modifying the

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landscape (Kozumplíkova et al, 2018) as this adds to the challenge which is for many the draw to the sport. Similarly, to other recreational activities, the main issues with tree pests and diseases are of safety for the forest users and the potential to aid in the spread of the pest or disease (Potter et al, 2011). Bike parks and mountain biking trail centres always offer a unique experience, even places that are geographically very close to one another, due to subtle differences in geology, soil type, gradient and the individuality of trail builders. (Taylor, 2010). Mountain bikers are very receptive to differences in soil type, frequently using words such as 'loamy' 'clayey' and 'sandy' to name a few (Cherrington and Black, 2019). As a result, riders will typically visit many spots in an area while they are there, becoming effective vectors for disease.

3.1.4 Cultural Politics of Mountain Biking

There is a strong community spirit within mountain biking, including across various subgroups (King and Church, 2018; Cherrington, 2021). The mountain biking community can be understood using the concept of neo tribalism, with bonding taking place through shared experience, for example, talking about equipment, favourite places to ride, techniques for riding a specific section of trail, or online content (Maffesoli, 1996; Brown, 2016). This ranges from novices and cross-country riders, the most common public perception of mountain biking, to the more extreme downhill and freeride enthusiasts seeking an adrenalin rush (Felton, 2004; Pickering et al, 2010). Despite many places encouraging mountain biking, riders often feel unwelcome due to negative comments, disapproving looks or attempts to physically restrict the use of trails (Brown, 2016). As a result, many mountain bikers ride in secret locations where it is hoped that the trails will go undetected. This makes management more challenging and can lead to added disapproval from other users of the forest (ibid). Mountain biking often gets blamed for a disproportionate amount of ecological damage, despite little evidence that it is more damaging than walking or horse riding (Heer et at, 2003). For many years, the acceptance of mountain bikers as outdoor citizens has been contested with some even labelling riders as the outdoor 'anti-citizen' (Matless, 1998). Continued work is needed to promote tolerance between recreational users of forests (Ranthum, 1995).

Aesthetics play a crucial role in user experience for outdoor recreation; however, this can be extended to the feel of trails, e.g., roots, rocks, compacted soil, gravel, obstacles (Brown, 2017). Most cyclists overlook the time that goes in to constructing mountain bike trails, but within dedicated niche communities, trail builders are regarded highly due to the time and effort required (Button, 2024; Cherrington, 2021). The construction of trails is varied depending on the location. Local routes tend to be maintained by volunteers using hand tools and natural resources available to them (Cherrington, 2021). In contrast, at large commercial bike parks, construction and maintenance typically requires heavy machinery and imported material, especially if the natural landscape is void of a certain terrain e.g., large rocks. Soil types and hydrology will also affect the effort required to maintain trails (Stavi et al, 2020). Areas with heavy rain fall and porous soils will usually require more maintenance although arid areas with very dry soils also degrade easily. To a mountain biker, dirt plays a dynamic role in a rider's experience (Goudie, 2013; Cherrington and Black, 2020). Trees and rocks work to hold trail networks together. Some routes are deliberately more 'natural' depending on the mountain bike niche, 'natural' here meaning that the route is only maintained by regular riding not with an explicit aim to create features. The approach to trail building will change the environmental footprint, especially in terms of ground pressure, vegetation damage and the disturbance of natural cycles (Cherrington, 2021). Trail building has developed with the sport as technology has improved and riders continue to push the limits (Gibbs and Holoway, 2017). For example, Coed Y Brenin, the UK's first trail centre, was groundbreaking in the mid 90's when it was designed. Some of the terrain on offer was very different to what mountain bikers had previously experienced, especially for public trails and on the types of mountain bike available. Today, bike parks and trail centres are always trying to balance safety with the draw of the thrill (Gibbs and Holoway, 2017). Challenging features endorsed by professional riders can be a huge draw for the community, however the needs of insurance and liability must be balanced.

3.2 Forest landscapes in the Anthropocene

3.2.1 Tree pests, pathogens and environmental pressures

There is a plethora of literature around the subject of tree pests and pathogens (Augspurger and Kelly, 1984; Holdenrieder et al, 2004; Eyles et al, 2010; Tubby and

Webber, 2010; Jactel et al, 2012; Boyd et al, 2013; Lovett et al, 2016; Green et al, 2023). Common themes include how most attempts to prevent the spread of tree pests/diseases have failed and that the impacts are comparable to climate change in terms of ecosystem damages but are far less talked about (Potter et al, 2011). Much of the literature has focussed on commercial forestry as this is economically and politically significant. As a result, there has been an increase in literature focussed on the impact of pests/disease on semi-natural woodland systems. Mountain biking is not limited to either woodland type. Tree pathogens are a natural occurrence and have always been a feature of ecosystems. In natural ecosystems they are a key disturbance dynamic along with fire, drought, climate etc., (Castello, 1995; Jasinski and Payette, 2007). Naturally occurring tree pathogens would have been highly destructive, but ultimately a normal process, allowing new species to thrive (ibid). The impacts of such outbreaks can be observed in the stratigraphic record, for example the Mid Holocene decline of the Hemlock in North America (Davis 1981; Waller, 2013), and the Pan-European Elm (Parker et al, 2002). These were usually triggered by other forcings such as drought or natural climate variability (Marsicek et al., 2013).

Trees perform many ecosystem functions, acting as a habitat for many species, carbon storage, hydrological function (Boyd et al, 2013). Additionally, trees provide many anthropogenic services such as improved air quality (Nowak et al, 2006), physical and mental health benefits (O'Brien et al, 2010). pests and pathogens pose a great threat to remaining forested areas, with many leading to extremely high mortality rates, such as Dutch Elm Disease (Potter et al, 2011). Historically, the protection of trees against diseases and pests has focused on commercial forestry although there is also significant public interest in the threat to semi-natural ecosystems and the functions they provide (Boyd et al, 2013). Typically, monoculture forests are more vulnerable, which means that foresters must choose the right species to plant to create resilient forests (Webb et al, 2023). Contemporary pests and pathogens are a combination of natural disturbance mechanisms, but exacerbated by climate change, monoculture forestry and global transport networks (Qin et al, 2017) increasing the dominance of invasive tree epidemics (Mageroy et al, 2023). The slow growth rate of trees increases their susceptibility to climate change, especially drought and heat, as they are unable to adapt on short timescales (ibid). Some prominent examples affecting UK forests include pathogens such as Ash Dieback, Dutch Elm Disease and *Phytophthora*

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Ramorum, and pests such as the Oak Processionary Moth and the Asian Long Horn Beetle.

Ash dieback is likely the most well-known current threat to trees in the UK due to its widespread impact and the cultural significance of Ash trees and their position as a keystone species (Pautasso et al, 2013). Many pests and pathogens affect commercial forestry, causing economic damage but out of sight for a lot of the public (Boyd et al, 2013). Ash trees are often found in semi-natural, broadleaved woodland. Ash is fast growing which has made it a popular crop for commercial purposes (Dobrowolska et al, 2011). Ash Dieback spread rapidly across the country (Gross et al, 2014) so currently the primary objective when it comes to managing the disease is to find resistant Ash trees (Gossner et al, 2023). However, assuming this is successful, factoring the growth rate of Ash trees and climate uncertainty, a good outcome for the full return of Ash would be around 200 years (ibid). The management of Ash Dieback seeks to avoid the severe consequences of Dutch Elm Disease. This was a prime example of an outbreak worsened by globalisation. Much of the way woodlands are managed to prevent the spread of pest and pathogens today is due to the severity of the Dutch Elm Disease outbreak in the early 1970's, and the public upset it caused (Potter et al, 2011). The disease rapidly swept through almost the entire 30 million Elms in the UK, which were a common sight in hedgerows in southern England (ibid).

The Asian Long Horn Beetle is a wood boring insect that causes economic damage in the millions each year (Zheng et al, 2024). So far prevention methods have proved unsuccessful, and the insect has spread across much of the world, damaging the structure of many species. This makes forests unsafe and reduces the value of the wood. Another pest impacting woodland is the Oak Processionary Moth which can severely limit the growth of Oak Trees, and the tree's ability to grow leaves (Suprunenko et al, 2022; Arnold et al, 2023). It is thought the pest first appeared in the UK in 2006 (Groenen and Meurisse 2012) and that since an abrupt increase in the rate of spread in 2015, eradication is no longer possible (Suprunenko et al, 2022). Hairs from the caterpillars are also a threat to humans and animals, causing skin and lung irritation (ibid). This is a particular challenge in urban areas but also in any woodlands that are used for recreation containing large numbers of oak trees (Tomlinson et al, 2015). Once again, its presence in the UK is a product of

globalisation with the impacts of the moth exacerbated by climate change. Warmer winters mean more Moths are surviving through to spring and changing climate patterns have impacted migrating birds which are the main predator of the moth. Oak trees are a valuable timber as well as a culturally significant species. However, they are extremely slow growing, which makes them especially susceptible to damaging pests, and slow to adapt.

Currently, decisions around the management of affected areas of forest are made by considering many factors (Wainhouse, 2005). The management of tree pests and diseases has historically centred around commercial forestry (Boyd et al, (2013). Other factors that are considered include the cultural importance of the tree species within the community, the ability of the disease/pest to spread and the potential for public harm (ibid). Clear felling has been the dominant strategy for the last century as it is quick and effective at removing the pest or pathogen (Mason et al, 2022). The landowner can also typically recoup cost through the selling of the timber with subsidies to replant also available. Legislation in the UK varies between species and the pest or pathogen in question. Often, legislation is vague giving local land managers options. Factors at play include the nature of the threat, risk of further spread, impact on timber prices, safety risk, proximity to humans and if the species is native or not. Furthermore, Britain's exit from the European Union has created uncertainty around international frameworks for reducing the spread of pests and pathogens via imports and exports. The European Union, through several initiatives such as the plant health strategy, require member states to act against invasive pests based on their research (Klapwijk et al, 2016). However, the UK is still required to follow UN regulations under the International Plant Protection Convention (Eyre et al, 2024). Management will often consider public opinion especially when on public land. The public favour natural, targeted management over chemical and widespread (Fuller et al. 2016). Typically, tree pests and diseases are managed using selective felling of infected trees and preventative felling by creating buffer strips. By 2019 at least 20,700 hectares of Japanese Larch across the UK had been killed or felled (Dun et al, 2022). By selectively felling only the infected trees, damage to the forest is reduced although this will always be a destructive process. This management is also time consuming and expensive. To undertake requires removing public access to the forest, causes major disruption to ecosystem and for most pests/diseases has little success controlling the spread, raising the debate of whether this type of management is ideal.

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3.2.2 New strategies for managing tree pests and pathogens

There is certainly scope for innovation in management (Boyd et al, 2013; Green et al, 2018). Studies show that the methods used to control the spread of tree pests and pathogens are unpopular although public awareness of the issues is low (Urquhart et al, 2017). Preventative felling often destroys survivor trees which cannot be identified, limiting the species ability to develop resistance (Budde et al, 2016). Felling also destroys the forest ecosystem and stops all recreational or commercial uses of the forest (ibid). Tree pests and diseases can be limited using biological control (Balla et al, 2021). This is risky as it involves introducing a species that is alien to the current ecosystem (ibid). It is impossible to truly assess the potential of introduced species to become invasive and destructive. However, if successful in neutralising the pest/disease, can be the ideal solution, requiring no ongoing management or destruction to the forest (Perumal et al, 2023). Biological control can also reduce dependence on pesticides. For example, Zheng et al, 2024, outlines the potential for a fungus to reduce the impact of Asian Long Horn Beetle. It was found that the fungus was effective at weakening the beetles in a controlled environment although further research is needed to be effective in a commercial forest.

A method with great potential for combating infectious tree pests and diseases is selective planting of genetically resistant individuals (Pike et al, 2020). This is a long process, requiring the regrowing of forests and will in nature occur slowly and organically. With human intervention, resistant individual trees can be cultivated and used in the regeneration of forests along with other specially selected species. However, some studies have proved successful (Sniezko et al, 2023). Over the last ten years, several resistant Ash genotypes have been discovered (Gossner et al, 2023; McKinney et al, 2014). In the US, a handful of species populations are increasing after successful selective planting including a few species of Pine, Port-Orford Ceder and Koa in Hawaii (Pike et al, 2020). However, other trials have proved less successful and without adequate funding, some argue that this strategy is unlikely to be the primary strategy for combatting pests and pathogens (Sneizko et al, 2023). The major issue with creating a species that is genetically resistant to invasive species is that new pests are always going to emerge. It is impossible to

predict when this will happen and can make selective breeding programmes futile. Genetic diversity is also reduced which can make the woodland vulnerable to environmental changes (Budde et al, 2016).

A worthwhile strategy could be 'do nothing' (Foster and Orwig, 2006). This is always a strategy that is considered in environmental management, even just to establish a base for comparison. However, in this case, doing nothing reduces the harm to the forest ecosystem to that caused only by the pathogen, and creates the best environment to produce resistant individuals (Foster and Orwig, 2006. This strategy is also cheap. The main issues are the concerns around safety and the controlling further spread. For both *Chalara* and *Ramorum*, there are very few areas remaining where they have not already spread (Forest Research 1 and 2, no date), with many experts suggesting it is now too late to control the diseases (Potter et al, 2011). However, tree diseases, especially *Ramorum*, can quickly become extremely destructive, causing great damage to the timber industry, hence the current protocol to immediately fell infected areas (Forest Research 2, no date). Additionally, the safety concerns are still very valid, especially on private land with paying customers and mountain bike trails all over the forest.

The best way to reduce the future impact of tree pests and diseases is to plant resilient forests. This involves carefully selecting trees that will be more likely to survive outbreaks, such as survivor trees and even genetically manipulated trees (Cao et al, 2022). Planting a variety of trees can be effective as well as increasing biodiversity. However, this can increase felling costs if the woodland is commercial and add complexity if one of the species becomes threatened by pests.

Satellite and LiDAR are useful tools for monitoring tree health, although sometimes lacking in spatial resolution (Hartmann et al, 2018). This is an area that be certainly be improved for future monitoring, allowing for a better understanding of causal relationships and monitoring individual trees remotely (McDowell et al., 2015). Tree mortality is complex and often driven by multiple factors (Hartmann et al, 2018). To better understand tree health, an international monitoring network could be extremely useful but would require high levels of collaboration between scientists (ibid). Monitoring and research are essential for preventative management of new

threats as without proper evidence to the destructive potential of a new pest or pathogen, it is difficult to justify the necessary action (Potter et al, 2011). High resolution remote sensing is already being tested for identifying tree mortality due to infestations, such as Pine Shoot Beetles in Southwestern China (Wang et al, 2024). The technology was effective at identifying infested trees. However, due to the nature of the pest, trees were often identified during the latter stages of the infestation, highlighting an issue with the technology. Remote sensing can allow for far more widespread monitoring, at a lower cost, than traditional ground surveys. However, from above, it is only possible to see the tops of the trees, limiting accuracy. This was seen at Revolution Bike Park, where only a small number of trees were identified as potentially diseased, leading to action being taken with insubstantial evidence.

The problem of combatting tree diseases and pests is one that lends itself well to citizen reporting (Green et al, 2023). If the public could be encouraged to report outbreaks early then they could likely be dealt with quicker and more cost effectively (White et al, 2019). In practice this is always challenging, largely as citizens are often hesitant to report outbreaks as they know this could lead to the closure of the woodland (Pocock et al, 2020). It is likely mountain bikers would react similarly.

3.2.3 Woodland Management in the UK

While tree pests and pathogens are a major threat to UK woodlands, there are also other challenges to consider which will be outlined here. The impact of human activity is far reaching hence the wide acceptance of the Anthropocene, the idea that humans are now the dominant forcing for the current geological period. As a result, nowhere on earth is entirely 'natural'. Habitat fragmentation is a significant issue for UK woodlands, due to the extremely low forested area (Kennett et al, 2024). As a result, woodlands tend to be small and disconnected, interrupting species interactions and movements (Fagan et al, 1999), changing micro-climates (Murcia, 1995) and disrupting vegetation networks. From a recreational perspective, habitat fragmentation leads to a concentration of human activity in a small area, increasing environmental stress. Footpaths may also contribute to habitat fragmentation by trampling vegetation and compacting soils (Miller et al, 1998). However, research is still inconclusive on this subject with some experts, for example Kennett et al,

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(2024), finding footpaths to have little environmental impact, albeit within one specific area. Another issue facing UK woodlands is pollution, most often from the air or water courses. Pollution can alter nutrient cycles, disrupting the local ecology and enabling non-native species to take hold. Pollution is higher in regions with large urban areas and industry although recreation tends to bring pollution to remote areas. However, woodlands also reduce pollution and with increasing demand for publicly accessible outdoor spaces, the creation of new woodland can provide many ecosystem services (Murkin et al, 2023). Since the pandemic, more people have been enjoying the outdoors, and this trend is set to continue with population growth, leading to access issues. Public access rights are current issue, with the Conservative Government having proposed new trespass laws in 2021 which could have led to one of the greatest limits of freedom of movement of recent times (Cherrington, 2021). In contrast, with devolved powers, Scotland passed far more liberal laws relating to the right to roam, and legalising wild camping (Breen et al, 2023), although the potential for environmental damage must be considered. Creating resilient forests is the main aim for foresters today and this mean choosing the correct species to plant. A balance must be struck between biodiversity, resilience to climate change and pests, retaining semi-natural native woodland and allowing public access, whilst maintaining a profit from timber production (Boyd et al, 2013). Research is essential for creating sustainable forests however, funding is under pressure. The environmental conditions of the next 100 years are impossible to predict precisely, and it is unknown which species of trees will perform the best in the future. However, research gives woodland managers the best chance to plant future proof forests.

3.3   Methodological Approach

To investigate the relationship between forest pests and pathogens and mountain biking, as well as the scale of the sport in the UK and other challenges facing outdoor recreation in woodlands, four methods were chosen to build on existing studies. The methods chosen were a GIS analysis using Strava and land use data, interviews of bike park managers, video analysis of online content and a Survey of rider habits and attitudes. To establish the scale of the issues, it is first necessary to investigate the size of UK mountain biking as well as the importance of woodland to the sport. This was done through a naturalistic investigation, that is one that draws

upon visual and GPS content to draw qualitative conclusions (Strauss and Corbin, 1998). This has proved successful for studying cycling, but there are few studies focussing on off-road cycling. Both visual and GPS data lends itself well to understanding rider habits, especially with improvements to action camera technology which has been an issue in the past due to the limits of attaching cameras to bicycles. Naturalistic studies have often struggled to reach equal participation of women (Iuliano and Keith, 2023). To establish the importance of trees to the sport, a survey was circulated around several mountain biking groups to understand the views of the general rider. This information was compared to the views of experts from the interviews and land cover data.

Initial research was done via the literature review. This included current strategies for management, government policy, alternative approaches, safety concerns, limiting the spread of pests/diseases, immunity in certain tree species, ecological impacts and recreational impacts. It is hoped that these two major case studies of mountain bike parks will help direct future strategies for dealing with outbreaks in general along with the specific management needs of mountain biking. Mountain biking is inherently dangerous with riders negotiating steep, uneven terrain, large jumps and drops. Therefore, mountain bikers are willing to accept higher risks within affected areas although it must be clear that liability cannot be passed to the landowners or business owners.

The second part of the research focussed on forested areas used for mountain biking that have been affected by tree pests/diseases, referencing case studies and specific challenges and opportunities within mountain biking. Literature surrounding this niche line of investigation is limited (Wheaton et al, 2010). Therefore, this part of the investigation was centred around interviews with owners of forested areas used for mountain biking, both those running bike parks/trail centres and the landowners. The aim of the interviews was to speak to experts from a range of mountain biking locations to find out if they are aware of tree pests/diseases present in their woodland, whether authorities have been in contact about this and if any management strategies have been proposed to them. A survey was conducted to assess the views and habits of mountain bikers. A major aim of this was to gauge riders' openness to new strategies and how to deal with the safety concern of having the public interact with infected trees.

3.3.1 Review of Strava Data

Further investigation was carried out using GIS. By combining digital mapping of tree diseases with PPGIS data from riders, the scale of the issue can be visualised. There is a wealth of crowdsourced data in existence for mountain biking, in the form of Strava Metro (Sun et al, 2017). Strava is a fitness app where athletes can upload a GPS file of their activity, usually cycling or running, comparing data with their friends. Strava creates a heatmap (Figure 2, UBDC, 2024) based on activities uploaded to the app, this is done passively even if the activity is not listed publicly. Strava data has been used to study cyclists' behaviour, mainly in terms of commuting, for the best part of a decade, due to its superior spatial and temporal range compared to traditional counting based methods (Sun et al, 2017; Jestico et al, 2016). This investigation used Strava Heatmap data to analyse off-road cycling which has not been done before. The data has great potential to investigate mountain biking as it records the position of the rider anywhere and does not snap to the road network. This means it is possible to see the trails riders are using if they are unknown even to the footpath network, which is often the case in mountain biking.
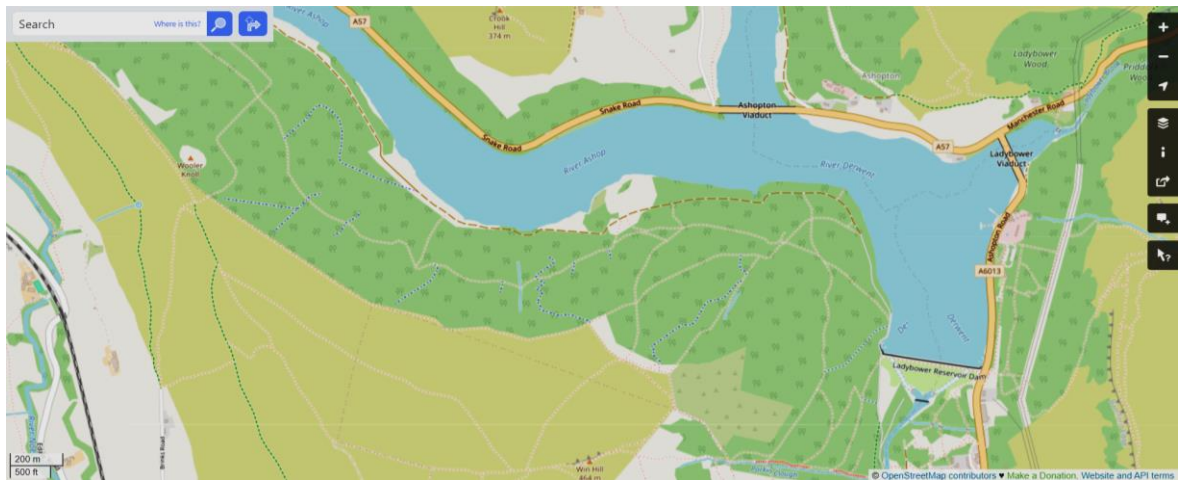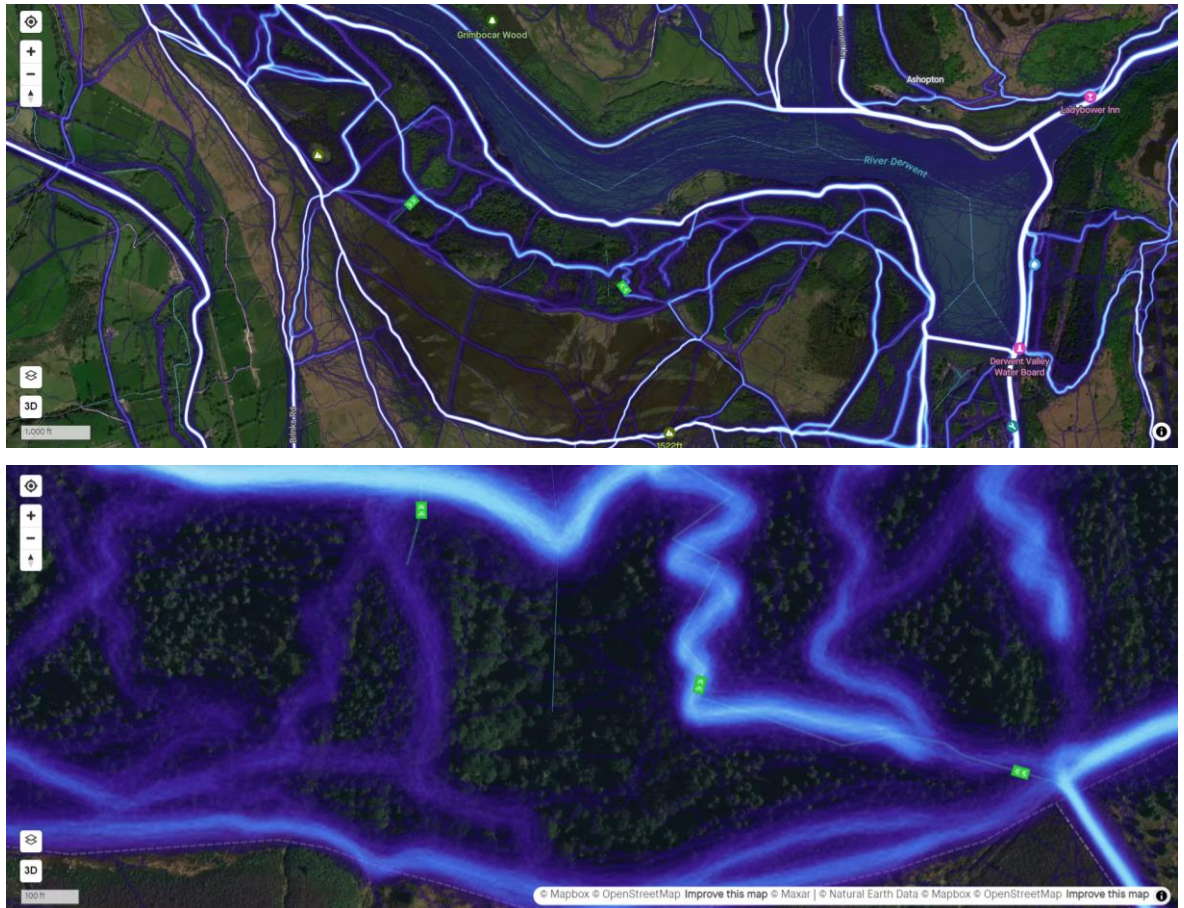
Figure 3 – OpenStreetMap view of the Ladybower/Win Hill area (Top) and Strava Heatmap data from the same area (Middle). Below is a zoom of that area showing the extremely high spatial detail available. Strava heatmap shows everywhere Strava athletes choose to cycle, run and walk. The data does not snap to the footpath network meaning that many unofficial trails are exposed. This is great tool for recreational users but can also be extremely useful for researching patterns of recreation in outdoor areas.

The study used information from Trail Forks, which is an interactive map of mountain bike trails, created by user submissions. This was used as an additional source of data to help map out mountain biking locations and was especially helpful for mapping out unsanctioned trail systems and seeing the geographical extent of trail networks. Trail Forks has not been used in an academic context previously. Trail Forks allows riders to upload information about trails using GPS files but also including other information such as trail difficulty, condition, direction, accessibility, photos and videos. All the data on Trail Forks is submitted voluntarily, unlike Strava heatmaps which are obtained passively. As a result, Trail Forks data is detailed with a wealth of qualitative information including trail descriptions/reviews, trail grading, seasonal changes, and photo/video content. This could bridge a key weakness of

Strava data which is good for demonstrating trends but lacks detailed information of the ground condition (Lawrence & Oxley, 2019). The trade-off is that the data is difficult to process quickly compared to the standardised Strava data. Another issue with Strava data is that it is aimed at fitness cycling. This means there is a bias to cross country mountain bike riding and the more fitness conscious user, not the casual downhill rider, whereas this study aimed to investigate both.
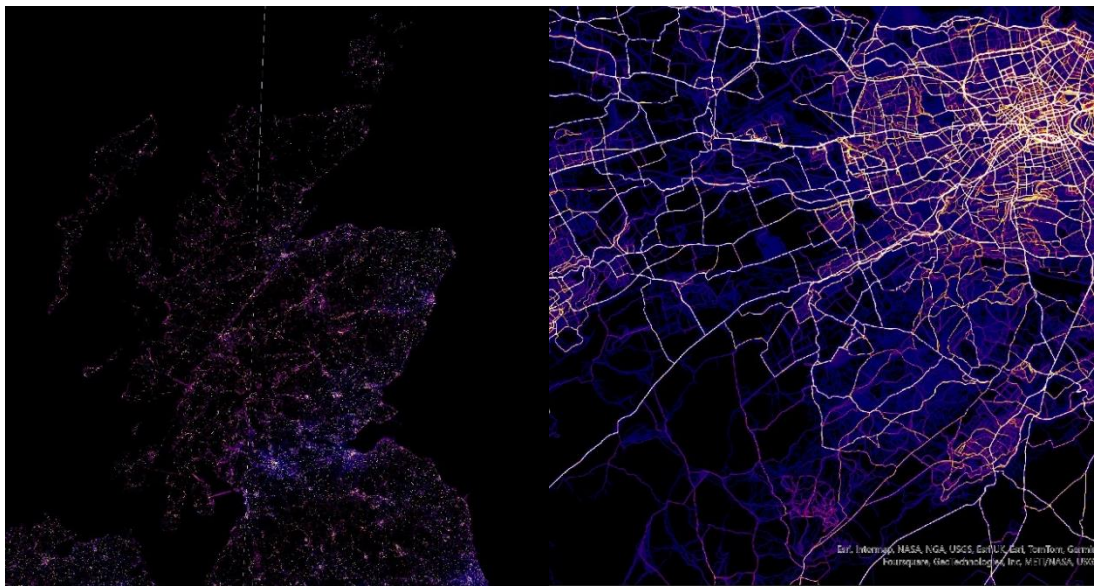
Figure 4 – A heatmap of Strava segments for Scotland 2017 (left) and a close up of the segments around Edinburgh (right). The more popular routes appear more orange, and this can be useful for investigating patterns for many outdoor leisure activities. Source: (UBDC, 2024)

3.3.2 Review of interviews for geographical studies

Interviews have long been a valuable technique for geographical investigations, as they can provide a wealth of geographic information, with more depth than many quantitative methods. Interviews are excellent for uncovering local and tacit knowledge and gaining lots of information from a small sample size. Interviews are also great for tapping into historical knowledge and placing the power in the hands of local stakeholders or those directly impacted by a geographical challenge (Young et al, 2017). Interviews have typically been a technique used for human geography investigation with conservation geographies historically void of qualitative data (Sutherland et al, 2018). However, for the reasons listed, interviews are increasingly being used for physical geographies (Young et al, 2017), especially to tackle wicked problems (Sutherland et al, 2018). Often, physical geographers struggle to effectively utilise qualitative techniques (ibid). When conducting interviews, it is essential to clearly define the methodology, including pilot interviews, and a clear rationale for questioning (Baxter and Eyles, 1997). Having a reasonable interview structure is essential, for example, the choice of sample size, which even if it is small, must be justifiable with its limitations acknowledged (ibid). The use of quotations can be effective as they allow undiluted responses from the interviewees to be communicated. Again, the number and length of quotations should be appropriate to the study. Interviews will be crucial to this investigation as the landowners and bike park managers are in the best position to inform about the best management practices for bike parks. From these interviews it is hoped that it will be possible to gain an understanding of how various management options would be received both in terms of viability and local acceptance.

3.3.3 Visual content from action cameras

Visual methods have been incorporated into countless geographical studies, and every year, high quality cameras become more accessible meaning that the availability of recorded content only increases (Bertone and Burghardt, 2017). As a result, visual methods have become a prominent sub discipline within human

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geography, enabling researchers to engage with space, movement and human experience (Rose, 2016; Pink 2015). Photo and video content contains a huge amount of detail and can be analysed thoroughly after the event. It is also largely objective, giving a true representation of what was happening at the time. However, it is still important to consider the motivations of the researcher, how it's edited, and what context the footage is viewed in. Visual content can be paid with GPS and remote sensing data to add context to the recorded content.

Mountain biking is a highly recorded sport with riders often recording a video of them completing a section of trail (Brown and Spinney, 2010). 'Action camera' (i.e. GoPro or similar) footage should be useful in documenting a rider's path through the surrounding landscape, especially as improvements in technology allow for better image stabilisation and 4K footage. Videography can be useful for documenting a rider's interaction with the terrain, for example speed, excitement and difficulty (Brown and Spinney, 2010). Modern action cameras are small and lightweight allowing them to be used with minimal obstruction to the cyclists, something that early studies struggled with (Iuliano and Keith, 2023). Without this it can be challenging to record data whilst simultaneously participating (Brown and Spinney, 2010). There is a huge amount of content available online which can be analysed. Some studies have already proved action cameras to be a useful tool for geographical investigation, incorporating themes around video-ethnography and auto-ethnography (Spinney, 2011). For example, Iuliano and Keith (2023) were able to analyse dangers to cyclists in an urban environment such as the proximity of oncoming cars. A similar study by (Pink et al, 2017), analysed data from 18 cyclists in Melbourne and found the cameras were effective in anthropological studies. Bourassa et al, (2023), found that it was possible to identify trees and other vegetation using bicycle mounted cameras, and that the video data could be an effective alternative to satellite imagery. Several other studies have investigated cyclist commuting patterns, but few have focused on recreational riding (Iuliano and Keith, 2023).

3.3.4 Review of surveys

Surveys have long been a popular technique for humanity studies as they allow the researcher to quicky obtain data from many participants. Traditionally, surveys have involved the researcher handing out a questionnaire in the field. Today, online surveys are a powerful tool as through social media, more people can be reached with minimal time cost. Surveys are a great way to engage the public in research when other methods such as interviews usually involve experts. Surveys can also be versatile, with questions ranging from multiple choice to long answer and can include visual media to help the participant. Online surveys also can automatically collate data, produce graphs and pick out key words across the responses which is great for analysing qualitative data. With all surveys, it is impossible to avoid bias in the sample group. People who answer surveys tend to have more free time and there is a certain type of person who likes to offer their opinion. When sharing a survey on social media, the respondents tend to be younger, though this can depend on the social media platform chosen. For a survey of mountain bike riders tend to be younger than the population average which will make the survey here more representative of the target group, however there will always be a skew in the sample group. Despite this, surveys are certainly a powerful research tool.

3.10 Literature Review Summary

To summarise, mountain biking is a fast-growing sport along with other forms of outdoor recreation. Mountain biking has the potential to cause environmental damage although current research is inconclusive and suggests it is no more harmful than hiking or horse riding. Mountain biking is a diverse sport with many sub disciplines (King and Church, 2019) but all dependant on woodland. Trails are typically built by local volunteers within communities using hand tools and local materials, with trails conforming to the terrain. However, at larger bike parks, heavy machinery can be used, and material imported. Mountain biking can be contentious due to land access issues and the perception of riders as anti-social. However, the sport can be an asset for upland economies which are typically dependent on tourism (Kozumplíkova, et al, 2018).

Trees provide many ecosystem services but across the world are threatened by pests and pathogens. This leads to heavy financial losses for timber production but

also can be a safety concern for the public, harm local ecology and damage culturally significant species. In the past, tree pests and pathogens have been significant enough to cause public concern, for example Dutch Elm Disease. The impacts of pests and pathogens have been worsened greatly by globalisation, due to the introduction of invasive species, and climate change which has altered the conditions native species are adapted to (Fuente et al, 2018). Traditional methods such as clear felling have proved largely unsuccessful for reducing the spread of tree pests and pathogens. They are also unpopular with the public (Urquhart et al, 2017). New methods such as selective planting of resistant trees, or biological control could prove useful in future outbreaks. However, catching a pest or disease early is essential in its containment.

There are several other issues that foresters must deal with, such as habitat fragmentation, pollution and land access rights. The most important aim for the future is planting resilient forests that can fulfil the various ecosystem benefits that we expect from trees. Research and monitoring are essential for creating sustainable woodlands and dealing with all the challenges mentioned although funding is currently below what is needed. Many governments across the world do not see the importance of research and the potential for future cost savings. Improvements in technologies such as LiDAR could prove to be very helpful in the creation of resilient forests.

This study employs a robust and interdisciplinary methodology to investigate mountain biking and forest health, with the aim of informing sustainable management practices that balance recreational use with the preservation of woodland ecosystems. By using multiple techniques, the views of experts and individuals have been considered, and placed into context provided by secondary data.

4. Methodology and Timings

4.1 GIS

4.1.1 Digitising mountain biking locations and investigating woodland distribution

Data analysis was done in ArcGIS Pro, a GIS mapping software developed by ESRI. The first step was digitising a range of locations used for mountain biking, which were selected based on existing knowledge, Open Street Maps (figure 2) and Trail Forks (figure 3). This produced a georeferenced layered map (shapefile) on ArcGIS which contained a sample of 70 locations including trail centres, bike parks, official and unofficial trails. The shapefile was first combined with the UK Centre for Ecology & Hydrology (UKCEH) 2020 Land Cover Map 2020, 10m resolution (Morton et al, 2021), to establish the proportion of woodland in these locations and the types of woodland that are most used for mountain biking.
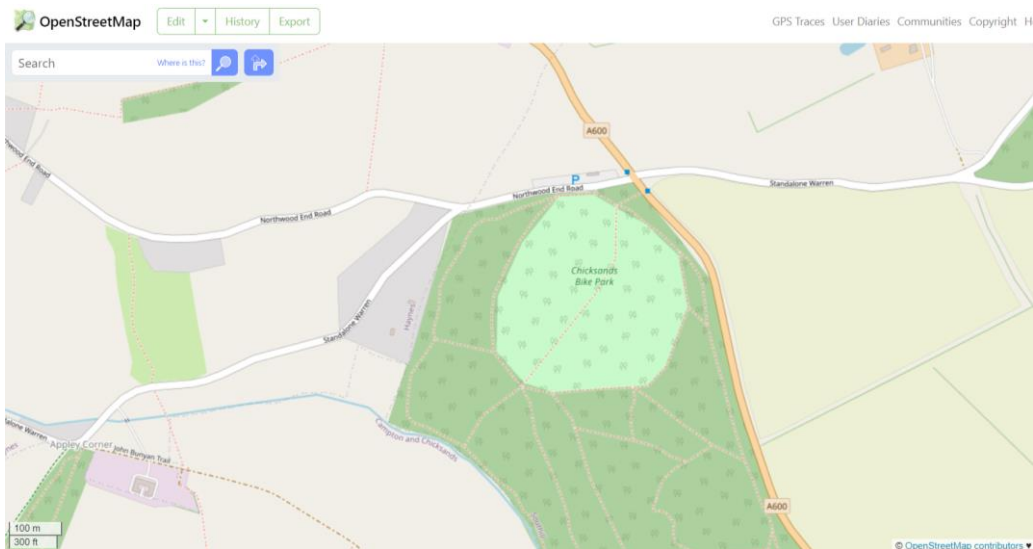
Figure 5 – Some bike parks, for example in this screenshot we see Chicksands Bike Park in Bedfordshire, had a clearly defined area on OpenStreetMap which could be traced in ArcGIS.
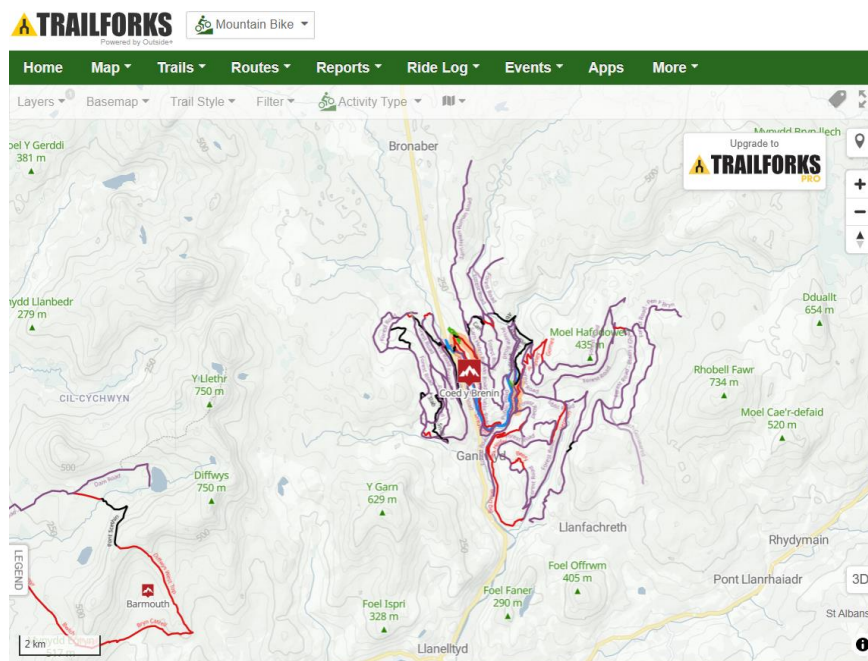
Figure 6 – Other locations were less well defined on traditional maps, but Trail Forks which allows users to upload trails, showed the extend of riding locations, in this case Coed Y Brenin in North Wales. The rough shape of these trails could then be traced on ArcGIS. This method was especially useful for the unofficial locations.

4.1.2 Sourcing and processing Strava Heatmap data

Strava Heatmap data was sourced from the Glasgow Urban Big Data Centre (UBDC). Strava is no longer offering its data for academic use and the UBDC was the only organisation willing to provide data for this study. The UBDC was able to supply Strava Heatmap data for the entirety of Scotland from 2015 to 2020 plus 2017 data for Wharncliffe woods, Sheffield. As a result, data analysis was completed for Scotland as a whole plus the Nevis Range, Innerleithen, and Wharncliffe/Grenoside woods to enable comparison between specific locations. Ideally, Strava Heatmap data for the entire UK would have been accessible. However, while not entirely similar, the trends observed in the data for Scotland are relevant to the rest of the UK. The analysis of specific locations demonstrates how powerful this technique could be for the managers of woodlands with high numbers of mountain bike trails.

The data provided by the UBDC included a shapefile for each area containing all the Strava 'segments', and rider usage data, which was within separate spreadsheets for hourly, daily, weekly, weekdays, weekends, monthly and yearly. The usage data

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could be filtered demographically. To understand trends within the dataset, these spreadsheets were joined to the main shapefile within ArcGIS Pro. It is important to note that the 'segments' in the data set are not the same as commonly known Strava segments which are sections of noteworthy road and off-road cycling routes where Strava users compete for the best time. The segments in the data set are defined by nodes where a node is an intersection between two lines (a road or other cycling route). Therefore, what would commonly be described as a single road could be split into several 'segments'.

The next stage was to combine the mountain biking locations shapefile with the Strava data to identify a few locations where rider usage trends could be observed. A major challenge was to determine which segments were off road trails as most of the dataset related to road cycling. This was done by finding the intersection between the Strava data segments and the digitised mountain bike locations. The assumption here is that all the segments within a mountain bike location are mountain bike trails. This is a reasonable assumption as most areas did not include roads. However, this will not be exact, and some segments will have been included which are not predominantly used for MTB.

Once the Strava data was cross-referenced with the location shapefiles, isolating, as best as possible, MTB trails, the final step was to add the rider usage data. This allowed the variety in spatial and temporal usage patterns to be analysed. Most often 'total activity count' was taken which takes the total number of recordings in either direction along a segment during the period selected. 'Total athlete count' was also used which counts the number of unique Strava users on a segment.

Other methods of isolating the off-road segments were considered with added complexity, which could be used in future studies. Downhill mountain bike trails are almost always unidirectional with separate 'push up' tracks, due to their steep and technical nature, which is unlike most other roads and footpaths which are multi-directional. It would therefore be possible to write code that only considers segments where, for example, greater than 95% of users travel a single direction. This technique would be less effective for other sub disciplines such as cross-country and would still encounter errors such as one-way streets.

Another method, in theory, would be to compare the segment data with a data set such as Trail Forks, or maps provided by mountain bike centres. Trail Forks did not respond to any data requests and would not necessarily be willing for their data to be used in an academic context. Using official MTB trail maps would guarantee that

all the trails considered are MTB trails. However, this would ignore unofficial trails which are a huge part of the sport, and the data would be less homogenised than using only Strava data, adding complexity. Combining multiple trail maps from various locations would be challenging, as each map will have been made by a different individual, with no intention of being consistent with other locations. However, this could be good for small case studies of official sites such as Coed y Brenin or the Forest of Dean.

4.1.3 Limitations

There are several limitations that should be noted due to the specific Strava data that was accessible. Firstly, only pre-covid data was available which means this study is unable to assess trends in outdoor recreation during or after the pandemic, which undoubtedly altered people's relationship with the outdoors. The data also centres around urban areas, except for Scotland. Although this has not been detrimental to the study, ideally more access to rural Strava data would be ideal for determining the relationship between mountain biking and woodlands. Another limitation was the vast amount of data available, which made processing time consuming and required high computing power. Even within the data available which only included small regions of the world over a handful of years, the full unzipped size was close to 1TB, which during processing, pushed the limit of the computing power available. The data is remarkably detailed with thousands of segments grouped into edges and nodes, each of one containing many attributes including number of athletes, total activities, directional information, total commutes, and time to complete, all recorded at the temporal resolution of an hour. This is both a challenge and a huge opportunity. With more time and resources, the is a huge potential to explore trends in the sport with Strava data, even in the data provided by the UBDC which only covers small areas over a handful of years.

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4.2 Interview methodology

A variety of methods were used to contact interviewees, depending on what seemed to be the preferred contact method of each bike park/trail centre. With minor pestering, interviews have been secured with relative ease using email, Facebook and Instagram to begin a dialogue.

Between March and July 2024, ten interviews were conducted with experts in forestry and mountain biking management. These included Tim Foster, owner of Revolution Bike Park, Ian Warby, owner of Firecrest mountain biking, founder and lead manager of Aston Hill Bike Park, a forester working at the Forest of Dean who conducts research for the International Mountain Bike Association, a forester and keen mountain biker based around Northampton, the lead specialist advisor for recreation safety for Natural Resources Wales, the chairman of the Hemlock Stone Trail Association, a forester at Longleat estate who oversees Windhill Bike Park, a trail builder at Bestwood Country Park secret trails, a trail builder at the Marlborough Club in St Albans and the manager of the St Albans Cycle Hub. For ethical reasons, the interviewees have not been named apart from Tim Foster and Ian Warby who gave their permission to be named as they are especially important to the investigation. The interviews were conducted either over teams or in person at the interviewees site.

The aim for the interviews was to speak to experts about the environmental challenges of running a bike park or trail centre, covering a range of official and unofficial sites and speaking to bike park managers, foresters and landowners. Getting in contact with interviewees was done through a mixture of social media, email or in person meetings. Crucially, the owners of all four case studies were interviewed providing a valuable insight into the specific challenges they faced. Discussions centred around forestry, land access and liability. One major limitation to the interview process was the inclusion of unofficial sites. Many locations are kept secret or at least not publicly advertised. This meant that finding people to speak to about these locations was only possible by chance encounter at the trail side, such as for Bestwood Country Park. These sites do not have any social media or website,

and therefore no way to contact them. Even if contact was made, the trail builders were not open to being interviewed. Unofficial trails are a large part of the sport but one that interviews were not successful at investigating. Other disciplines of mountain biking, such as cross-country are also challenging to investigate via interviews. Cross-country mountain biking is less 'clandestine' but tends to make use of the bridleway network which are not staffed as such, so there is no one to speak to about this.

4.3 Action Camera Methodology

For the purposes of this investigation 'review' style content was chosen where the aim of the video is to inform riders about a location who are thinking of visiting, as this style of video is usually clear, informative and features full length trail videos. Video data was added to a table for analysis of several points including tree cover, tree species, vulnerability of woodland, importance of woodland to the trail and more. It is hoped that this content can help identify trail conditions and signs of poor tree health.

4.4 Survey methodology

The survey was created using Microsoft Forms and distributed on Instagram and through several mountain biking WhatsApp groups. The aim was to establish rider attitudes to forest management and tree pests and pathogens. The questions fall under three categories. The first questions asked about the participants level of mountain biking such as how often they ride, how far they travel and the types of locations they prefer. The next group of questions aimed to answer the core objectives of the investigation including the importance of trees to the sport, the participants opinion of tree pests and pathogens and the impact of mountain biking on woodlands. These were typically long answer questions to get as much detail as possible from respondents. The final questions were about the demographics of the participants such as age and locations to put the other answers in context. The questions asked were as follows:

How often do you go mountain biking? Options: Daily, Weekly, Monthly, Every six Months Yearly, Other.

How far would you typically travel by car for mountain biking? Options: Less than 1 hour, 1-2 hours, 2-3 hours, 3-4 hours, 4+ hours.
Do you normally have to pay to ride where you ride? Options: Paid sites, Free, publicly accessible (Including sites where you only pay for parking), Both.
How important are trees to mountain biking? Do trees add an element of risk or thrill? Is there a balance to be struck between safety and excitement here? Please add any relevant examples. (Long answer question).
Are you concerned about the issue of tree pests and diseases? Options: Very concerned, concerned, somewhat concerned, not at all concerned, I know nothing about the issue.
Recently two major UK bike parks, Aston Hill in the Chilterns, and Revolution in North Wales, have closed due to outbreaks of woodland diseases. If you have an opinion on either case, please share it. Anything is useful. (Long answer question).
Do you take any steps to care for the places you ride, e.g., picking up litter, maintaining trails or reporting issues? (Short answer question).
Who do you think is responsible for taking care of the forest? Options: Riders, Bike Park/Trail Centre Team, Landowner, other users of the forest, other. (Select all that apply).
In locations that are shared between riders and other members of the public, how well does this work? A score of 1 means there are frequent conflicts between riders and other users. A score of ten means the space is shared by all users seamlessly. (Score from 1 to 10).
Do you ride off-piste/wild trails, if so, why? Please add any relevant examples. (Long Answer Question).
How old are you? Options: 18-24, 25-34, 35-44, 45-54, 55-64, 65+.
Please select your gender. Options: Man, Woman, Non-Binary, Other.
In which region of the UK are you based? Options: London, Southeast, Southwest, East of England, East Midlands, West Midlands, Northeast, Northwest, Yorkshire, Wales, Scotland, Northern Ireland.

Table 1 – *Survey Questions*

Overall, the survey achieved 70 responses. Most of the respondents were young and male as expected.

5. Results

5.1 GIS

5.1.1 Establishing Woodland extent in UK mountain biking

Combining the 2020 Land Cover Data with the mountain bike locations shapefile confirmed the importance of woodland to the sport with a 78% of the combined area of the locations covered in forest. (10m land cover map, 2020, Morton et al, 2021). The data also confirmed the dominance of coniferous woodland for mountain biking with broadleaved woodland accounting for only 5% of land used for mountain biking compared to 44% coniferous. As for the rest of the woodland area, 23% was either felled or young trees, which reinforces the trend of plantations being used for mountain biking. The remaining 6% is comprised of coppices, mixed woodland or map errors such as cloud cover or missing data.

Category	Area	Percentage of land used for mountain biking
All mountain biking	45.9 km^2	100%
Woodland Total	35.7 km^2	78%
Coniferous	20.2 km^2	44%
Broadleaved	2.4 km^2	5%
Felled or Young Trees	10.5 km^2	23%

Table 2 – Percentage of forest cover for UK mountain biking locations

Figure 7 - *Forest Cover for Coed y Brenin trail centre in North Wales. The blue area shows the extent of each popular location, the dark green is Coniferous forests, the bright green is deciduous, and the brown shows other woodland such as felled or young trees. (10m land cover map, 2020, Morton et al, 2021)*

Figure 8 *- Forest Cover for Bike Park Wales in the Brecon Beacons. (10m land cover map, 2020, Morton et al, 2021)*

Figure 9 - *Forest Cover for Surrey Hills AONB. (10m land cover map, 2020, Morton et al, 2021)*
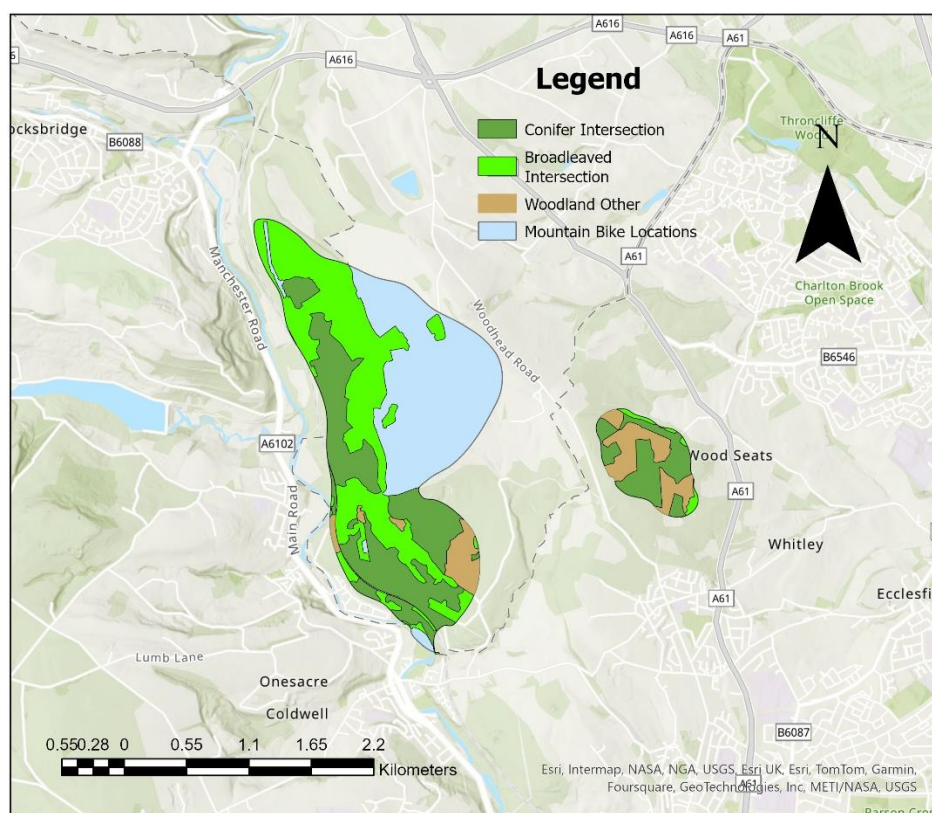
Figure 10 – *Forest Cover for Wharncliffe and Grenoside Woods near Sheffield. (10m land cover map, 2020, Morton et al, 2021)*

GIS allows the data to be viewed spatially which clearly shows the dependence of mountain biking on forested areas *(figures 7-10)*. This distribution is typical of Bike Parks and Trail centres across the country with a high level of forest cover, most of which is coniferous.

5.1.2 Strava Data Analysis

For the Strava analysis, different locations were selected due to the limitation of what data was available.

Trail Distribution
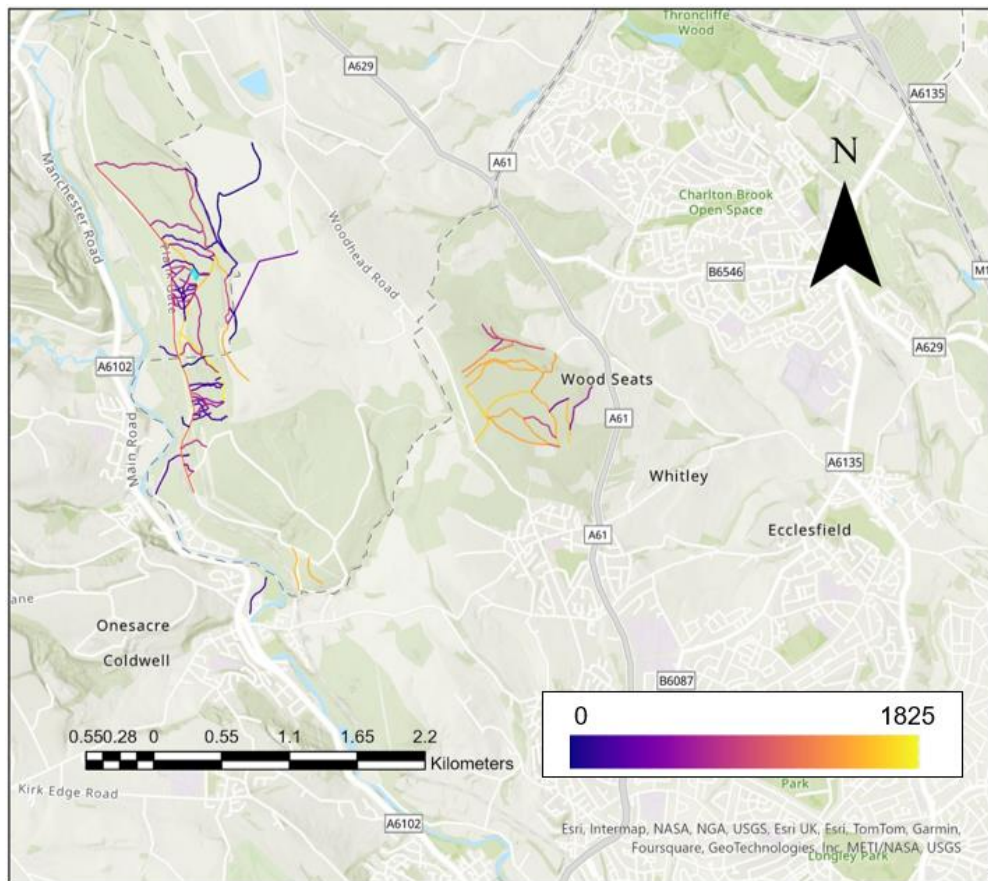
Figure 11 – The Distribution of mountain bike trails in Wharncliffe and Grenoside Woods near Sheffield. The colour scale shows the total number of times each segment was completed and uploaded to Strava during 2017. (UBDC 2024)
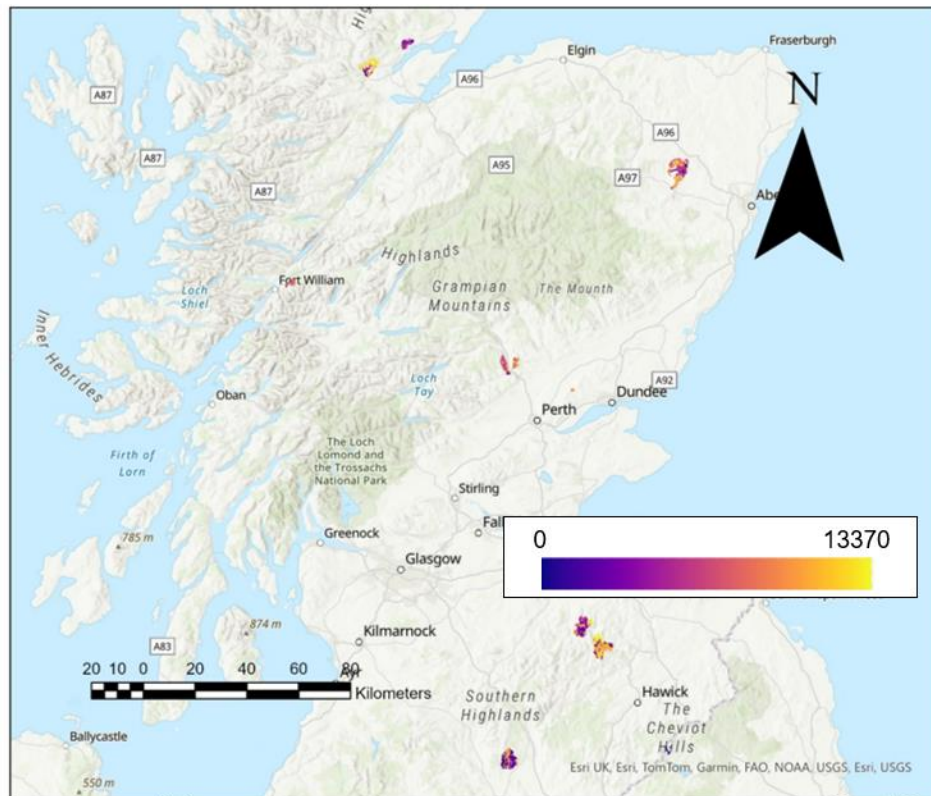
Figure 12 – *The Distribution of Mountain Bike Trails across Scotland in 2017. (UBDC, 2024)*
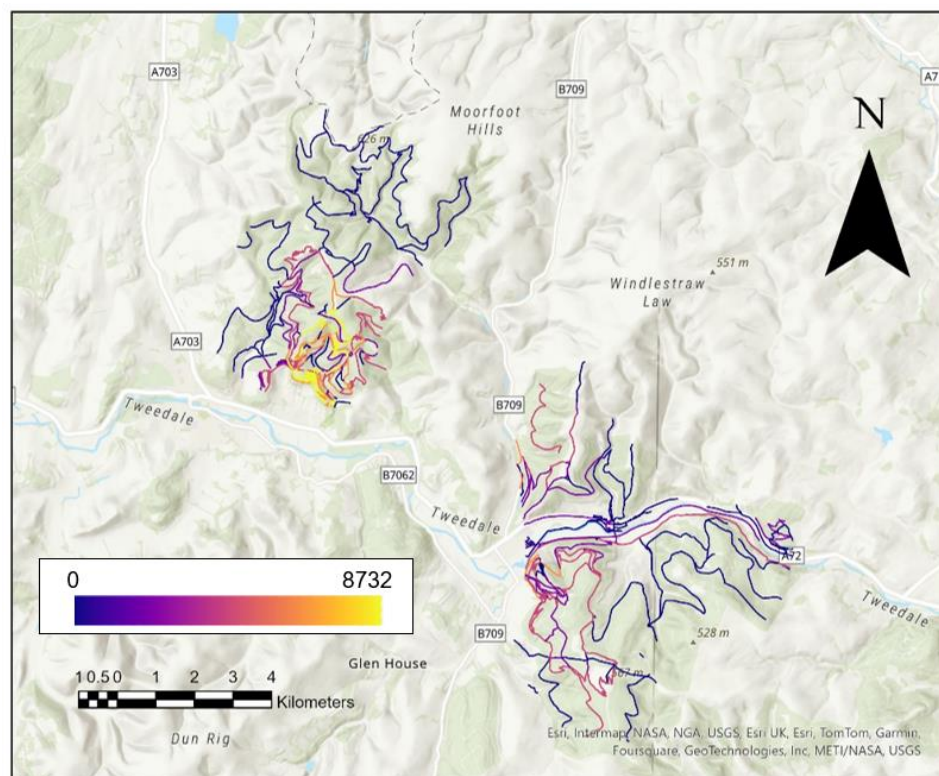
Figure 13 – *Distribution of Mountain Bike Trails at Innerleithen (UBDC, 2024)*
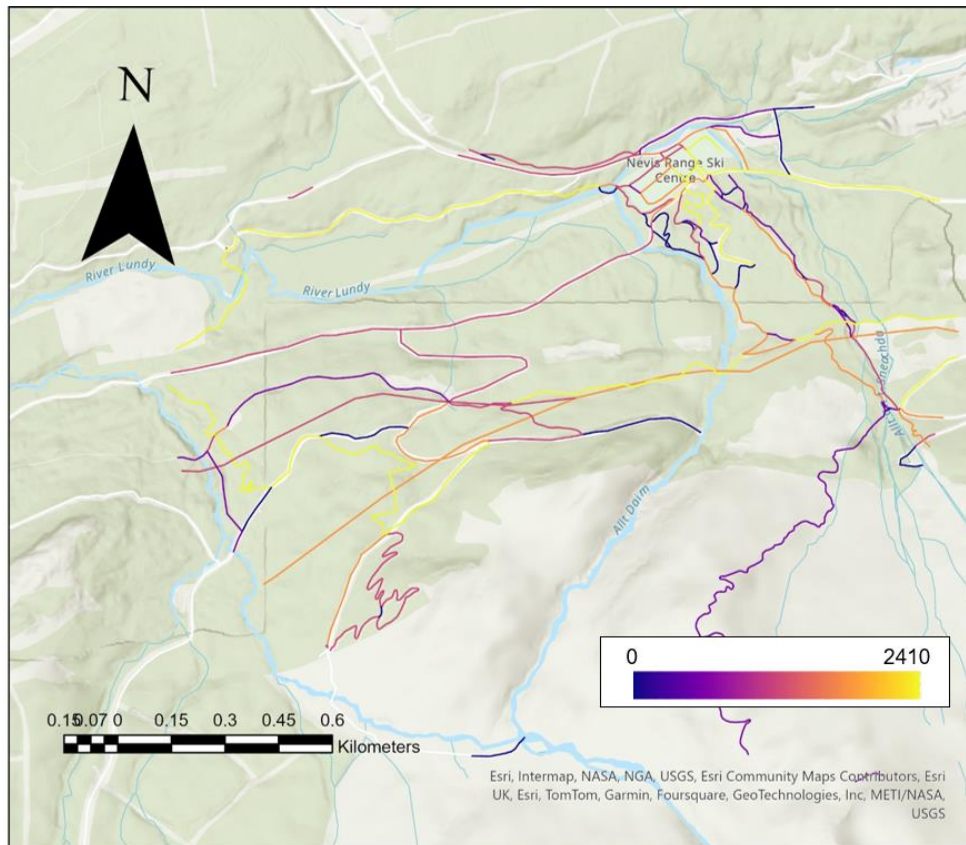
Figure 14 - Distribution of Mountain Bike Trails at Nevis Range, 2017. (UBDC, 2024)

Again, displaying the data spatially is an intuitive way to view the patterns. It is clear which trails are popular, and the data is not limited to the paths identified on traditional maps. This would allow forest and bike park managers to spot wild trails which would help with expanding bike parks or trail centres and reducing the environmental impacts of off-piste riding.

5 Year Trend: 2015-2019
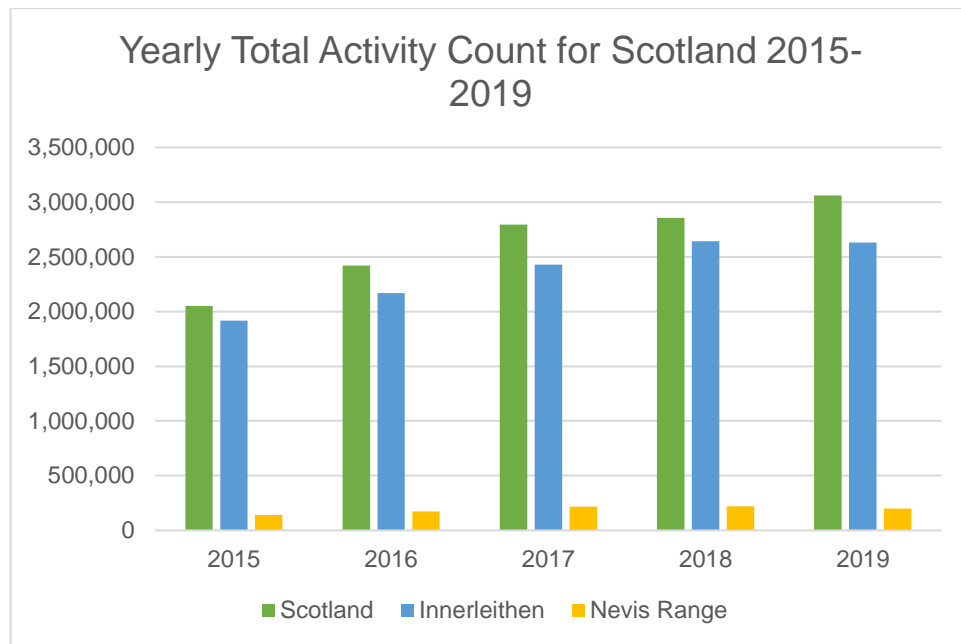
Figure 15 – *There is a clear trend in the number of Riders each year, demonstrating the continued increase in popularity of mountain biking. (UBDC, 2024)*

The continued increase in popularity of mountain biking agrees with previous studies. This demonstrates the importance of having a clear understanding of the best management approaches for forests with mountain bike trails within them

Monthly Usage
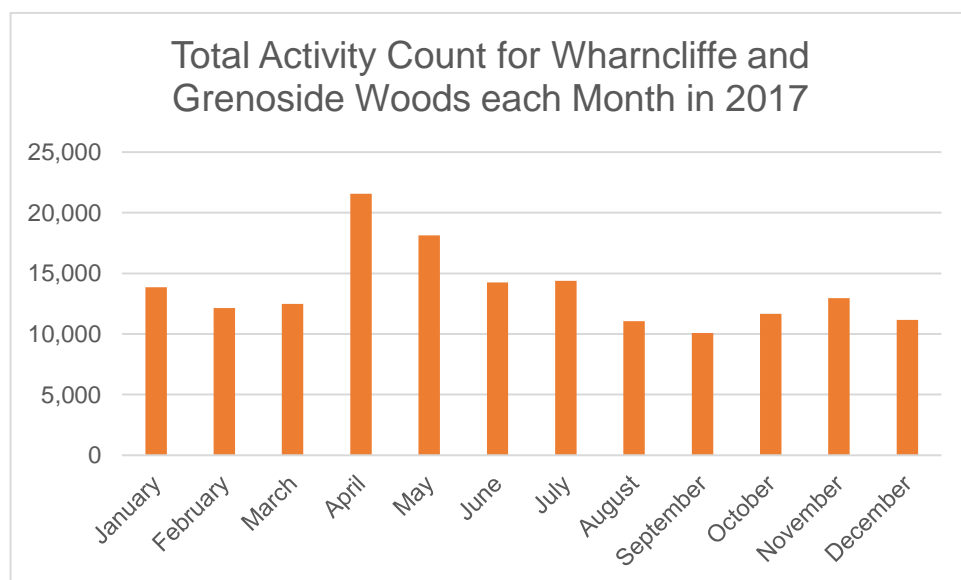
Figure 16 – *Total number of recorded completions of Strava segments within the Wharncliffe and Grenoside woods during 2017, total 163,610. (UBDC, 2024)*
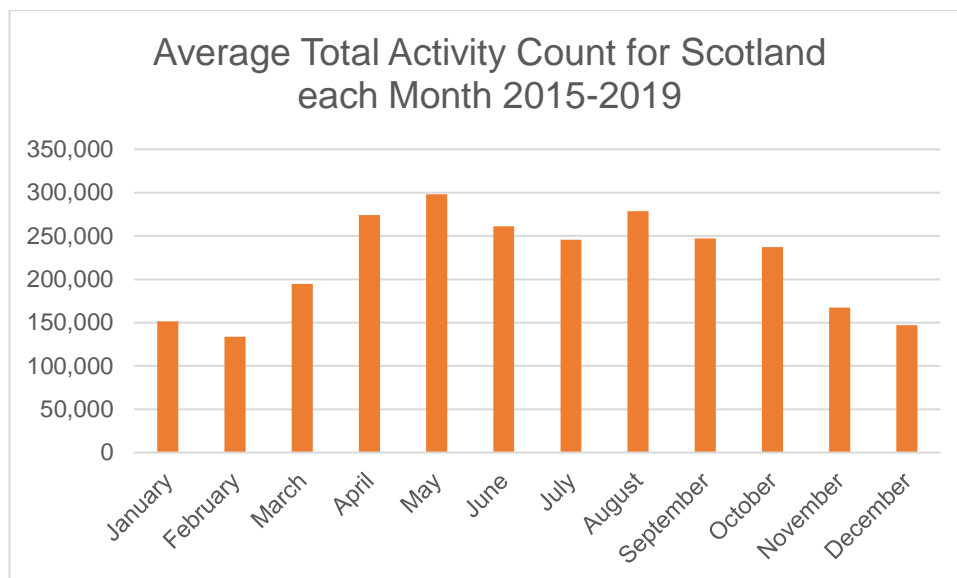
Figure 17 - *Average total number of recorded completions of Strava segments for Scotland each month 2015-2019, total 3,187,671. (UBDC, 2024)*
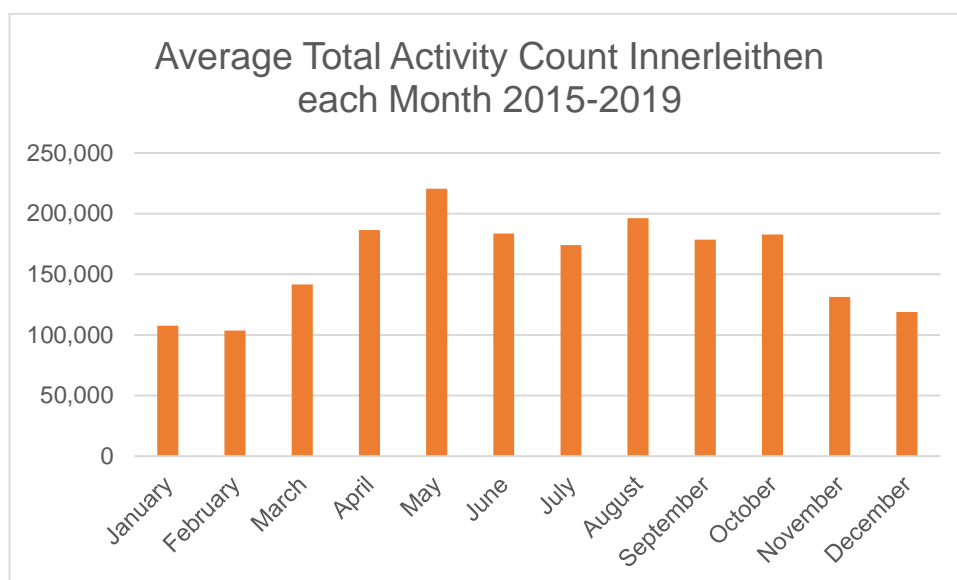
Figure 18 - *Average total number of recorded completions of Strava segments for Innerleithen each month 2015-2019, total 2,357,457. (UBDC, 2024)*

56
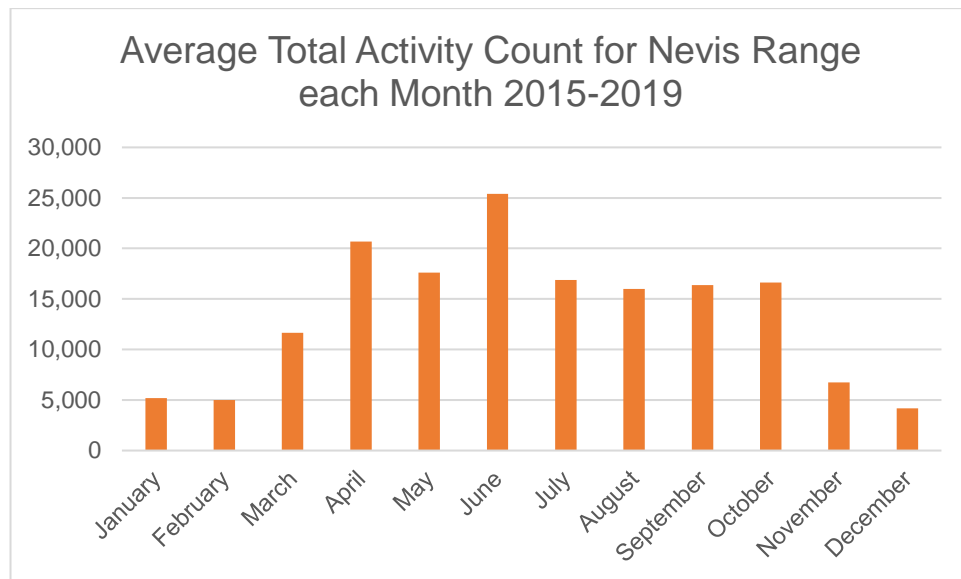
Figure 19 - *Average total number of recorded completions of Strava segments for Innerleithen each month 2015-2019, total 2,357,457. (UBDC, 2024)*

There are similarities and differences between each location. Mountain biking is clearly more popular during the summer; however, the peak popularity can vary between locations. In Wharncliffe woods, April is the most popular month, perhaps because riders are typically travelling further during the summer holidays and when days are longer. At Nevis Range, there is a more pronounced normal distribution as a result of the area being snow covered throughout winter. There are peaks during June and April when the world cup tends to visit as many visitors are attracted to the area around this time. The trends in usage data are important for management approaches, for example determining the best time of year to close a bike park/ trail centre.

Popular Trails

To demonstrate the spatial detail of the data, it is even possible to single out individual trails within a trail system, providing information about rider movement within a small area.
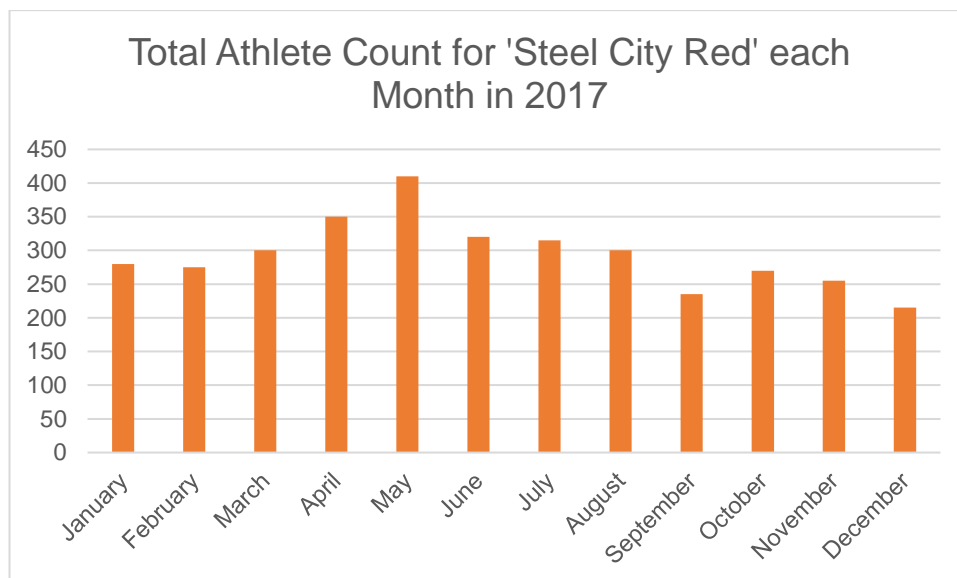
Figure 20 – *Number of individual Strava Athletes that rode 'Steel City Red' the most popular trail at Grenoside Woods*
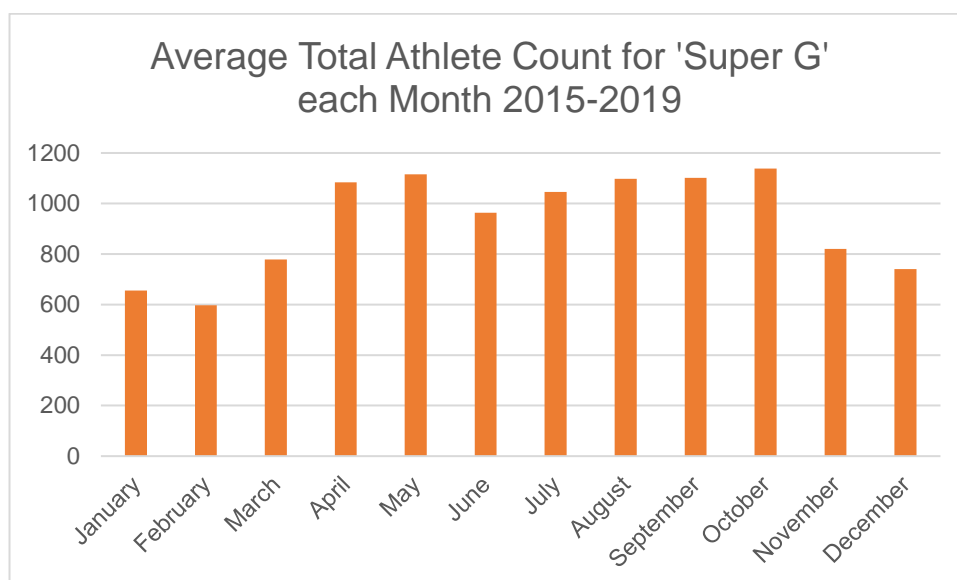
Figure 21 - *Number of individual Strava Athletes that rode 'Super G' the most popular trail at Innerleithen Downhill Park*

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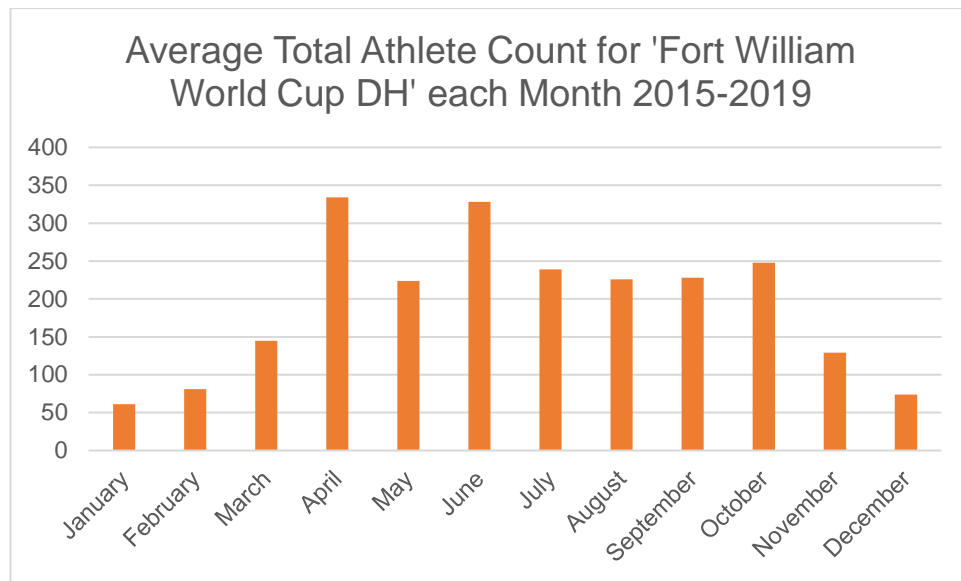
Figure 22 *- Number of individual Strava Athletes that rode 'Fort William World Cup DH' the most popular trail at the Nevis Range*

Weekend/Weekday trends
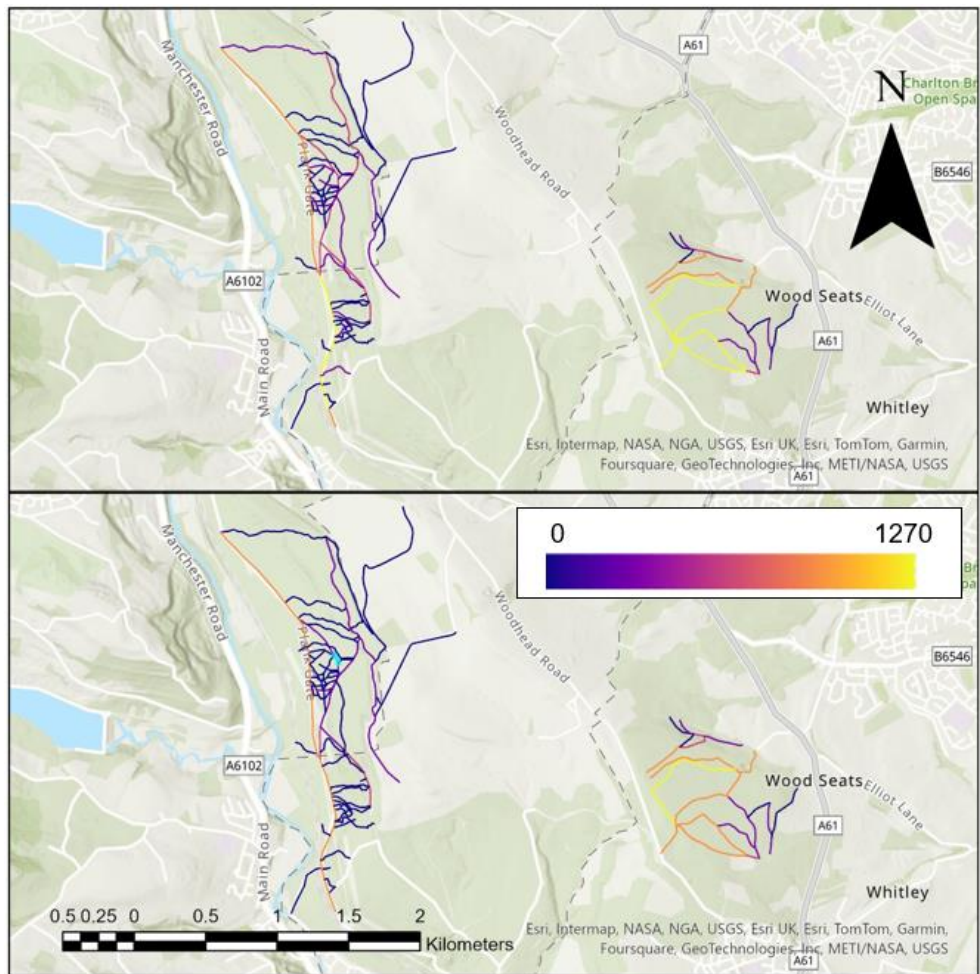
Figure 23 – *As expected, usage at Wharncliffe/Grenoside woods is higher on Weekends (Top half) than Weekdays (Bottom Half). Adjusted for the number of days, usage is around 2.7x higher on Weekends.*
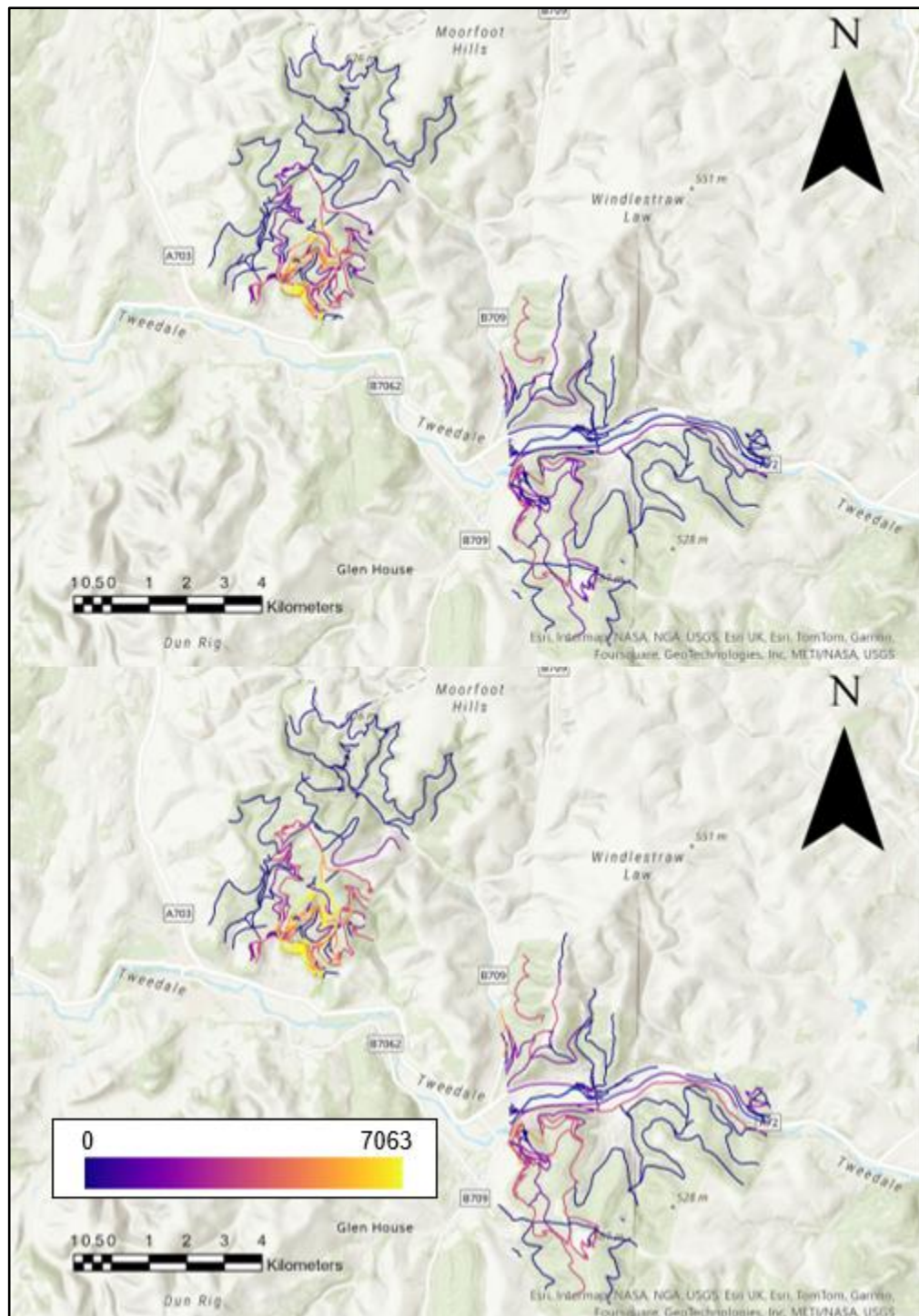
***Figure 24** – Similarly, usage at Innerleithen is higher on Weekends (Bottom half) than Weekdays (Top Half). Adjusted for the number of days, usage is around 3.4x higher on Weekends.*

It is easy to switch between weekend and weekday data so comparisons can be drawn. This could also be done with monthly and yearly data.

Location	Weekday Yearly Total Activity Count	Weekend Yearly Total Activity Count	Average Weekend Day/ Average Weekday
Wharncliffe	78550	85159	2.72
Scotland	821,529	882,665	2.70
Innerleithen	467,090	637,981	3.43
Nevis range	47,952	60,897	3.19

Table 3 – The difference between the total athlete count on Weekdays vs Weekends for Wharncliffe/Grenoside Woods, Scotland, Innerleithen and Nevis Range. The average daily difference was calculated by the ratio of the weekend total divided by 104, and the weekday total divided by 261 to account for the number of weekends/weekdays in a year.

The difference between rider numbers between weekdays and weekends is large. Clearly mountain biking is more popular on weekends, with rider numbers typically three times higher. The fact that the difference between weekday and weekend numbers in Wharncliffe/Grenoside Woods is smaller, highlights the difference in usage patterns for free to use, publicly accessible areas, and bike parks which are paid for. In public woodlands, riders are more likely to visit for a short time, such as a few hours after work, so a higher percentage of activities are on a weekday. Somewhere like Nevis Range, where you must pay for the uplift, people typically visit for a day, so weekend numbers are higher. The distance to travel also plays a role. Wharncliffe is 20-minute drive outside Sheffield and near the M1 so is easy to reach for many people in the Midlands, unlike Nevis Range which is in the Scottish Highlands. This contributes to a higher percentage of weekend visitors at Nevis Range. In general, at more remote locations, a higher percentage of riders will visit for a whole day, and this is more likely to be at weekends

Hourly trends
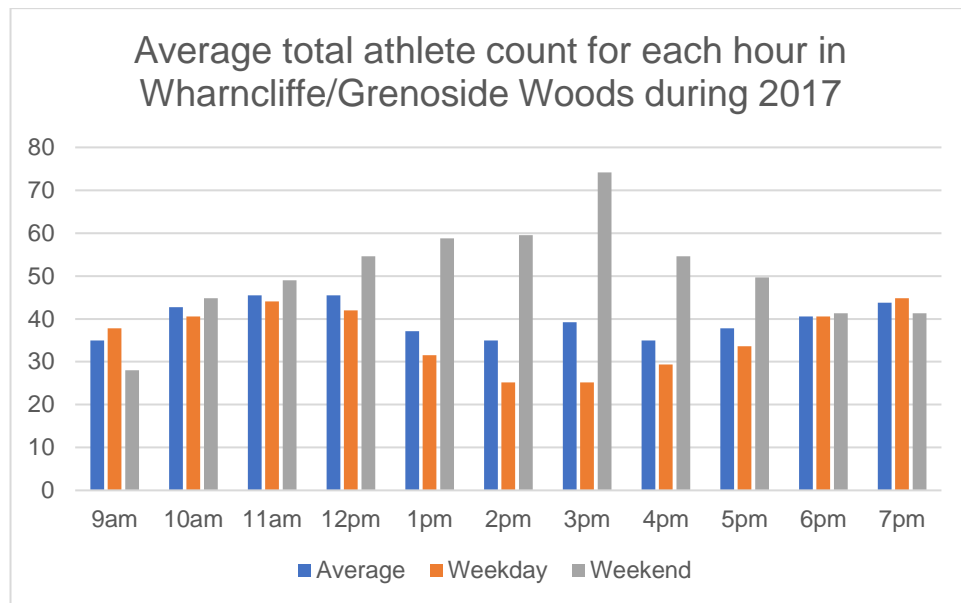
Figure 25 – Breaking down the Strava data by hour demonstrates the different usage patterns during the week and at weekends. At weekends, the number of riders each hour is closer to a normal distribution whereas during the week, peak hours are before and after work.
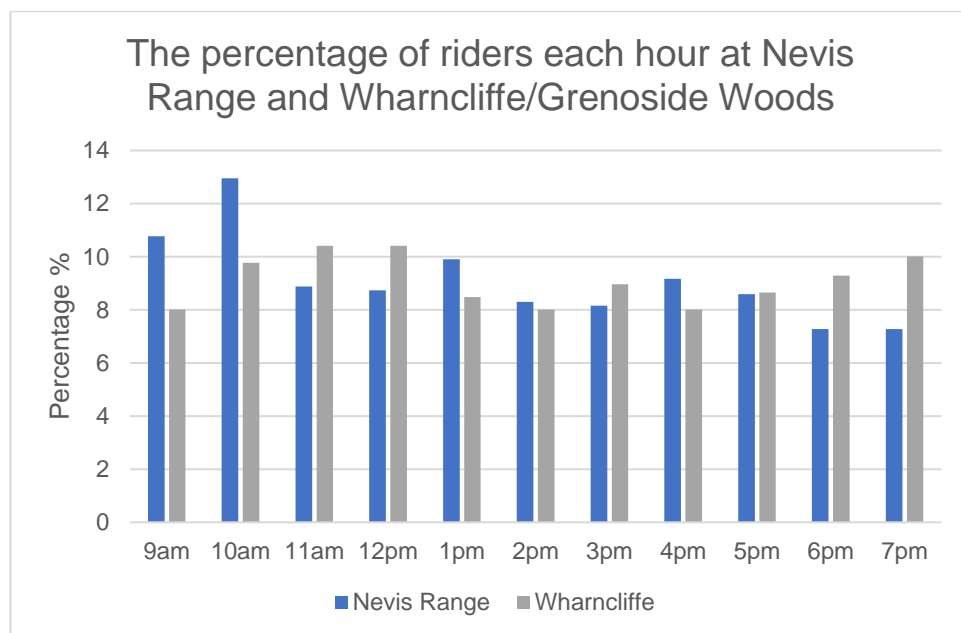
Figure 26 – Data is once again from 2017 for Wharncliffe/Grenoside Woods, and from 2015 to 2019 for Nevis Range. There is a clear difference in pattern here which aligns with the weekend/weekday data, showing the differences between paid for site and publicly accessible locations.

By comparing the hourly usage data for Wharncliffe/Grenoside and Nevis Range, the trends observed in the weekend data are reinforced. At Wharncliffe there is a clear peak in the morning and the evening, before and after work. This shows that

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riders are making short visits to the area to get a few hours riding in of a morning or evening. In contrast, at Nevis Range, where the uplift opens at 9am, there is a peak at 10am when most of the day's riders have got ready to ride. There is then a second peak after lunch at 1pm. There is still a peak in the data for Nevis Range around 4pm which shows that some people are still visiting the area after work for a few hours, just this is not the dominant way to ride there.

Demographics information
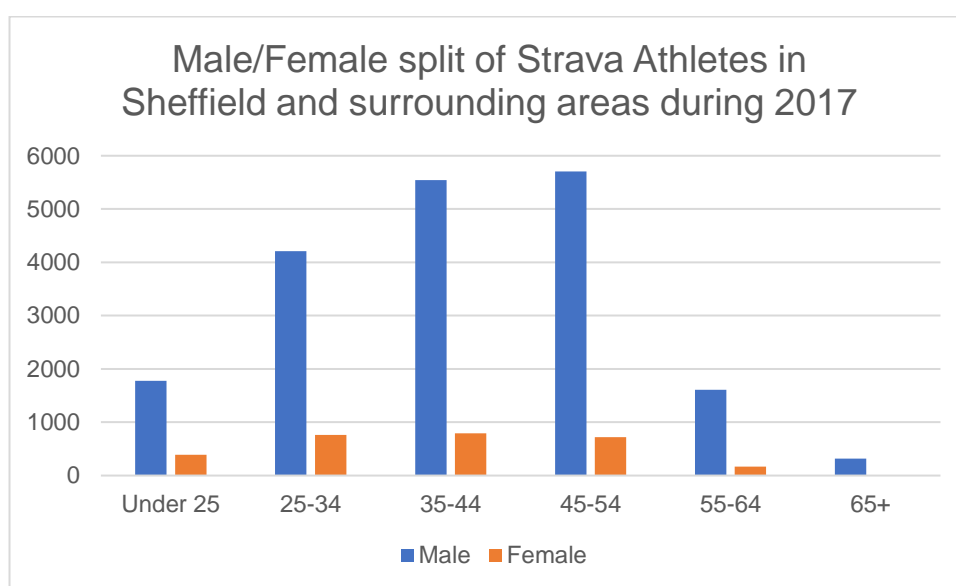
***Figure 27** – Age and Gender Split for Strava Athletes in and around Sheffield during 2017. This makes the average age for males 41 and for females 38.*
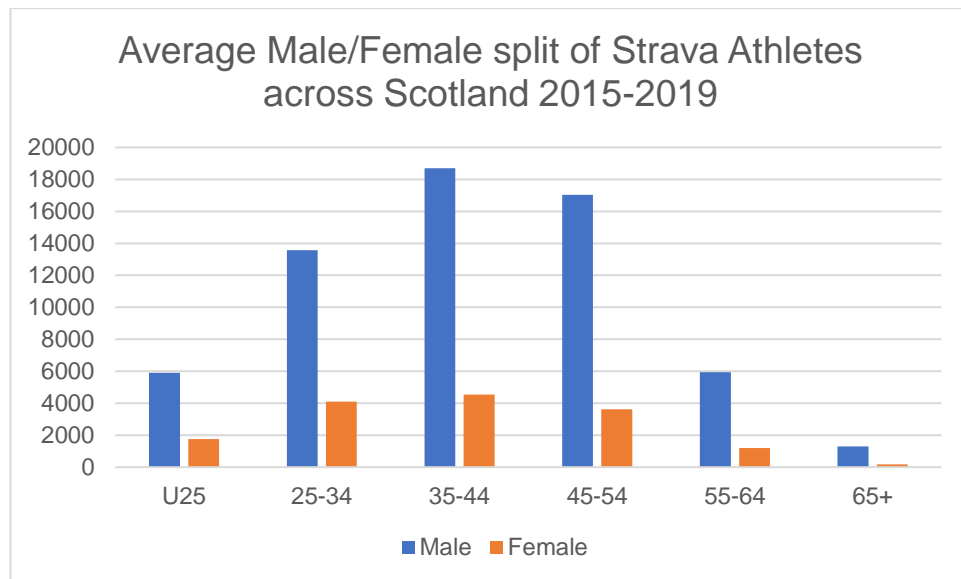
Figure 28 – *Average Age and Gender Split for Strava Athletes across Scotland 2015-2019. This makes the average age for males 41 and for females 39.*
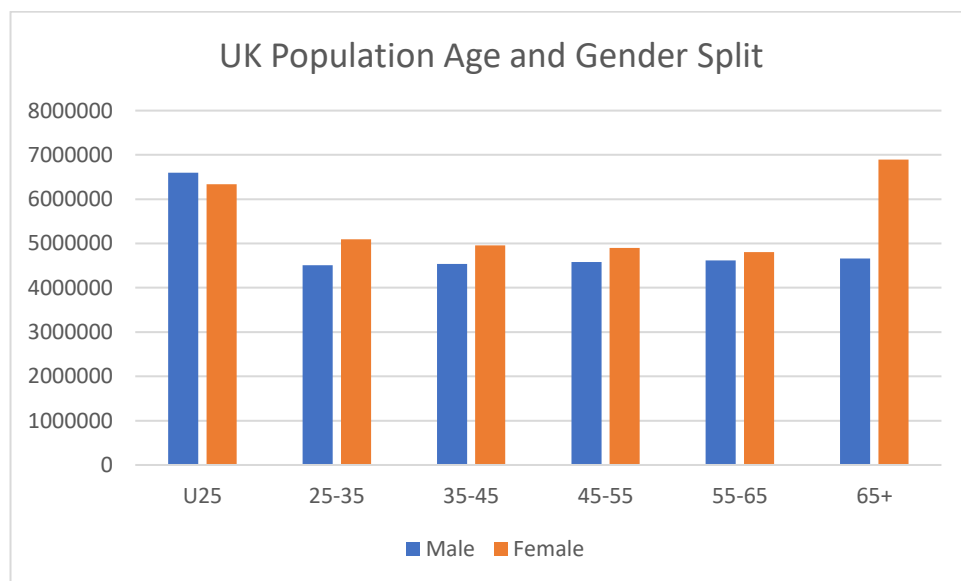
Figure 29 – *UK Population per age group 2022. Although the average age for the UK population in 2022 was the same as for the Strava Datasets, 41 years, the population spread is quite different with the Strava Data greatly underrepresenting Women but also the old and the young. The U25 here is from 10-25 as very few children ten and under will be mountain biking regularly. (ONS, 2022)*

5.2 Key Themes from Interviews

Participant	Role	Status (Employed/unemployed)	Site
1	Ian Warby, Head of Aston Hill Bike Park	Employed	Aston Hill, Rushmere Country Park
2	Tim Foster, Owner of Revolution Bike Park	Self-Employed	Revolution Bike Park
3	Forester, researcher for the IMBA	Employed	Forest of Dean and others
4	Forester and keen rider	Employed	Various sites in and around Leicestershire and Northamptonshire
5	Lead specialist advisor for recreation safety for Natural Resources Wales	Employed	Multiple across Wales
6	Chairman of the Hemlock Trail Association	Volunteer	Hemlock Stone
7	Trail builder	Volunteer	Bestwood Country Park
8	Head Forester	Employed	Longleat Estate
9	Trail Builder	Volunteer	Marlborough Club Trails
10	Shop owner and trail builder	Employed	St Albans Cycle Hub

Table 4 – List of interviewees.

5.2.1 Trail Development and Management

Many locations used for mountain biking started unofficially, with initial trails being unknown or unsanctioned by authorities. Over time, mountain biking became more mainstream and many riding spots became sanctioned. On a local level, spots such as the Marlborough Club St Albans and Hemlock Stone Nottingham became recognised by councils and after community support, became sanctioned (six, nine). In the 2000s, the Forestry Commission set out to incorporate mountain biking into recreational opportunities in several sites across the country including Aston Hill, Forest of Dean, Sherwood Pines and Cannock Chase (three, four, five). Allowing for

designated areas have often proved mutually beneficial with the landowner gaining control over mountain biking, and riders are able to build trails without worrying about them being destroyed (Ian, six, eight, nine). ***"We could put time into building the trails, knowing that they weren't going to be demolished the next day"*** says Ian. This means more innovative and ambitious trails can be constructed, adding to the thrill in a relatively safe way when guidelines such as OGB37 (Forestry Commission, 2009) are followed (five). However, some riders still get frustrated at the regulatory constraints when local authorities will not allow certain features to be built. This means that there will always be 'underground' riding spots such as Bestwood. Mountain biking is a constantly evolving sport due to improvements in technology and riders continuing to push the limits of what is possible. This means the trails must evolve too but authorities are often slow to keep up (nine), such as at Aston Hill where the trail 'Surface to Air' was once pioneering but is now typical of a trail across the UK and Europe (Ian, Tim). Regular trails inspections are conducted at all official sites for safety and liability. The frequency can vary between places, for example at Revolution this would happen every morning whereas trails centres, such as Coed y Brenin that cover a huge area, are inspected at greater intervals (Tim, five).

5.2.2 Environmental and Disease Management

Ash Dieback and *Phytophthora* provide the biggest threat to bike parks with most interviewees saying that at least one is present at their site (Tim, Ian, three, four, five). In extreme cases this has led to closure and extensive modification to the forests that bike parks rely on (Tim, Ian). Although the clear-felling at Revolution was common practice for Larch, the Ash Dieback management done at Aston Hill was one of the first times diseased ash trees have been dealt with so severely due to the amount of activity at that location (four). Typically, Ash trees with Ash Dieback are removed on an individual basis when they pose a threat to humans, for example an Ash tree on the edge of a footpath. Disease management practices are often criticized as ineffective or out of proportion, with any removal of diseased trees being unpopular (Ian). This could be improved through public education about the issues. This is something that Ian has particularly struggled with as people do not understand what is happening in the forest, but he does not have the ability to give

everyone a thorough explanation (Ian). Additionally, the removal of trees around mountain bike trails is often more challenging due to the steepness of the terrain (Ian).

Although the felling of larch was standard practice at Revolution Bike Park, this is due to the high-risk level placed on North Welsh forests. At the Forest of Dean, they also have Phytophthora present in their forest, likely more severe than at Revolution (three). ***"Already a lot have gone but, there's still large blocks of larch trees across the forest and the likelihoods and the risk is that the disease will eventually get to all of them in some shape or form"*** *(three).* However, in the West of England, they are allowed to take a less extreme approach, removing diseased trees individually. It is important to note that the Forest of Dean is a more diverse forest with small areas of Larch. The team there are advocates for this approach as it reduces destruction to the forest allowing it to perform its ecosystem services, whilst allowing survivor trees to reproduce which is vital for the resilience of the species (three). Lots of current research around the management of tree pests and pathogens points to the benefits of not clear-felling forests with low numbers of infected trees such as the forest at Revolution. Tim felt that the decision to clear fell at Revolution was taken too lightly and did not properly consider the social and environmental impacts. He takes the view that the decision followed 'draconian' practices and said, ***"it is a deeply flawed approach, which they're just following because they haven't come up with a better idea"***.

However, despite the situations at Aston and Revolution seeming desperate, there is also an opportunity to reopen the bike parks better than they were before. Both sites struggled with densely packed trees which were initially planted to generate a profit from timber production. In the future, the forests at both sites will be reengineered to be resilient to climate change and less densely planted which will bring ecological benefits while allowing for more interesting trails to be built. Creating less dense, more diverse forests will enable bike parks to be more resilient to climate change, especially by planting a mixture of native and non-native species. It is challenging to balance the importance of preserving native species such as Ash and Oak with non-native species such as poplar which are likely to fair better over the next decades (four, eight).

5.2.3 Economic and Community Impact

Bike parks generate significant economic benefits through tourism and job creation (Tim, five, ten). Even though managing recreation alongside forestry can be challenging, it is financially worthwhile, with the larger bike parks, such as Bike Park Wales or Revolution bringing in several million pounds of revenue a year (five). There is also increased footfall in the areas around the sites which are typically remote areas. Revolution would run at 99% capacity on weekends before *phytophthora* which is 130 people each day (Tim) visiting shops and staying at hotels. Bike Parks across the country are often fully booked highlighting the growing demand from the public for the sport. Even trail centres such as Coed y Brenin or Afan forest where there is no charge to ride, are a worthwhile investment for the Forestry Commission. Collectively, recreational activities bring in £40 million a year for Forestry Wales (five).

Many riders have a sense of environmental stewardship including litter picking and trail maintenance (nine, ten). In local riding places, there is often a strong sense of community and belonging that leads volunteers to take care of the trails (six, seven, nine, ten). However, there is certainly more that can be done to encourage riders to take care of places they ride, which would help change the public's perception of mountain biking as antisocial (six, ten). Initiatives such as trash free trails aim to spread awareness and offer funding to official locations that follow their guidance for being environmental stewards (three, nine).

5.2.4 Wild or Off-Piste Trails

Wild trails are a recurring theme (five, eight), and became a greater issue during COVID-19. They pose environmental and safety risks but are also a key part of mountain biking culture. The Forestry Commission recognise this saying *'informal community development has been at the heart of many of the new routes that the Forestry Commission has expanded, improved, or replaced'* (Forestry Commission, 2009, page 10). There is a balance between adopting some wild trails into official networks and closing others due to safety or ecological concerns. For example, wild trails can remove topsoil, altering the hydrology of a hill side which can lead to further consequences (five). Wild trails can also be a threat to other

users of the woodland (five). However, many official places people ride would not exist if there had not been wild trails initially and for many the thrill of riding unmonitored routes is a huge draw to the sport (six, seven, nine, ten). It is difficult to balance the need for safety with a huge and probably vital part of the sport. Clear signage with difficulty grading and trail maps are important, allowing the landowner to use *Volenti non fit injuria* in court which can reduce liability for accidents on off-piste tracks (five). However, often the landowner will remove these trails as it is not worth the risk for them which is what happened to some trails at Hemlock Stone (six). Wild trails are the biggest threat when they are near to sanctioned trails, leading riders onto routes that are not inspected and unknown in difficulty, which can be a challenge from a liability standpoint. ***"And none of my defences in court now stand up. And what they did was quite reasonable. They just went left instead of right 'cause they were, you know, they nobody was telling them otherwise. And that's why it's such a terribly difficult thing to defend against in court"*** (five). In contrast, many unofficial trails are allowed to continue because they are hidden, such as a popular trail called 'Reaper'. **"*There's a fantastic trail just outside Aberystwyth. It's called the Reaper… but there are no public rights of way. There are no forest roads. You have to know where it is to get to the top of it. You know, it's not like you can end up there by accident. And it's fantastic*"** (five). The trails at Bestwood Country Park just north of Nottingham are another example of this. No public rights of way lead to the area, meaning that riders are making a clear conscious decision to act dangerously, and as a result the landowner feels comfortable letting the riders continue (seven). However, this can lead to issues with nearby landowners who object to riders accessing the trails through their land. On Forestry Commission sites, wild trails will usually only be removed if there is a specific issue such as a threat to rider safety, environmental damage or if the area is of historical significance. ***"In some cases, there has to be kind intervention, teams go in to remove wild trails generally for a very specific reason"*** (three).

5.3 Videos

Analysis of YouTube videos further evidenced the importance of trees to the sport of mountain biking. 35 videos by various content creators were watched, covering the same sites used for the GIS analysis. The videos took place between 2019 and 2024 with all the locations containing at least some tree cover. Commentary in the videos frequently mentioned trees either directly or the indirect effect of the trees in providing an obstacle. For example, *"Into the trees now"* and *"Gnarly roots in this section, let's hope it stays dry"* were both comments made by creators, while viewers made comments such as *"Root canal is savage"* and *"The trail was thick with pine needles on the bottom section which made it incredibly fast with no root exposure"*. Viewer comments often sparked viewers to talk about their own experiences for example *"I've been riding here for many years and finally hit the log drop!"*. The most common theme was the impact of roots on the trail, especially in the rain and mud where roots become slippery and much more challenging. This impacts line choice and can transform a trail depending on the weather conditions, with creators saying, *"savage roots and rocks"* and *"concentration is high in this wooded section"*. Trees can create a variety of ground types from hard pack dirt to loam and leaves, which often changes depending on the season, for example *"Loamy tracks full of leaves"* said one creator. Trails, or sections of trails are often named after trees for example 'root canal', 'root manoeuvres' or 'turns in the ferns', and 'triple trees' which was a section of a trails at Aston Hill called 'ricochet' another reference to tree roots. Another common theme was the sense of speed trees provide when in proximity. Trees force the rider to make tight turns and look for smoother lines. The video analysis reinforced the importance of off-piste tracks, with many of the videos featuring such trails. One viewer commented *"I love the off-piste trails as they are steep and hidden"*.

Figure 30 – *A screenshot from the YouTube video 'I CHECKED OUT AND RACED CAERSWS BIKEPARK!!' by Ben Deakin. Videos such as this give a great view of trees, roots and ground conditions of a trail. (Deakin, 2024)*
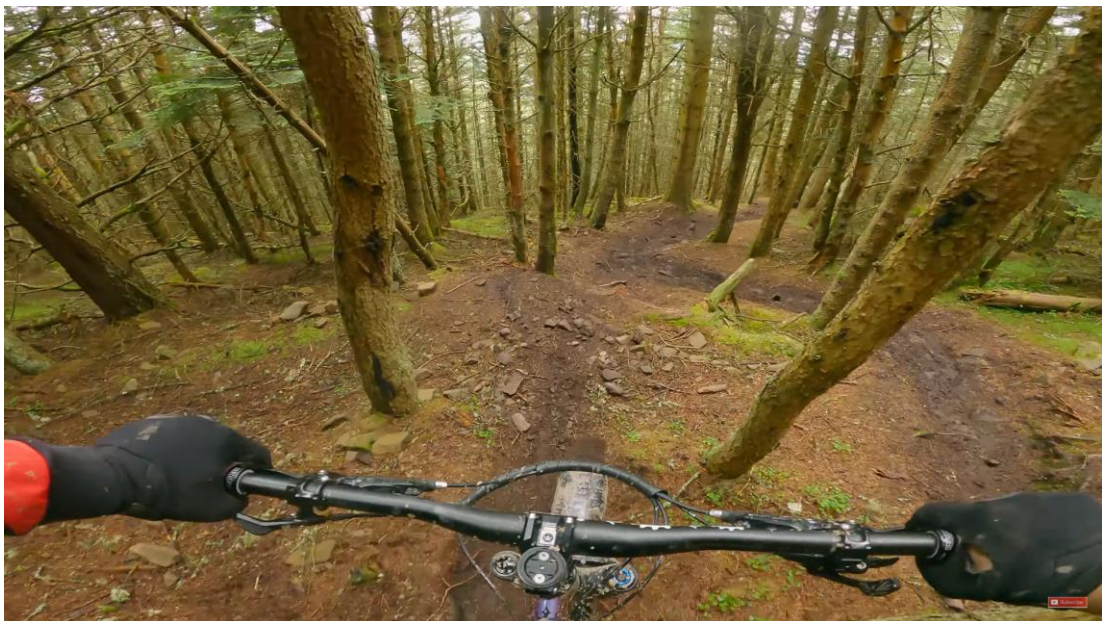
Figure 31 – *A screenshot from the YouTube video 'Innerleithen Shred - Adrenalin Uplift EPIC!' by Mike's cycling adventures on the trail 'the Cresta Run'. The trail has to make tight turns around the Douglas Fir and Scots Pine trees. (Jones-Price, 2021)*

5.4 Survey

There were 63 responses recorded for the survey, with most responses being men aged 18-24 from the Southeast or East Midlands. 31 of the responses were aged 18-24, 57 were from individuals identifying as male, 18 were from the Southeast and 17 from the East Midlands. The results of the survey are as follows:

Question 1
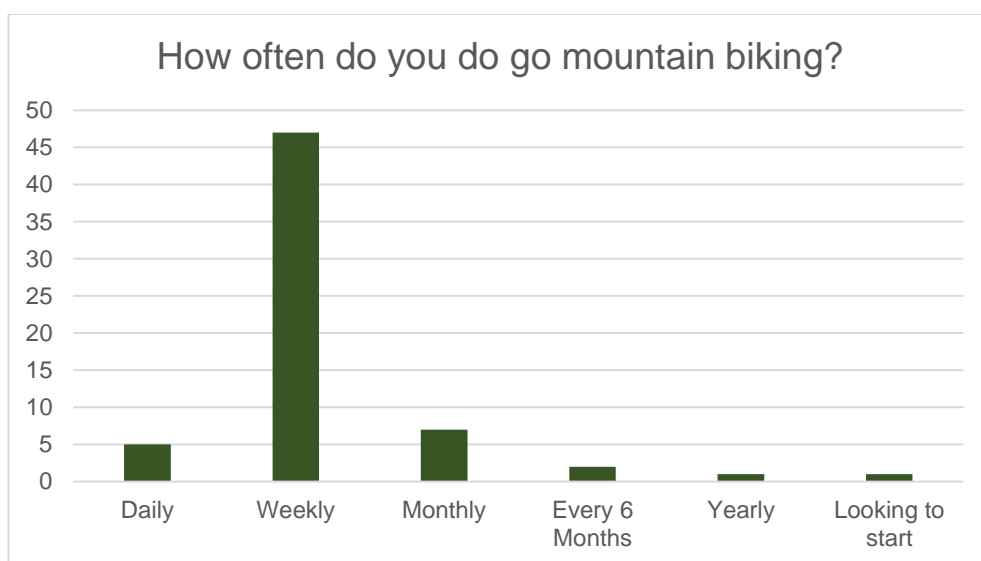
***Figure 32** – From the responses to question 1 we can see that most mountain bikers ride Weekly. This means that most of the responses to the survey are from regularly active members of the community.*

Question 2

How far would you typically travel by car for mountain biking?
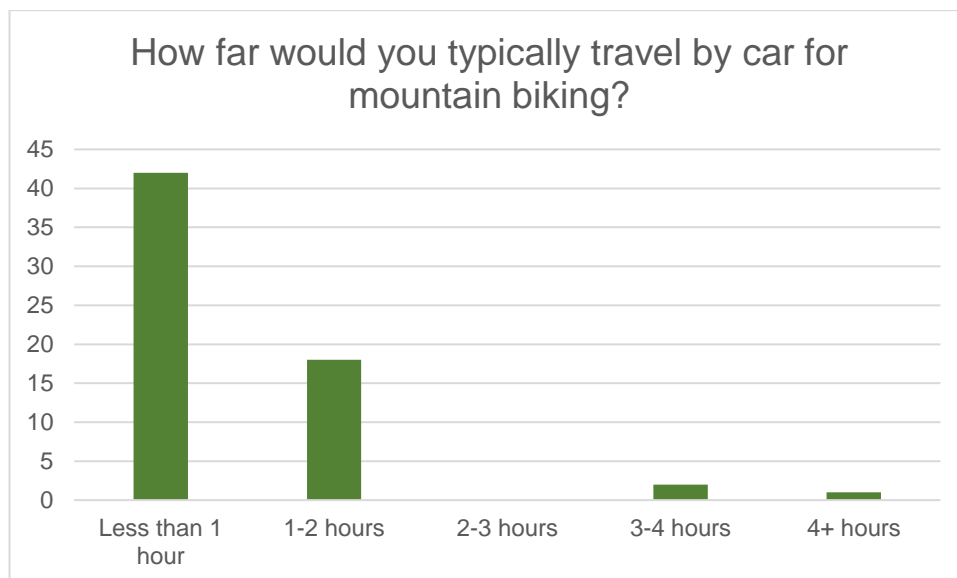
Figure 33 – Riders typically travel less than an hour to ride, highlighting the importance of local trails which was probably exacerbated by the pandemic. Some riders are still willing to travel great distances to discover new locations.

Question 3

Do you normally have to pay to ride where you ride?

- Paid Sites
- Free, publicly accessible (Including sites where you only pay for parking)
- Both
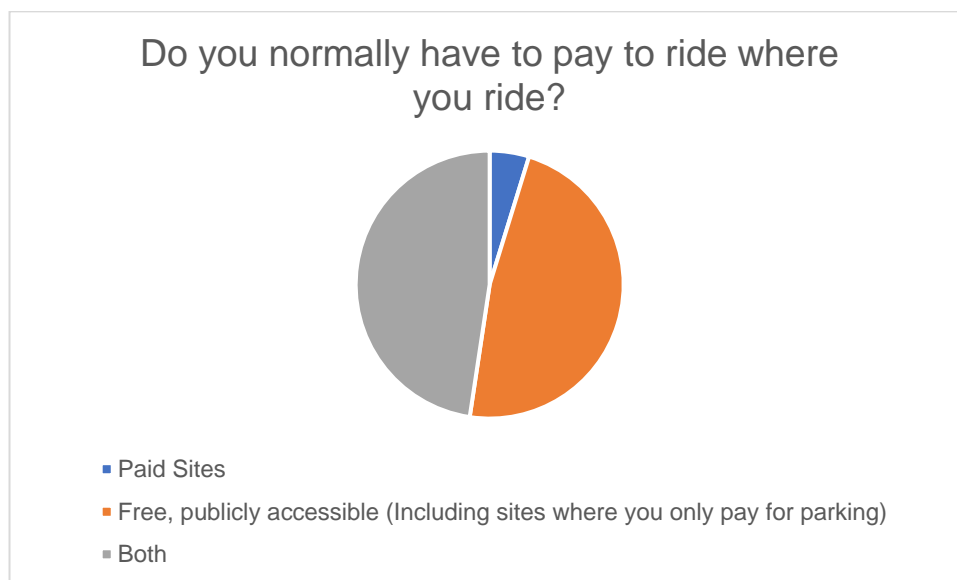
Figure 34 - Riders tend to opt for locations that are free to ride although a little over half of respondents regularly ride at paid bike parks demonstrating the demand for high quality trails and that mountain bikers are active participants in the economy.

The results of questions one, two and three give us insight into the survey group. Most riders do so regularly, at least weekly and use a variety of location types. Most of the riders preferred to ride close to home, less than one hour.

Question 4

Question four asked about the importance of trees to the sport, including the balance between safety and enjoyment. There were 61 respondents to this question, with the overwhelming majority saying that trees are essential to mountain biking, for example *"(Trees are) vital, they add so much to the environment we ride through".* Respondents commented on several services trees provide such as trail design and variety, providing shelter from the wind and the ecological benefits, for example *"They have both an environmental aspect and a technical benefit offering roots and trunks as obstacles as well as an ability to protect the soil from erosion"* and *"(Trees) are important because they provide shade, shelter and excitement!"*. Stress and mental health were common themes mentioned by participants, *"There's no better feeling then flying down a trail between trees also feeling surrounded by nature they add to the experience and the environment however they also do not move when you hit them !",* demonstrating the power of forests to provide an escape from the stresses of urban environments. There were also comments relating to the risk of trees with some responses indicating they had collided with trees in the past and this can often be serious *"Trees … add to the feel of being in nature (helps relax from daily stress), but they do add risk and thrill. Unfortunately hitting them hurts"*. However, even these riders still advocated for the importance of trees if adequate precautions are taken such as site inspections, removal of low hanging branches and padding around trees that are likely to be hit.

Question 5
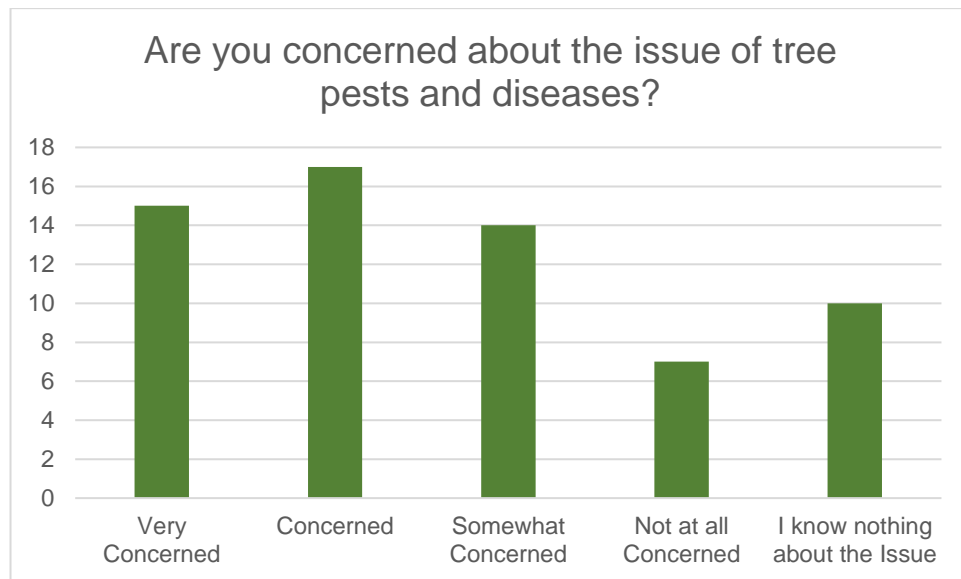
Figure 35 – *Question five demonstrates that there is a range of views about the threat posed by tree pests and pathogens in the mountain biking community.*

There is a range of views about the threat posed by tree pests and pathogens in the mountain biking community. The majority are aware of the issue and are concerned, likely more than the public, as mountain bikers have been directly impacted by the issue. Despite this, a significant group are completely unaware of the issue, suggesting that more education could be beneficial. Furthermore, this survey only asked if people are concerned to some extent, not if they have a further understanding of the specific management challenges.

Question 6

Question six aimed to build on question five, asking respondents directly about the closure of Aston Hill and Revolution. Unsurprisingly, almost all responses expressed disappointment at the closures and empathy for the people who run the sites, *"It's very sad and a big shame that tree diseases are having such a large effect on the number of high-quality locations to mountain bike. I used to enjoy going to revolution bike park but sadly I can no longer"* and *"Absolutely gutted for them, government needs to do more for the sustainability of woodland & manage recreational activities within them"*. Many mentioned the individuality of both locations, for example *"(Aston Hill was) one of the 'prime' bike parks in the vicinity of London, this will likely have significant impacts on London-based MTBers"* and *"Revs was the only place truly for the hardcore downhill riders"*.

The experience provided by a location is almost impossible to replicate elsewhere with riders extremely perceptive to subtle variations in trail design. One response raised the point that the closure of official locations would lead to a rise in wild trails in the area, something that could lead to further conflicts, *"I live near Aston Hill, and it had been closed for a couple years. It's been a shame that it's closed with limited communication from forestry England. It has also caused local riders to create more 'unofficial' trails that can cause conflict with walkers etc."*

Most responses took the view that the closures were wrong, saying that more should be done by local authorities to prevent this and that communication, especially around Aston Hill has been lacking. A couple of responses criticised the management approach, saying that clear felling is outdated, and not enough consideration was given to the recreational and economic value of the woods compared to a normal plantation, *"I think the management of diseases is often done in a manner that is easiest to determine the eradication of a disease with mass cut and fell that can feel insensitive to a local environment"*. However, many responses, despite their disappointment, seemed to agree that the decision taken was probably necessary and that stopping the spread of diseases is important. Several responses took the view recreation in woodlands is a positive, but the health of the habitat and ecology should always be the priority over human enjoyment. The responses reflect the varying levels of understanding in the mountain biking community, especially around the closure of Revolution. Some respondents said they think it is a shame that 'nature' was destroyed whereas some riders have an awareness of the monoculture, and the problems associated with this, *"Need to stop single species crop."*.

Question 7

Question seven asked respondents about how they care for the trails they ride. Most respondents claimed to take some action to protect the places they ride indicating a general feeling of stewardship, for example, *"Maintaining trails and clearing up litter at my local. I also make a point of cleaning my bike before going somewhere new, to reduce the chance of spreading tree disease"* and *"Yes; I*

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regularly collect litter not dropped by me". Many spoke about leaving the trails as they found them which could be in the form of taking their litter home or repairing any damage to the trails they cause, *"I help out by building and helping maintain certain areas and try and keep it clean as possible"* and *"I am careful how and when I ride, to minimise trail erosion"*. Some respondents spoke about taking a more active approach to caring for the places they ride such as attending 'dig days' where trails are built, conducting litter picks, reporting issues to rangers or cleaning their bike after every ride to stop the spread of disease, *"Picking up litter is a must, just common sense. Maintaining trails is best left to the trail crews unless they specifically want it, and reporting issues definitely helps get rider's opinions"*. Several responses agreed with the idea that trail building should be organised and led by single individual or group. At many places this is essential to keep good relations with the landowner, while also ensuring different features link together. There was also discussion raised about the public perception of mountain biking with some saying that mountain bikers should do more and other saying the sports reputation is unfair, *"Litter free and do not damage any trees except for reasonable size branches. Frustrating to hear complaints mountain bikers create to nature when a few months later the landlord will send heavy machinery to cut down the trees and completely destroy the surrounding nature"*.

Question 8

Who do you think is responsible for taking care of the forest?

- Riders
- Bike Park/Trail Centre Team
- The landowner
- Other users of the land
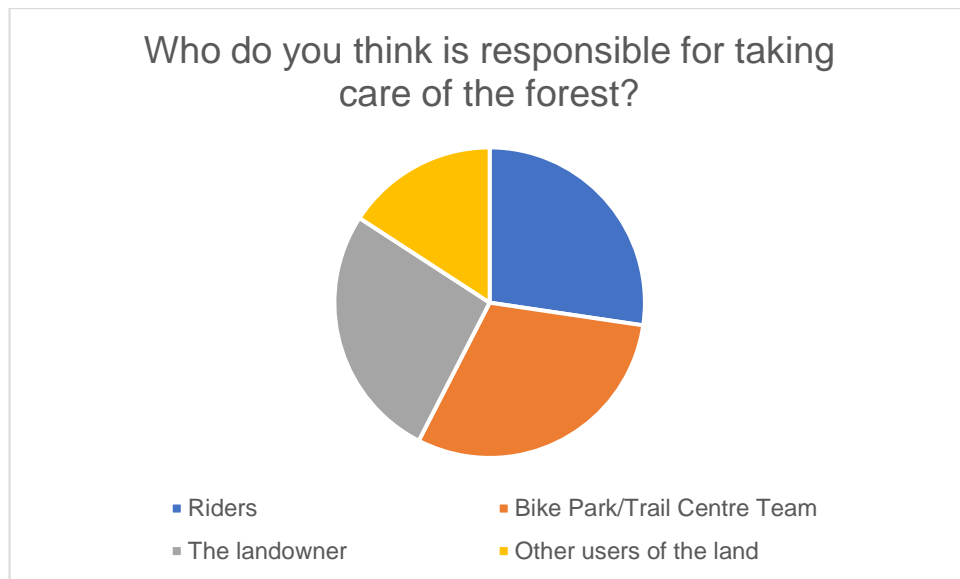
Figure 36 – Results showed that riders see the responsibility to look after the forest as shared.

Respondents were largely in agreement that it is everyone's responsibility to care for forests. Overall, respondents feel that slightly more responsibility lies with the owners of the bike park/ trail centre, whereas other users of the forest are seen as less responsible. There was some discussion about how this varies between location; for example, if the forest is public then there might not be a team looking after trails in which case responsibility lies with the individual user or the landowner. Regarding wild/illegal routes, the people building them have a responsibility to ensure other users of the woodland are safe.

Question 9

In locations that are shared between riders and other members of the public, how well does this work?
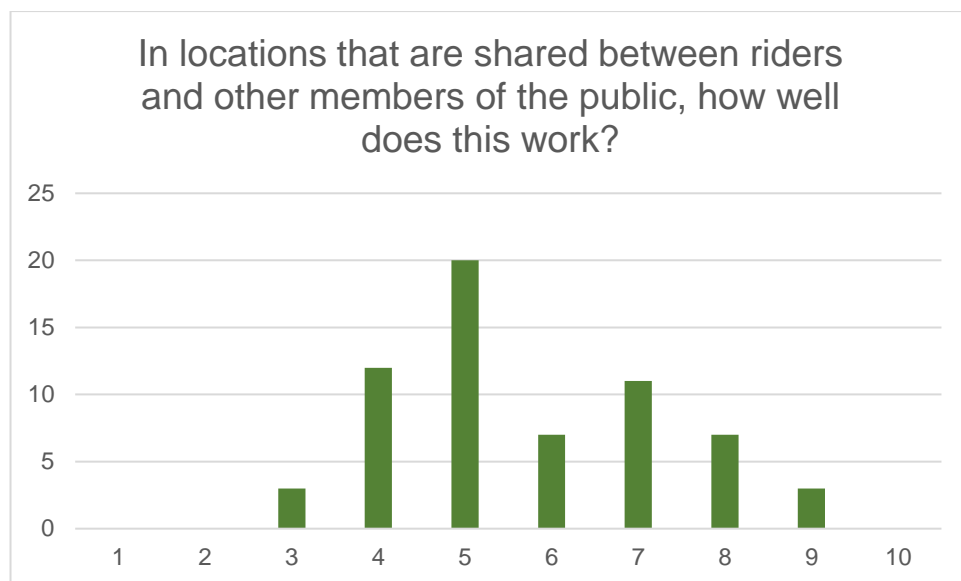
Figure 37 – *For question nine, respondents gave an average score of 5.7, lower than expected. This indicated that there are significant levels of conflict between riders and other users of woodland. Sources of conflict could be anti-social behaviour, riders using routes they should not be on, dangerous riding or destruction to the woodland. It would be interesting for a further study to look further into these issues.*

Question 10

Question ten asked about the use of off-piste/wild trails. Interestingly, despite the responses to previous questions indicating a high level of stewardship within the mountain biking community, placing a priority on woodland health over recreation, respondents almost unanimously answered positively towards off-piste/wild trails. Mountain bikers seem to generally be aware of their environmental impact, but not regarding off-piste riding, *"Yes. Because they're great fun and I don't do any damage."*. This also contradicts the views of those interviewees who were generally opposed to wild trails due to safety, liability and environmental concerns. Responses frequently referred to the thrill of off-piste routes, the variety and uniqueness that cannot be replicated by sanctioned trails, for example, *"It offers a completely different style of riding. They are often much steeper and narrow which offers more of a challenge. Examples are Sutton bank and Wharncliffe"* and *"They are more unique and give a sense of exploration"*. A huge part of the draw to off-piste riding is the sense of rebellion, exploration and lack of restrictions which can lead to an exciting experience, *"Yes, because they are quiet and a different style of riding that feels more like exploring. With friends it feels like an adventure.*

You can get really silly moments that you wouldn't get on trails like super muddy steep stuff to slide down" and *"Most of the time the off-piste trails are more fun and have more challenging terrain."* Many said that they ride off-piste trails as they are within riding distance of their house which is important for those who ride daily or weekly, such as, *"Occasionally, mostly when they are easier to access/closer to home than official trail centres"* and *"I live in the peaks and that's basically all of our riding around here"*. Many riders began by exploring local trails as they are easily accessible and free to ride. The responses to this question demonstrate the importance of off-piste trails to the sport.

Demographic Information
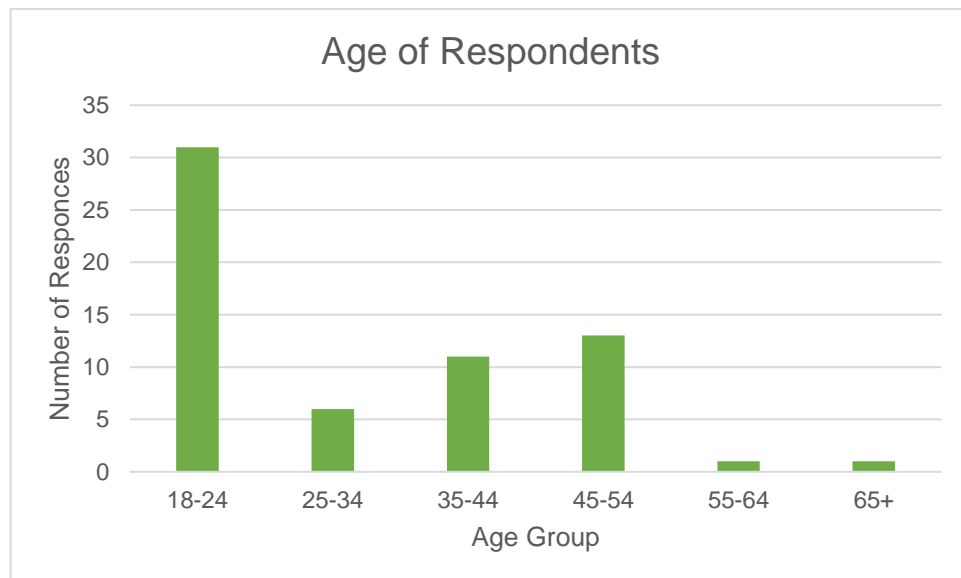
***Figure 38** – The ages of respondents to the survey. As expected, most respondents were young, in the 18-24 category.*
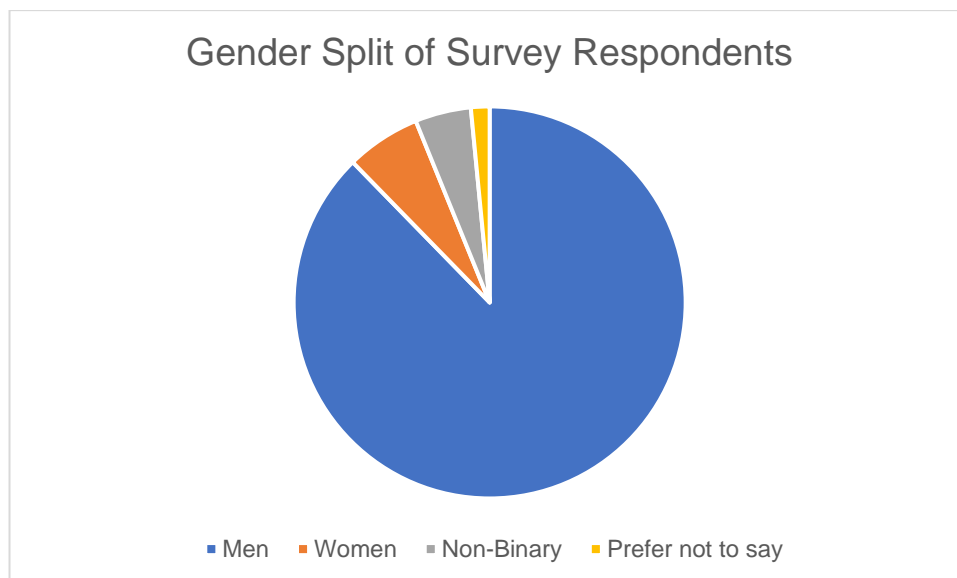
Figure 39 – *Unfortunately, men are greatly overrepresented in the survey responses. This is to be expected as mountain biking is a male dominated sport. However, ideally the survey would have reached more women.*
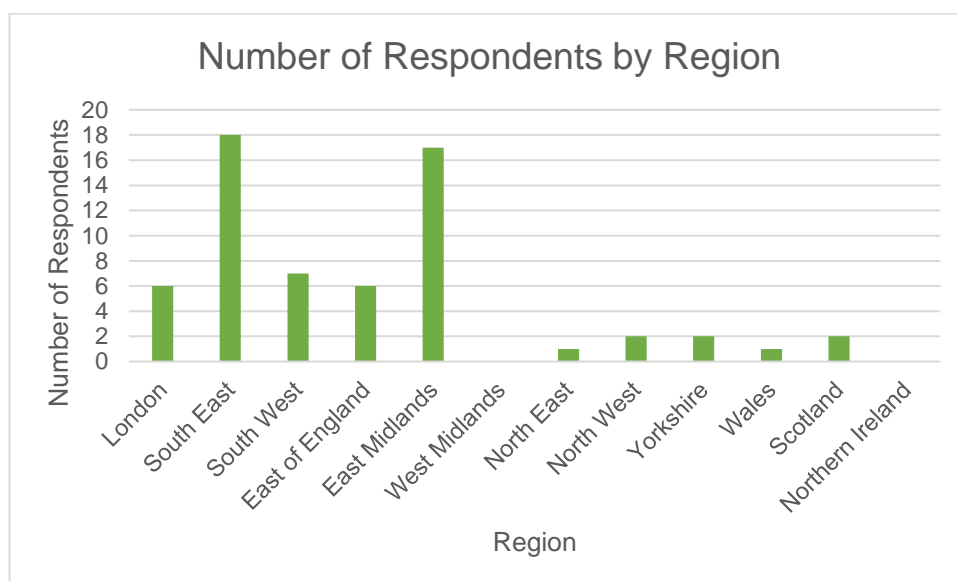
Figure 40 – *Overall the survey achieved some responses from most regions of the country, however many responses were from the Southeast or East Midlands with the North, Scotland and Wales underrepresented.*

The survey's demographic data highlights several representation challenges, though these do not undermine the validity of the results. In terms of age and regional distribution, the survey helps address gaps in the Strava data, which tends to skew towards older riders and primarily focuses on northern regions of the UK. However, women remain underrepresented in both the survey and Strava datasets, a persistent issue in this investigation. To improve female representation in future

studies, a more effective approach could include conducting female-only surveys or using targeted advertisements aimed at gathering a more balanced sample across gender, age, and region.

6. Analysis

6.1 Points of agreement

6.1.1 Coniferous vs broadleaved

The results highlight several key findings that help answer the objectives of this investigation. Integrating information from the results provides a balanced view of the issue, combining both empirical data and subjective insights. The dominant theme from all the results is the importance of trees to mountain biking. All forms of the sport from cross country to downhill, take place in locations with a high proportion of tree cover. Land cover data indicated a tree cover of 78% across the assessed locations. This agrees with preliminary investigations, existing literature, the video analysis, and survey results. From the results of the video analysis, both the creators and commenters frequently mentioned the importance of trees without prompt. The respondents of the survey unanimously commented on the importance of trees saying that the sport would not be the same without them. Key themes were the importance of trees for trail design, shelter and the enjoyment that comes from being in a forest. It would be difficult to find a mountain biker who would disagree that woodland is essential to the sport, and this is reinforced by the distribution seen in the land cover analysis. Trees provide psychological benefits for riders, as well as weather protection and an escape from urban environments.

Another point of agreement was in the type of forest being used for mountain biking. The land cover data showed that most locations were in coniferous plantations, and this agreed with the existing literature and expert views from the interviews. Several interviewees mentioned the rarity of sites like Aston Hill which are in broadleaved woodlands. Semi-natural woodlands offer a highly aesthetic experience many riders appreciate, which can be viewed through the lens of the biophilia hypothesis (Wilson, 1984). More commonly, sanctioned trails will be in coniferous plantations which are already less-natural ecosystems, so there is less potential for damage. Less natural woodlands are usually more compatible for mountain biking as they are fast growing and easier to manage. An example of this is Windhill Bike Park in the Longleat Estate, Wiltshire. Broadleaved, semi-natural woodlands are rare in the UK, and usually more highly protected, although some survey respondents commented on the sensory experience of broadleaved forests. Mountain biking often must find a balance between ecological neutrality and experiential richness. Today, human

activity is a major influence on all ecosystems. Mountain biking is no exception, even though many enjoy the sport because they feel it allows them to engage sustainably with nature. This raises the question of whether the protection of woodlands should be from or for people.

6.1.2 Economic importance

Multiple results raised points about the economic benefits of the sport. Several interviewees said that bike parks and trail centres can bring in millions of pounds in revenue and bring tourism to remote areas. Similarly, survey respondents talked about that economic losses that will be faced by the owners of Aston Hill and Revolution, and to the surrounding areas. The location data highlighted the number of bike parks and trail centres in upland regions, especially North Wales and the Highlands, identifying these areas as the most likely to suffer from future closures.

6.1.3 Off-piste/Wild trails

The topic of off piste/wild trails was frequently mentioned in in all four results sections. Both the videos and survey responses demonstrated the common view amongst riders that off-piste riding is enjoyed by most and is seen as an integral part of the sport. Most riders seem to be unaware of the potential environmental damage they are causing and often do not distinguish between the types of riding. In semi-formal trail systems, such as Hemlock Stone, there is typically less information to distinguish between sanctioned and unsanctioned trails so for those riding off-piste, it does not feel like they are doing anything 'wrong'. The emergence of location-based fitness apps such as Strava or Trail Forks can expose unsanctioned trails, increasing accessibility and to an extent, legitimising them. On the flip side, for some, mountain biking is a form of guerrilla recreation, with riders resisting over-commercialised outdoor spaces, hence the appeal of unregulated excitement.

6.2 Points of disagreement

Overall, the results of this investigation build on and agree with themes from the existing literature such as the dominance of coniferous forests, economic importance and both the potential for environmental damage but also how to reduce it. However, there are a few points of contention where the results did not entirely align with the literature. Previous studies have tended to focus on the economic

benefits of outdoor creation and the potential to damage the environment whereas the community benefits, which are harder to place an economic label on, have been underrepresented. Both the interviewees, comments on videos and survey respondents talked about the community spirit associated with local trails, the volunteering that goes into their construction as well as the mental and physical health benefits of outdoor exercise.

Academic literature on wild/off-piste trails is limited, although what does exist focusses on the liability and environmental concerns around them, and how this has led to many sanctioned trails opening. Although the results of this investigation, specifically the views of interviewees, agree with these points, the importance of wild trails to the sport was highlighted. Several interviewees said that despite the issues, they still ride off-piste trails and believe that when designed sensibly, can provide unique a riding experience without drawbacks. For example, at the Forest of Dean, unless a specific threat is identified, wild trails are allowed to continue, and the managers will look to adopt them into the official trail directory. Ultimately, mountain biking would not be the same without off-piste trails, which was a view shared almost unanimously by the survey respondents and reinforced by the Strava data.

6.3 Analysis of Case Studies

One of the primary aims of this investigation was to examine how the four case studies manage conflicts, particularly in relation to disease management. The interviews and land cover analysis have been able to provide valuable insights into how these sites are governed. This research has provided a more comprehensive understanding of each case study from both environmental and recreational perspectives. Furthermore, this approach can be applied to other forms of outdoor recreation, especially where conflicts arise between different stakeholders.

6.3.1 Revolution Bike Park

Figure 41 – a group of riders on 50to01 line, one of the largest jump/freeride lines in the UK, rivalling European bike parks in terms of size and scale. (Revolution Bike Park, 2023)

Land cover analysis showed that trees account for 72% of the park area (Morton et al 2021) of which was almost exclusively Japanese Larch, with some Sitka Spruce and Douglas Fir. Due to *Phytophthora Ramorum's* high tendency to spread through water courses and the position of the park near the headwaters of the Severn, the decision to fell the Larch Trees was ultimately understandable. However, the bike park supported 30 jobs and brought tourism to the area, additional factors compared to a typical plantation that should have been factored into the final decision made by Forestry Wales. The park was shut for two years for felling work, leading to large financial losses when the business was still recovering after Covid-19. The steep nature and remoteness of the site added to felling costs. The significant threat posed by *Phytophthora Ramorum* was not explained properly to the owners who saw the decision as outdated and draconian. Despite the devastation caused by the clear felling and loss of income, Revolution has survived and saw a limited reopening in summer 2024.

Through social media, especially the YouTube channel, Revolution Bike Park has been able to educate riders about the impact of tree disease, leading to an increased sense of stewardship amongst enthusiasts. Trees take many years to mature so Revolution is still a long way from the established, diverse woodland it needs to create the ideal mountain bike trails. In addition to the proposed upgrades to the bike park, Revolution plans to diversify the site by introducing indoor and family-friendly trails, along with a café and cycle hub aimed at attracting road

cyclists. While these changes have been met with resistance from many existing fans of the park, who appreciate Revolution for its hardcore, adrenaline-driven appeal, such diversification may be essential for the business's survival, as its original income streams have proven to be unreliable.

6.3.2 Wharncliffe and Grenoside Woods

Wharncliffe woods in an unofficial location with many mountain bike trails near Sheffield, over an area of 4.7km^2 . There are no official records for rider numbers but the Strava data for 2017 shows that several trails had around 3500 unique athletes across the course of the year, which only includes riders uploading to the app (UBDC 2024).

Figure 42 – A rider on the track 'Varsity' in Wharncliffe woods in 2015, taken from https://www.trailforks.com/photo/11928174/*. (Taylor, 2015)*

Most of the trails are situated within the woodland, with 85% of the area forested (10m land cover map, 2020, Morton et al, 2021). Most trees are coniferous with some smaller areas of broadleaved species (ibid). Like any forest in the UK, Wharncliffe Woods host several tree pests and diseases; however, there are currently no indications that drastic measures are required to prevent their spread. The future of the Grenoside trails looks certain with major upgrades being completed in 2022. The unofficial trails in Wharncliffe also look likely to stay

although there it is always possible that the Forestry Commission could decide that they are too dangerous or result in too many conflicts with other users of the forest, which poses a more realistic threat than pests.

6.3.3 Aston Hill Bike Park

Aston Hill, founded in 2002, was one of the most popular downhill bike parks in the south of England until its closure in 2020. During peak years, the park saw around 15,000-20,000 visitors a year but despite this funding was always a challenge. The site covers an area of only 3.3km, on Forestry Commission land and was set up as an initiative to encourage mountain biking in the 2000s along with several other sites such as the Forest of Dean and Cannock Chase. Its main income sources are funding from the Forestry Commission and sponsors. With the area sanctioned by the Forestry Commission, trail building at Aston was assured and the designers were able to create cutting-edge trails which pushed the boundaries for UK downhill mountain biking at the time. Trails such as 'Surface to Air' contained large jumps and drops on a scale rarely seen in a public mountain bike trail. After initial discussions, the Forestry Commission would rarely object to an idea for a trail allowing the builders nearly free reign to build what they desired.

Figure 43 – A rider on the track 'Root Canal' at Aston hill in 2020, before the closure of the park. (Aston Hill Bike Park, 2020)

The area is entirely forested, with a mixture of broadleaved species, including around 30% Ash trees. This makes it unusual as most bike parks are within coniferous plantations. In 2019, 60 diseased ash trees were identified which rose to 200 in 2020, at which point the Forestry Commission stopped counting and decided to close the park. Full closures of woodlands due to Ash Dieback are rare in the UK, with signage and partial closures favoured. However, at Aston Hill, due to the amount of people using the site, and the inherent risk of mountain biking, the site was fully closed while all ash trees were removed. As a keystone species, the removal of Ash trees will have a significant impact on the ecology of the woodland, destroying the complex interspecies networks that have developed in the woodland over many years. The felling work was supposed to take 12-18 months but is still ongoing which has frustrated local riders. The decision to close the site was ultimately justified, but despite this, the Aston Hill team are positive about the future of the park with the Forestry Commission promising continued support. By removing the Ash trees, the area is almost unrecognisable, but this provides an opportunity to design completely new tracks, keeping Aston Hill at the forefront of UK mountain biking. To combat the reduction in soil retention from removing trees, additional drainage work has been implemented. Replanting is underway with a focus on species that are most likely to be resilient over the next decades. Additionally, reducing woodland density will allow for more freedom when designing trails and benefit the ecosystem of the woodland by improving light penetration.

6.3.4 Hemlock Stone Trail Association

Hemlock Stone is a relatively small location in an area 0.36km^2 mainly ridden by locals. It is difficult to estimate visitor number as no records are kept but on a weekday around ten riders is typical, with upwards of 30 at weekends and maintenance days. Numbers are higher in summer although due to the sandy soils which drain well, the site rides well year-round. It has a strong sense of community with trail maintenance days attended enthusiastically. The trails were established from grass roots after discussions with Broxtowe borough council who visit the site every few months to address safety concerns. The leaders of the Hemlock Trail association have a strict agreement to follow which includes keeping the woodland tidy, maintaining signage and sticking to the designated trails which the council has approved.

***Figure 44** – Riders at Hemlock Stone on the 'Original' trail during the Maintenance Day 28/04/2024. (hemlocktrailassociation.co.uk, 2024)*

Hemlock stone is in a difficult position in terms of scrutiny, sitting awkwardly between completely unofficial trails which are usually condemned by landowners, but left alone, and established bike parks which have clear authority to exist. Most of the time, walkers and riders share the space without issues, and walkers are well used to the trails. The entire site is within the woodland area which is comprised of a mixture of broadleaved tree species.

Hemlock Stone is a great example of a community coming together to create an asset for the area, inspiring the next generation to take up the sport and enjoy the outdoors. However, the relationship with the council means that the future of the sight is always precarious. Misuse of the woods is common, such as motorbike riders, litter and fires, which only increases scrutiny from the council.

Tree diseases are not a primary concern for trail builders at Hemlock Stone Woodland, despite the presence of pests like Ash Dieback and Oak Processionary Moth. Neither the trail builders nor the council actively monitor for these threats, meaning action is unlikely unless an outbreak poses a clear public safety risk. The local council, misuse of the woods or negative interactions with other users of the area pose a far greater threat to Hemlock's existence than tree pests or diseases.

6.3.5 How the types of mountain bike location could lead to different management approaches.

Purely by investigating these four locations in depth it is clear to see that each site is facing different threats and therefore should be managed differently. Official sites can create initiatives and adapt to threats. At less official locations, safety concerns relating to tree pests and pathogens often go unnoticed. When a threat is identified, somewhere like Wharncliffe woods where trail building is secretive and undesignated, would struggle to respond to threats as a collective, and are not held accountable for miss use of the woodland. The Hemlock Stone model can be effective as it allows trails to exist without having to be secret, whilst allowing local authorities to have a say and reduce risk. A drawback is that many of the restrictions at Hemlock feel arbitrary and this impacts the freedom to build trails which is important to the sport. However, through the Hemlock Trail Association, the riders have a voice, and the council have a point of communication. This enables plans to be implemented efficiently, drawing a balance between rider enjoyment, and the risk of liability. Another difference between official and unofficial locations is the integration to the local economy. Revolution for example, had 30 employees and brought international visitors to the area who often stay for several days at a time. Aston Hill brought many visitors from London who would spend money in the nearby towns. In contrast, at unofficial mountain bike trails, there are no employees, and the rider base will be local as knowledge of the trails spreads by word of mouth. This means locations such as Wharncliffe and Hemlock will bring less of a boost to tourism, functioning more as an asset for the local community. Even across these four areas, there is a diverse range of woodland types from semi-natural to monoculture conifer plantations. This will have a significant impact on the optimal management approach for example clear felling or thinning. The species of trees and planting density will impact the risk to human health also.

Another factor in the management of mountain biking trails is the differences between bike parks and trail centres. Bike parks tend to be smaller and have a defined area set out purely for mountain biking. There may still be public rights of way through the site but compared to a trail centre, management will be almost exclusively to maintain mountain biking trails. Trail centres function over a much larger area, with less defined borders. Typically, mountain biking is not the only activity encouraged, with walking, running and horse-riding trails. There will be much more scope for off-piste riding compared to a bike park where unofficial trail building is quickly spotted and the owners will tend to use all the available space to maximise the number of trails. As well as serving multiple types of outdoor recreation, trails centres will have to balance other forest management, such as timber production. Natural resources Wales harvest 750,000 cubic metres of timber each year from their forests whilst maintaining public rights of way and recreational opportunities.

7. Discussion

7.1 The extent of current UK mountain biking and the future of the sport

7.1.1 Overview of Key Findings

This study had several key objectives, determine the scale of UK mountain biking and the main issues facing the sport; find out how tree pests and pathogens impact mountain biking locations; evaluate the current strategies for managing tree pests and pathogens; suggest new strategies; and evaluate the potential of the methods used. The results, which are a mixture of discrete data and subjective information, have something to contribute to each of these objectives, simultaneously proving their potential for further research.

7.1.2 Scale of UK mountain biking

The GIS analysis has demonstrated that UK mountain biking continues to grow and can be a key tourism economy for many upland regions (Kozumplíkova et al, 2018). mountain biking provides another option for outdoor recreation, improving the mental and physical health of riders. By encouraging people to get outdoors, people build respect for the environment and develop an attitude of stewardship. However, the negative view of mountain biking by management programs can be problematic and create confrontation (King and Church, 2019). The data has shed light on the way people ride, and why certain locations are popular at certain times. It is also clear that the sport depends on woodland areas and would be very different without them. This can be seen in the land cover data and is reinforced by the views of the survey respondents. Trees absolutely shape the sport, marking turns, creating a sense of speed and reducing erosion. Moving forward, this information will be of great use for making management decisions surrounding the sport informing local authorities about how to grow the sport in a sustainable and profitable way.

7.2 Impact of Tree Diseases and Pests on Bike Parks

The main aim of this investigation was to investigate the impact of tree pests and pathogens to the sport, which is one of the biggest threats to mountain biking across the world. Tree pests and pathogens have the potential to be catastrophic to a bike park, as was seen at Aston Hill and Revolution where the sites were closed indefinitely. However, pests and pathogens are likely present at every mountain biking location. In some sights, such as the Forest of Dean, the issue is acknowledged and preventative measure are taken, albeit not as drastic as a full closure. At unofficial sights, such as Hemlock Stone, this issue is not acknowledged by the trail builders or local authorities, however this does not mean these sites would be immune to an outbreak. Regardless of the type of location, riders are unfortunately a vector for spreading the disease. Compared to walkers, mountain biking riders can be worse for spreading pests and pathogens for several reasons. They can cover more distance than walkers, have more equipment to carry disease, cause more damage to the ground, and often visit many locations in a short period to enjoy different styles of riding (Kuwaczka, 2023). Additionally, tree pets and pathogens can be a danger to the public and riders at any location. It is interesting to see how different woodland managers have varied levels of concern about the safety aspect of tree diseases, considering their liability when running a site. Some locations take many preventative measures to ensure they are not liable for injuries. For example, at Coed y Brenin and the Forest of Dean, OGB37 is followed to ensure no unsafe trees are near trails (Forestry Commission, 2009). This contrasts with Hemlock Stone where no thought has been given to tree disease, or at Revolution where *Ramorum* was detected but not seen as an issue for the safety of the riders. The type of disease plays a significant part in the safety concerns. *Ramorum* does not tend to cause catastrophic failure of the trees so is not especially dangerous compared to Ash Dieback which makes infected trees very unstable. Another factor is tree density. At a site such as Revolution, the Larch was packed very densely to maximise profits which would make it difficult for a tree to fall over. Most locations used for mountain biking are in commercial forestry (Bayne et al, 2020) but in semi-natural woodlands, trees have more room to fall, and are monitored less frequently, leading to increased risk.

7.3 Current Management Strategies

Based on the findings of this study, it is essential to keep questioning the effectiveness of traditional management approaches, such as clear felling, for reducing the impact of tree pests and pathogens although no strategy is perfect. To the owners of bike parks, management decisions can often feel arbitrary, inconsistent or outdated. Better explanations from authorities would be helpful, especially in the case of Revolution Bike Park, so the owners could understand the reasoning behind the clear felling. The decision was on balance the best strategy although certainly not without question. Modern strategies, such as biological control or selective breeding, have the potential to be great although need more research. The severe consequences that pests and pathogens can have mean that stakes are high, and new approaches can increase risk. As a result, the old methods are often the best choice. Each outbreak should be treated separately and given great thought before actions are taken due to the many variables at play such as the specific threat, location, risk of spread and potential for economic damage (Wainhouse, 2005). Additionally, mountain bikers are not a homogenous group, and so management needs to reflect the variety in riders and what motivates them (Zajc and Berzelak, 2016). For example, some riders may be motivated by fitness, when others are seeking thrill and excitement (Skår et al, 2008). In the case of Revolution bike park, this was not done adequately enough. Controlling the spread of pests and pathogens is extremely difficult, so there is a valid 'do-nothing' argument. Most major tree diseases have spread across the entire country so sometimes it is not worth fighting, unless there is a public safety concern, and this allows resistant trees to survive (Foster and Orwig, 2006). Climate change is going to apply increased pressure to the UK's ecosystems, making them more vulnerable to disease (Qin et al, 2017). This only emphasises the important of continued research into management strategies.

7.4 New Management Approaches

Over the next few decades, the management of tree pests and pathogens may look different. There are several other approaches that could prove effective. Monitoring technologies such as LiDAR, and drone surveys will become even more common, allowing for early detection (Hartmann et al, 2018). This may allow for less drastic steps to be taken when reducing the spread of pests and pathogens, which will

allow recreational areas to stay open for longer, or lead to more partial closures of forests. Mixed species planting is already a strategy being used by foresters such as at Longleat Estate, to create resilient woodlands. This is highly applicable to mountain bike locations as seen at Revolution with the recent creation of a bespoke forest for mountain biking. Mixed species planting has a dual benefit for mountain biking as it can improve the experience for the rider as the terrain is more varied and therefore interesting.

As established from the results of the survey, public awareness of this issue is minimal despite the major threat it poses to mountain biking. If more aware, riders could help in the protection of forests, something that many survey respondents placed a high value on, often above being able to enjoy riding. Bike parks could work with riders to implement early warning systems and encourage the cleaning of equipment after each ride. Smartphones provide a great opportunity to proactively tackle environmental issues (Green et al, 2023). It is likely there would be some resistance to this as riders may fear that by submitting a report, they risk their favourite location being closed. However, previous studies have shown that mountain bike riders are willing to engage in PPGIS and take on a stewardship role. Clearly, this strategy would not be possible at unofficial sites such as Wharncliffe although local authorities can still place signs with information about protecting the environment. Balancing recreation and conservation are key for any forest that is open to the public. Access issues can be challenging as recreation always leads to some environmental damage. Many land managers are tolerant of trail building when it does not interfere with other forest services, suggesting that public access could be less restricted, such as in Scotland with the right to roam. However, it is difficult to open an area to the public whilst restricting access to only desired areas and types of users. Many mountain bike locations struggle with motorbike riders who, compared to mountain bikers, cause significantly more ground damage, noise and disapproval from other users. It is important to establish where it is best to allow access that will provide the greatest physical and mental health benefit, versus where must be protected from human interference. This is especially challenging in the UK where woodland area is so low and population density is high, leading to strain on remaining publicly accessible woodlands. This high demand can feed into other issues faced by UK woodlands and this needs to be considered in management strategy. For example, mountain biking has the potential to increase habitat fragmentation and pollution.

7.4.1 Specific management for bike parks and trail centres

When addressing environmental concerns associated with bike parks and trail centres, it is essential to consider the implication this has for management approaches. The felling work at Revolution and Aston Hill has been devastating for those whose livelihoods depended on them and has been a significant loss for the mountain biking community. Despite this, it seems that in both cases the work was necessary and the correct action to take. With climate change and an increasingly globalised world, new threats to the UKs forests are inevitable, so there will be similar cases in the future. However, the examples of Aston Hill and Revolution, can act as examples for securing the future of recreational woodlands, particularly the efforts at Revolution to create a forest that is diverse and resilient to climate change. As mountain biking continues to grow, the revenue generated by bike parks and trail centres creates an opportunity to design woodlands to be ecologically rich, without the restrictions of timber production usually placed on commercial forestry. Forests used for mountain biking, and other forms of outdoor recreation, need to be treated differently, where possible, from areas of woodland that a purely used to produce timber. The first step in any environmental management is monitoring and with bike parks and trail centres there is an opportunity for this. These locations are heavily used by riders and maintenance teams, who can report issues early. This may allow for more partial closures, ensuring the operations of the area are least impacted. During management, the economic importance of these locations must be considered as they can be vital for remote upland areas, as well as the physical and mental health benefits of exercise. Learning from Aston Hill and Revolution, plans can be made to allow riders to return to affected locations quickly through mixed planting, reimagining trails and diversifying the area. Although the loss of income can be very difficult for bike parks and trail centres, many of which are small businesses, this can turn devastation into an opportunity and create a resilient forest that can still provide services to people.

7.5 Environmental and Economic Impacts

7.5.1 Environmental Impacts

Mountain biking, as an outdoor activity, can exert various pressures on the environment. The construction and use of trails in bike parks or natural forests can lead to soil compaction, erosion, hydrological changes and habitat disruption although the extent of this compared to other forms out outdoor recreation such as walking, or horse riding is still debated. For example (Pickering et al, 2010) suggests the sport is no more damaging that other forms of recreation whereas some experts and many members of the public are quick to say the sport causes significant ecological damage. Mountain biking often has a bad reputation as it is a relatively new form of recreation (Skår et al, 2008) and is seen as insensitive to the surroundings. However, trail building can lead to erosion and root damage which can enable mountain biking to take hold, especially those that are easily spread through the movement of soil such as *Phytophthora Ramorum*. This is worse if wild trails are allowed as this can lead to uncontrolled ecological damage, such as unplanned hydrological impacts. Furthermore, unmonitored trails are a safety risk for riders as they are not maintained and are constructed without expertise. Closing sanctioned trails will often lead to an increase in wild/off-piste riding, and this is very difficult to prevent. As e-bikes become more popular, mountain bikers can cover more ground, with the potential for more environmental destruction (Kuwaczka, 2023). This will only make wild/off-piste riding harder to control.

7.5.2 Economic Impacts

Mountain biking can be hugely important for the tourism economy, especially in upland areas where tourism can be less dependable (Iverson et al, 2023). Mountain biking creates a new stream of income, bringing business year-round. Many trail systems built by the Forestry Commission were created to stimulate rural development (Forestry Commission, 2009). Not only does this bring money to the bike parks and trail centres, but to hotels, bike shops, supermarkets, restaurants, and other tourist attractions. Mountain biking is often most popular in rural areas which see high levels of deprivation. In the Scottish highland, at locations such as the Nevis Range, mountain biking creates a reason to visit the area during summer when skiing is not possible, making use of the skiing infrastructure. Every year a round of the world cup downhill is hosted at Fort William, bringing huge numbers of international visitors to the area. Both the potential for ecological damage and

economic importance of mountain biking, highlights the need to smartly manage bike parks and trail centres using the latest methods and monitoring.

7.6 Synthesis of Public and Expert Opinions

From the results of this investigation, it is interesting to see the comparisons between expert opinions, from the interviews, and the views of the general rider, established from the survey. There is a mixture of agreement and disagreement between the two groups, which is unsurprising as they have different motivations. Firstly, communication came up in several discussions as a challenge, however, many riders feel that more communication would be better. For example, the Aston Hill Team haven't released an update about the Ash Dieback management for two years now as the Forestry Commission have continued to push back the opening date. Riders kept getting frustrated about this, so the team decided to release no more communication until a more concrete opening date provided by the Forestry Commission, which has led to even more frustration from riders. However, Ian Warby, the head manager at Aston Hill says he lacks the platform to fully explain the issues they are facing and wishes he had a better way of communicating with riders. In contrast, most riders are satisfied with the communication from Revolution Bike Park, even if some of the plans have been controversial. Since the closure, the bike park has been releasing regular videos on YouTube with high production value, explaining in detail the current situation of the park. However, Aston Hill has been shut for longer and has faced more complications, which has contributed to the lack of communication. Even outside of tree pests and pathogens, woodland managers struggle to communicate with the public, leading to access and usage issues. Public education around the issue of tree pests and pathogens is poor and most people are unaware entirely which needs to change if management approaches are to be accepted (Urquhart et al, 2017). This highlights how important communication and education to manage locations used for outdoor recreation. This allows the public and experts to work together to maximise the services provided by forests whilst protecting them.

A key difference between riders and experts lies in the issue of liability, which falls on the landowner and bike park management. While many riders may not consider this when they visit a bike park or trail centre, landowners face significant financial risks if accidents occur, and they are found liable. A defence commonly used in

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these situations is volenti non fit injuria (the acceptance of risk by the participant), which can protect the bike park from liability. However, for this defence to be effective, trails must be well-maintained with clear signage to inform riders of potential hazards. This is why unauthorized, off-piste trails often present serious challenges—they lack the necessary safety measures and can expose landowners to legal and financial risks.

This issue also ties into broader concerns about land access. Riding in undesignated areas can pose risks not only to other users of the land but also to the environment, potentially causing ecological damage. Interestingly, despite most survey respondents acknowledging the importance of off-piste or "wild" trails to the sport, many also expressed that protecting the environment should take precedence over the sport. Many bike park managers agreed with this and were motivated to make sure that any work they did for the bike park also encouraged biodiversity. For example, at both revolution and Aston Hill, replanting efforts are underway which favour mixed planting of native species and rewilding areas. At Windhill Bike Park in the Longleat Estate, the head forester designated the bike park to focus the environmental damage to a small area, whilst allowing large areas of the estate to grow into semi-natural woodlands. At the Forest of Dean, several members of the team are working with 'Trash Free Trails', an initiative to encourage stewardship from riders and site managers.

7.7 Implications for better management of recreational woodlands

Mountain biking will always be challenging for forest managers as it is a contentious activity. Compared to traditional ways to enjoy woodland, e.g., walking, running, horse riding, Mountain bikers are often loud and viewed by many as reckless, disturbing peaceful areas of forest. Perhaps because mountain biking is still a relatively new sport, many see it as not being in keeping with values of traditional forest users, and as a result, a disproportionate amount of blame for ecological damage is placed on mountain biking. Repeatedly landowners have resisted allowing mountain biking, however, this almost never prevents riders from constructing trails. Often, landowners will choose to incorporate mountain biking into their trail network, which gives them some control over where and how riders use their woodland. This has the added benefit of tapping into the MTB economy and

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gives users of the forest a new way to engage with the outdoors, bringing with it health benefits. It is also a great way to engage younger people with outdoor spaces who are drawn to the excitement. However, MTB, especially DH and freeride, will always be contentious. These riders, looking for extreme terrain, will always create wild trails with dangerous features. This can be shocking for other users of the forest, many of whom have a very different idea of what mountain biking is. Unfortunately, the thrill of being rebellious is a huge part of MTB and this will not change. This is similar to the culture of skateboarding or parkour, where a huge draw is the illegitimate nature of the sport. Over time, mountain biking will become more accepted as each decade, more people will have grown up with mountain biking being commonplace.

7.8 Evaluation of Methods

It is always important to evaluate the methods used to inform future research. Although each method used in this investigation yielded some results, some were more successful than others and all methodologies could be improved.

7.8.1 GIS analysis

GIS is a vastly powerful tool, hence its wide scope in contemporary Geographical studies. In this investigation, GIS allowed for the processing of large datasets, with high spatial and temporal accuracy. This produced results that have provided detail, information about the impact of tree pests and pathogens on woodlands used for mountain biking. This investigation was the first to use Strava data to analyse off-road cycling, with previous studies focusing on commuting, road cycling or fitness. Although Strava data is not perfect for researching mountain biking due to mountain bike riders having different motivations for riding, this investigation has proved it has potential. With more time and data that is centred around rural areas, Strava could provide deeper insights into the world of mountain biking. Strava Metro also records node data for the intersection of two segments, and origin to destination data. Both could be interesting to analyse in the future and may highlight other trends in mountain biking. For future research it would be ideal to use a more rigorous method for identifying mountain biking trails to ensure the results are focussed. This investigation underrepresented unofficial locations which are a huge part of mountain biking. If these locations were better identified some results would be altered. For example, unofficial locations are more likely to be in broadleaved woodlands and this would have management implications. Unfortunately, it is very

difficult to adequately represent every unofficial location as there will be some trails that are only known by a few people and locations are constantly changing. At unsanctioned trail systems, riders are less likely to use Strava so even with a perfect method of identifying mountain bike trails, unofficial routes would be underrepresented. For these reasons, funding for mountain biking often ignores unofficial trail systems.

It is difficult to get round the demographic issues with Strava data, with the vast majority of uploads to Strava across the world being male dominated. It would be possible to address the partially by separating results by gender or algorithmically equalising the weighting of different groups, however this would never be perfect. In social studies it is always a balance between catering for the majority versus ensuring that all discrete subsets of a population are considered.

 It would be interesting to compare Strava data to other methods of counting numbers to increase its accuracy. In a future study, it would be fascinating to use Trail Forks, which is a mountain bike focussed interactive map with a vast amount of user submitted subjective information and visual content, as the centre of an investigation. This has never been done before and unfortunately Trail Forks do not currently allow their data to be used for research. Analysing patterns through Trail Forks would be challenging as there is a huge amount of subjective user submitted data which would be difficult to analyse automatically. However, there is a huge potential to gain a deeper understanding of the key environmental challenges associated with mountain biking, compared to Strava data which mainly limited to the number of athletes, where they went and when.

7.8.2 Interviews

Interviews are a tried and tested method used in geographical studies as they allow the researcher to gain detailed information for experts, which was no different in this investigation. The interviews enabled the views of a range of bike park managers, trail builders, landowner and foresters to be captured, from the biggest bike parks in the country such as Revolution to secret unofficial locations such as Bestwood. A lot of the management of both outdoor recreation and tree pests and pathogens is location specific and complex, relying on many factors, so it is useful to interview experts to ask detailed information. With more time, a greater number of individuals could have been spoken to, representing more viewpoints and cementing key themes. Most interviewees were from official locations as these have contact details

and employees. Unofficial locations have no one to contact and if the location is secret, will actively discourage knowledge about the trails becoming known. For unofficial locations the only option is to speak to a landowner or local authority who will often be less knowledgeable, which is unfortunate as the optimum management approaches for these locations is less studied.

7.8.3 Videos

Action camera footage is another novel technique with only a handful of other academic uses in the study of cycling. The technique shows promise, especially today where 4k action cameras are common with improved stabilisation and high-quality audio. A trained eye would be able to identify species of tree or gauge the ground pressure caused by riders and trail managers could create their own videos if they wanted to target specific areas. Visual content uploaded on sites such as YouTube could be used to aid the detection of tree pests and pathogens, discover wild trails and identify what riders enjoy about an area. In a further study, it would be interesting to include videos from a wider range of social media platforms, including shortform content which would allow for quick analysis of many trails.

7.8.4 Survey

As expected, was able to gather a wealth of information, including long answer questions, from members of the public in a short period of time, with minimal effort. Surveys are an excellent method for investigating the environmental issues associated with mountain biking as they allow the researcher to easily obtain the opinions of the target demographic. Learning what riders understand about the issues facing their sport will prove invaluable for future management and from this study riders have shown a willingness to contribute. In a future study, the survey could have been circulated more widely, such as on Facebook groups for mountain biking across the country, to address the bias in these results. An incentive could also be useful to encourage the respondents to give better answers however this can lead to problems also. It would also be interesting to chase up some of the questions that were raised in the answers provided. Surveys are good at reaching lots of people, but struggle to get detailed information as respondents often loose interest or miss the point of the question. In an interview, if the interviewee did not understand a question, the researcher could simply rephrase it, which is not possible on a survey.

7.8.5 Areas for future research

Additionally, to expanding on all four of the methods used in this investigation, there are several areas for future research. Firstly, there is always scope for innovation in the management of tree pests and pathogens. Technological advances means that there are always new techniques that could prove beneficial such as genetic manipulation or biological control. The huge number of factors that impact the spread of a pest or pathogen mean it is difficult to model or predict how a management approach will work. Furthermore, climate change only increases the unpredictability of the issue. Secondly, there is a huge scope for further research into mountain biking on which there is little literature despite the sport continuing to grow and becoming a significant market. It is important that mountain biking grows in a sustainable way, balancing economic and environmental concerns. For example, the true physical environmental damage done by mountain biking is still debated which makes it difficult to manage. From the research carried out here, it is possible to make a better-informed decision for future environmental issue facing the sport. However, it would be interesting to conduct further surveys to understand the opinions of the general rider about each management approach. This would be challenging as surveys struggle to convey complex ideas but an attempt to understand this would be useful.

8. Conclusions

This investigation has shown that although the extensive felling work at Aston Hill Bike Park which is ongoing since 2020, and at Revolution during 2023, was devastating for both locations, the management approach was necessary. At Aston Hill the case was clear, with the diseased Ash Trees, which made up around 30% of the woodland, posing a serious health risk to riders. At Revolution, the decision was less clear cut, with minimal safety concern due to the nature of *Phytophthora Ramorum*, and the lack of clear identification of the disease. However, *Phytophthora Ramorum* can spread easily, especially through water courses (Grünwald et al, 2008), and so drastic preventative measures are justified. Furthermore, the monoculture of Japanese Larch was far from a natural ecosystem. So far, plans to reopen the bike park are going smoothly. The forest has been replanted with a mixture of species which will create a resilient and dynamic area to ride. Similar replanting work has happened at Aston Hill, with the Forestry Commission continuing to support its existence.

Although the future of both locations seems promising, there is still scope for improvement in the techniques used to stop the spread of pests and pathogens. The closure of these bike parks has put many jobs at risk, removed two areas of outdoor recreation, and likely had knock on implications for the tourism economies of both regions. The approaches used did not consider the unique impacts associated with the bike parks compared to a traditional timber plantation. In the future, better monitoring, and public engagement could help identify tree pests and pathogens sooner, leading to less full closures and more small-scale management. New techniques such as genetic resistance (Budde et al, 2016; Green et al, 2023) and biological control could further help control the spread of tree pests and pathogens which are a major problem across the globe.

In addition to evaluating the closures of Aston Hill and Revolution, this investigation explored other environmental issues associated with mountain biking. Trees could not be more essential to the sport, not only in practical terms such as for trail design or shelter from the elements, but also in terms of the rider experience and connection to nature. Further light was shed on the controversial subject of wild/off-piste trails, from the point of view of experts and the general rider. It was found that although wild trail can be problematic, they are essential to the sport. The adoption of wild trails can create new recreational opportunities and engage the community

(King and Church, 2018). Additionally, sanctioned trails can be monitored, reducing risks such as negative interactions with other users of the forest, injury to riders and environmental or cultural damage. By using Strava data supplied by the UBDC (2024), which has not been done before to study off-road cycling, the scale of UK mountain biking was visualised. The data showed that the sport continues to gain popularity and shed light on usage patterns. The idea that mountain biking often takes place in rural upland regions was also confirmed, proving the importance of bike parks and trail centres to these areas (Kozumplíkova et al, 2018; Iversen et al, 2023). Ultimately, mountain biking is still an understudied form of outdoor recreation, despite its significance. Various environmental issues will continue to threaten the sport, but with clever management strategies, a balance can be stuck between the environment and recreation that ensures a sustainable future.

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