PREDICTING USER NUMBERS OF AN URBAN FRINGE PENNINE MOORLAND USING TIME AND WEATHER VARIABLES

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requirements of Liverpool John Moores
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Originality Statement

The work presented in this thesis is my own work and contains no previously published material. The work has been generated through my PhD programme of study at LJMU. This work is submitted for the award of PhD at LJMU and has not been submitted for any other award at LJMU or any other institution.

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Date: 5th February 2018.

Abstract

This study develops and conducts a 15-month, high resolution 24/7 user counting exercise on an area of urban-fringe moorland. The results of this study are discussed and used to predict future land use. The results of this study are compared with results from lower resolution user counts in other wilderness areas.

This study was conceived to address a gap in data around recreational moorland use and provide 24/7 data on user numbers in order to develop models to attempt to predict use of urban-fringe moorland from time and weather variables. The data collection strategies utilised were manual counts by an observer, supplemented by Arduino micro-computers and passive infrared sensors. These sensors were designed and developed specifically for the purpose of remote high resolution counting of visitors at low cost, producing reliable 24/7 data for 15-months.

Time and synchronous local weather variables at 30 minute, 1 hour, 3 hour and 6 hour resolution were compared with 30 minute moorland user data to assess how these factors affected counts. The study found that the strongest variable affecting visitor counts was daylight. User counts were highest in summer, at weekends and during afternoons. Surprisingly, very little change in user counts was detected during school, bank or religious holidays. Generally, there are trends toward using the moor when temperature is higher and humidity lower. Cloud, visibility, wind chill, wind speed and wind direction had no influence on user counts.

User counts, time and weather information were modelled using two approaches: (1) weighting factors and (2) multiple regression. The best model was able to explain 52% of variation in use. The predictive capability of the model increased to 58% during summer and on weekends. Data suggest that there are two groups of users on the moor. A group that have become acclimatised to the prevailing weather conditions and use the area regardless of the weather, this first group will use the moor regularly throughout the week. The second user group is more likely to use the moor during the weekend. These users are more influenced by time and weather factors. An important social discovery was made through anecdotal observation and discussion indicating that the urban fringe moorland is utilised by users beyond the expected dog walkers, hikers and cyclists.

Key words: Urban-fringe; Moorland; User Counting; Remote Counting Methods.

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Special acknowledgement is given to my dear friend, from the University of Huddersfield Caving Society: Mr Yared Edery, who sadly passed away while completing his PhD at the University of Huddersfield. Yared gave me motivation, encouragement and insight in the final year of my undergraduate degree, and first year of PhD study.

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Chapter 1 Introduction and background.

Since 1893 Ilkley Moor has been owned and managed by various local authorities for the people of the district. Initially bequeathed to the people of Ilkley Urban District Council, it is currently in the control of City of Bradford Metropolitan Council (CBMC). Since the start of public ownership this moorland has been managed with a focus on recreation (CBMC, 1988; Perham, 2013. Pers. Comm. Richard Perham is employed by CBMC as Ilkley Moor manager).

Over a bank holiday Monday in August 1988 a 100-respondent survey was conducted into the moor's use and its users (CBMC, 1988). The survey demonstrated that users rarely travel more than five miles to use the moor and are generally regular, repeat visitors who usually come back within a month. Another similar, but unpublished, 391-respondent survey was conducted over seven days in early August 2013 (CBMC, 2013). The 2013 survey used a questionnaire approach, asking users about their activities, whether they ventured off tracks and the frequency of users visits. These two user surveys are the only known attempts to assess usage of the moor.

CBMC notes (CBMC, 1998) and the moorlands manager (Perham, 2013. Pers. Comm.) both claim that Ilkley Moor is unique in being the only moor to be owned by a municipality which permits grouse shooting. However, shooting on the moor is a topic of contention (Literature Review chapter, p. 17).

A freedom of information request (Butterfield, 2015. Pers. Comm. Suzanne Butterfield is employed by Calderdale Council as a Land Manager) illustrated that the neighbouring district of Calderdale owns a smaller area of moorland at Norland Common, also managed for public recreation and enjoyment. Calderdale Council holds no information on users of Norland Common (Butterfield, 2015. Pers. Comm.)

Further documents obtained from CBMC (2013) suggest that the council owns, or at least manages, other areas of fringe moorland in the district at Penistone Hill (Oxenhope), Keighley Moor (Keighley) and Harden Moor (Bingley).

Within 30km of Ilkley Moor, further areas of moorland on the urban-fringe, that are not municipally owned, can be found around Saddleworth, Marsden and Holmfirth forming part of the National Trust's Marsden Moor estate.

This study proposes that these urban fringe moorlands are different from the wild high moorlands of the remote North Pennines, Peak District and Scotland. This study aims to investigate whether these areas of "urban-fringe" moorland should be managed differently to their counterparts located further away from the population. For example, Holden *et al.* (2007) claim that a current trend in management of moorlands is the process of ditch blocking, and the creation of boggy areas. At both Ilkley Moor and Norland Common ditches have been cleared on a regular basis, to allow drainage of the moors, to promote a safe walking environment for the general public (Perham, 2013 Pers. Comm.) Which in turn has altered the vegetation and dried out the less boggy soils.

For the purposes of this study, urban fringe moorland is described as moorland that is located within relatively easy access of sizable areas of population, usually at the interface between town and countryside. Bryant *et al.* (1982) refer to this as "The City's Countryside".

Natural England (Edwards, 2007) studied recreational users on the National Trails that they manage, classifying their users into the following:

- 6% Amblers (visit length <1 hour)

- 44% Ramblers (visit length 1<4 hours)
- 50% Scramblers (visit length >4 hours)

The National Trails are generally based away from the urban fringe moorlands in the wilder environments of the UK. This study shows that user data from these does not apply to the “urban fringe” moorlands. One can spend an hour at Whetstone Gate car park, one of the main access points to Ilkley Moor, and watch users come and go. It is quite rare to see anyone spending more than one hour on the moor, and very uncommon to see someone spending more than four hours at the moor. This exercise suggested that Ilkley Moor may have a different type of user to the more remote moorland locations.

This study aims to discover who uses these areas of urban fringe moorland and what factors affect user numbers, as one of the first steps toward providing more information which can potentially be used for management.

1.1 Statement of the problem: need for more information on visitor numbers

In recent years there have been calls for accurate data on visitor numbers at a range of wilderness attractions from a wide range of authors (Ankre *et al.* 2016; Cessford and Muhar, 2003; Jones and Ohsawa, 2016; Kajala *et al.,* 2007; Miller *et al.,* 2017).

Information on user numbers at outdoor attractions could be useful for a range of purposes including:

- Improvement of recreation opportunities (Ankre *et al.,* 2016).
- Management of the environmental impact of visitors (Cessford and Muhar, 2003).

- Assessing visitor contributions to the local economy, bringing jobs and economic prosperity (Bateman *et al.,* 2006; Comley and Mackintosh, 2014; Jones *et al.,* 2003; Schanger *et al.,* 2017).

- Understanding how the use and contribution of recreational areas [health, economic etc.] can perhaps defend them from alternative competing land uses (Eagles, 2014; Mackintosh *et al.,* 2016; Schanger *et al.,* 2017). In the case of the Pennine moorlands this could be agriculture, forestry, shooting or water collection (Holden *et al.,* 2007). Records show that in the 1950s there was a planning application to drill for natural gas on Ilkley Moor (West Riding County Council, 1953).

- User numbers are useful for solving user group conflicts (some of which are highlighted in the Literature Review chapter, p. 17), improvement of recreation facilities and to allow the managers to ensure that the land evolves to meet trends and changes in recreational use (Kajala *et al.,* 2007).

- Data on visitor numbers is highly important to assess the relevance and economic value of different ecosystems and landscapes. Bateman *et al.* (2006) and Jones *et al.* (2003) claim that accurate user numbers provide data for the provision of efficient management and capital allocation.

- Resource allocation and the supply of appropriate visitor facilities (Schangner *et al.,* 2017).

- Avoidance of visitor crowding and people management (Hadwen *et al.,* 2007).

- Data required by EU Biodiversity Strategy 2020 (Maes *et al.,* 2013).

Though all these justifications for counting user numbers have been put forward, neither CBMC nor Calderdale Council could provide any substantial information on user numbers for the moors they manage. This is a worrying pattern repeated at a wide range of sites. Jones and Ohsawa (2016) claim that there is a lack of data on Japanese nature based tourism and Miller *et al.* (2017) claim that there is a lack of visitor monitoring in coastal country parks in Sweden.

Schagner *et al.* (2017) created a Europe wide geo-database of visitor counts (discussed in the Literature Review Chapter, p.17). They called for visitor count data to be submitted to their database. When complete, this study will be submitted to this database to assist recreation managers, academics and other interested parties in the understanding of these "urban-fringe" moorlands. The International Union for Conservation of Nature (IUCN) is presently also gathering funding for a global nature site user database (Schangner *et al.,* 2017).

1.2 Statement of the problem: need for research into moorland in urban fringe areas.

Large cities and conurbations are often within reach of less developed areas where the local population may seek refuge, relaxation and escape from their urban lifestyle (Figure 1.1, p. 7). Many of these areas are generally designated as "country parks". However, there are often other areas that fall outside of this designation; areas of semi-wilderness trapped between the urban fringe and moorland, mountain, fen or wetland. Often this area of urban fringe may be part of a larger body of land, for example, Ilkley Moor is a small area of the larger, more remote Rombold's Moor complex.

These areas are often not fully covered by the literature that covers their more remote counterparts. The Literature Review in this work demonstrates that there has been a good deal of research into uplands and moorland (e.g. Charman, 2002; Holden *et al.*, 2007; Tallis, 1997; Taylor, 1983). These works often suggest management tactics to improve conservation or shooting quality, but overlook recreation offered by these, often smaller, areas of urban fringe.

Another large body of literature exists discussing the use and management of municipal parks and recreation facilities (Cohen *et al.*, 2007; Honold *et al.,* 2015; Larson *et al.* 2016). This often refers to local parks within walking distance of users' homes. Urban fringe moorlands often require the user to drive a short time to access them. Figure 1.1 (p.7) shows the proximity of northern cities to areas of moorland.

As can be seen in Figure 1.1 (p.7) many Lancashire and Yorkshire Towns and Cities are within 10km drive of a block of Pennine moorland. For example, the Peak District comes within 10km of Sheffield City Centre and a 10km drive from Manchester would bring people to the edge of the Pennines. A 10km drive from Blackburn would see the driver in the Forest of Bowland or a 10km drive from Bradford would see people on the Thornton or Howarth moors.

Urban fringe moorland managers, such as McDermott (2017. Pers. Comm. William McDermott is a Local Farmer and Game Keeper) and Perham (2013. Pers. Comm.), agree with literature such as Leung *et al.* (2015) and Smallwood *et al.* (2011) in claiming that more reliable and comprehensive data is required about moorland users. To provide some of that required data, this study looks at the numbers of people who use an area of urban-fringe moorland, how their use varies over time, and the effect of weather conditions.

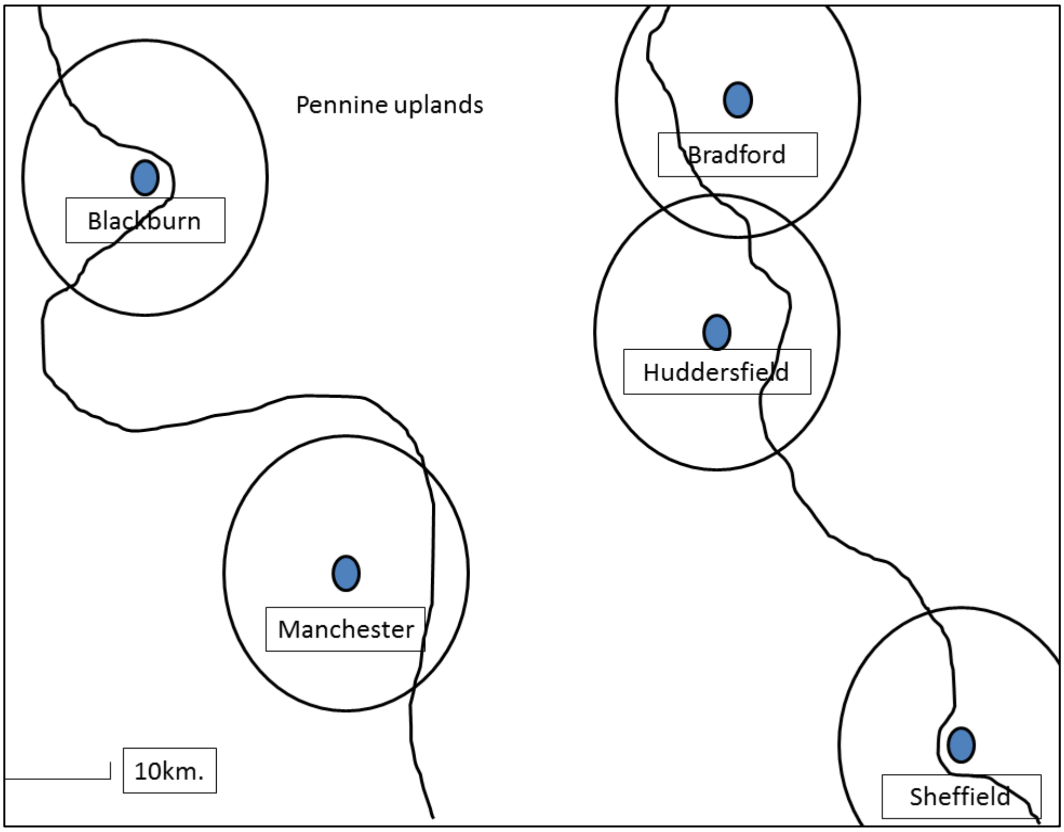


Figure 1.1 Proximity of Northern Towns and Cities to areas of upland.

1.3 Classification of moorland

Many local terms exist for moorland: Charman (2002) and Taylor (1983) use the term mire, Tallis (1997) uses peatland, and Holden *et al.* (2007) use moorland, sometimes interchangeably with upland. Older local residents use the terms bog or mire, whilst other residents use the term mountain [although this has been ruled out, as UK Government classification of a mountain is over 600m, Ilkley Moor being 450m]. The European Union (EU) and Department for Environment Food and Rural Affairs (DEFRA) class uplands as Less Favoured Areas (LFAs) from an agricultural subsidy point of view (DEFRA, 2010). This work will use the terms ‘moorland’ when describing the area and ‘peat’ when describing the soil.

Britain's peat landscapes, both moorland and lowland fen, cover an area of 25,000km^2; this equates to 10% of the world's total (Taylor 1983). Tallis (1997) reported that only 3% of the world's surface is covered by peat and goes on to note that a combined area of up to 3,500km^2 of British peat is in a state of erosion.

Charman (2002), Holden *et al.* (2007), Tallis (1997) and Taylor (1983) describe moorland as land with base deficient peat soils and sensitive ecological systems. Both Holden (2007) and Taylor (1983) describe the formation of peat as taking place in areas of high rainfall and underlying impermeable rock. Charman (2002) claims that, in Britain, peat up to eight metres thick has been observed. Banister (1985) found peat in the survey area up to four metres thick. Holden (2007), Tallis (1997) and Taylor (1983) discuss the processes of peat formation and accumulation which is outside the scope of this work.

1.3.1 Access to moorlands

Under the Countryside and Rights of Way (CROW) Act (2000) all moorland became classed as open access land over which any member of the general public has the right to roam. Moorlands are generally managed for red grouse shooting (*Lagopus lagopus scoticus*), upland agriculture, forestry or water collection (Holden *et al.,* 2007). This potential conflict is highlighted in the Literature Review (chapter 2, p. 17).

1.4 The survey area

This study focuses on Ilkley Moor, an area of moorland owned and managed by CBMC. Ilkley Moor is a constituent part of the larger Rombolds Moor complex. Figure 1.2 (p.10) shows the study area in the context of its surroundings.

CBMC (1998) claim that this is the world’s most famous piece of moorland due to the local song “On Ilkley Moor Bah Tat”. The study area is 903,937m^2 (using Google Earth Pro polygon tool). In 2006 the CBMC archive was flooded destroying most documents relating to the moor (Perham, 2013. Pers. Comm.) Copies of all surviving documents are with the author.

Under the 1976 Local Government Act (Local Government Act, 1976) Ilkley Urban District Council (IUDC) and Ilkley Moor became part of City of Bradford Metropolitan Council (CBMC, 1988).

This survey area was chosen as it is in public ownership, so documents and information should be readily available. The area was known well by the author and is easily accessible.

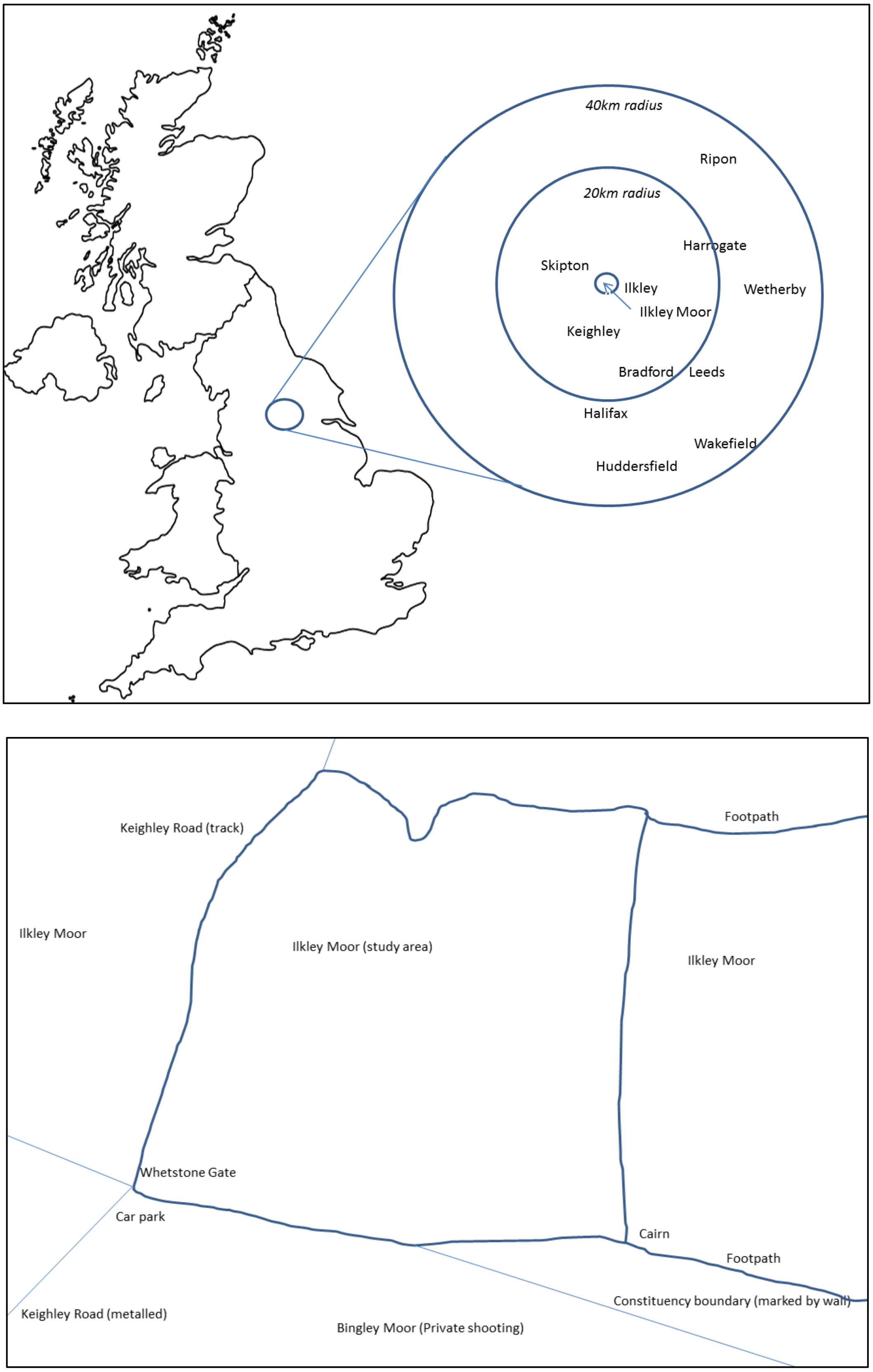


Figure 1.2: Location of Ilkley Moor within the UK and proximity to local towns and cities (top). Large scale view of the study area (bottom).

1.4.1. Previous research in the study area

Whilst little research has been conducted on users of the moor, there is a large body of research around the ecology and geology of the moor, partially due to its ownership and ease of access, physically and legally. Previous research on the moor includes: Smith and Rankin (1903) who produced a vegetation map, Dalby *et al.* (1971) created biological resource maps, CBMC (1977) conducted vegetation surveys, as did Hale and Cotton (1988; 1993) and Cotton and Hale (1989; 1994), Wharfedale Naturalist Society (1993) conducted bird surveys, and CBMC (1989) carried out a recreational impact assessment.

1.4.2. Recreational impacts

CBMC management plans (CBMC, 1977; 1988; 1998) suggest that this particular area is being damaged through erosion and high visitor use. An article in the Independent (Ritson, 1988, p.21) claimed that:

> “[Ilkley Moor has] rubbish all over the moor and no bins to put it in”

Many moorland areas have experienced significant degradation, erosion, flooding and loss of biodiversity due to their management (Holden *et al.,* 2007). Many implications arise from the degradation of moorland communities. The major implications are:

- Habitat loss and conservation issues (Yalden, 1981)
- Global climate change [carbon storage] (Heathwaite, 1993)
- Loss of grazing land (Yalden, 1981)
- Loss of reservoir capacity (Labadz *et al.,* 1991)
- Discolouration of drinking water (Pattinson *et al.,* 1994)

There is a consensus among researchers to suggest that access to the countryside provides a range of health and wellbeing benefits. The Countryside Recreation Network (2016) claims that access tends to have a calming effect in reducing stress and mental health issues. Hines (2017) claims that access to countryside and open space offers the user restoration from mental fatigue and an improved sense of wellbeing. Dustin *et al.* (2010) claim that access to the countryside can reduce obesity, assist with high blood pressure and heart problems. The health benefits of green space were raised at Prime Ministers questions on 6th September 2017, where the member for Faversham called on the PM to consider access to green space for all. The PM responded in agreement that there is ever more recognition of the link between green space and mental wellbeing, citing a DEFRA report due to be published (Commons Hansard Debates, 2017 col. 628).

These and a range of other papers make claims that the countryside has a calming effect on the user, although very few offer empirical evidence to back up such claims. Korpella *et al.* (2014) claim that there is evidence to suggest that there is a link between outdoor recreation and emotional wellbeing, but also claim that further evidence is required to attribute causality.

1.5 Research questions

1. **How does visitor use vary over time?** To predict user numbers on the moor and provide adequate facilities, resources and management of the area it is essential to know how time factors affect users. For example, if users are concentrated around one particular point in time, perhaps management can use publicity to extend this time period and try to alleviate potential overcrowding [leading to a more pleasant user experience]. Alternatively, management could ensure that

maintenance works are undertaken outside these key times or that there is a managerial presence during peak usage.

Knowledge of user times would also be useful for stakeholder management. For example, red grouse (*Lagopus lagopus scoticus*) shooting could be scheduled away from peak recreational user flows.

Time factors considered in this study are: Day of the Week, Month, Season, Year, Holidays (religious, bank and school) and Weekends.

2. **How are visitor numbers affected by weather?** To further predict user numbers in these moorland locations it would be useful for managers to be able to understand the impact of weather on visitor presence. Using the data from this study combined with long range weather forecasts, predictions could be made of potential user numbers. This could then lead to appropriate resource allocation. In addition, the long term impacts of climate change could perhaps be predicted through understanding users' sensitivity to climatic factors.

Climatic factors considered in this study are: Temperature, Dew Point, Humidity, Wind Speed, Wind Direction, Visibility, Rain, Fog, Cloud and Sunlight.

3. **Can amenity use be predicted?** The study will develop the outcomes of research questions 1 and 2 and build several models to predict future moorland usage from time and weather variables. The outcome of this exercise may be useful for a range of management processes such as resource allocation and funding applications.
4. **Who uses the moor?** Evidence would need to be collected on the types of user and their activity while in the survey area. The data is critical for understanding the

user groups on the moor. When managers understand the user groups in the area managed, they can begin to understand the stakeholder conflicts that arise among users and find ways to alleviate resolve or avoid such conflict.

The first two research questions lead directly into the third question, the outcome of the third and fourth question link directly into “urban fringe” moorland and other urban fringe area management plans (demonstrated in Figure 1.3).

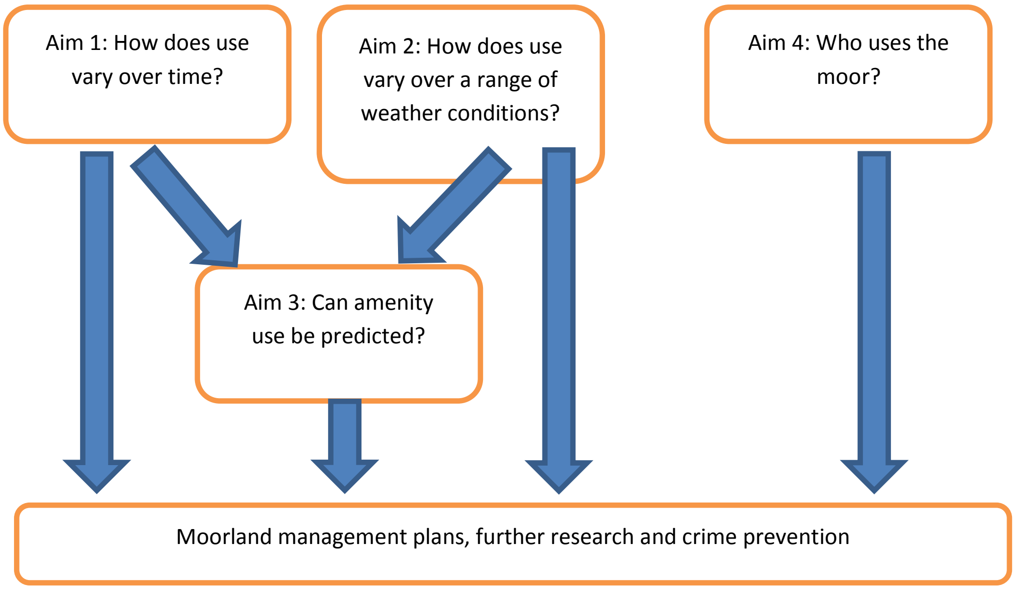


Figure 1.3: Relationship between the aims and wider use of this thesis.

As demonstrated in Figure 1.3 the first two aims link directly into the third aim, since without accurate information on time and weather variables it would be impossible to predict user numbers. However, each of the first two aims also link directly into management plans and further research.

1.6 Organisation of the study

The study took a two part approach. The MPhil (2011-2014) element considered a range of impacts on “urban fringe” moorland. These were discussed in the MPhil-PhD transfer report (Appendix one, p.240). The PhD element of the study (2014-17) focused on user numbers.

Data gathered in the MPhil work was used to inform and create the PhD study. The Discussion Chapter (Chapter Seven, p. 172) brings both elements of the study together, considering the knowledge gained in both elements of the study and making recommendations in light of other works.

This study is presented in eight linked chapters (Figure 1.4, p. 16). Chapter One (p. 1) sets the scene, develops the aims and gives the reader an introduction to the problem. This is then built on through an in-depth Literature Review (Chapter Two, p. 17) around moorlands, their history, present usage and development. The Literature Review links into the data collection strategy (Chapter Three, p. 43) where more literature is considered, and appropriate data collection methods are developed.

Then follows two results chapters (Chapters four, p. 76 and five, p. 109), which are seen as autonomous as neither depends on the other for its outcome. Whereas, Chapter Six (p. 144) depends on both Chapters Four and Five to try to develop predictive models of moorland usage. Chapters Four, Five and Six are then summarised and discussed in Chapter Seven (p. 172), the discussion, with contributions from the MPhil study. Conclusions are drawn from this work, further opportunities for study are highlighted and further recommendations are made in Chapter Eight (p. 207).

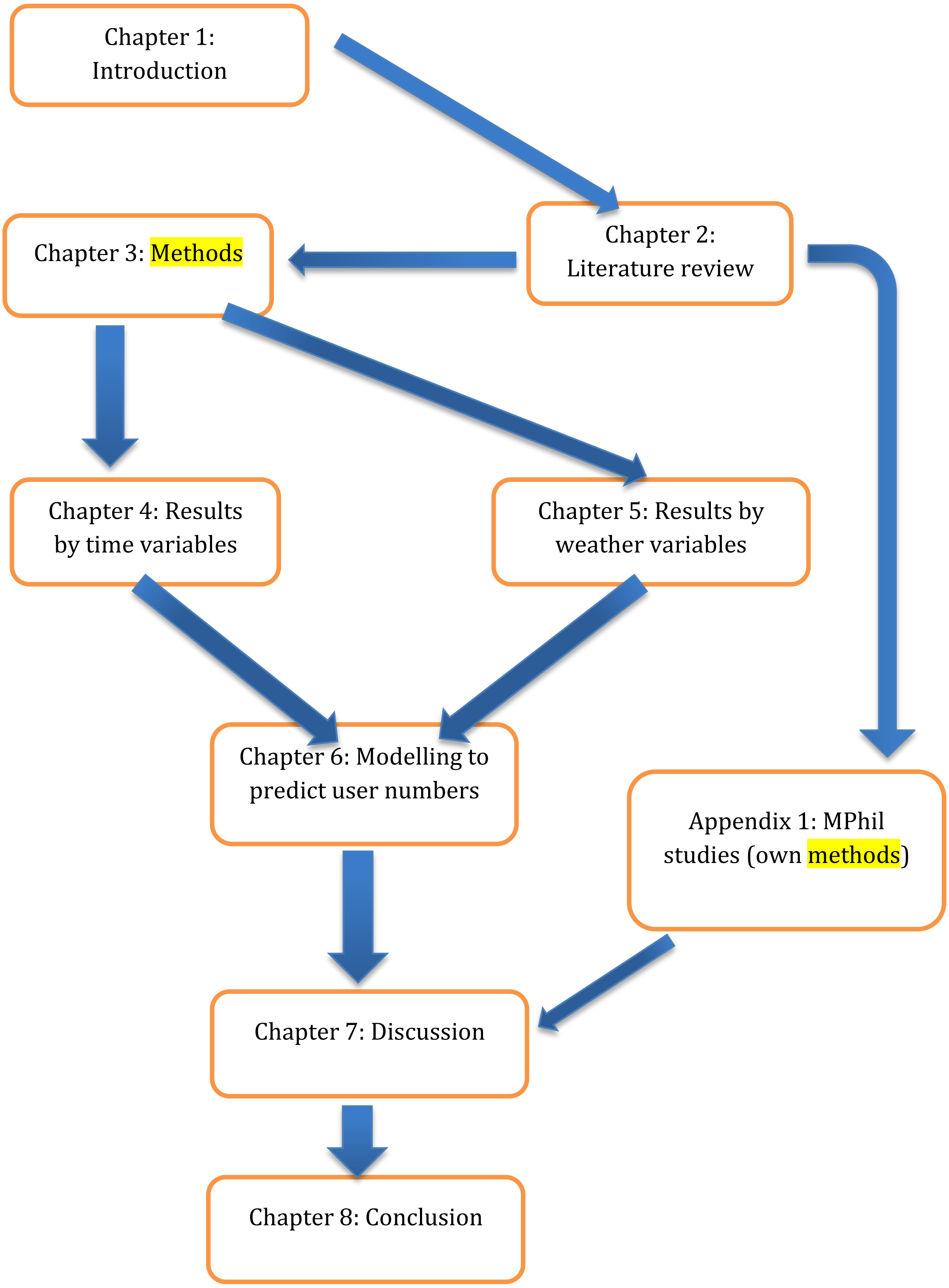


Figure 1.4: Structure of the PhD thesis.

Chapter 2 : Literature Review; the impacts of recreation on moorlands

2.1 Moorland Management

Until recently the countryside was managed for agriculture, quarrying and shooting: two pursuits that kept the moorlands fenced in and private. MacEwan and MacEwan (1982) give an account of political events that were to open up the countryside to the general public:

> "In the 1932 ramblers from Manchester and Sheffield, organised a trespass onto Kinder Scout, executing what has become known in folk lore as 'The Mass Trespass'. The effect of this event, similar events and public demand led to the 1949 National Parks and Access to the Countryside Act" (MacEwan and MacEwan 1982, p.8).

Brown and Sheaves (1995) stated that the 1949 act opened up the countryside to many from urban areas and encouraged them to take part in recreational activities on the moorlands. This opening of moorlands did not affect the status of Ilkley Moor, as it had been open to the general public since 1893, when it was given to the people of Ilkley (CBMC, 1998).

Traditional management of moorlands has included rotational heather burning to create a patchwork of varied age heather growth. McDermott (2017. Pers. Comm.), Perham (2013. Pers. Comm.) and Wilkinson (2004. Pers. Comm. Edward Wilkinson is a local farmer) agree that this management practice focuses on creating prime habitat conditions for red grouse (*Lapogus lapogus scoticus*) as this species requires a diverse age structure in the heather to feed, nest, roost and raise young. Douglas *et al.* (2015) and the Moorland Association

(2006) claim that UK grouse moors are a unique, un-replicated environment and need to be stocked to >200 birds per km^2 to achieve an economic shoot.

Heather burning is a major area for conflict between Ilkley Moor stakeholders, with McDermott (2017. Pers. Comm.), Perham, (2013. Pers. Comm.) and Wilkinson, (2004. Pers. Comm.) making contradictory statements about the benefits of heather (*Calluna vulgaris*) burning. Academic arguments for continuation of burning practices are given below:

- Reduces wildfire risk (Boer *et al.,* 2009)
- Controls forest succession (Sah *et al.,* 2006)
- Enhances grazing pasture (Augustine and Milchunas, 2009)
- Enhances game breeding grounds (Kilburg *et al.,* 2015)
- Mimics natural wild fires (Williams *et al.,* 2012)

However contrary to these arguments, research shows the following are negative impacts of heather burning:

- Soil erosion (Cawson *et al.,* 2012)
- Alteration of soil processes (Neary *et al.,* 1999)
- Decreases in water quality (Battle and Golliday, 2003)
- Air pollution (Tian *et al.,* 2008)
- Habitat and biodiversity impacts (Suarez and Medina, 2001)
- Long term loss of a carbon store (Lindsay *et al.,* 1998)
- Detrimental to sphagnum (*Sphagnum sp.*) moss communities (Grant *et al.,* 2012)

Altangerel and Kull (2013) weigh up these positives and negatives, concluding that there is not accurate data for the extent of burning across the UK and there is concern that burning could release carbon from the peat soils. Bain *et al.* (2011) claim that there are around 3.2 billion tonnes of carbon stored in the UK peat reserves. DEFRA (2007) currently recommend burning in small strips up to 2 hectares, in 10–25 year rotations.

In 2016 local residents and moorland users successfully petitioned CBMC to stop burning heather on Ilkley Moor (Change.org, 2016). Several papers have assessed the alternatives to heather burning: Cotton and Hale (1994) compared various heather (*Calluna vulgaris*) cutting and flailing methods with burning on Ilkley Moor, concluding that cutting was less effective as there was a one year time lag for cut heather to catch up with burnt heather. They also discovered that where heather was flailed at ground level rejuvenation was less successful than following a burn, this is contrary to the actions of CBMC. Douglas *et al.* (2015) demonstrated that burning for game management in UK uplands had increased at a rate of 11% per year from 2001 to 2011.

Local land manager, McDermott (2017. Pers. Comm.) disagrees with some contemporary literature claiming that the side effects of moorland burning are: more grasses [*Molinia sp.* and *Agrostis fescue*, enhanced grazing] for sheep (*Ovis aries*) grazing and easier walking for recreational users. Davies *et al.* (2016) call for informed and unbiased debate around the role of burning in moorland management. They claimed that the debate over the use of fire in moorland management is highly charged and will not be resolved until more research is conducted into the longer term effects of burning, the media stop twisting research for political aims, and stakeholders discuss the issue in a constructive manner. Holden *et al.* (2016) agree with Davies *et al*. (2016) that informed and unbiased debate is required. However, they claim that Davies *et al.* (2016) misrepresented Holden *et al.* (2007) research into burning. Monibot (2016a; 2016b) takes this further, criticising the Davies *et al.* (2016) paper and suggesting that, in addition to environmental impacts, moorland burning and game shooting is a social class division and that burning sustains an impoverished habitat at the expense of richer ecosystems that would otherwise prevail.

Modern moorlands are used for a wide range of activities; Holden *et al.* (2007) list these as: agriculture, arboriculture, country sports, recreation, water collection and military training. However, Holden *et al,* (2007) fail to note that these land uses are usually inter-twined and that one land use often works alongside another, for example shooting, water collection and farming. It is often the case that one sustains the other. A farmer may be paid subsidies by the local water authority to support their farming practices in a way that does not compromise water quality (McDermott, 2017. Pers. Comm.). Burt (2001) agrees and notes that until recently land use has been seen as a block singular function. Burt also claims that in more recent times land users have had to share areas of land, and claims that there are a *“wide range of interests now operating in the countryside”* (p. 276). Ratcliffe and Thompson (1988) add that the Pennine moorlands are of national and international significance for their conservation value. With these competing interests from a range of stakeholders McDermott (2017. Pers. Comm.) notes that there are significant conflicts of interest among countryside users in this area and in the country as a whole. He cites a recent killing of a peregrine falcon (*Falco peregrinus*) in Nidderdale (20km from the survey site) as the result of poor planning and communication between the shooting estates and conservation/reintroduction projects. The Guardian claims that the Royal Society for the Protection of Birds (RSPB) logged 200 similar crimes against birds of prey in 2015 (Barret, 2017). McDermott also goes on to cite situations where ramblers have wondered through farmsteads, dogs have attacked sheep, and other incidents where stakeholders have come into conflict with rival groups.

Holden *et al.* (2007) point out that there are drivers of change both facing and having faced moorland managers, and note the key changes as: changes of livestock, hardier breeds of sheep that can survive longer seasons on the moor etc. McDermott (2012. Pers. Comm.) shows that the reality, in this area, contradicts Holden *et al.* (2007) comments that sheep are kept on the moor for shorter periods than they used to be due to less demand

and a change in agricultural subsidy from the Common Agricultural Policy to the Cross Compliance scheme. Holden *et al.,* (2007) also claim that current managerial responses to change include gully and ditch blocking, moving from burning to flailing (this is in contradiction with Douglas, (2015) who claimed to have evidence to suggest an 11% rise in burning) grazing and reforestation. On Ilkley Moor, CBMC have installed new ditches down either side of Keighley Road (western perimeter of the survey area) and in places on the top track (southern perimeter of the survey area).

A large area of the moor, outside the survey area (to the west), has been forested in a 1952 planting scheme by the Forestry Commission (Ministry of Agriculture Forestry and Fishing, 1952). CBMC have also moved away from burning toward flailing heather (CBMC, 2012b; Change.org, 2016). These actions, which are contrary to the Holden *et al.* (2007) current management thinking, may be as a result of this particular moor being owned by a municipal body and managed for the favour of voters rather than for conservation.

2.1.1 Ilkley Moor management

Management plans have been obtained for Ilkley Moor (from CBMC), which state management priorities as: Conservation, Shooting and Recreation (CBMC, 1998). Where these three priorities are in conflict, conservation should take priority. However, there is no recognition of what should take priority when shooting and recreation may have come into conflict. Shooting has been a controversial issue on Ilkley Moor, with regular campaigns among the population of Bradford Metropolitan District calling for gun sports on the council controlled moor to be banned (Jackson, 1995). This has been from the general population (Change.org, 2016) and has been used by politicians such as George Galloway [former MP for Bradford West] as part of political campaign strategies

(Wainright, 2012). From 2012-2016, CBMC banned shooting on the moor, resulting in a loss of income of £40,000 (CBMC, 2016). In 2016, shooting was re-introduced, with the rights being re-let to the neighbouring Bingley Moor Estate for £10,000 per year (CBMC, 2016). Shooting on the moor is a highly political class issue within the Labour majority council. Currently there is a Facebook campaign with 3,582 members petitioning CBMC to stop the shoot (facebook.com/stoptheshoot, 2017). Bingley Moor Estate claims that while they shot the moor on six days in 2011, their management of the moor was carried out on all 365 days (CBMC, 2012a).

The 1998 management plan was heavily influenced by an article in The Independent on the 25th February 1988, *“Ilkley Moor shows signs of wear and tear”* (Ritson, 1988). While this article was generated in response to one subjective letter to the newspaper’s editorial column, CBMC as land managers, responded with a survey of 100 visitors on the August bank holiday weekend in 1989 (CBMC, 1989). The survey found that 42.5% of visitors claimed that they visit the moor more often than once a month and the majority of people felt that footpath erosion was the major issue on the moor.

The 1989 survey concluded that this moorland’s sphere of influence only extended to the local population and that the vast majority of visitors stayed on the edges of the moor; 11.3% reach high moorland, 65% on foot and 15% picnic. These figures are of interest as the high moorland is the survey area, and picnicking could be a source of litter, a recreational impact on the moor. However, this survey was conducted on one weekend from a range of 52, did not assess use from weekday only traffic and only surveyed the first 100 people across the whole moorland area. The data from this survey cannot be seen as representative of all modern moorland recreation users. While the 2013 survey had a larger population, it was still limited to 381 users across 7 summer days. This would not accurately be able to show user preferences outside the summer season.

2.2 Environmental impacts of visitors on moorland

2.2.1 Recreation on the UK moorlands

Following the Mass Trespass (1932) (described in MacEwan and MacEwan, 1982) and the National Parks and Access to the Countryside Act (1949) described in Brown and Sheves (1995), the 2000 Countryside and Rights of Way (CROW) Act (2000) allowed free access to the vast majority of British moorland for all, giving the right to roam across vast swathes of open moorland. For a while before this act, academics raised concerns about open moorland access. Gliptis (1995) calculated that only 10% of the country's population could read a map. This inability to read a map could lead to major health and safety issues on the moors, particularly in the more isolated areas. This lack of understanding had previously been raised by authors such as Donzelot (1979) who proposed a tutored access system, whilst Ravenscroft (1995) proposed a managed environment. If Donzelot or Ravenscroft's access systems had been adopted, then the Countryside and Rights of Way (CROW) Act (2000) may not have been approved on economic grounds. McDermott (2012. Pers. Comm.) suggests that unguided use of the moorland can be dangerous and calls for everyone *"who comes up here"* to be *"properly trained and tested"* [In map reading and navigation]. He goes on to cite several cases of people being lost or dying on the moor, due to naivety and incompetent moorland skills. McDermott's opinion can be supported through the records of the Upper Wharfedale Fell Rescue Association, showing that the rescue team were called out 43 times, accumulating 1851 man hours, in 2013 (Upper Wharfedale Fell Rescue Association, 2013) [Upper Wharfedale covers the Rombolds Moor complex, and the southern edge of the Yorkshire Dales around Bolton Abbey].

Access to open land has been linked with quality of life, public health and social diversity (Bathe, 2007). However, Bathe also suggests that 55% of open access land is also registered as Sites of Special Scientific Interest (SSSI), highlighting the conflict between amenity and conservation values.

2.2.2 Changes and impacts on vegetation

Holden *et al.* (2007) claim that moorlands are often referred to by their species; for example grouse or sedge moors, and they note that moorland habitats can be categorised into one of the following; heathland, mire, bog, or acid grassland. Holden *et al.* (2007) give a guide to why plant communities develop. These include; precipitation, gradients, drainage, management, wildfires and grazing pressure. Smith and Rankin (1903) first mapped Ilkley Moor for vegetation in their vegetation map of the former West Riding of Yorkshire [modern West Yorkshire, areas of South Yorkshire, Saddleworth and Craven Districts] which should be used as a guide rather than an exact reference, as their map has very low resolution. Woodhead (1929) gives a history of vegetation on Pennine Moors and their journey from woodlands to the 1929 state of heather (*Calluna vulgaris*) dominance.

The Manpower Services Commission (MSC), under the direction of Fidler *et al.* (1970), produced a vegetation map of Ilkley Moor. The MSC volunteers were trained in plant recognition by Cotton and Hale (1989), but inaccuracies may occur in this survey from lack of comprehension of their vegetation identification training. Banister (1985) took peat cores from the moor for analysis and provides vegetation data from 10,000 BP (before present) to 1985. Leeds University (Perham, 2013 Pers. Comm.) set up transects on the moor, between 1961 and 1969 to measure the advance of crowberry (*Empetrium nigrum*) and bracken (*Pteridium aquilinum*). Their study called for concern over the spread of these plants, but was not published. Hale and Cotton (1988) created transects on the moor to investigate how to encourage heather (*Calluna vulgaris*) rejuvenation.

Comparison of the Smith and Rankin 1903 map, and the 2010 CBMC management map show a large reduction in heather (*Calluna vulgaris*) with an increase in bilberry (*Vaccinium myrtillus*)(MPhil, Appendix 1, p.265). Cotton and Hale (1989) discuss vegetation change on Ilkley moor, noting crowberry and bracken as a threat to the moor. This generally agrees with literature demonstrating a reduction in heather (*Calluna vulgaris*) on other moorland areas (Anderson and Tallis, 1981; Fyfe *et al.,* 2014; Holden *et al.,* 2007; Littlewood *et al.,* 2014). Anderson and Tallis (1981) claim that this general change in vegetation is from a change in sheep stocking densities. However, this does not fit with other literature, such as the study by Milligan *et al.* (2015) who believe that removal of sheep would not automatically increase abundance of key species, and state that some species require interventionist approaches.

Work has been undertaken to assess the impact of erosion on generic moorland footpaths. Dixon and Hawes (2015) claim that hardening surfaces of paths generally stops the spread of the path into bordering vegetation. This is a method that CBMC have used on some pathways, however it is a costly exercise (CBMC, 1998). Worryingly, Sterl *et al.* (2008) surveyed 271 users regarding their usage of the Donau-Auen National Park in Austria, finding that 60% of their sample was unaware that footpath erosion was an issue. In the Peak District National Park user survey (Peak District National Park, 2005) they found that 97% of people did not stray away from the footpath.

2.2.3 Impact on animals

Gutzwiller (1991) noted two methods for studying the impact of recreation on bird populations, observational and experimental, suggesting a note of caution with experimental studies. The majority of studies in this field are observational (Finney *et al.,* 2005; Innies, *et al.,* 2016; Pearce-Higgins and Grant, 2006; Thearme *et al.,* 2001).

Pearce-Higgins and Grant (2006) discuss the relationship between moorland birds and moorland vegetation, concluding that losses in heather over the last two decades have significantly impacted upland species. However, McDermott (2017. Pers. Comm.) suggests that only red grouse (*Lagopus lagopus scoticus*) actually live on the grouse moor, the other birds just feed on the moor. So, Pearce-Higgins and Grant's (2006) conclusions may be focused on the feeding aspect of the other species. Thearme *et al.* (2001) discuss the management of moorlands for grouse and the subsequent effects on other birdlife; they conclude that such management practices as burning, flailing and beating are unsuited to meadow pipit (*Anthus pratensis*), skylark (*Alaunda arvensis*), whinchat (*Saxicola rubertra*)and crows (*Corvidae*). The comments of Pearce-Higgins and Grant (2006) and Thearme *et al.* (2001), are in conflict with McDermott (2012. Pers. Comm.), the local game keeper, who suggests that he sees many crows and other birds feeding on the local grouse moors. When presented with the statements made by Thearme *et al.* (2001), that management of moorland is not compatible with a range of other species, McDermott (2012. Pers. Comm.) agreed stating that game keepers have used management techniques that involve killing other species, pointing to a case on a nearby moor that had recently been reported in the press where a gamekeeper had been convicted of killing a peregrine falcon *(Falco peregrinus)*.

Brown and Shepherd (1991) conducted a breeding bird survey of the South Pennine moorlands. They noted the significance of these moorlands as a breeding hotspot for upland birds, which is in contrast to McDermott's (2012. Pers. Comm.) suggestions. Anderson (1990) looked into disturbance of birds from recreation in the Peak District, while Yalden and Yalden (1989) noted that recreation creates some disturbance for moorland birds. Watson (1991) criticised the scientific basis of Yalden's claims; claiming that their arguments of lower bird counts near paths is likely to be as paths tend to avoid boggy or wet areas of land, where birds may be more likely to frequent, rather than the implication that walkers on the paths had unsettled birds. Howarth and Thompson (1990) reviewed factors associated with distribution of upland birds in the South Pennines, noting that topography is the major factor in bird distribution. Calladine *et al.* (2014) produced a report on upland birds, noting that there was no convincing evidence for a negative effect on moorland birds from nearby mining activities.

In 1995, the Nature Conservancy Council (NCC) stated that the South Pennine moorlands area held 8.7% of Britain's breeding merlin (*Falco columbarius*), 3.1% of Britain's breeding golden plover (*Pluvialis apricaria*) and several peregrine falcons (*Falco peregrinus*) (Brown and Stillman, 1998).

Bradford Council (CBMC, 1977; 1998), Wharfedale Naturalists (1993) and Bradford Ornithological Group (No date) have all produced notes of birds that are seen on Ilkely Moor. These surveys cannot be compared to show change over time, as each uses different survey areas and different counting methodologies. A coordinated method, such as all adopting the British Trust for Ornithology (BTO) Breeding Bird Survey (BBS), would have allowed for comparison and the creation of a valuable model to assess bird population change over time. This is further discussed in 8.2 Further work, p. 210.

Taylor *et al.* (2005) state that, wherever people walk dogs, it is inevitable that there will be canine exposure to wildlife. Shaw *et al.* (1995) agree, adding that canine exposure to wildlife can include effects such as trampling vegetation, altered soil conditions and alterations in water quality. Banks and Bryant (2007) believe that on-leash dog walking can decrease bird species by 41%, with ground nesting birds being the prominent species to show decline [eg. red grouse (*Lagopus lagopus scoticus*) is ground nesting], although this is an Australian study and different bird species may react differently to canine disturbances. As this study and the CBMC (1988) study indicate a high number of dog walkers there is potential conflict between the grouse shoot, ornithologists and dog walkers.

2.2.4 Erosion impact

Brown and Sheaves (1995) noted that there have been a number of research projects looking at the environmental impact of recreation; e.g. Burden (1972) on destruction from foot erosion, Watson (1982) reporting on the disturbance to habitats and Yalden (1981) on the potential loss of flora and fauna as a result of recreational walking. The CBMC (1988) study highlighted that users felt there was an issue with erosion on the moor. However, Perham (2013. Pers. Comm.) believes that these issues are being managed through the use of hard surfaced paths in the survey area.

Holden *et al.* (2007) surveyed over one hundred peat restoration and monitoring projects. This information was used to create a publicly accessible database of restoration techniques. They suggested that peat restoration is often carried out in order for governments to meet European biodiversity targets. They also note that peat restoration is a slow process; this is contested by Perham (2013. Pers. Comm.) who claims that his peat restoration projects have been seen to be working within a year. However, Perham's

(2013. Pers. Comm.) comments are derived from personal observations, with no empirical measurement or evidence to back up his claims.

2.2.5 Impact of litter

Anderson and Brown (1984) look at the psychology of dropping litter, suggesting that noise, overuse and encounters with others were the main causes of dropping. Perham (2013, Pers. Comm.) stated that there have been no monitoring of litter or faeces on Ilkley Moor during his time as manager. He also claims that there is not a litter problem in the survey area. Fourteen percent of the visitors in the 1989 survey (CBMC, 1989) are reported to have considered litter a problem on the moor. An article in The Independent (Ritson, 1988), discussed earlier in this work, noted that the moor had an unappealing volume of litter. The CBMC (1989) response to the 1988 study highlights the fact that it would be awkward to place bins on the moor as they would need to be added to a bin collection route for regular emptying, suggesting that over-full bins may have a worse effect than no bins at all.

A range of litter sampling techniques can be found in the works of Golik and Gertner (1992), Merrell (1984), Velander and Mocogni (1999) and Willoughby *et al.*, (1997). Velander and Mocogni (1999) discuss 16 methods of litter counting, with varying degrees of accuracy. While their survey looked at beach litter it is possible to implement some of these methods in a moorland context.

2.3 Use and Economic impact of Pennine Moorland

2.3.1 Agriculture

As discussed in 2.1, agriculture has traditionally played a large part in moorland management with moorland used for grazing sheep (*Ovis aries*) (Holden *et al.,* 2007) and tougher breeds of cattle (*Bos Taurus*) such as the saler breed. Cumulus Consultants, on behalf of RSPB (Cumulus Consultants, 2012) and Holden *et al.* (2007) acknowledge that upland farms are increasingly introducing hardier breeds of sheep and cattle onto moorland. Cumulus Consultants (2012) stated that hill farmers are generally cutting down on the number of cattle while increasing sheep on moorland and moving toward indoor or lower land for over wintering (in contrast to comments made by Holden *et al.* (2007), discussed in 2.1, p. 17). Cumulus Consultants (2012) also note that there is a decrease in hill farms, and a subsequent decrease in employment, but do not offer any figures to support these claims.

Khan and Powell (2010) claim that there are 3,914,000 hectares of rough grazing land in the UK, which is 25% of the total 15,333,000 hectares used in UK agricultural production. Higgs (1976) provides an overview of the development of upland agriculture in Europe. DEFRA (2010) and Dwyer *et al.* (2015) agree that the state of upland farming in the UK is in decline, with the average upland farm only providing 49% of the farmstead's income. Dwyer *et al.* (2015) report most farmers having considered some form of diversification and 21% of upland farmers did not expect their business to continue beyond the next five years.

Thompson (2009) warns that if the financial reward of sheep farming does not increase there will be a consequent reduction in upland agriculture and notes the impact that this may have on plant control. Farm Business benchmarking data, provided by Askham Bryan

College (2016) for Yorkshire and Lancashire, indicate that the average upland sheep makes a margin of £43.80 [based on 66 flocks surveyed in the 2015 harvest year]. Another issue affecting upland agriculture is succession, with Yorkshire Dales National Park Authority (2004) claiming that the average Dales farmer was 55 years of age. Dwyer *et al.* (2015) report on the state of Exmoor farming, stating that there is no direct succession for 27%, and questionable succession for 36% of Exmoor farmers. While Exmoor is 400km from Ilkley Moor it is likely that the same issues are faced in many upland areas.

Dwyer *et al.* (2015) give a good overview of the various farm payments schemes; from the UK Hill payment of the 1950s, through the Common Agricultural Policy, both designed to increase agricultural output, to the current basic payments scheme. They note that the basic payments scheme is a subsidy based on land area rather than per head of sheep or cattle as in the previous schemes. The NFU Hill and Upland Farming Group (2014) argue that farming plays a critical role in the management of the uplands, dictating its appearance, accessibility and economy; they feel that for the last two decades hill farmers have wrongfully been ignored or considered as a problem in moorland management. Calladine *et al.* (2014) claim that while there has been considerable investment in agri-environment schemes with outcomes for moorland bird habitats, there has still been a decline in bird abundance.

On Ilkley Moor, sheep quotas are monitored by Bradford Council and “gates” are auctioned off yearly [a gate is the right to keep two sheep on the moor] (McDermott, 2017. Pers. Comm.) A freedom of information request has been submitted to the council asking for copies of agricultural incomes from Ilkley Moor but no response was received. However, Perham (2013. Pers. Comm.) noted that this was a minimal income. The byelaws of Ilkley Moor (Ilkley Urban District Council (IUDC), 1954) give the right for common grazing on areas of the moor, so some sheep and cattle seen on the study area may not be revenue generating for CBMC.

2.3.2 Sport (Grouse, Pheasant etc.)

As previously discussed in 2.1 the moorlands have been extensively managed for grouse shooting. This has been a controversial practice in the case of Ilkley Moor, an area of land owned by the people of Bradford district, traditionally a Labour stronghold. Newspaper reports have been published in the local area both for and against shooting (Langan, 1997; Ritson 1997; 1998). While these newspaper reports contain many opinions and are not peer reviewed, they show that shooting on the moor has been an important topic of debate for local residents. CBMC (2012; 2016) record their incomes as £10,000 per year from letting the shooting rights.

2.3.3 Recreation

Recreational use of Ilkley Moor is probably the most predominant use; however, there are only the 1989 and 2013 surveys of the moorland recreational users. The 1989 survey counted 100 respondents on one summer bank holiday Monday (CBMC, 1989). The 2013 survey took a slightly broader approach considering seven days of data collection in July and August (it is not clear if these were consecutive days) and surveyed 391 people (CBMC, 2013). The 2013 survey asked people if they used the moor in different seasons, however neither survey counted people in any other season than summer. Neither survey considered weather variables and neither survey considered holidays / school holidays. The surveys probably also suffer from a high auto-correlation, for example the 2013 survey suggests that 18% of the respondents only use the moor in summer – this may not be an accurate reflection of real moorland use as the survey was only conducted in summer, not giving representation to potential users who only use the moor in other seasons.

The surveys are also based on honesty, asking people: Did you leave the main track? Why are you using the moor? What activities are you undertaking? In response 96% of people said they never left the main track, and no one reported that they were using the moor for any dubious activity. This may be a limitation in their survey methods as both McDermott (2017. Pers. Comm.) and Perham (2013. Pers. Comm.) report anti-social activity and other minor crimes on Ilkley Moor. However Peak District National Park, (2005) found that similarly 97% of people stayed on the track in their user study.

Comley and Mackintosh (2014) estimated that on average a visitor to the outdoors in the UK spends £3.21 [in 2012, £3.57 in 2017 with inflation], (Bank of England, 2017), whereas the Peak District National Park (2005) estimate the average daily user spends £9.81, [£13.03 at 2017 values (Bank of England, 2017)]. Very little data is published regarding the economic impact of outdoor pursuits in the uplands. There is no data showing how much the average person spends on a trip to Ilkley Moor. However, the 1988 CBMC survey data show that people do not travel far so may bring their own packed lunches and supplies or return home for food. Retail outlets on the moor are: A café, pub and ice-cream bar at Whitewells on the Ilkley side of the moor and a pub on the Riddlesden side of the moor. The landlord of the Willow Tree at Riddlesden claims that he does receive occasional customers who have been walking their dogs on the moor; however exact numbers could not be provided. Even with the existence of the 1989 and 2013 CBMC surveys, freedom of information requests to CBMC in 2013 and 2017 show that they are unaware of the number of visitors to the moorland complex.

There have been relatively few attempts to provide simplistic moorland use data: North Yorkshire Moors National Park (NYMNP) (2014), provides data for 2013, suggesting that there are 40 million visitors per year to the upland national parks, spending £1.78 billion on their visits [£44.50 on average per person]. Their report does not give detail of which national parks are classed as upland, and the figure £44.50 per person on average is significantly higher than the £3.21 Sport and Recreation Alliance figure quoted earlier. It may be that the NYMNP figure includes overnight accommodation in their account; this is unclear in their text. On a broader scale, Schagner *et al.* (2017) estimate that two billion recreational visits were conducted to national parks across Europe in 2015, with these consumers spending €45billion. This would be a €22.50 spend per person [£20.64 at 04.09.2017], again slightly higher than the sport and recreation alliance estimate (Comley and Mackintosh, 2014), but lower than the NYMNP quote. This may be because Schanger *et al.,* (2017) looked across a range of European nations, with a range of wealth and pricing strategies.

Saayman and Viljoen (2016) proposed a typology for recreational users, categorising them as: Admirers, Adventurers and Amateurs suggesting that categorisation would help wilderness managers to market to, and cater for appropriate user groups. However, compounding the range of users into three simplistic groups may not cater for the needs and requirements of all users. Perhaps this system could be modified to include sub-groups for example: Adventurers could become the overall group, but then be divided into hikers, cyclists, climbers, off roaders etc.

2.4. User numbers at other remote attractions

In 2000 Arbinger and Brandenburg (2002), using aggregated methods, counted that there were 400,000 users of the Lower-Austrian section of the Danube National Park. This count used a combination of data collection strategies [video, observation, network maps and infrared sensors]. They used 15 minutes from each one hour recording of video to create an aggregated total time; this may have led to reduced accuracy in their count data. Smallwood *et al.* (2011) provided destination and path use data for users of the Ningaloo National Park, Australia during 2010. Their data came from 1208 site based interviews, and this was then aggregated to represent a 24/7 count, so the reliability of the count data may be open to question. Cole and Daniel (2003) call for more information on visitor numbers to national parks and wilderness areas, citing the current data as 'sketchy', claiming that the majority of data is based on verbal surveys and aggregated data – they go on to suggest that accurate user information would be highly useful in the development of simulation models to enlighten management planning. Orellana *et al.* (2011) provide spatial data using GIS software for movement of users across the Dwingerlderveld National Park, Netherlands, discovering that 85.9% of users took a route that included a geographical feature of the park. This data was provided using visual observations that did not run for the full 24/7 data collection period. Again, the data provided is aggregated and may not be a true representation of the movement pattern across the full time of the survey. For example, is the movement distribution different at night time? Do different days have different distribution patterns? Orellana *et al.* (2011) suggest that generally visitors spend around seven minutes in the car park. Smallwood *et al.* (2011) provide data for users in the Ningaloo Marine National Park, Australia [for the year 2007], counting visitors from an aircraft with which 34 random flights were made over the year (all departing at 08:00 hours), three per month extended to four during peak season [April –

October]. They go on to give user information; stating that this is an expensive method of data collection and again uses aggregation. An issue with the Smallwood *et al.* (2011) study is that aircraft could be seen to cause a disturbance to users of the study area and could potentially cause modification in their behaviours. Bishop *et al.* (2001) suggested a novel approach to visitor planning which involved the creation of an accurate virtual environment model where the virtual visitor is presented with a series of choices. Their choices are then monitored and their path decisions analysed – however a virtual environment may not realistically take into account fatigue, weather conditions or other moorland users, which may limit the accuracy of their results.

Taczanowska *et al.* (2014) tried to provide recreational user numbers for the Tatra National Park, Poland. Again, they use an aggregated counting method [surveying on 15 random days over a year]. While their count data may be inaccurate because of the aggregated data collection method, they produced some useful guideline statistics about moorland users, claiming that 41% visit at least once a year, 52% were male, 60% had a higher education experience, the predominant age group was 16 - 30 and 85% lived in a city area. Their survey population suggested that the reasons for visiting included: escape from urban life, contact with nature, social time with friends, health benefits and physical activity. Over half, 52% of respondents, noted that silence was a motivating factor. These results cannot be seen as indicative of all moorland and general upland user groups as Muhar *et al.* (2007) found that rural Alpine recreationalists were generally older than shown in Taczanowska's (2014) Polish report, the average age being over 40.

Schangner *et al.* (2017) called for funding and more attention to be paid toward the science of user counting. Developing on this call, Schangner *et al.* (2017) started to develop a Europe wide database of user surveys, suggesting that the majority of current studies are characterised by "rudimentary" reporting. Schagner *et al.* (2017) provide evidence to show that there is a generalisation for managers to over-estimate user numbers. However, Lupp *et al.* (2016) provide contrary evidence, suggesting that there is a generalisation for management to under predict user numbers at wilderness attractions. [Sensors in this study had a tendency to overestimate user numbers (Table 4.3, p.78)].

2.4.1 Counting people

As discussed in 2.4.1 there are a host of surveys in wilderness locations, using a variety of methods. Arbinger and Brandenburg (2002) use a mixed methods approach (video, manual and infrared counts), Smallwood *et al.* (2011) and Orellana *et al.* (2011) used manual counts with Smallwood *et al.* (2011) using manual counts from aircraft.

Cessford and Muhar (2003) reviewed models for visitor monitoring in national parks and looked at issues with calculating visitor numbers in remote attractions, highlighting the various advantages and disadvantages of a range of electronic sensing equipment, along with the associated cost. Ploner and Brandenberg (2003) took visitor monitoring further, by modelling attendance by day and by weather. McDermott (2012. Pers. Comm.) and Perham, (2013. Pers. Comm.) noted that accurate visitor information is needed in a range of conditions [time and weather variables]. Cope *et al.,* (2000) split visitor monitoring into three categories; counting, profiling and surveying. Yalden and Yalden's (1989) study of The Pennine Way footpath users noted that 32% of walkers strayed from the defined footpath; but they also claimed that moorland users are widespread, and unpredictable in terms of their recreational interests [e.g. walking, running etc.]. However, CBMC (1998) claimed that footpath erosion is not an issue, indicating that people do not stray from paths, which agreed with the Peak District National Park report (2005) which stated that 97% of users did not leave the footpath. CBMC (1989) also classified visitors into three types [walking, cycling and running] which contrasted with Yalden and Yalden's view of moorland users as being widespread and unpredictable.

Davies (2006) provided user data for a range of remote moors across the Peak District. Their data was collected over six days across 2004/2005 taking into account peak and off peak periods. While not a full 24/7 user survey this is an improvement on the CBMC 1989 and 2013 attempts.

2.5 Summary of Literature Review

2.5.1 Moorland or Parkland

Through this Literature Review it has been demonstrated that there is a large body of work around moorland management, with some aspects proving to be controversial [eg. heather burning and grouse shooting]. There is literature, such as the work by Arnberger and Bradnenburg (2002), which has argued that nature attractions near large conurbations are different to the wild national parks, they attract different users, at different times and require a different managerial approach. However there appears to have been very little work that focuses on providing data for the management of 'amenity moorland'.

2.5.2 Summary of impacts and conflicts

This Literature Review has highlighted a range of potential impacts to moorland ecosystems, with a degree of conflict regarding the causes. A Table has been provided (Table 2.1, p.39) to give a summary of these impacts and the relevant literature.

Table 2.1 Summary of impacts highlighted in this Literature Review

Impact	**Cause**	**Key references**
Vegetation change	Sheep (disputed by Milligan and Thompson)	Anderson and Tallis (1981)
	Climate and management	Littlewood *et al.* (2014) Fyfe *et al.* (2014) Holden *et al.* (2007)
	Recreation	Dixon and Hawes (2015)
Erosion	Recreation	Yalden and Yalden (1989) Liddle (1997) Burden (1972) Watson (1991)
Decline in bird species and abundance	Recreation	Innies *et al.* (2016) Finney *et al.* (2005) Gutzwiller (1991)
	Vegetation change	Pearce-Higgins and Grant (2006)
	Management for grouse	Thearme *et al.* (2001)
Litter	Recreation	Golik and Gertner (1992) Velander and Mocogini (1998) Merrell (1984) Willoughby *et al.* (1997)
Upland agriculture	Decline in returns	Thompson (2009)

2.5.3 Summary of stakeholder conflicts

Stakeholder conflicts have been highlighted throughout this Literature Review. Table 2.2 gives a summary overview of the conflicts listed in this Literature Review.

Table 2.2 Moorland stakeholder conflicts

Conflict	**Key references**
Recreation and conservation	Bathe (2007) Sterl *et al.* (2008)
Sheep and heather conservation / vegetation change	Anderson and Tallis (1981) Milligan *et al.* (2015) NFU Uplands Group (2014) Yalden and Yalden (1989) Thompson (2009) Dwyer *et al.* (2015)
Grouse shooting and recreation / conservation	Ritson (1997) Langan (1997) CBMC (1998, 2012a)
User spending	North Yorkshire Moors National Park (2014) Peak District National Park (2005) Comley and Mackintosh (2014)

2.5.4 Conceptual framework

This Literature Review provides an overview of current knowledge around the moorland ecosystem, economy and general context. There is strong, often contradictory, literature regarding grouse management, agriculture, ecosystem services, recreational impacts on animal and plant populations and environmental impacts. However, there is very little data on user numbers. Smallwood *et al.* (2011) claim that understanding movement and numbers in parkland is a key dataset for management of the park. This will enable management to minimise recreational impacts and manage routes. A conceptual framework is given in Figure 2.1.

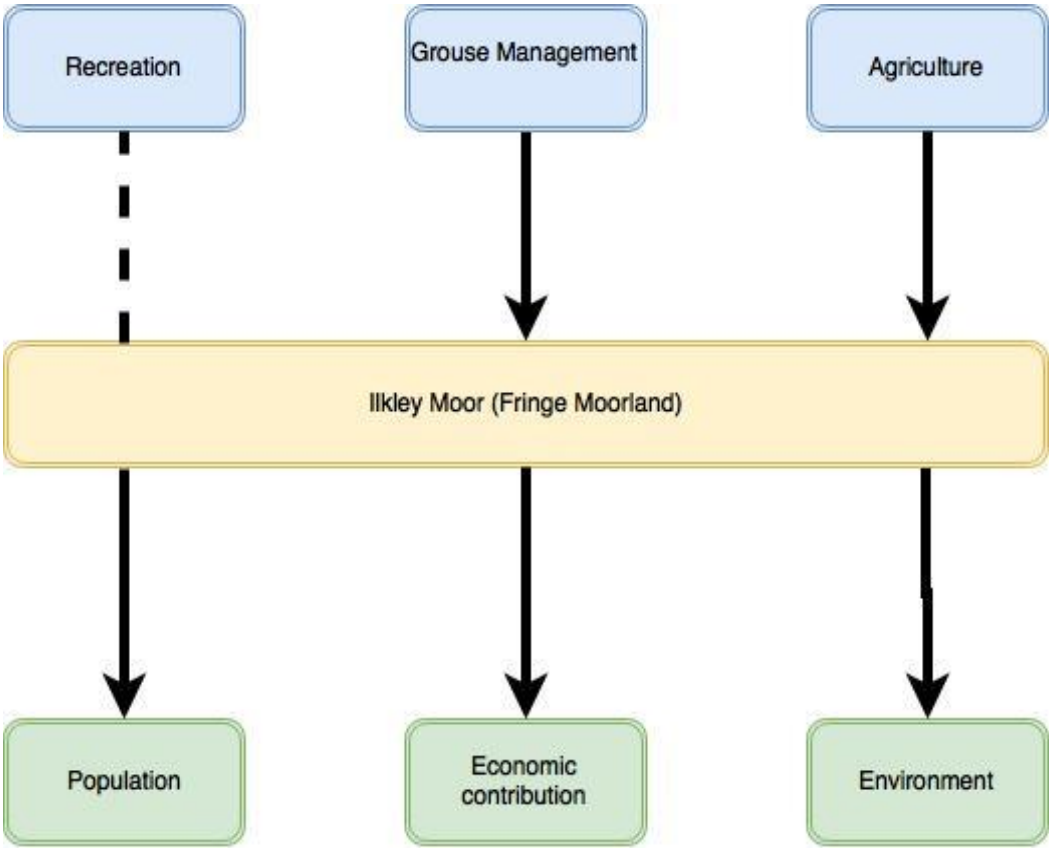


Figure 2.1 Conceptual Framework

This work aims to meet the academic calls made by Leung *et al.* (2015) and Smallwood *et al.* (2011) and the grounded calls of Perham (2013. Pers. Comm.) and McDermott (2017. Pers. Comm.) who call for more reliable and comprehensive data on moorland user numbers through collecting and providing information on moorland users. This work will concentrate on one urban fringe moorland, providing specific data for amenity moorland rather than data that cover all wild lands. The data from this project could then be used to inform future moorland management plans.

Chapter 3 Methods.

3.1: Research questions

The Literature Review showed that there is a gap in research around recreation on uplands (Figure 2.1, p. 41). Leung *et al.* (2015), McDermott (2017. Pers. Comm.), Perham (2013. Pers. Comm.) and Smallwood *et al.* (2011) call for more comprehensive data on moorland users. The Literature Review also showed that there is a large body of research around "wilderness" and remote moorland, but less research around "urban fringe" or "amenity" moorland. Some literature on public parks covers elements of "urban fringe" moorland, usually categorised with country parks. However, no studies to date give 24/7 user data for amenity moorland.

3.1.1 Previous similar works

People counting is a discipline that has many techniques and applications, from simplistic manual count data through to high tech tracking devices (Cope and Hill, 1997). In the commercial arena count data is used for metrics such as: footfall, conversion to sales, new retail location planning and human resource planning. A range of options are given below for counting people:

- Manual counts (Arbinger and Brandenburg, 2002; Cessford and Muhar, 2003)
- Simplistic automated counters (Cessford and Muhar, 2003)
- Areal counting, via drone or plane (Orellana, *et al.* 2011)
- Wifi tracking (Woo *et al.,* 2011)
- Mobile phone signal (Alzantot and Youssef, 2012)

- Video camera tracking* (Miller *et al.,* 2017; Xu *et al.,* 2010)
- Image background subtraction (Yao and Odobez, 2007)
- Infrared beam sensors (Amin *et al.* 2008)

**Amin et al. (2008) claim that visual cameras have inherent limitations such as lighting, and limited ability to process colours. They go on to claim that Infrared overcomes these issues, highlighting 18 experiments where infrared sensors have given a more accurate reading than a standard video camera.*

A range of suitable outdoor monitoring options are discussed in the works of Arbinger and Brandenburg (2002), Taczanowska (2014), Bishop *et al.* (2001), Smallwood *et al.* (2011) and Orellana *et al.* (2011). These are considered in the context of this project in Table 3.1 (p.45).

Kajala *et al.* (2007) published a guide to wilderness monitoring, suggesting the following methods: signs of use (a reactive approach, and difficult to quantify), guest books (only one hotel near the survey area and CBMC (1989) survey showed that most people travel within one hour to reach the moor so probably do not stay over when visiting Ilkley Moor), fishing and hunting licences (none issued in the survey area other than the grouse shoot), manual observation (time consuming and cannot provide 24/7 data), air observations (expensive and intrusive) or vehicle counters (not all visitors arrive to the survey area by vehicle), mechanical counters (a range of counters are discussed in Table 3.6, p.58).

This study is taking place in an area of open moorland that is used by members of the general public for their peaceful enjoyment and recreation. Any methods must be unobtrusive, legal and considered ethical. In addition, the use of any electronic devices would have to consider power supply sources, safety of equipment and reliability when left in a hostile (acidic peatland) environment for prolonged periods of time. One such unobtrusive method would be the use of buried pressure pads, as used by Millhausler *et al.* (2016) to monitor traffic at a Swiss national park between 2008 and 2015. This study could not use this style of counter as permission may not have been granted to dig and install this type of monitoring equipment.

Cessford and Muhar (2003) pull together numerous suggestions for people counting at outdoor attractions, which included: manual observation, camera recording, remote sensing, infrared, magnetic sensing, microwave (radio) sensing, visit registers, permits/bookings, indicative counts and interviews. This study has grouped the range of tools for visitor counting, provided by a range of authors, into three categories; Active, Reactive and Suggestive (Table 3.1).

Table 3.1 Grouping of potential count methods

Active	Reactive	Suggestive
Manual observation	Litter counts	Permits
Camera recording	Damage/erosion counts	Bookings
Remote sensing (Arial)		Visitor logs
Remote sensing (microcomputers) i.e. Infrared, microwave etc.		Interviews
Wifi tracking		
Mobile phone signal		
Image background subtraction (machine learning/image manipulation)		

While active counts could potentially establish an actual number of users, reactive counts could only ever predict a number of users that have visited an area in the past as it would be difficult to quantify the exact number of users from monitoring damage to an environment. Suggestive counts rely on the user to “sign up” and take part in these counts. If a user signs up to take part in a survey or count they might have a bias toward wanting to conserve the area or other motive. Not all users of the moorland would be willing to sign up to such a system. There is only one guest house near the moor at Whitewells, ~2km from the survey area and it is unlikely that many of the users of the survey area would have stayed there so using the guest book at that hotel would not be indicative of the survey area use.

For the aforementioned reasons, it has been decided that this study should only use active observation methods as the primary purpose of this data collection is to ascertain accurate usage numbers for the survey area. Table 3.2 (p.47) considers the active observation methods.

Table 3.2 Advantages and disadvantages of methods of observation methods.

Observation method	**Advantages**	**Disadvantages**	**Application to this work**
Video **(High cost)**	Gives an image of the user so user behaviours and activities can be understood. Night vision equipment could be used to give 24/7 surveillance.	Time consuming to analyse data. Would not guarantee anonymity of the general public as they could be identified from the video (leading to potential ethical issues). Video equipment requires large amounts of power and memory. Equipment often expensive and un-concealable.	This option has been ruled out as it does not give anonymity to participants, is costly to install and would require large amounts of power. Security of equipment could not be guaranteed as it is not concealable. Amin *et al.* (2008) argues against using video
Time lapse photography	Gives an image of the user, so user behaviours could be understood.	Time consuming to analyse data. Does not guarantee anonymity.	This option has been ruled out as it does not give anonymity to participants.

(Medium cost)	Night vision equipment could be used to give 24/7 photography.	Would require a heavy power source. Equipment often expensive and un-concealable.	Security of equipment could not be guaranteed as it is not concealable.
Human Observation (Aggregated data or high cost of man hours)	Considered reliable. Accurate if 24/7 counts are undertaken.	Expensive and time consuming. Would need to aggregate data if 24/7 counts could not be undertaken.	Option has been used in the MPhil study to give a base line assessment of the moorland usage. Option ruled out for the PhD study as it does not give 24/7 surveillance without large amounts of man power.
Micro Computer and sensors **(Medium cost unless own**	Small and can be concealed. Home-made devices can be created at low cost (see 3.3). Data can be downloaded for analysis in a .CSV file, does not need playback	Commercially built sensors are available but expensive.	This option has been adopted for the PhD phase of this study as this can be a relatively cheap solution (3.3) and gives 24/7 data collection.

sensors are used)	or interpretation. Large body of research around this area with regard to application in retail.		
GPS Sensor **(Low cost)**	Would show exact routes of users (even if modified through the observer effect).	Not all users would agree to carry a token or app etc. Relies on participant's informed consent to take part and carrying a GIS sender unit (i.e. a mobile phone or token). Informed consent could lead to modified behaviours.	This option has been ruled out as it would not be used by all participants and may be biased if certain groups are keen to use the technology, but other user groups are less willing to (or refuse) to embrace.
Mobile phone tracking	Would show high accuracy routes of users (not as accurate as GPS). Ideal	Legality issues around using mobile phone signal in the UK.	This method has been ruled out as it is potentially illegal.

(low cost)	over larger distances, such as the whole of Rombolds Moor.	Does not give anonymity.	
Virtual Environments **(Medium cost)**	Allows researcher to question participants about their choice of route in a controlled environment.	Behaviours and choices of direction may not be influenced by "real" weather or time conditions. Programming a realistic virtual environment accurately reflecting the survey area would be time consuming and expensive if contracted to a professional.	This method has been ruled out as it may not accurately reflect the choices made by "real life" users who are exhausted from walking, weather, time or other environmental conditions that may be apparent at the time of their physical visit to the moor.
Aerial observations **(High cost)**	Gives a clear view of the moor (on clear days) and can show what behaviours and activities people are undertaking.	Not anonymised. Flights would be dependent on weather. Expensive (cost could be reduced by using a drone rather than a light aircraft). Only gives aggregated data (unless aircraft was	This option was ruled out on a cost basis. This option was also ruled out as having an aircraft or drone overhead in this location could cause issues with the nearby RAF listening station at Menwith Hill.

		permanently above the moor). Aircraft or drone could be seen as obtrusive and lead to modified behaviours.	The method could lead to modified behaviours and alienation of the moorland users.

Some of the methods in Table 3.2 (p.46) could use either aggregated or 24/7 data collection methods. Aggregated counts are where data is collected for a smaller time period then multiplied to give a predicted use. This method has been used in the MPhil study, to give rough usage figures, and to justify the more in-depth second level PhD study. The PhD study used 24/7 data collection as this reported accurate user numbers. While this work used the term aggregated, Schagner *et al.* (2017) use the term “up-scaling”. This study acknowledges that these two definitions refer to the same phenomenon.

Machine learning could have been used with the video and photography techniques to speed up data processing. This is the process of the computer looking at an image or video and picking out a particular pre-defined set of pixels (i.e. a plant, tree or person). In this instance the machine would have to be taught to recognise a person. This would require large files with high resolutions to allow the machine to distinguish between person, path, animal and moorland. Very high resolution files would allow the machine to decipher the activity that the user was undertaking. However, accuracy of this may be questionable. Machine learning would not give anonymity as the researcher could identify the user before the machine scanned the image.

3.2: MPhil surveys

This project took a two phase approach, phase one (the MPhil element) provided aggregated user numbers based on three hours of manual observation over three vantage points across one day per month. These were then multiplied by weighting factors calculated on observations over all daylight time for a full week in January 2013 and two weeks (seven consecutive days) observations of half days in June 2013, AM and October 2012, PM. The data from the AM and PM observations is multiplied by two to give a full day of aggregated data. This can be seen in Table 3.3 (p.53). Note that this data is composed of aggregated data and therefore is not accurate but indicative of moorland use.

Table 3.3 Day weightings based on data from the MPhil

Day	June	October	January	Average	Percentage	weighting
Monday	51	30	17	32.7	54.8%	0.55
Tuesday	48	36	12	32	53.7%	0.54
Wednesday	57	28	8	31	51.9%	0.52
Thursday	43	42	1	28.7	48.0%	0.48
Friday	45	17	10	24	40.2%	0.40
Saturday	120	41	18	59.7	100.0%	1.00
Sunday	113	40	19	57.3	96.1%	0.96
Total	477	234	85	265.3		

Percentage is as a percentage of the Saturday counts. (The October PM and June AM counts have been multiplied by two to give a full day data.)

Example; if one Saturday there are 100 people on the moor, it would be fair to assume that the following Sunday there will be 96 people on the moor (100 x 0.96).

This method allowed recording of the type of activity that users were involved with, where they flowed and information on their impact. Key results from the MPhil phase are presented below (rather than in a results chapter) as this led on to and allowed further development of the phase two methods. The full results of the MPhil studies are contained in Appendix 1 (p.240).

The MPhil work gave figures for three hourly observations between Jan 2012 and March 2013, these can be seen in Figure 3.1.

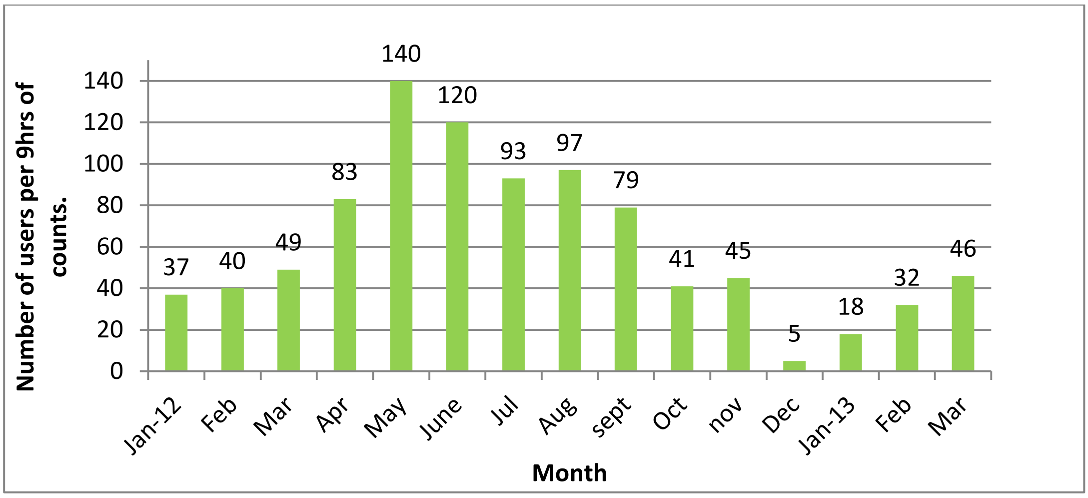


Figure 3.1 MPhil user numbers by month (based on 3 hourly counts)

On average the MPhil study showed that the moor was used by 62 people per survey day (with a standard deviation of 38.5).

Data from the MPhil study was open to criticism as many factors could have influenced the use of the survey area at the point of the counts (i.e. bad weather, a local football match etc). However, the MPhil survey provided valuable user data in terms of user activities (Figure 3.2).

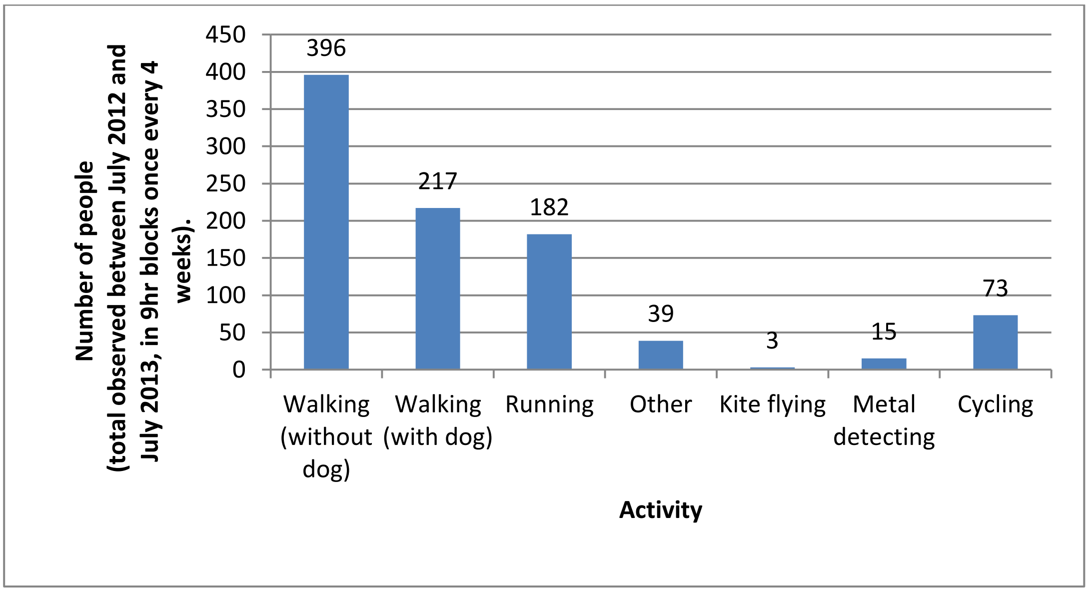
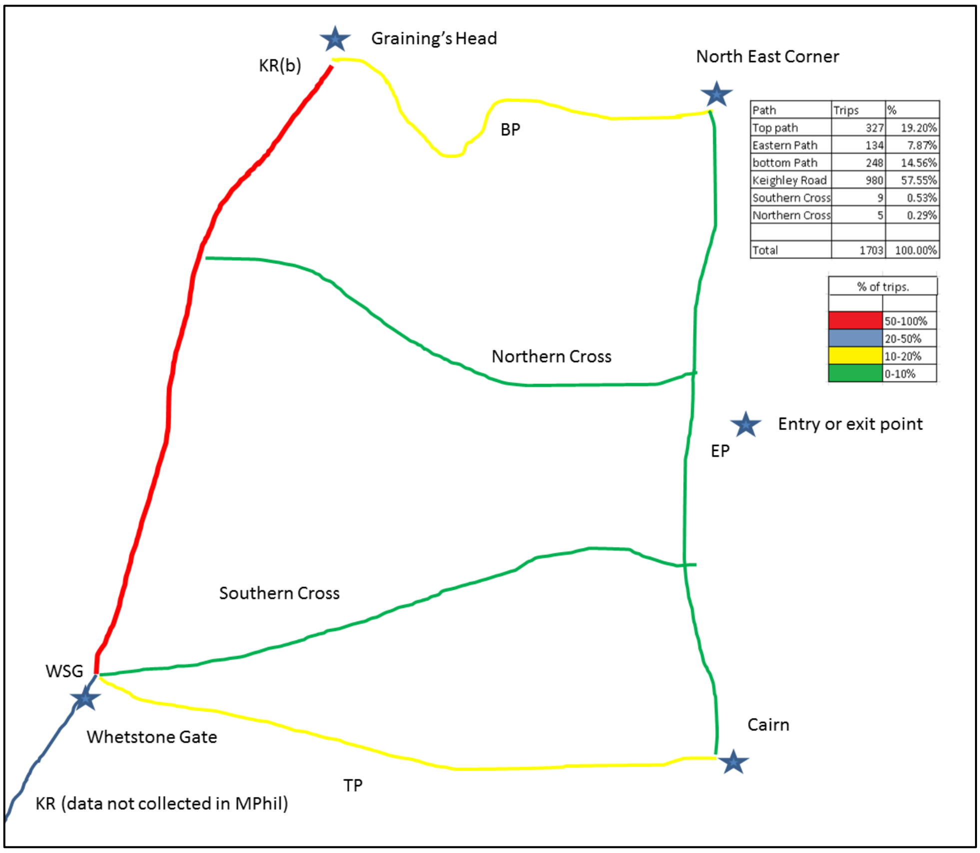


Figure 3.2 Users by activity (based on the MPhil data).

Note: Other category consists of model aircraft flying, picnicking, recreational drug use, off road driving and parking on the moor.

Data were collected showing where users visited on the moor. During observations no one was observed leaving the path. This may be due to the observer effect but at most times people would not have been aware that they were being observed. Moorland path usage is shown in Figure 3.3.



Path	Trips	%
Top path	327	19.20%
Eastern Path	134	7.87%
bottom Path	248	14.56%
Keighley Road	980	57.55%
Southern Cross	9	0.53%
Northern Cross	5	0.29%
Total	1703	100.00%

% of trips.	
🟥	50-100%
🟦	20-50%
🟨	10-20%
🟩	0-10%

Figure 3.3 Areas frequented by users (from MPhil data).

Often people took more than one path. The percentage is worked out as % taking individual paths against number of paths taken. If someone was to walk all the way around the perimeters of the survey area they would have taken 4 paths but been classed as one visitor. Entering a journey on one path, then reversing to the start classed as a trip on the path for reporting purposes.

Data were also collected on entry and exit points (Table 3.4).

Table 3.4 Entry and exit points (based on MPhil data).

Entry Point*	Count	%	Exit*	Count	%
Whetstone gate	401	43.35%	Whetstone gate	491	53.08%
Cairn	129	13.95%	Cairn	102	11.03%
North East Corner	82	8.86%	North East Corner	100	10.81%
Graining's Head	311	33.62%	Graining's Head	220	23.78%
Other	2	0.22%	Other	12	1.30%
Total	925	100.00%	Total	925	100.00%

*These points are labelled on the map shown in Figure 3.3.

3.3: PhD study plan

The second phase of this project used the data gained from the MPhil studies to locate microcomputer based data loggers across the moor to gather 24/7 information. These data could then be considered with time and weather data to provide 24/7 statistics on users in different time and weather conditions. Weighting factors could then be created from the MPhil data to give an idea of what users activities included in the survey area.

Thought was given to the use of video loggers at the survey area, however this raised privacy issues (Cessford and Muhar, 2003), power supply issues and computer ability to process the files (Bauer *et al.,* 2009). Microcomputers were used based on the arguments presented for and against the active methods discussed in Table 3.1 (p.45).

The MPhil study showed that the main point of entry onto the survey area was Keighley Road, so data loggers were placed at Keighley Road and Whetstone Gate. There was no evidence of anyone accessing the area through Whetstone Gate and turning left so data loggers were constrained to the right side of the moor. The MPhil showed very few people using the defined transecting paths to cross the survey area. These locations are exposed and offered very little scope for concealing data loggers. A decision was made to only count users traversing the perimeter paths. The MPhil survey also showed that users only accessed the moor from one of the four corners of the survey area so anyone using these transecting paths would be counted before they reached that path. Emphasis was placed on counting traffic at Whetstone Gate and Keighley Road as these showed in the MPhil study to be the highest use areas.

3.3.1: Data loggers.

Human traffic data loggers were priced for the project (ranging from £300 - £2,000 per unit). Even the cheapest of these were out of the scope of this project; an alternative approach was taken, to build bespoke data loggers. Microcomputers have been used with various sensors and card readers to provide a cheaper alternative to the commercially available data loggers.

At the start of this study (2012) the two main microcomputers on the market were the Arduino Uno and the Raspberry Pi. [Since this date many more have appeared on the market, often smaller and more powerful, such as the DigiSpark.] The Arduino was selected over the Raspberry Pi platform as Arduino is an open source freeware product that uses C Sharp programming language [the researcher had a little prior experience of this, but had friends with experience of this language] whereas the Raspberry Pi is a commercial licenced product. Table 3.5 (p.58) compares the two micro-computer options.

Table 3.5 Comparison of Arduino and Raspberry Pi microcomputers.

Computer	**Raspberry Pi**	**Arduino Uno**
Price	£65	£5
Programming language	Python	C++
Internet support network	Closed, some community forum	Open source, large community forum
Researchers personal support network	Low	High

A range of sensors were considered as potentially suitable for human motion detection, these are listed in Table 3.6, with a brief description and a range of considerations.

Table 3.6 A review of various microcomputer sensor options.

Type of counter	**Description**	**Appropriateness for this study**	**Notes**
Light	Detects changes in light (lumens)	Could be used at any point on the moor during daylight.	This method requires the moorland user to cast a shadow on the sensor (this could also be created by livestock etc.) Trials of the light sensor proved ineffective.
Active Infrared	A sender unit sends an infrared signal to a receiver unit.	Could be used across pathways	This method requires a sender and receiver unit to be positioned directly in line with each other. Any misalignment would result in no readings.

			Sensitive to adverse weather conditions (Dharmarjru *et al.,* 2001).
Passive Infrared (PIR)	A receiver unit detects an infrared signal emitted from users.	Could be used across pathways	This method is similar to active infrared but only requires one sensor (so no alignment issues) and uses less power. Sudden light changes may trigger false counts (Cessford *et al.,* 2002). *Weather patterns generally change gradually so there are low chances of sudden changes in lighting at the survey area.* May have difficulties counting closely walking people (Bu *et al.,* 2007)*. The calibration exercises proved that the average group size was one person.*
Thermal cameras	Camera detects heat from an object as it passes	Could be concealed in walls	Cope better with changing lighting conditions than conventional cameras, but are prohibitively expensive (Chan and Bu, 2005).
Laser	A sender unit sends out a laser beam, which is reflected off anything in the	Could be used across pathways	Lasers are known to be dangerous to sight, if the beam became misaligned and shone upward it could potentially blind a user.

	way (i.e. people)		Closely spaced users are usually undercounted (Bauer *et al.,* 2009). Limited in snow and fog (Chan and Bu, 2005).
Ultrasound / Echo	Sends out and measures distance of an ultrasonic noise	Could be used across pathways	Can be affected by air temperature. Doppler principle can be used to determine objects speed and direction (very complex process). Detection will vary based on detected persons clothing and weather conditions (Chan and Bu, 2005).
Radio / Echo sensor	Sends out and receives a radio signal, when the signal is broken there is an indication of movement	Could be used across pathways	Potentially obtrusive to animals (some dogs may be able to hear the sound), costly equipment. Issues with reliability and proof of accuracy (Bauer *et al.,* 2009).
Seismic / Pressure pads	Measures vibration or changes in pressure.	Could be used under boardwalk or stepping	Requires everyone to step on that particular board or stone to be counted. A pressure pad on a path may be

		stones	considered obtrusive. Some systems can differentiate pressures so would be able to choose between cycle, dog and pedestrian. (Dharmaraju *et al.,* 2001). Timers can be installed to eliminate dual counting from double stepping on the sensor pad (Bu *et al.,* 2007).
Inductive sensor	A copper loop is installed underground then when a metallic object passes through the field electromagnetic sensors detect a signal	Could be used on Keighley Road to detect cars.	Would involve digging the road up and associated permissions. Would only detect pedestrians if they were wearing / carrying something metallic (Kajala *et al.,* 2007).
Mechanical Counters	A clicker mechanism installed in gateways, boardwalks etc.	Could be used on the top path boardwalk and Whetstone Gate	Moving parts are subject to mechanical burdens (Kutti, 2012). Often need to be built into an existing structure (Cessford *et al.* 2002).

From the notes given in Table 3.6 (p.58) it was decided to trial three types of sensor (infrared (PIR), light and echo). Each of these three types of sensor was acquired and set up with an Arduino computer in the car park at Askham Bryan College, North Yorkshire. These were set to count human passes over a one hour period with a human taking manual counts as a control verification. The light sensor showed a lower accuracy than the other two sensors, which both showed 100% accuracy. A second test was conducted to see if the infrared or echo sensor had any impact on dogs. A member of teaching staff walked past the sensors ten times walking a range of dogs. The sensors only recorded one pass when both the human and dog passed through the sensor area, this may have been due to no break between the dog and the human. However, the process was repeated 10 times so should have compensated for this occurrence. There was no visible impact or change in behaviour of the dog when passing through the sensor field (echo or PIR). The echo sensor should have detected the dog, however the PIR sensor used was designed to sense infrared at higher rates than that emitted by a dog. Based on the trials and notes in Table 3.5 (p.58) the decision was made to use passive infrared sensors. A straight funnel lens was used to allow a rough line to be detected.

The hardware configuration included: an Arduino Uno, Infrared Sensor, SD card and card reader/writer powered through a nine volt battery. Micro computers were programmed using the Arduino freeware programming suite and adapting freely available code. This code follows a simple loop, where the Arduino computer repeated the same loop every second. The code can be seen with a line by line explanation in Table 3.7 (p.63). A simplified process is that the computer sends a signal to the sensor. If no one is present the sensor sends a signal back to the computer. If someone is present no signal is sent back. The computer receives the signal and goes back to sleep or does not receive the signal and writes to the memory card “Motion detected, Timestamp” then returns to sleep mode. This process is repeated at one second intervals. The period of sleep mode helps to conserve the battery.

Table 3.7 Line by line description of Arduino code.

Arduino Code line	**Explanation**
#Include <SD.h>	Command to begin set up process
#define PIRPIN 3	Receives signal from PIR sensor on port 3
#define TRIGPIN 2	Sends signal to PIR sensor on port 2
Void Setup	
{	Starts setup loop
pinMode (PIRPIN, INPUT)	Tells computer pin 2 is an input
pinMode (TRIGPIN, OUTPUT)	Tells computer pin 3 is an output
	Sensor Calibration
	Normal running loop
{(TRIGPIN, LOW)	No power to pin 3
Delaymicroseconds (100)	Wait 1000 microseconds
(TRIGPIN, HIGH)	Sends signal to pin 3
	Saving to SD Card
if(PIRPIN=HIGH)	If distance is lower than at setup
Whetstone1 = SD.open (“whetstone.CSV,	Opens .CSV file for this sensor location.

FILE_WRITE);	
Whtestone1.Printin (“Motion Detected”)	Write “Motion Detected” on memory
Whtestone1.print (“,”)	Adds comma after the text “Motion Detected”
Serial.Printin (Millis());	Adds time of motion detection
Whetstone1.Close();	Closes file
Delay(1000)	Delays for 1 second
}	Finishes and repeats the loop again

Time on Arduino computers is set in one second increments from when power is connected. The computer believes that when the computer is connected it is the start of time, at one minute the computer records this as 60 seconds, at two minutes the computer records this as 120 seconds etc. Highly accurate records needed to be kept of when the battery was connected to the microcomputer to understand the computer timestamp. The user records were then downloaded from the Arduino by changing the SD card and battery on a monthly basis. These CSV files were opened in excel, the time and date calculated using a formula and data cleaned for processing.

All batteries were wrapped in bubble wrap to insulate and prolong battery life, all equipment was shrink wrapped and housed in a Tupperware container with a packet of silica gel to control moisture. Sensors were the only exception; these had to be protruding from the box to collect their signal. All sensors were placed higher than surrounding vegetation to avoid false detections. Sensor areas were checked for obstructions on a monthly basis but no obstructions were recorded.

3.3.2: Counter locations

The sensor locations can be seen in Figure 3.4.

Keighley Road (KR)

A sensor was positioned on Keighley Road to count the amount of traffic passing up to the moor. This was placed at a point where the road narrows and after any turn offs, traffic passing that sensor could only be assumed to be accessing the car park at Whetstone Gate. This sensor was located inside a traffic bollard (shown in Figure 3.5a).

A magnetic sensor was considered for this location, as it may have detected cars and potentially weights/sizes to differentiate between car, van, motorbike and cycles. However, a magnetic sensor would not have detected traffic on foot using Keighley Road.

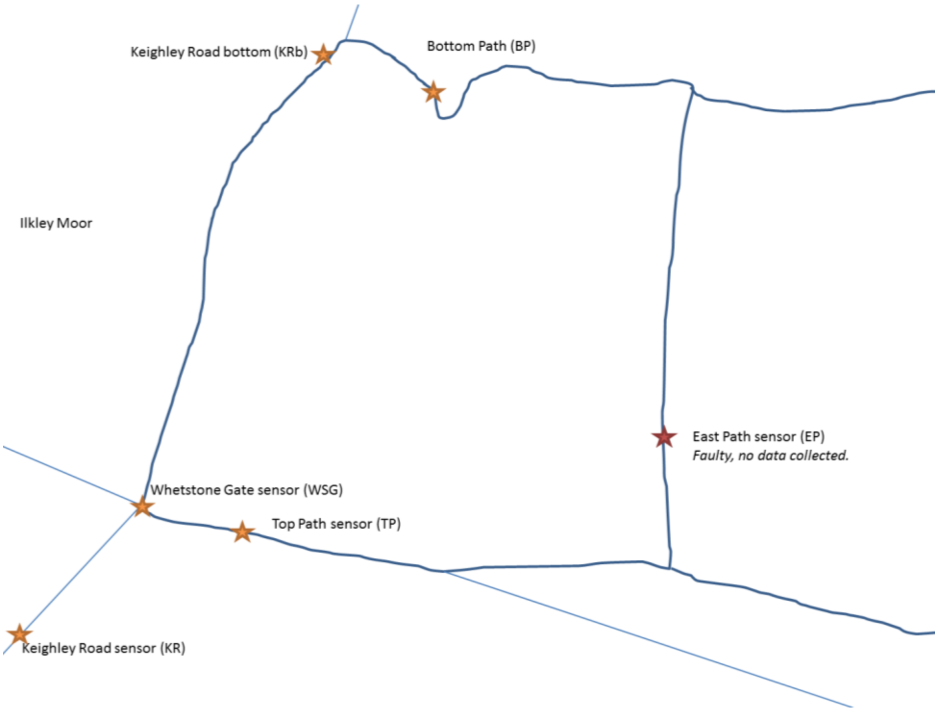


Figure 3.4 Sensor locations across the study area

Whetstone Gate (WSG)

A sensor was located at Whetstone Gate (shown in Figure 3.5b) to count the amount of traffic passing through the gate to or from the moor. This sensor was located on the car park side of the gate wall, the gate could only swing open on to the moor, this stopped the gate opening into the sensor area and minimised wrong counts.

Top Path (TP)

Two sensors were hidden in the dry stone wall on the top path, exactly one metre apart (Shown in Figure 3.5c). It was hoped that these sensors would provide data on travel speed between the two sensors in addition to visitor counting.

East Path (EP) (*no data used*)

A sensor was located at East Path (Shown in Figure 3.5d). However, this sensor could not be disguised in a natural feature so was mounted on a pole, driven 20cm into the ground. This sensor was removed or seen laying on its side on several occasions so data from this sensor was not used in this study.

Bottom Path (BP)

A sensor was located in the earth bank on the bottom path (Shown in Figure 3.5e). This was at a point where the path was against the banking and there was a drop at the other side of the path so all users would have to pass through the sensor field.

Keighley Road bottom (KR(B))

A sensor was located in the bank on Keighley Road, to the south of the point where the bottom path meets Keighley Road (shown in Figure 3.5f).

The sensors at Bottom Path and Keighley Road bottom were disguised by applying a coating of mud to the front of the Tupperware boxes (avoiding the sensors). From this point forward sensors will be referred to by their initials.

Figure 3.5a Keighley Road sensor (In traffic bollard).

Figure 3.5b Whetstone Gate sensor (In dry stone wall).

Figure 3.5c Top path sensor (In dry stone wall).

Figure 3.5d East Path sensor (inside post).

Figure3.5e Bottom Path sensor (in earth banking).

Figure3.5f Keighley Road (bottom) sensor (in earth banking).

Figure 3.5 Sensor locations

3.3.3: Overcoming anticipated flaws, anonymity and risks

3.3.3.1: Theft of equipment.

It was anticipated that there would be theft of equipment during the project. As a complete data logger cost under £20 this was not a financial issue, but a data loss issue. Data was backed up every month so at a maximum only one month of data would be lost. It was unfeasible to collect data more frequently than this, and batteries were found to not last much longer than this. Two spare data loggers were created to act as replacements for any stolen equipment. In the end, one of these spares needed to be deployed. During the duration of this study only one data logger was removed from the moor without the knowledge of the researcher. It is assumed that this was stolen. The missing data was dealt with in accordance with 3.5.1.

3.3.3.2: Faulty readings.

All data loggers were tested before deployment at the site. This was through counting people passing down corridors, through the wildlife gardens or through car parks at Askham Bryan College. All data logger results were validated through the processes discussed in 3.4. Patterned "anomalous" readings were investigated through subsequent visits to the moor at the time of these occurrences; for example at 0400 – 0500 hours, in early July sensors were regularly triggered on top path, Keighley Road and Whetstone Gate. The researcher visited the location twice at these hours in July 2017 [two years after the data collection] and confirmed that on both occasions there was user activity other than the researcher on the moor.

3.3.3.3: Distortion of data on special days

The data was analysed with anecdotal evidence that there are certain “high user” days on Ilkley Moor, where use is assumed to be higher than average, such as 1st August (Yorkshire Day), in 2014 potentially attracting over 300 visitors across the whole moor, not just the study area (Friends of Ilkley Moor Group, 2014. Pers. Comm. A discussion with various members at the study area). It was noted earlier about visiting the moor on 12th August (Glorious 12th, start of the grouse shooting season) by both sides of the shooting divide and 1st December (anniversary of Ilkley Moor alien sighting). While this may be seen as trivial this particular sighting has a large cult following. Data were analysed to compare these days with the average day. The results of this can be seen in Chapter Four (p.76).

3.3.3.4: Micro Electronic issues

Extensive testing was conducted and several projects completed by the researcher using this technology before this project was undertaken. These included counting the number of students passing through a lecture theatre door, setting sensors to detect movement on a scout campsite as a primitive form of intruder alarm and using sensors to estimate queues at a Cavebus attraction.

3.3.4: Downloading and storing the data

Data were retrieved from the sensors at monthly intervals. This was downloaded at the scene by swapping the memory card and battery, the used memory card being taken out and the battery changed to reset the clock and minimise the chance of battery failure.

Data were then taken to the researcher’s desktop computer and stored in a Microsoft Excel document for each sensor, with new tabs for each monthly download. These Excel documents were then backed up to two USB sticks, one normally kept at the researchers home and another kept at the researchers work premises to minimise the chances of all data loss.

3.4: Validation of the data

Through the survey period, the researcher randomly visited the survey location and manually counted visitors. This was recorded in a Google sheet from a mobile phone while at the location then checked with the main dataset once that months’ data had been downloaded.

On two occasions Askham Bryan College students visited the moor and spent several hours stood near a sensor manually recording data, in a replication of the sensor. The students were not aware of the sensor locations to avoid disturbance or tampering. The students’ data were analysed and compared with the corresponding sensor data once that month had been downloaded. There is a potential issue of the observer effect here, students physically observing may have changed behaviour. However, this method proved that the sensors were reliable and only lasted for short periods of time, so any modified behaviours during these few hours would not significantly affect the full PhD phase dataset spanning 15 months.

The student sampling exercise demonstrated the following accuracies: Keighley Road: 91%, Whetstone Gate: 89%: Top Path: 87%, Bottom Path: 94% and Keighley Road Bottom: 95%. These errors may be due to the students’ miscounting users rather than sensor errors. To ensure reliability, on both occasions, students worked in pairs, and the researcher and a colleague checked on students from a distance. Both student groups were considered to be trustworthy at the college. Matthews and Poigne (2009) reported similar error rates [97%, 86%, 85%, 84% and 64%] in a similar PIR counting exercise. While their sensors were set up in a shopping mall the technology is similar and the error rates are comparable. The validation exercises confirmed that the average group size in the study area was 1.02 persons.

3.5: Weather data.

A weather station was built using an Arduino Uno processor with rain, humidity, wind speed and light sensors. Unfortunately, this was removed from site once and data received from this weather station could be described as “patchy”. This data also did not correlate very well with any other weather data sources.

Several other sources were considered for weather data, Airport METAR records, Leeds and Bradford Council parks department’s observations and Met Office records. METAR data were selected as this is the only data source that gave observations on a 30 minute cycle, all others gave daily averages. Weather data were downloaded for Leeds Bradford Airport (LBA), Oxenhope Moor Airfield and RAF Linton on Ouze. The aim was to triangulate this data and provide accurate weather records for Ilkley Moor. However, data received for Oxenhope Moor was highly incomplete, with less than 3% of entries present and RAF Linton on Ouze is in the Vale of York situated 350m lower than Ilkley Moor. Therefore, only weather data for LBA were used. There is an average 135m altitude difference between LBA, 220m above sea level, and the study area, 308-401m above sea level. LBA and Ilkley Moor are 12km apart and located on the same Pennine ridge. Weather at Ilkley Moor was observed and recorded on monthly data collection visits, when compared with LBA METAR data 98% accuracy is achieved.

Three sources were considered for METAR data acquisition (NAVLOST, OGIMET and Gladstone websites). LBA air traffic control recommended using OGIMET (LBA Control Tower, 2015. Pers. Comm. Email communications between author and LBA Control Tower). All data were downloaded from all three sources, the first day of each month was decoded and compared to check for any errors. All entries were identical across all three sources for the first day of each month. OGIMET offered the least missing entries over the full trial period so OGIMET was used as the standard source of weather data in this work.

3.5.1: METAR Conversions

METAR data is coded and recorded in a way that is useful for short transmission to pilots. This piece of work decoded METAR data using a programme called NIRSOFT, then exported into an Excel document. At 30 minute intervals, from the trial period this presented 44,000 data points.

METAR data recognises cloud as an abbreviation rather than an Okta scale, so this study developed the METAR conversion displayed in the Table 3.8 (p.73).

Table 3.8 METAR to Okta conversions.

METAR cloud classifications	Okta equivalent range
SKC (No cloud, sky clear)	0
CLR (Clear up to 3,700m)	0
NSC (No significant cloud)	0
FEW (Few clouds)	1-2
SCT (Scattered)	3-5
BKN (Broken)	6-7
OVC (Overcast)	8
VV (Vertical Visibility)	9 (this is an extra category added for the purpose of this study)

Where only one condition has been recorded on the METAR scale this study acknowledged them as the lowest number in the corresponding Okta equivalent range, where METAR recorded several sky conditions i.e. SCT80, BKN120, this was categorised as the highest number in the Okta equivalent range.

Other data such as temperature was stored as ^{o}C. This was rectified by a simple find and replace task in Excel to delete any non-numeric characters so that calculations such as maximum, minimum and average on the dataset could be made.

3.6: Time data

All times used in this study are Greenwich meantime (GMT, +0hrs). School holiday dates were obtained by telephone calls to Craven, Leeds and Bradford Schools departments. For the period of this study the three districts had holidays on the same dates. This has been discussed in Chapter Four (p. 76). Religious festival dates were provided by Bradford College Student Services. Other dates were taken from the standard UK calendar of bank holidays.

3.7: Data analysis

3.7.1 Missing data.

Missing user count data have been categorised into two categories. 1. Breaks in the data that are less than one day and 2. Breaks in the data longer than one day. Category one breaks have been backfilled with the value zero as this is the modal entry for similar times throughout the dataset (Table 4. 1, p. 77). Category two gaps in the data have been filled using linear regression.

Missing weather data have been categorised into two groups. 1. Less than four hours and 2. More than four hours. Group one gaps have been infilled through interpolation of the data at each side of the gap. Group two gaps have not been backfilled (Table 5.1, p. 109).

3.7.2 Data processing

Initial data analysis focused on providing simple statistics (reported at the start of Chapters Four, p. 76 and Five, p. 109). Further data analysis was provided through searching for differences at different time conditions, such as day Vs night, holiday Vs working day and rain Vs no rain. This data analysis used the ANOVA test for difference.

Further analysis used correlation and regression to find links between ratio based datasets and visitor numbers. Finally, data was modelled using multiple regression and weighting factors to develop a model to provide future user predictions. Multiple regression used dummy variables to regress non-numeric data. Multiple regression had to use SPSS as other regression tools could not handle the number of regressors caused by using dummy variables.

3.8 Summary

The methods chapter provides a range of different monitoring options for the survey area. These have been considered for appropriateness and several options tested. The manual counting in the MPhil proved useful to aid the deployment of the automatic counters in the PhD phase of the study.

Echo, light and passive infrared counters were selected for trial. Of these the passive infrared and echo counters were selected as the most accurate and suitable for this study. Further reading showed that the echo sensor was prone to temperature fluctuations so the passive infrared sensors were adopted as the standard sensor for this study.

These were then deployed at key points around the survey area (Figure 3.4, p.65), informed by the MPhil manual counting study. Data was collected from these regularly and analysed to look at variation in use by time (Chapter Four, p.76) and weather (Chapter Five, p.109).

Chapter 4 Results: Variation in visitor numbers by time.

The user count data was split into 30 minute intervals over the period 28th June 2014 to 28th September 2015. Thirty minute intervals were chosen to fit with weather data (as described in the Methods Chapter, p.43). For each sensor there should be 21984 data points. At certain times sensor errors have left spaces in the dataset [1825 points, 1.69% of total visitor count]. The missing data were on Top Path, Bottom Path and Keighley Road bottom.

Missing user count data have been classified into two categories, 1. Short breaks in data under one full day and 2. Long breaks in data, over one full day. Category one breaks have been backfilled with the value zero as this is the modal entry for other similar conditions throughout the dataset (Table 4.1, p. 77). For example, data missing on Monday 3/11/14 between 0020 and 0550 for KR(B) have been filled with 0 as this is the modal number for KR(B) on all Mondays between the times 0020 and 0550. Table 4.1 shows where gaps have been filled using this method.

Table 4.1 Missing data filled with the value 0.

Missing data				**Rest of dataset for these times and days**	
Date	Day	Time	Sensor	Mode	Average
03.11.2014	Monday	0020 – 0550	KR(B)	0	0
08.01.2015	Thursday	0020 – 0550	KR(B)	0	0
26.05.2015	Tuesday	0020 – 0550	KR(B)	0	0
30.11.2014	Sunday	0020 – 0550	BP	0	0
05.05.2015	Tuesday	1820 – 2350	BP	0	0
01.06.2015	Monday	0620 – 1150	BP	0	0.7
24.06.2015	Wednesday	0020 – 0550	TP	0	0
20.09.2015	Sunday	0020 – 0550	TP	0	0.39

There is only one gap that falls into the category two description; Bottom Path from 28/12/2014 to 02/02/2015 [1728 data points, 1.60% of the count dataset]. This gap was due to the sensor not being refitted correctly after the data were downloaded. These data have been backfilled using linear regression, where KR was considered the X, independent variable. KR was selected as it was the variable with the closest correlation with the BP data.

These back filling methods produced data that are in line with other data in the set. These methods have not changed the average, standard deviation, standard error, mean, mode, maximum or minimum of the dataset (Table 4.2, p. 78)

Table 4.2 Simple descriptive statistics for the dataset.

	KR	WSG	TP	BP	KR(B)	Total
Original data points	21984	21984	21960	20219	21948	108095
Backfilled data points	0	0	24	1765	36	1825
% generated through backfill	0.00%	0.00%	0.11%	8.03%	0.16%	1.69%
MEAN	1.28	0.79	0.64	0.48	0.74	
MAX	20.93	20.47	20.88	25.38	36.10	
MIN	0	0	0	0	0	
COUNT (after backfill)	21984	21984	21984	21984	21984	
Standard Deviation	1.83	1.45	1.41	1.33	1.61	
Standard Error	0.01	0.01	0.01	0.01	0.01	

Sensor errors have been linked to battery output, snow cover and a sensor not being refitted properly after data download.

Data collected from the PIR sensors have been multiplied by a weighting factor. The weighting factor given in Table 4.3 has been calculated through manual observations of the sensor line on two, two hour occasions. (3.4 Validation of the data, p.70). This takes into account animals that may have triggered the sensors, more than one person crossing the sensor line at the same time and other anomalies.

Table 4.3 Sensor accuracy.

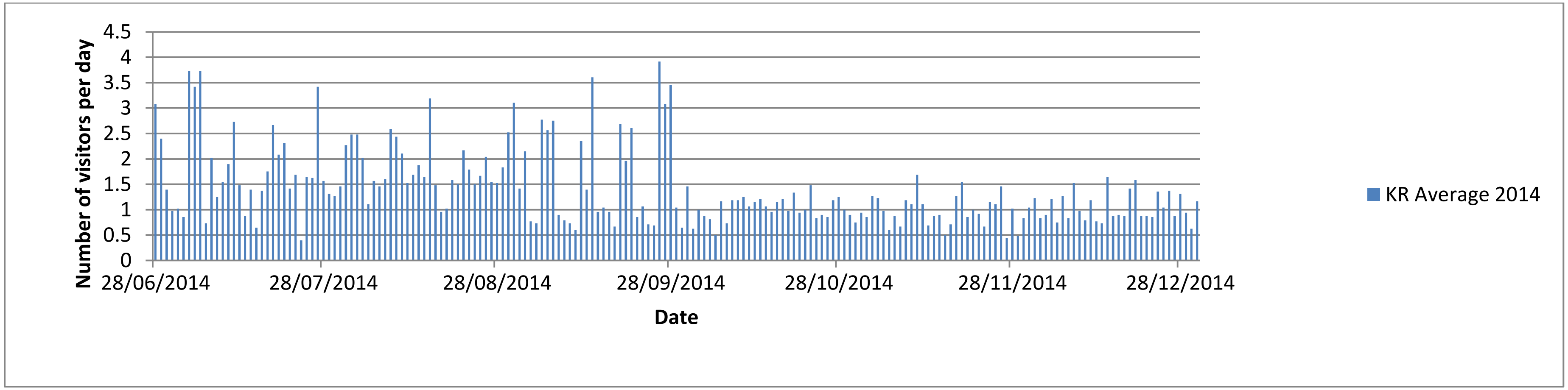
Sensor	KR	WSG	TP	BP	KR(B)	Average
Accuracy	91%	89%	87%	94%	95%	89%

The data for KR [the sensor located next to the metalled access road] shows number of sensor disturbances, rather than number of people, indicating that one break may equal one vehicle passing, but one vehicle may have more than one passenger.

As these data represent count values, after the weighting was applied, data points have been rounded to one significant figure.

4.1 Yearly and summer comparisons

As the dataset runs from 28/06/14 to 28/09/15 this allowed for a comparison of summers. Figure 4.1a shows average counts per day over the first year of the survey period. Figure 4.1b shows the same 2014 data, with the 2015 counts overlaid in red. 2015 Data in figure 4.1b have been offset at -1 day to allow direct comparison of like days (i.e. Saturday 28/06/2014 compared against Saturday 27/06/2015). This produced a spiked pattern around weekends.



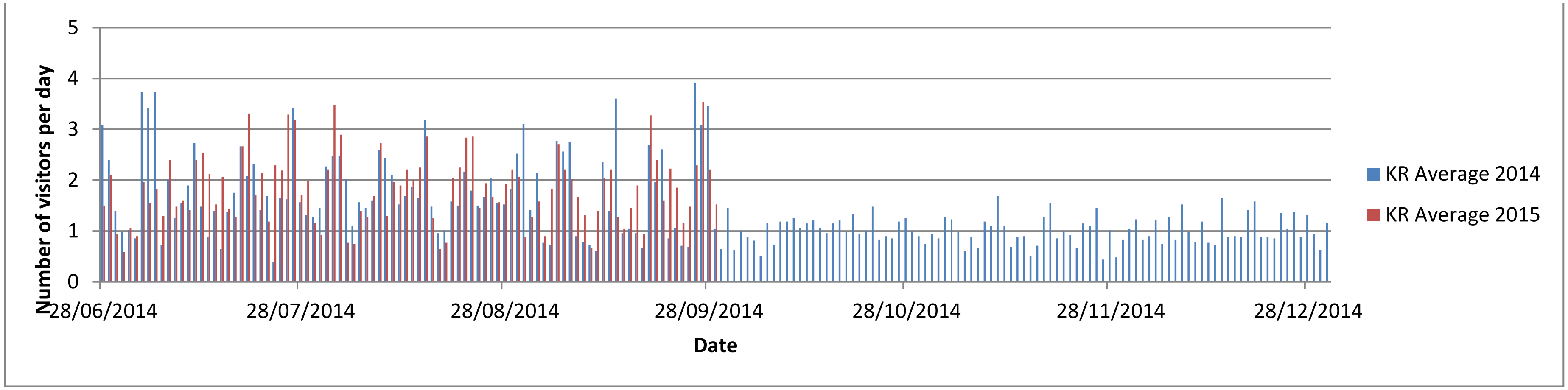


Figure 4.1a. View of the 2014 data (top). b. Year on year view of the dataset (bottom).

Table 4.4 ANOVA, by year.

	F Value	P Value
Keighley Road	73.02	P<0.001
Whetstone Gate	59.21	P<0.001
Top Path	10.87	P<0.001
Bottom Path	11.47	P<0.001
Keighley Road Bottom	18.88	P<0.001

ANOVA (99% CI) shows significant differences between the months of year (P<0.01). Further analysis using the Tukey post-hoc test showed no significant difference between overlapping months (P>0.01, June 2014 and June 2015, August 2014 and August 2015 and September 2014 and September 2015). As expected the Tukey post-hoc test showed that there was a significant difference between the non-overlapping months (I.e. June, 2015 and November, 2014).

4. 2 Day of the week

To analyse user number by day of the week, the dataset was cut to one year (01/07/2014 – 31/06/2015) to avoid bias created by having data for a second summer. Day of the week had an effect on user numbers. The peak day of the week was Sunday (Figure 4.2, p.82), the quietest day of the week being Thursday. The average showed a decline on Thursday, and a peak on Sunday.

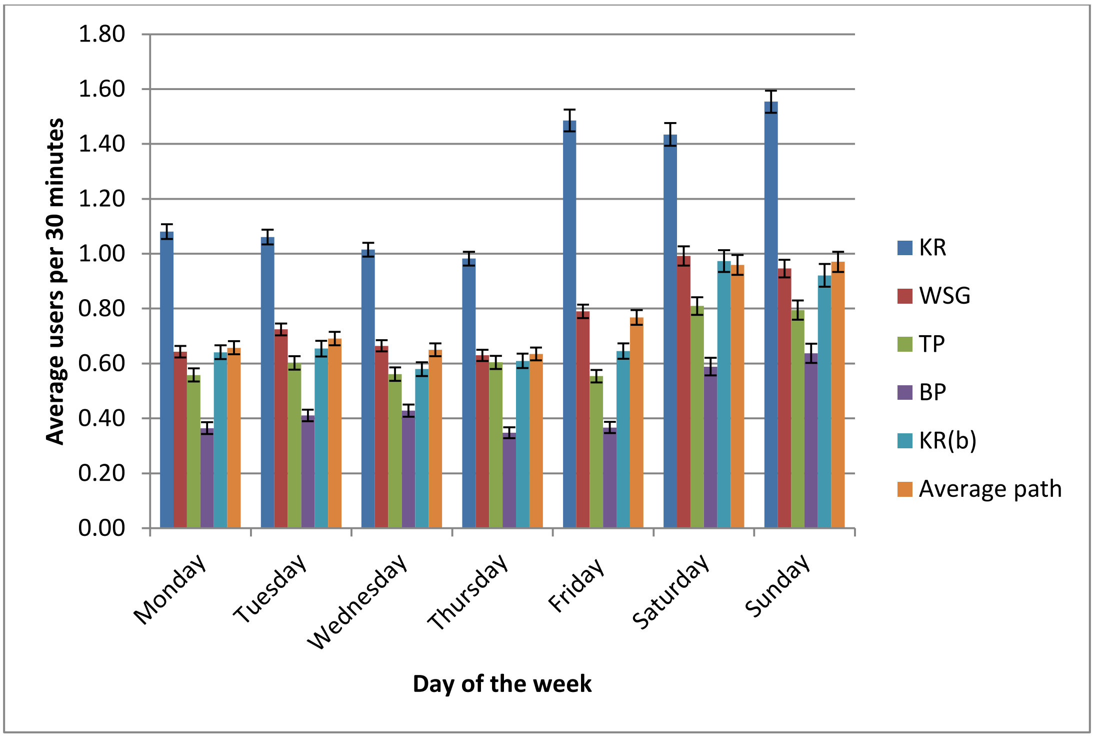


Figure 4.2 Average users by 30 minute period, by day of the week.

Table 4.5 ANOVA by day of the week.

	F Value	P Value
Keighley Road	71.12	P<0.001
Whetstone Gate	46.84	P<0.001
Top Path	28.28	P<0.001
Bottom Path	33.77	P<0.001
Keighley Road Bottom	45.05	P<0.001

ANOVA analysis showed that there was a significant difference in user by day of the week, ANOVA data are reported in Table 4.5. Given the significant ANOVA (P<0.01) a Tukey post-hoc test was completed to show where the differences occur. The result can be seen in

Table 4.6. Generally, Tukey tests showed a difference toward the end of the week (Friday, Saturday and Sunday).

Table 4.6 Tukey Pairwise grouping for day of the week.

Day of week	(Days that do not share a letter are significantly different)				
	KR	WSG	TP	BP	KR(B)
Monday	A	C D	C	B	C D
Tuesday	A	C	C	B	C D
Wednesday	A	C D	C	B	D
Thursday	A	D	C	B	D
Friday	B	B	C	B	C
Saturday	B	A	A	A	A
Sunday	B	B	B	A	B

Reporting day of the week by % of the average day showed that Monday, Tuesday, Wednesday and Thursday were less than the average. KR and WSG showed higher than the Friday average counts whereas TP, BP and KR(B) were lower than the Friday average. Saturday and Sunday were above the average (Table 4.7, p.84).

Table 4.7 Day weightings as a percentage of the average day.

	KR	WSG	TP	BP	KR(B)
MONDAY	88	84	87	81	89
TUESDAY	86	94	94	91	91
WEDNESDAY	82	86	88	95	81
THURSDAY	80	82	94	78	85
FRIDAY	121	103	86	82	90
SATURDAY	117	129	126	131	136
SUNDAY	126	123	124	142	128

Above average percentages are in red.

4.3 Time of day

Time of day has been reported based on a one year cycle (01/07/2014 to 31/06/2015) to avoid double summer bias.

Figure 4.3 (p.85) shows a general trend in all paths to have no patronage between 0150 and 0250, then picking up gradually to a large increase at 04:50 – 06:50. Then there was generally a steady increase up to 11:50 where a further large increase was seen, levelling out at 12:50. A dip was seen at 15:50 – 16:50 then there was a spike around 16:50 – 17:50 declining to no patronage at 01:50.

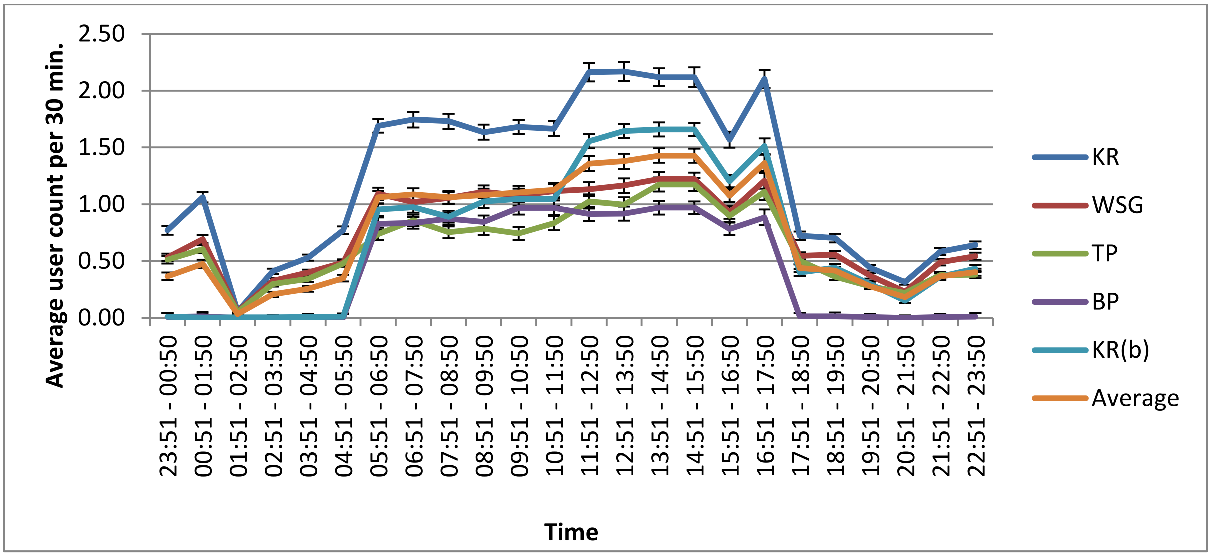


Figure 4.3 Comparison of sensors by time and user.

ANOVA analysis showed that there were significant differences between the various times of day (P < 0.01) as shown in Table 4.8.

Table 4.8 ANOVA, by time.

	F value	P value
KR	158.72	P<0.001
WSG	63.52	P<0.001
TP	42.06	P<0.001
BP	106.19	P<0.001
KR(B)	127.48	P<0.001

As the ANOVA analysis reported a significant difference ($P < 0.01$) a Tukey post-hoc test was conducted to highlight the significant differences and show time periods that were statistically similar (Table 4.9). Excluding Top Path there is a general trend toward two groups of user times (06:50 – 17:50 and 17:50 – 00:50).

Table 4.9 Tukey pairwise grouping for time of day.

<table>
<tr><th colspan="6">(Times that do not share a letter are significantly different)</th></tr>
<tr><th></th><th>KR</th><th>WSG</th><th>TP</th><th>BP</th><th>KR(B)</th></tr>
<tr><td>23:51 – 00:50</td><td>D</td><td>D E</td><td>H I J</td><td>B</td><td>F</td></tr>
<tr><td>00:51 – 01:50</td><td>C</td><td>C D</td><td>G H I</td><td>B</td><td>F</td></tr>
<tr><td>01:51 – 02:50</td><td>H</td><td>G</td><td>L</td><td>B</td><td>F</td></tr>
<tr><td>02:51 – 03:50</td><td>F G</td><td>E F</td><td>J K L</td><td>B</td><td>F</td></tr>
<tr><td>03:51 – 04:50</td><td>D E F G</td><td>E F</td><td>J K</td><td>B</td><td>F</td></tr>
<tr><td>04:51 – 05:50</td><td>D</td><td>D E</td><td>I J</td><td>B</td><td>F</td></tr>
<tr><td>05:51 – 06:50</td><td>B</td><td>A B</td><td>F G H</td><td>A</td><td>B C</td></tr>
<tr><td>06:51 – 07:50</td><td>B</td><td>A B</td><td>C D E F</td><td>A</td><td>B C</td></tr>
<tr><td>07:51 – 08:50</td><td>B</td><td>A B</td><td>E F G H</td><td>A</td><td>C</td></tr>
<tr><td>08:51 – 09:50</td><td>B</td><td>A B</td><td>D E F G</td><td>A</td><td>B C</td></tr>
<tr><td>09:51 – 10:50</td><td>B</td><td>A B</td><td>F G H</td><td>A</td><td>B C</td></tr>
<tr><td>10:51 – 11:50</td><td>B</td><td>A B</td><td>C D E F G</td><td>A</td><td>B C</td></tr>
<tr><td>11:51 – 12:50</td><td>A</td><td>A B</td><td>A B C D</td><td>A</td><td>A</td></tr>
<tr><td>12:51 – 13:50</td><td>A</td><td>A B</td><td>A B C D E</td><td>A</td><td>A</td></tr>
<tr><td>13:51 – 14:50</td><td>A</td><td>A</td><td>A</td><td>A</td><td>A</td></tr>
<tr><td>14:51 – 15:50</td><td>A</td><td>A B</td><td>A B C</td><td>A</td><td>A</td></tr>
</table>

15:51 – 16:50	B	B C	B C D E F	A	B
16:51 – 17:50	A	A	A B	A	A
17:51 – 18:50	D E	D E	H I J	B	D E
18:51 – 19:50	D E	D E	K L	B	D
19:51 – 20:50	E F G	E F	J K L	B	D E
20:51 – 21:50	G H	F G	I J K	B	E F
21:51 – 22:50	D E F G	D E	I J K	B	D E
22:51 – 23:50	D E F	D E	I J K	B	D

Reporting time of day by percentage (Table 4.10) showed that peak activity was around 05:51 – 17:50 with less than average activity at other times. There was also an increase of activity around midnight at the Keighley Road, Whetstone Gate and Top path although this nocturnal activity was not significant enough to meet the average use per hour.

Table 4.10 Time weightings by percentage of the average.

%	**KR**	**WSG**	**TP**	**BP**	**KR(b)**
23:51 – 00:50	63	69	79	2	2
00:51 – 01:50	87	90	94	3	0
01:51 – 02:50	4	7	8	0	1
02:51 – 03:50	33	42	46	0	1
03:51 – 04:50	43	52	53	1	1
04:51 – 05:50	63	63	74	1	1
05:51 – 06:50	138	141	114	184	132
06:51 – 07:50	142	132	133	185	135

07:51 – 08:50	141	136	117	193	124
08:51 – 09:50	133	143	122	187	142
09:51 – 10:50	137	139	115	214	145
10:51 – 11:50	136	144	129	214	145
11:51 – 12:50	177	146	159	202	216
12:51 – 13:50	177	150	154	203	228
13:51 – 14:50	173	158	182	215	230
14:51 – 15:50	173	158	182	215	230
15:51 – 16:50	128	120	139	174	167
16:51 – 17:50	172	156	172	196	210
17:51 – 18:50	59	71	78	3	56
18:51 – 19:50	57	72	56	3	61
19:51 – 20:50	36	48	43	2	41
20:51 – 21:50	26	30	34	0	21
21:51 – 22:50	48	63	58	2	50
22:51 – 23:50	52	70	59	2	60

Above average percentages are in red.

4.4 Month

Data based on months of the year have been reported using all full months in the dataset (07/2014 – 08/2015) to allow comparison of overlapping months.

Figure 4.4 shows that there was a trend to have high visitor counts in the spring/summer months and lower counts in the winter months. There was a severe depression in the January counts. This could have been due to the survey area being largely inaccessible due to snow for one week in January 2015.

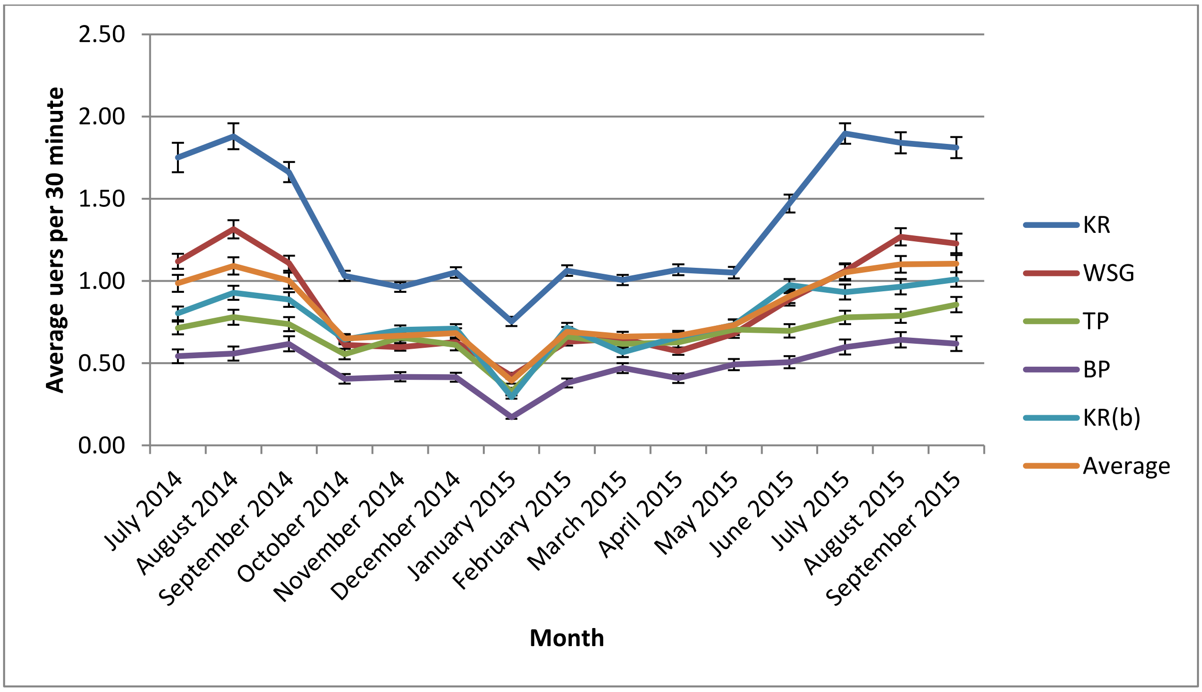


Figure 4.4 Average count per 30 minute, by month.

Data have been analysed using ANOVA to check for significant differences between months. This analysis is shown in Table 4.11 (p.90). Each sensor displayed P = <0.01 indicating that there was a significant variance between different months of the year. As all ANOVA analyses show a significant result, a Tukey post-hoc test was conducted and results reported in Table 4.12 (p.91).

Table 4.11 ANOVA by month.

	F value	P value
KR	76.07	$P<0.001$
WSG	63.13	$P<0.001$
TP	11.50	$P<0.001$
BP	11.82	$P<0.001$
KR(B)	19.68	$P<0.001$

Table 4.12 Tukey pairwise grouping by month.

(Times that do not share a letter are significantly different)					
	KR	WSG	TP	BP	KR(B)
July 2014	A B	B C	A B C D	A B C D	A B C D
August 2014	A B	A	A B C	A B C	A B
September 2014	B C	B C	A B C	A B	A B C
October 2014	D	E	D	C D	D E
November 2014	D E	E F	B C D	C D	C D E
December 2014	D	E	C D	C D	C D E
January 2015	E	F	E	E	F
February 2015	D	E	B C D	D	C D E
March 2015	D	E	B C D	B C D	E
April 2015	D	E F	B C D	C D	D E
May 2015	D	E	A B C D	A B C D	B C D E
June 2015	C	D	A B C D	A B C D	A
July 2015	A	C D	A B C	A B	A B
August 2015	A B	A B	A B	A	A
September 2015	A B	A B C	A	A B	A

The Tukey post-hoc test shows that like months (July 2014 and 15, August 2014 and 15 and September 2014 and 15) shared a group. Sensors that were further from the car park tended to share groups more than sensors close to the car park at Keighley Road. This may be due to the sensors located further away being triggered fewer times and by more experienced regular walkers.

Monthly data have also been reported by percentage of the average month in Table 4.13.

Table 4.13 Monthly weighting by percentage of the average month.

	KR	WSG	TP	BP	KR(b)
July 2014	129	131	106	112	104
August 2014	139	154	116	116	121
September 2014	123	130	109	128	115
October 2014	76	72	82	84	84
November 2014	71	70	97	86	91
December 2014	78	74	91	86	92
January 2015	56	50	49	36	38
February 2015	79	74	98	79	93
March 2015	74	76	91	97	74
April 2015	79	67	93	85	86
May 2015	78	80	105	102	95
June 2015	109	104	103	105	127
July 2015	140	124	115	124	121
August 2015	136	149	117	133	126
September 2015	134	144	127	128	131

Above average percentages are in red.

All paths showed a higher than average reading for June, July, August and September, with the lowest readings shown in January.

4.5 Season

Seasonal changes in user counts are shown in Figure 4.5, displaying a trend to high summer and lower winter counts. Even though winter counts are lower than the summer counts there were still some data showing evidence that people used the moorland in winter. The dataset has been trimmed to September 1st 2014 - 1st September 2015 to allow a full year analysis. There is not enough data to create a full analysis of summer 2014 (1st – 27th June 2014 outside the collection window) or autumn 2015 (October and November outside the collection window) so these seasons have been excluded.

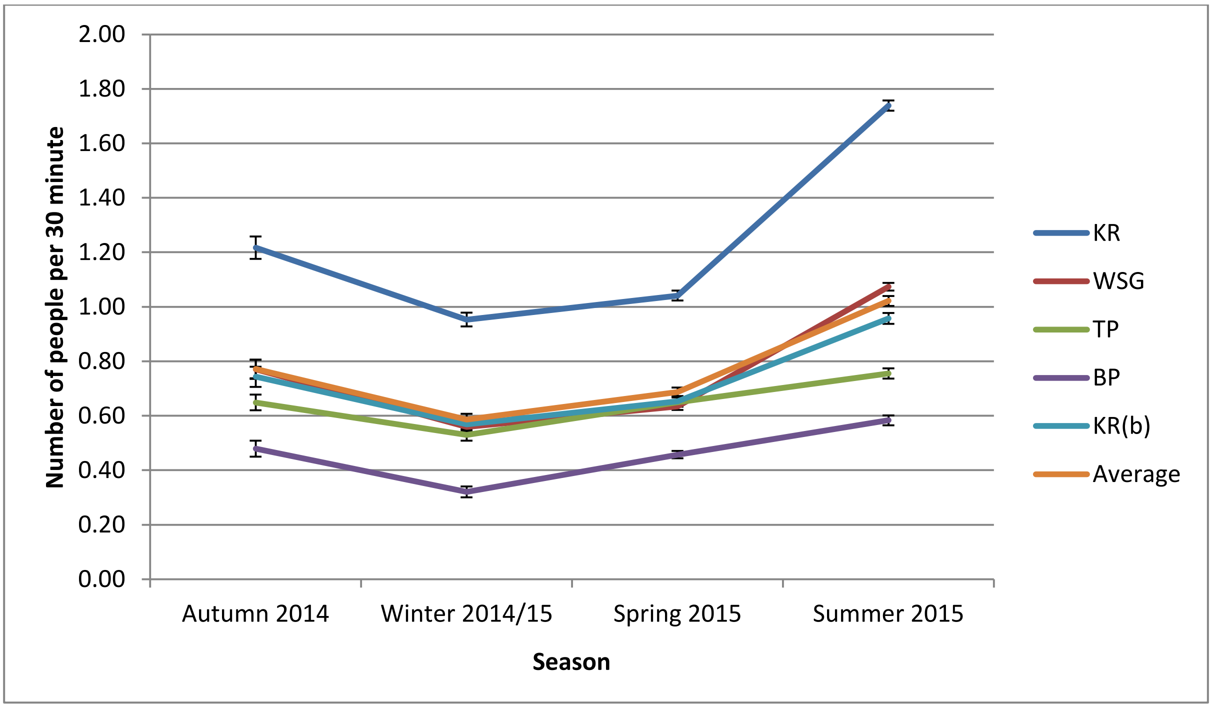


Figure 4.5 Average 30 minute counts by season.

As the data indicated significant differences between seasons ANOVA analysis has been conducted. Table 4.14 (p.94) shows the ANOVA statistics. There was a significant difference between months for all paths (p = < 0.01). This is reported in Table 4.15 (p.94), to show where the differences are. These results are displayed in terms of percentages in Table 4.16 (p.95).

Table 4.14 ANOVA, by season.

	F value	P value
KR	173.39	P<0.001
WSG	135.56	P<0.001
TP	18.84	P<0.001
BP	21.63	P<0.001
KR(b)	36.99	P<0.001

Table 4.15 Tukey pairwise grouping for season.

(Seasons that do not share a letter are significantly different)					
	KR	WSG	TP	BP	KR(B)
Autumn 2014	B	C	B	B C	B
Winter 2014/15	C	D	C	D	C
Spring 2015	B	D	B	C	B C
Summer 2015	A	B	A	A	A

Table 4.16 Seasonal weighting by percentage of average season.

	KR	WSG	TP	BP	KR(b)
Autumn 2014	98	101	100	104	102
Winter 2014/15	77	74	82	70	78
Spring 2015	84	84	101	99	89
Summer 2015	140	141	117	127	131

Above average percentages are in red.

These data showed that there were higher than average user counts in autumn and summer with fewer than average in winter, the anomaly being Top Path during Spring 2015. This may be due to the smaller number of persons using the top path.

4.6 Holidays and local days of interest

Public holidays and local days of note have been picked out of the dataset and compared with the average data and similar days to assess for differences. Similar days are usually defined as the same day of the week previous and the same day of the week after.

Holidays were compared against similar data for non-holidays (Tables 4.17, 4.18 and 4.19). Where possible, data have also been provided for the average of the same day one week before and one week after the holiday, for comparison. It is important to note that this average is based on two days rather than a large dataset, and is therefore more open to bias (i.e. if the weather was cold on one of those days, or there was a football match on the television etc., these factors may skew the comparison).

Comparisons have been made from a two week period as any larger period may have resulted in auto-correlation with other factors.

Note: The comparator is the average of the two numbers in red. These are provided to show where the comparator has originated.

Table 4.17 Year on year comparable bank holidays.

	KR	WSG	TP	BP	KR(B)	Average
18th August 2014	0.96	0.46	0.83	0.35	0.30	0.58
1st September 2014	1.14	0.52	0.50	0.7	0.31	0.64
August bank holiday 2014 comparator	1.05	0.49	0.67	0.54	0.30	0.61
August bank holiday 2014	1.50	0.23	0.27	1.03	1.75	0.95
24th August 2015	1.94	0.73	0.65	0.56	0.35	0.85
7th September 2015	1.67	1.52	0.85	0.44	0.65	1.03
August bank holiday 2015 comparator	1.80	1.12	0.75	0.50	0.50	0.94
August bank holiday 2015	0.88	1.06	0.67	0.50	0.83	0.79

On KR, there was an increase in traffic during the 2014 August bank holiday, but this increase was not reflected in the sensor counts on the moor. There were fewer counts at WSG and TP but there was an increase in counts at the sensors in the lower part of the survey area [BP and KR(B)]. This may have been due to more people walking up to the survey area from Ilkley, but not actually reaching Whetstone Gate. The increase in KR counts may have been from evening traffic. There is not a strong link between August bank holidays year on year.

Several holidays are not comparable year on year [due to changing dates or days of the week, i.e. Christmas, Eid etc.] (Table 4.23, p. 106). Christmas day showed an increase in counts on Keighley Road, but a decrease at all other sensors. This may have been due to increased evening traffic. Boxing Day showed an average decrease on all sensors except for WSG. New Year's Day showed a decrease in all sensor counts, to the point where there are virtually no users in the survey area. Good Friday, Easter Monday, May Day and Spring Bank Holiday also showed an average decrease in use.

Note: The comparator is the average of the two numbers in red. These are provided to show where the comparator has originated.

Table 4.18 Non comparable bank holidays, by 30 minute count.

	KR	**WSG**	**TP**	**BP**	**KR(b)**	**Average**
11th December 2014	0.79	0.63	0.52	0.27	0.56	0.55
18th December 2014	0.88	0.35	0.77	0.31	0.98	0.66
Christmas day comparator	0.83	0.49	0.65	0.29	0.77	0.61
Christmas day	1.04	0.21	0.14	0.29	0.44	0.79
12th December 2014	1.19	0.63	0.56	0.60	0.88	0.77
19th December 2014	1.42	0.54	0.48	0.73	0.88	0.81
Boxing day comparator	1.30	0.58	0.52	0.67	0.88	0.79
Boxing day	1.38	0.24	0.10	0.58	0.92	0.64
9th Jan 2015	0.69	0.25	0.15	0.15	0.17	0.28
16th Jan 2015	0.65	0.38	0.10	0.13	0.15	0.28
New Year's day comparator	0.67	0.31	0.12	0.14	0.16	0.28
New Year's day	0.06	0.04	0.05	0.00	0.00	0.03
27th March 2015	1.35	0.69	0.90	0.38	0.38	0.74
10th April 2015	1.44	0.75	0.54	0.54	0.52	0.76

Good Friday comparator	1.40	0.72	0.72	0.46	0.45	0.75
Good Friday	1.21	0.22	0.15	0.46	0.56	0.52
30th March 2015	1.50	0.73	0.63	0.83	0.56	0.85
13th April 2015	1.69	0.52	0.90	0.22	0.50	0.76
Easter Monday comparator	1.59	0.62	0.76	0.53	0.53	0.81
Easter Monday	0.96	0.23	0.14	0.23	0.21	0.35
27th April 2015	1.31	0.63	0.67	0.54	0.60	0.75
11th May 2015	1.23	0.52	0.46	0.29	0.83	0.67
May Day comparator	1.27	0.57	0.56	0.42	0.72	0.71
May Day bank holiday	0.75	0.16	0.20	0.04	0.67	0.36
18th May 2015	1.02	0.42	0.60	0.65	1.19	0.77
1st June 2015	1.21	0.46	0.44	0.29	0.73	0.62
Spring bank comparator	1.11	0.44	0.52	0.47	0.96	0.70
Spring bank holiday	0.85	0.15	0.17	0.40	0.96	0.51

Comparators for Christmas Day and Boxing Day were drawn from like days on the previous two weeks as the following week is New Year’s Day and 02/01/2015 (still holiday time and may be affected by New Year’s celebrations). New Year’s Day comparators were drawn from the following two weeks as the previous two weeks included Christmas Day.

Local holidays and days of particular interest have been highlighted and compared in the same way as bank holidays (Table 4.19, p.99). The holidays selected were; the statutory public (bank) holidays, Yorkshire Day [as the Ilkley Moor anthem, “On Ilkley Moor Bah Tat” (On Ilkley Moor, without a hat) is commonly accepted as the Yorkshire Anthem], Eid as there is a large Muslim community near the survey area (Keighley and Bradford) and the Glorious 12th as this is the date when the English grouse shooting season starts.

Note: The comparator is the average of the two numbers in red. These are provided to show where the comparator has originated.

Table 4.19 Local holidays and days of particular interest.

Occurrence	KR	WSG	TP	BP	KR(b)	Average
17th May 2015	0.54	0.69	0.48	0.40	0.65	0.55
31st May 2015	2.31	1.50	1.35	1.06	1.60	1.57
Whitsunday comparator	1.43	1.09	0.92	0.73	1.12	1.06
Whitsunday	1.29	0.20	0.14	0.27	0.58	0.50
21st July 2014	2.31	1.02	0.35	0.02	0.85	0.91
4th August 2014	2.31	1.02	0.35	0.02	0.85	0.91
Eid comparator	2.31	1.02	0.35	0.02	0.85	0.91
Eid 2014	1.56	0.22	0.24	0.13	0.54	0.54
25th July 2014	1.65	1.29	0.46	0.42	0.50	0.86
8th August 2014	1.60	0.77	0.48	0.65	0.58	0.82
Yorkshire Day 2014 comparator	1.62	1.03	0.47	0.53	0.54	0.84
Yorkshire day	1.52	0.26	0.24	0.44	0.53	0.60
25th July 2015	1.85	1.25	0.83	0.64	1.94	1.30
8th August 2015	2.73	1.71	1.10	1.67	1.94	1.83
Yorkshire Day 2015	2.29	1.48	0.97	1.15	1.94	1.57

comparator						
Yorkshire Day 2015	2.30	1.30	1.00	1.20	1.80	1.52
5th August 2014	1.10	1.54	0.38	0.00	0.69	0.74
19th August 2014	1.02	0.92	0.46	0.02	0.56	0.60
Glorious 12th comparator	1.72	1.15	0.62	0.53	0.66	0.67
Glorious 12th 2014	1.52	0.26	0.24	0.44	0.65	0.62
5th August 2015	1.40	1.02	0.58	0.50	0.56	0.81
19th August 2015	2.04	1.27	0.67	0.56	0.75	1.06
Glorious 12th comparator	1.72	1.15	0.62	0.53	0.66	0.94
Glorious 12th 2015	3.00	1.46	1.08	1.19	1.98	1.74
15th August 2015	1.46	1.48	0.79	0.33	0.81	0.97
29th August 2015	1.31	0.88	0.50	0.44	0.60	0.75
Eid 2015 comparator	1.39	1.18	0.65	0.39	0.71	0.86
Eid 2015	1.85	1.67	0.52	0.54	0.75	1.07

Whitsunday, Eid 2014, Yorkshire Day and the Glorious 12th showed an average decrease in use on the survey area. Whereas the Glorious 12th 2015 and Eid 2015 showed an average increase in use, the Glorious 12th occurred on a Saturday in 2015 and this may be a reason for the increase in user counts for this occurrence. It is not feasible to compare Eid, Yorkshire Day and the Glorious 12th year on year as these occurrences fell on different days of the week in each year. As there were differences between the data for holidays and non-holidays, ANOVA analysis has been used to compare data (Table 4.20, p.101).

Table 4.20 ANOVA, by holiday.

	F Value	P Value
KR	4.69	P<0.001
WSG	5.94	P<0.001
TP	2.03	0.002
BP	2.99	P<0.001
KR(b)	3.21	P<0.001

As the ANOVA tests reported a significant difference at all sensors, at the P<0.01 level (in Table 4.19, p.99) a Tukey post-hoc test was completed to show where the differences occur, this is reported in Table 4.21.

Table 4.21 Tukey pairwise grouping for holidays and comparators.

Days that do not share a letter are significantly different. C indicates comparator data. B/H = Bank Holiday.					
	KR	WSG	TP	BP	KR(b)
All data, excluding holidays	C D	D E F	A B C	A B C	B C D
August B/H 2014 C	C D	D E F G	A B C	A	B C D
August B/H 2014	A B C D	A B	A B C	A B C	A
Christmas Day C	C D E	D E F G	A B C	A B C	A B C D
Christmas Day	B C D E	C D E F G	A B C	A B C	B C D
Boxing Day C	A B C D	D E F G	A B C	A B C	A B C D
Boxing Day	A B C D	D E F G	A B C	A B C	A B C D
New Year's Day C	D E	F G	C	B C	D
New Year's Day	E	G	B C	B C	C D
Good Friday C	A B C D	E F G	A B C	A B C	B C D

Good Friday	A B C D E	C D E F G	A B C	A B C	B C D
Easter Monday C	A B C	D E F G	A B C	A B C	B C D
Easter Monday	C D E	C D E F G	A B C	A B C	B C D
May Day B/H C	A B C D	C D E F G	A B C	B C	B C D
May Day B/H	C D E	B C D E F G	A B C	A B C	A B C D
Spring B/H C	C D	E F G	A B C	A B C	A B C D
Spring B/H	C D E	B C D E F G	A B C	A B C	A B C D
Eid 2014 C	A	C D E	A B C	A B C	B C D
Eid 2014	A B C D	A B C D E	A B C	C	B C D
Eid 2015 C	A B C D	C D E	A B C	A B C	A B C D
Eid 2015	A B C D	A B C D E	A B C	A B C	A B C D
Whitsunday C	A B C D	E F G	A	A B	A B
Whitsunday	A B C D E	C D E F G	A B C	A B C	A B C D
Yorkshire Day 2014 C	A B C	A	A B C	A B C	A B C D
Yorkshire Day 2014	A B	A	A B C	A B C	B C D
Yorkshire Day 2015 C	A B C D	A	A B C	A B C	A B C D
Yorkshire Day 2015	A B	A	A B C	B C	A B C D
Glorious 12th 2014 C	A B C D E	A B C	A B C	B C	B C D
Glorious 12th 2014	A B C D	A B C	A B C	A B C	A B C D
Glorious 12th 2015 C	A B C D	A B C D E F G	A B C	A B C	A B C D
Glorious 12th 2015 C	A B C D	A B C D E F G	A B C	A B C	A B C D
August B/H 2015 C	A B C D	A	A B C	A B C	A B C D
August B/H 2015	A B C D	A B	A B C	A B C	A B C D

Tukey post-hoc tests showed that there were no significant differences between days and their comparator, the exception being August Bank Holiday 2014. The comparable August Bank Holiday (2015) did not differ significantly from its comparator. There was no continuous significant difference between holidays and their comparative days. The majority of these days were also not significantly different from the average of the whole dataset excluding holidays.

School term time and school holidays were also considered to see whether there was any difference in use, this is reported in Table 4.22 (p.104). School holiday dates were taken from CBMC (Keighley, Bradford and towns to the south of the moor), Craven Council (Skipton and villages to the north) and Leeds City Council (Ilkley and villages to the North East). For the trial period all three councils had school holidays on the same dates. Holidays and term time have been divided up into each individual occurrence rather than presented as a binary division into Term Time and Holiday Time to minimise auto correlations with time of year.

Table 4.22 School holidays compared to term time (average count per 30 minutes).

	KR	WSG	TP	BP	KR(b)	Average
Summer term 2a	1.49	0.96	0.47	0.35	0.62	0.78
Summer holiday	1.53	1.06	0.61	0.38	0.59	0.84
Autumn term 1	1.18	0.72	0.56	0.42	0.66	0.71
October half term	1.02	0.55	0.66	0.34	0.73	0.66
Autumn term 2	1.06	0.59	0.61	0.43	0.68	0.67
Christmas holiday	0.89	0.54	0.55	0.32	0.58	0.58
Winter term 1	0.82	0.49	0.42	0.24	0.44	0.48
February half term	0.98	0.53	0.75	0.41	0.73	0.68
Winter term 2	1.04	0.66	0.64	0.40	0.60	0.67
Easter holiday	1.14	0.57	0.70	0.50	0.66	0.71
Summer term 1	1.02	0.60	0.60	0.43	0.68	0.67
May half term	0.93	0.65	0.59	0.54	0.71	0.68
Summer term 2b	1.12	0.68	0.55	0.34	0.70	0.68

Data in Table 4.22 have been generated through using a year dataset with weekends removed. This allowed for a fair comparison of school holidays with term time. Holidays have been picked out in red. Summer term two was been split into a and b; summer term 2a refers to data up to the July end of term, whereas summer term 2b refers to data from May and June 2015. The number one after a term title indicates that it is the first part of the term up to the half term break, the number two indicates that it is the second half of the term, after the half term break.

Summer holidays, February half term and Easter holiday show an increase in counts when compared with counts from the previous and following half term, whereas October half term shows a decline when compared with the following and previous half terms. Christmas and the May half term show an increase compared to one term, but a decrease or equal with the other bordering term.

As there were both increases and decreases in visitor counts during various holidays Table 4.23 (p.106) shows term times and holidays as a percentage of the average user counts. It is important to note that these figures may be skewed through auto-correlation with weather or month.

Table 4.23 Holidays and term time as a percentage of the yearly average (without weekends).

Average	**KR**	**WSG**	**TP**	**BP**	**KR(b)**
Summer term 2b	133	139	82	92	99
Summer holiday	136	154	107	100	94
Autumn term 1	105	105	97	109	105
October half term	90	80	115	89	117
Autumn term 2	94	86	106	111	108
Christmas holiday	79	79	95	84	93
Winter term 1	73	71	73	62	71
February half term	87	76	131	107	116
Winter term 2	93	96	111	105	96
Easter holiday	101	83	121	129	106
Summer term 1	91	88	105	112	109
May half term	82	94	103	140	114
Summer term 2a	100	98	96	88	112

Above average percentages are in red.

Higher than average counts were around Summer holiday and Easter, with highest individual sensor counts on the more remote paths spreading further into Autumn and February. Since there are changes in the data (Tables 4.22, p.104 and 4.23, p.106), ANOVA analysis has been conducted to test for significance. ANOVA statistics are given in Table 4.24 (p.107). ANOVA analysis showed that there are significant differences between the variables (P<0.01). A Tukey post-hoc test was completed to assess where the differences occur, this can be seen in Table 4.25 (p.108).

Table 4.24 ANOVA, by term time and school holiday.

	F Value	P Value
KR	21.62	P<0.001
WSG	28.14	P<0.001
TP	4.47	P<0.001
BP	4.76	P<0.001
KR(b)	3.81	P<0.001

Table 4.25 Tukey post-hoc results for term and holiday time.

(Days that do not share a letter are significantly different)					
	KR	WSG	TP	BP	KR(b)
Summer term 2b	B	B	A B	A	A
Summer holiday	A	A	A	A	A B
Autumn term 1	B C	B C	A	A	A
October half term	B C D E	B C D E	A B	A B	A B
Autumn term 2	C D	D E	A	A	A
Christmas holiday	D E	C D E	A B	A B	A B
Winter term 1	E	E	B	B	B
February half term	B C D E	C D E	A	A	A B
Winter term 2	C D	C D	A	A	A B
Easter holiday	B C D	C D E	A	A	A
Summer term 1	C D	C D E	A	A	A
May half term	C D E	B C D E	A B	A	A B
Summer term 2a	B	B	A	A B	A

Tukey post-hoc results showed that there were significant differences between the different holidays, but only the summer holidays were significantly different from both the previous term (summer) and the following term (winter). This difference may have been due to auto-correlation of weather, season or month.

Chapter 5 Results: The effect of weather variables on users.

5.1: Notes on the weather data.

Weather data were obtained from Leeds-Bradford Airport (LBA: EGNM) [12km from the survey area] as described in the Methods Chapter (p. 109). There were several gaps in the weather data; these are described in Table 5.1. There were 21,984 30 minute periods in the data collection period.

Table 5.1 Simple descriptive statistics for the weather data.

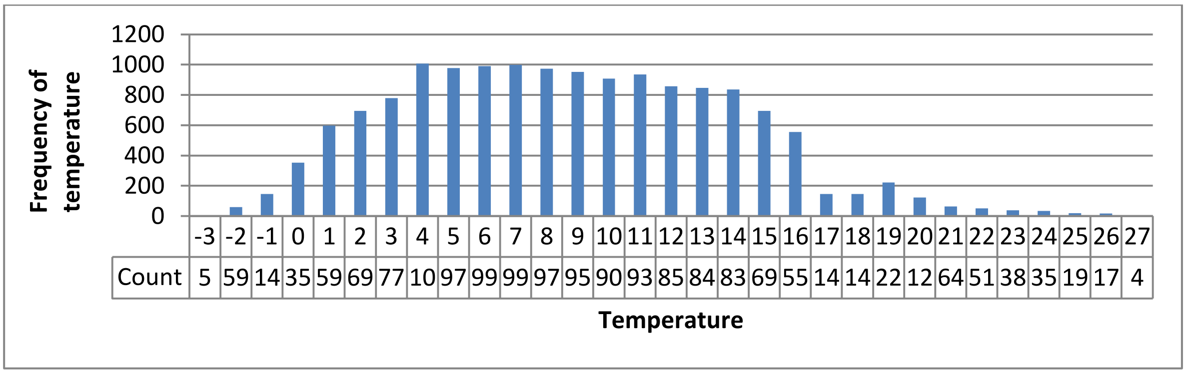
	Temp	**Dew Point**	**RH**	**Wind Dir***	**Wind Speed (km)**	**Visibility**	**Cloud ***	**Rain***
Mean	9.8	7.0	0.8		15.2	8991.1		
Max	27.0	23.0	1.0		50.0	>10,000		
Min	-3.0	-10.0	0.2		2.0	<99		
Count	19430	19430	19430	20157	20157	21820	17249	21,984
% missing	11.6%	11.6%	11.6%	8.4%	8.4%	0.7%	21.5%	0%
Standard Deviation	5.3	4.6	0.1		7.8	2532.2		
Standard Error	0.04	0.03	0.00		0.06	17.14		

* METAR weather reports give wind, rain and cloud in descriptive text rather than numeric data, to aide user understanding. However, this prevented some statistics being prepared for these data.

Gaps in the weather data were due to missed recordings at the airport. Data gaps have been filled using interpolation, or filled with the median count (as described in the Methods Chapter, p. 76). Gaps in weather data were spread evenly throughout the dataset. User count data was manipulated in the same way as Chapter Four.

5.2: Temperature

Using one year of data (01.07.2014 – 31.06.2015) 15,028 data points (one per 30 minutes) were collected. Figure 5.1 shows the range of temperatures and number of occurrences (-3 to +27 degrees) across a skewed curve, with the maximum occurrences achieved around four degrees.



	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Count	5	59	14	35	59	69	77	10	97	99	99	97	95	90	93	85	84	83	69	55	14	14	22	12	64	51	38	35	19	17	4

Figure 5.1 Number of counts at each temperature.

Temperatures compared to average user counts on all five sensors showed a generally positive relationship (Figure 5.2, p.111). The extremities of the dataset had fewer occurrences at each temperature range. (-3 N=5, +23 N=38, +24 N=35, +25 N=19, +26 N=17, +27 N=4). At these extremities one value may have had a skewing effect, thus causing the larger error bars due to small sample sizes (Figure 5.2, p.111). Figure 5.3 (p.112) has been created using a five point moving average to overcome the skewing effect of small sample sizes. Figure 5.4 (p.112) focuses on reliable data, only considering temperature values where there are over 100 user counts.

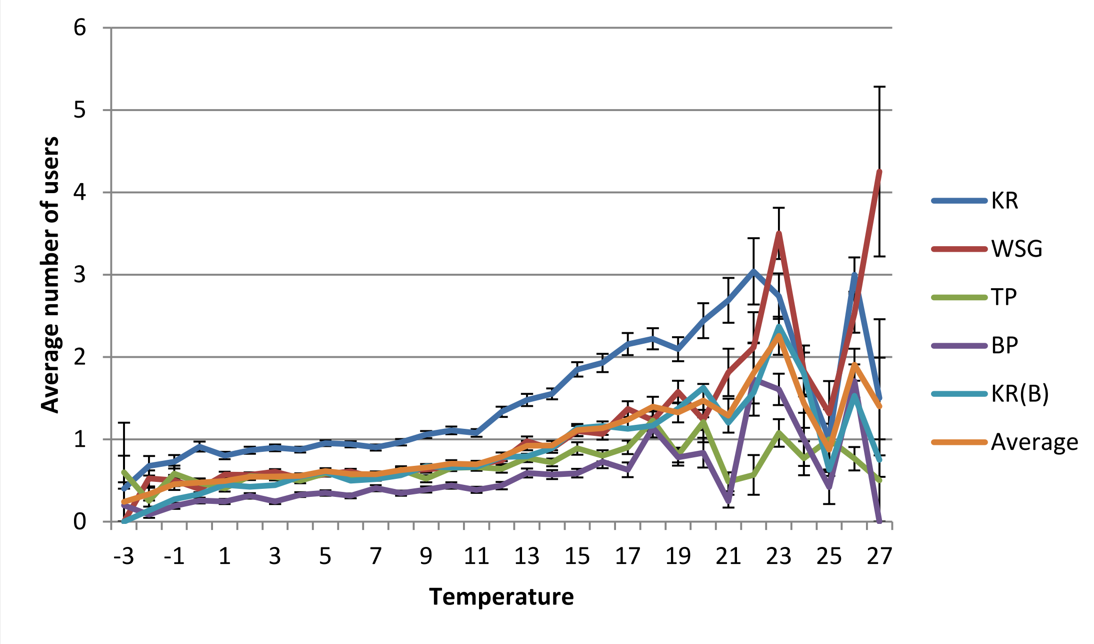


Figure 5.2 Average user numbers at each temperature.

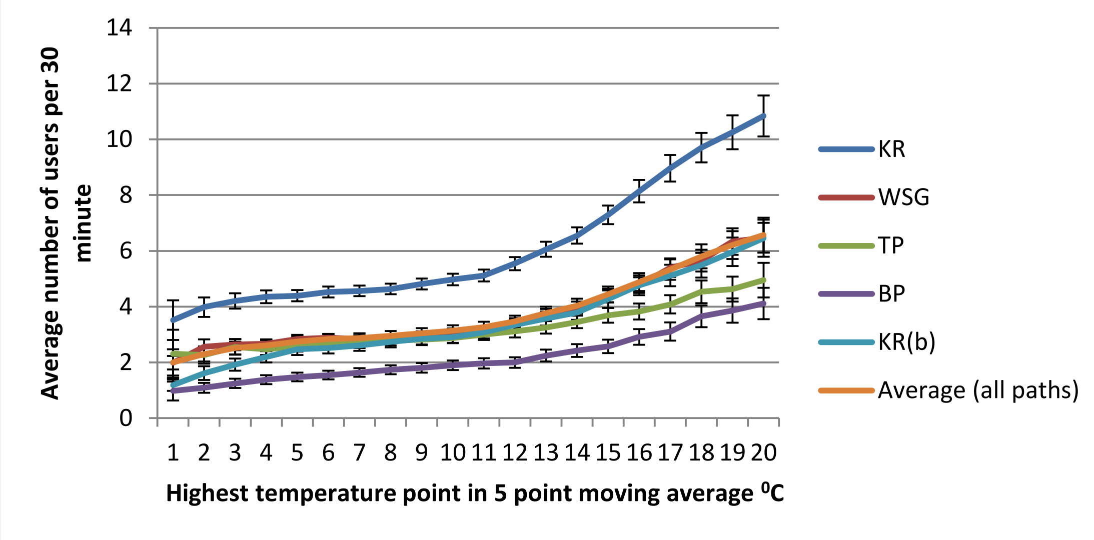


Figure 5.3 Five point moving average user numbers at each temperature.

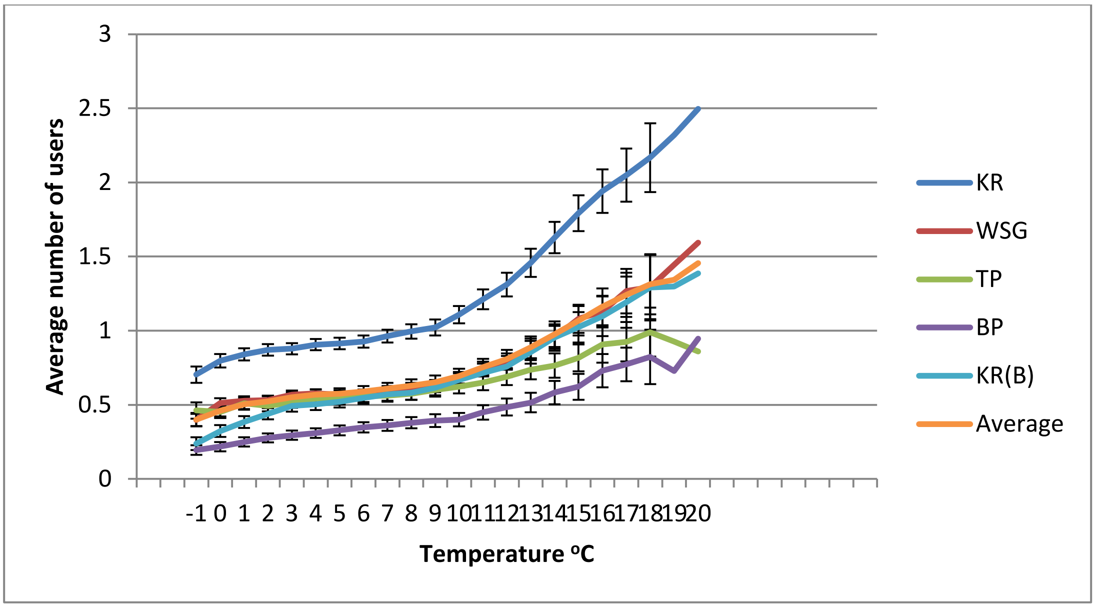
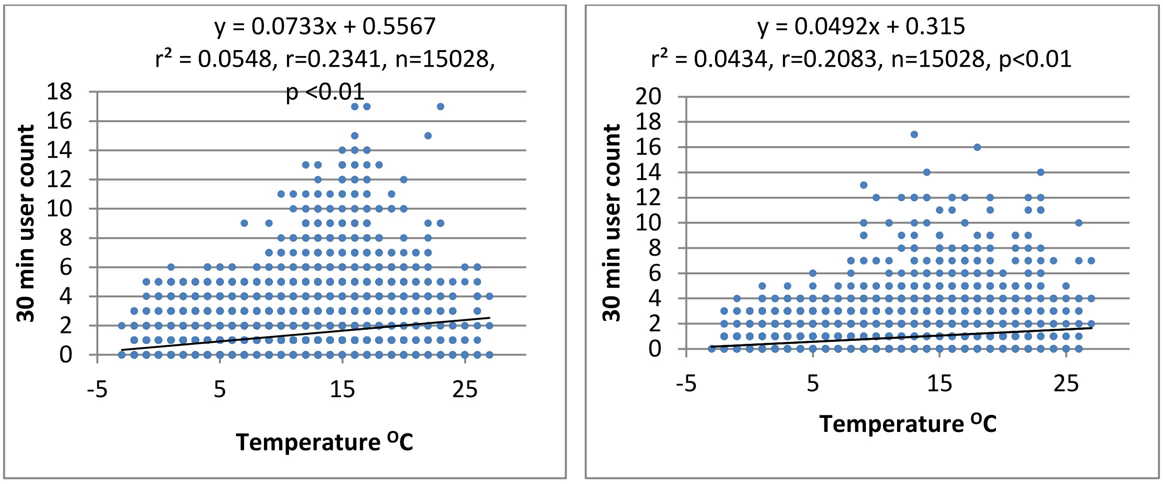


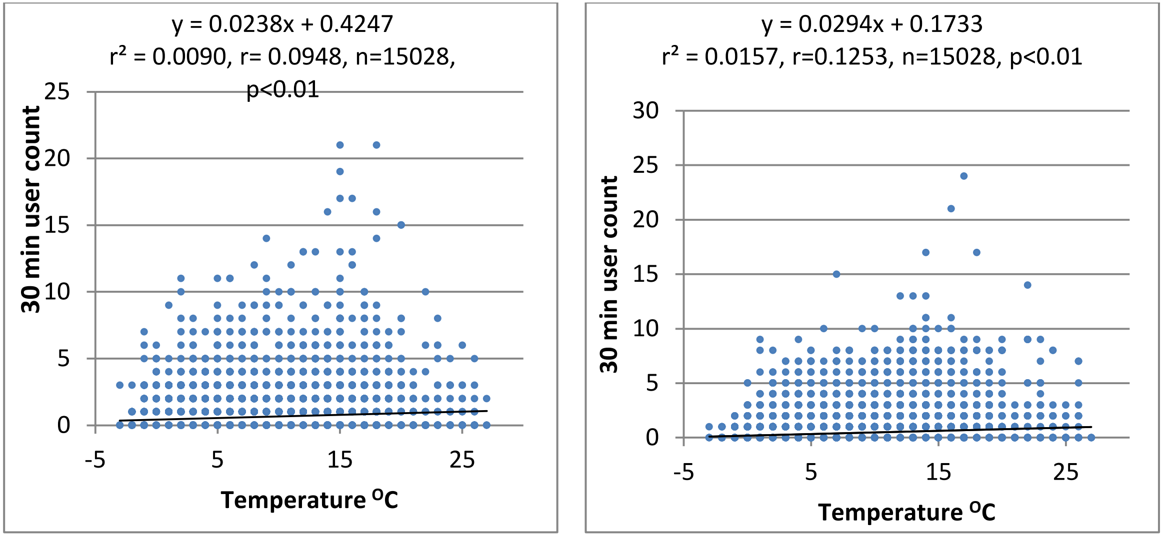
Figure 5.4 Five point moving average user numbers at each temperature with counts over 100.

As the lines in Figure 5.3 (p.112) and 5.4 (p.112) showed a largely monotonic relationship between –3 and +18, scatter graphs have been plotted to show the relationships between temperature and user numbers (Figure 5.5, p.113).



5.5A: Keighley Road

5.5B: Whetstone Gate

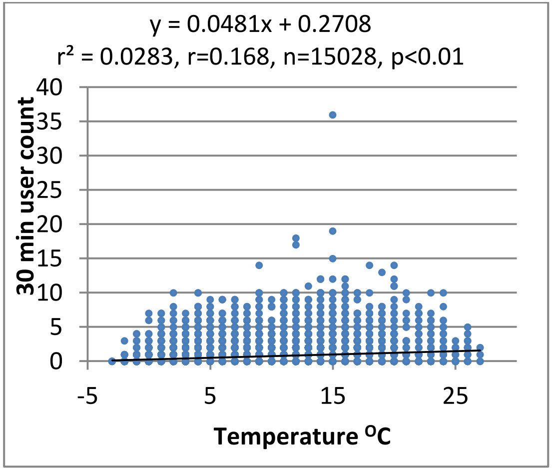


5.5C: Top Path

5.5D: Bottom Path

Comparison of the r^2 values presented in figure 5.23 (A-E).

Sensor	r^2
KR (Keighley Road)	0.0548
WSG (Whetstone Gate)	0.0434
TP (Top Path)	0.0090
BP (Bottom Path)	0.0157
KR(b) (Keighley Road Bottom)	0.0283



5.5E: Keighley Road (Bottom)

Figure 5.5 Scatter graphs for temperature and users.

The correlation coefficient provided a positive but weak link between the two variables. All findings were significant which may be due to the large sample size (n=15,028).

KR and WSG sensors saw a marginally greater link between temperature and user numbers, whereas TP, BP and KR(B) sensors were more distant from the main thoroughfare and had a weaker link between temperature and user numbers. This may have been due to the more distant sensors being triggered more by users who were prepared for, and less susceptible to changes in temperature. Sensors at KR and WSG may have been triggered by a more diverse user group.

Linear regression analysis showed a weak link between temperature and user numbers. Temperature was the independent variable (Table 5.2). There are more significant links (at the 0.05 level) at Keighley Road and Whetstone Gate than the other paths.

Table 5.2 Quadratic regression, temperature Vs counts.

	KR	**WSG**	**TP**	**BP R2**	**KR(B)**
R	6.1	5.5	0.9	1.7	3.0
Standard Error	1.6	1.2	1.3	1.2	1.5

Table 5.3 shows average users per temperature increment as a percentage of average users of the total sample, which gives a weighting factor for each observed temperature class.

Table 5.3 User counts per temperature band as a percentage of average temperature between 01.07.2014 - 30.06.2015.

Temp	**KR**	**WSG**	**TP**	**BP**	**KR(b)**
-3	27	0	88	35	0
-2	46	46	37	15	16

-1	49	44	85	34	32
0	*61*	*34*	*69*	*45*	*39*
1	54	50	59	43	52
2	58	50	81	56	49
3	61	53	79	43	52
4	59	46	73	58	64
5	64	50	86	62	70
6	63	53	79	56	58
7	61	46	78	72	60
8	65	54	92	61	66
9	71	55	76	69	78
10	75	58	96	78	76
11	73	60	97	68	77
12	90	65	94	77	91
13	100	85	113	105	92
14	105	77	105	101	104
15	125	96	130	104	132
16	130	93	117	129	135
17	145	119	132	112	131
18	150	107	180	202	135
19	141	137	119	139	159
20	164	108	177	148	189
21	181	158	71	44	140
22	205	185	83	306	182

23	185	305	158	284	275
24	121	159	113	177	209
25	67	115	146	75	73
26	202	221	112	302	178
27	101	371	73	0	87

Above average percentages are in red.

5.3 Dew Point

Dew point was collected as part of the METAR recording process. This is the atmospheric temperature at which point water droplets can begin to condense and dew can form. This is changeable depending on atmospheric pressure and humidity. There was a close relationship between Dew point and Temperature (Figure 5.6). There was a 0.87 correlation coefficient between the dew point and temperature data (significant at $p< 0.05$ significance level). Dew point has been left out of this analysis to avoid the auto correlation with temperature.

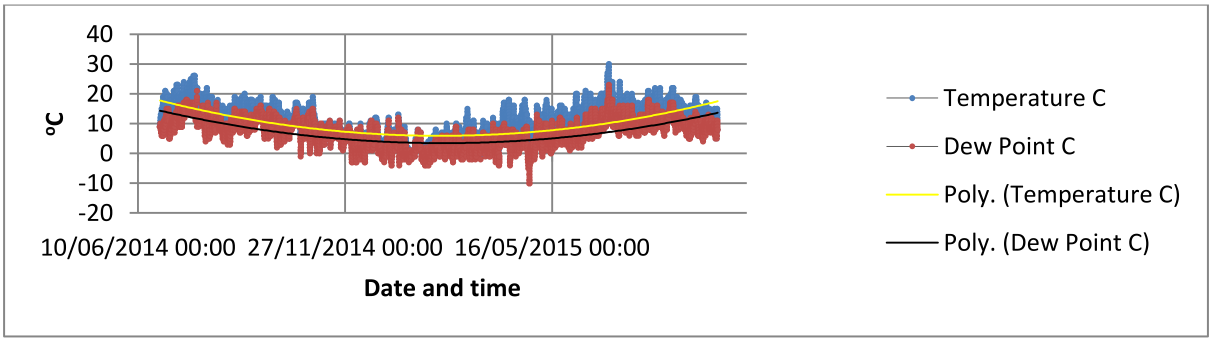


Figure 5.6 Comparison of temperature and dew point

5.4: Relative Humidity

Relative humidity (RH) was defined as the amount of water vapour in the air as a percentage of the amount of water vapour air can hold; a RH of 100% would indicate that the air is saturated. Users would likely be acclimatised to a particular range of humidity, so leaving this range could have caused discomfort and impact on user numbers. RH was measured on 17,515 counts between 1st July 2014 and 31st June 2015. The trend was to higher counts in higher humidity bands, with the majority of data in the 91-100% band (Figure 5.7). The survey area had an average RH of 84% (min: 23%, max: 100%) over the 12 month data collection period. RH has been grouped into bands for analysis.

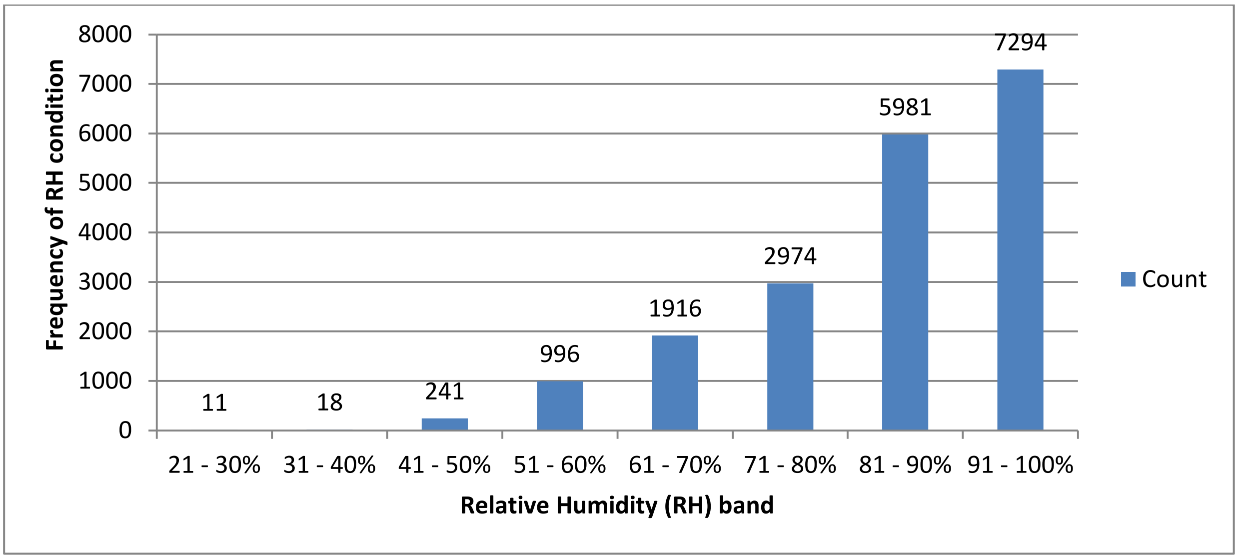


Figure 5.7 Number of counts per humidity band.

A negative linear relationship was displayed between humidity and average visitor numbers (Figure 5.8, p.118). The higher humidity bands (71 – 100%) accounted for 83% of all 30 minute observations. Figure 5.9 (p.118) focuses on average users per band where the band had more than 5% of RH occurrences (n = 972).

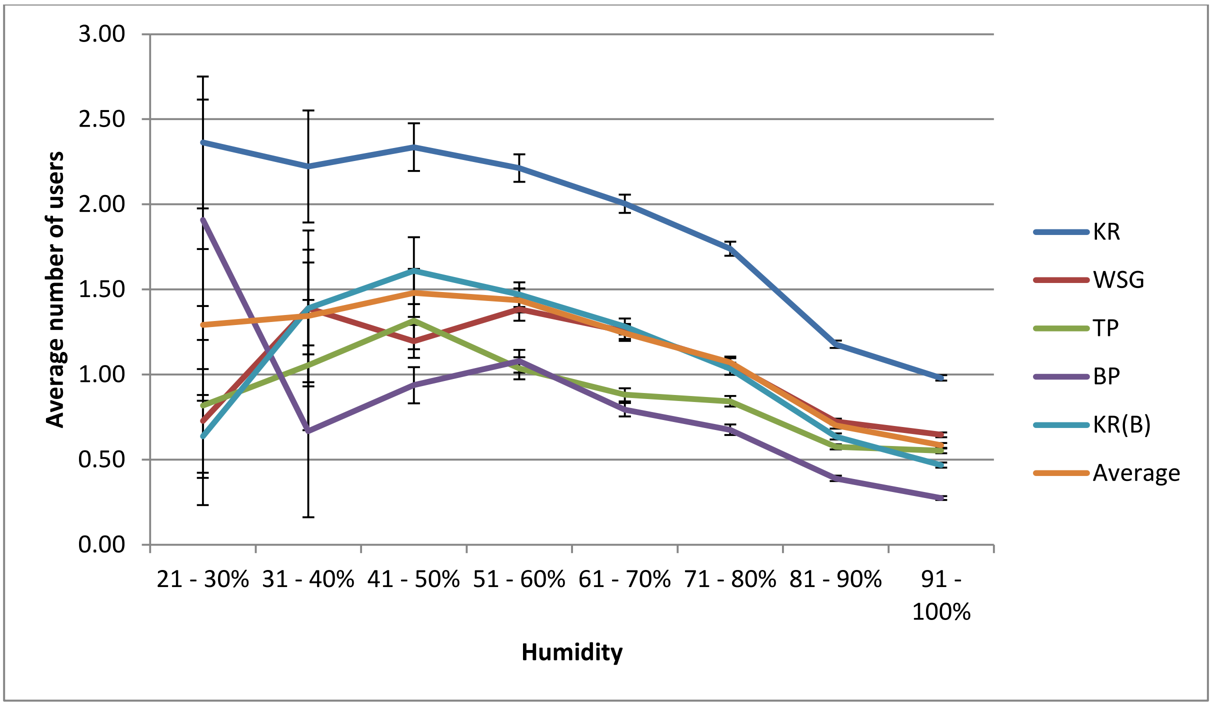


Figure 5.8 Average users by humidity band.

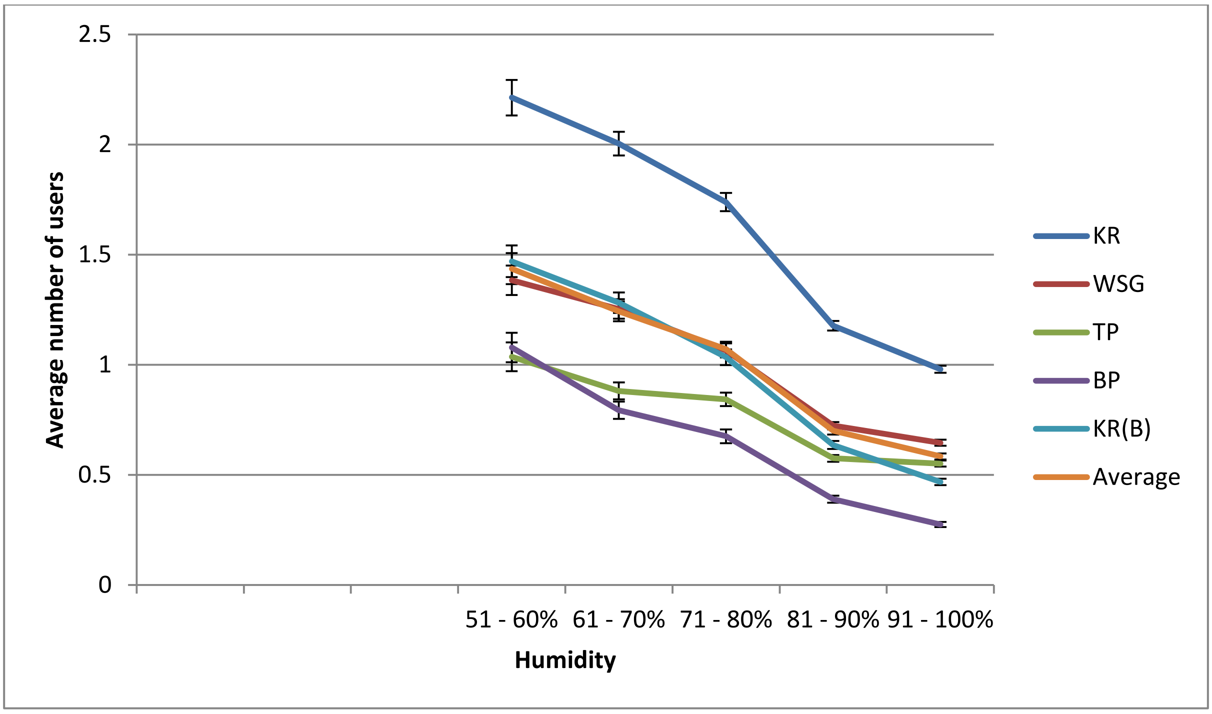
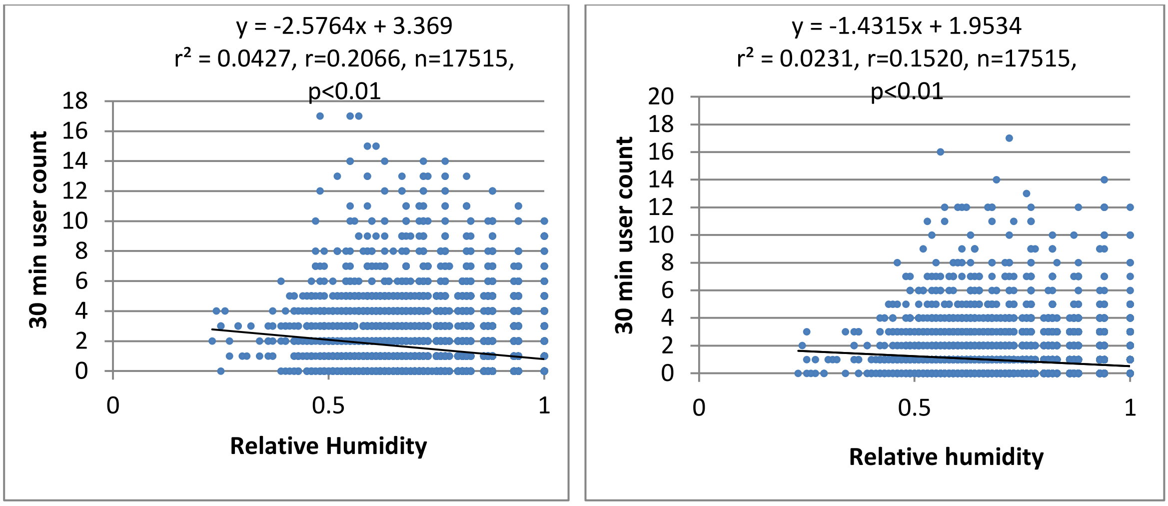


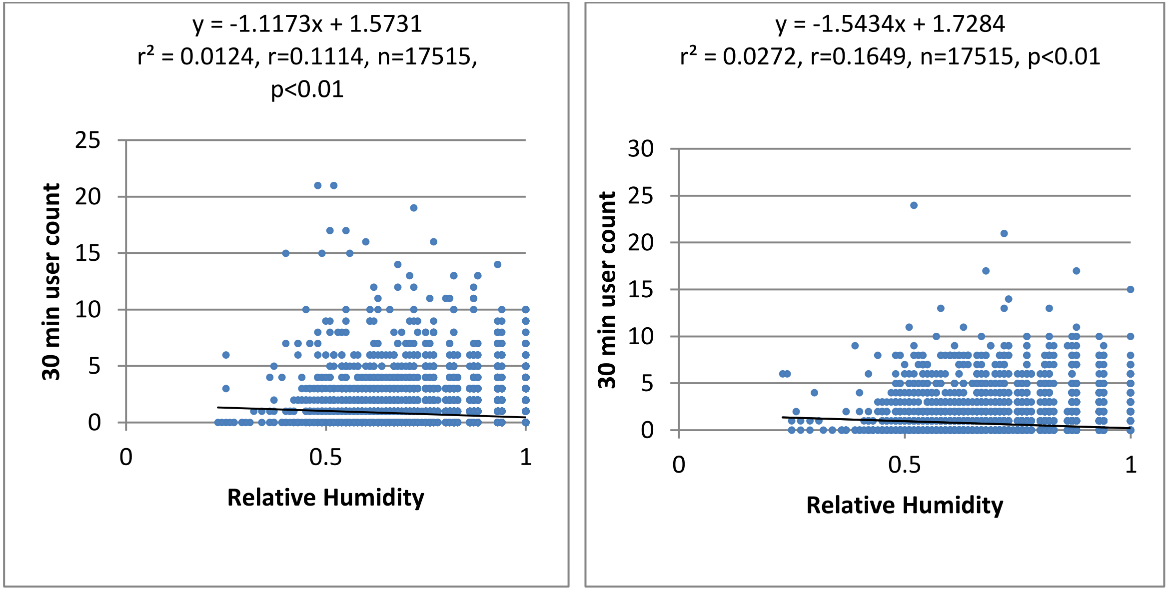
Figure 5.9 Average users per humidity band excluding bands with less than 5% of RH occurrences.

Pearson correlation coefficients show that there is a negative, weak correlation between the two variables, as described in Figure 5.10 A-E (p.119).



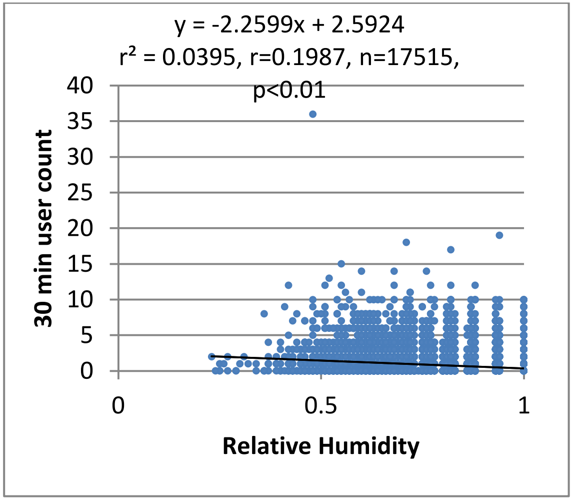
5.10A: Keighley Road

5.10B: Whetstone Gate



5.10C: Top Path

5.10D: Bottom Path



5.10E: Keighley Road (Bottom)

Note: All RH values were recorded in percentages (I.e. 0.4 = 40%)

Summary of figures 5.43 A-E

Sensor	r^2
KR (Keighley Road)	0.0427
WSG (Whetstone Gate)	0.0231
TP (Top Path)	0.0124
BP (Bottom Path)	0.0272
KR(b) (Keighley Road Bottom)	0.0395
Average R^2	0.0290

Figure 5.10 Scatter graphs for humidity and user counts.

All sensors reported a weak negative relationship (when there was high humidity there were fewer users) (Figure 5.10, p.119). The relationships are marginally stronger at the KR and KR(B) sensors (r^2 = 0.0427 and 0.0395) , compared to an average r^2 = 0.03 across the more remote sensors. This may be because visitors on Keighley Road were either in or quite close to their car and so were less affected by high humidity which is also correlated with rainfall – see section 5.8, p.139. Table 5.4 shows the average user number at different RH bands as a percentage of the overall average. This shows that generally there was higher than average use of the moor between 30 and 70% RH.

Table 5.4 Average users per humidity band as a percentage of the overall average.

Humidity	**KR**	**WSG**	**TP**	**BP**	**KR(B)**
21 - 30%	126	69	93	227*	60
31 - 40%	118	133	119	79	130
41 - 50%	124	114	149	112	151
51 - 60%	118	132	117	128	138
61 - 70%	107	120	100	94	120
71 - 80%	93	102	95	80	97
81 - 90%	63	69	65	46	60
91 - 100%	52	62	62	33	44

*There may be a skew caused by a very small sample: n = 5.

Above average percentages are in red.

5.5.1: Wind Direction

Wind is the movement of air from areas of high pressure to areas of low pressure. This movement brings other weather conditions. Northerly winds generally bring cold air from the polar region, north westerly winds bring cold moist air, south easterly winds generally bring warm dry air from the tropics (Africa), easterly winds generally bring dry cold Siberian air, and south westerly winds generally bring warm moist air from the Gulf Stream (Figure 5.11). Wind is defined from its origin, i.e. a southerly wind will be moving in from a southerly direction.

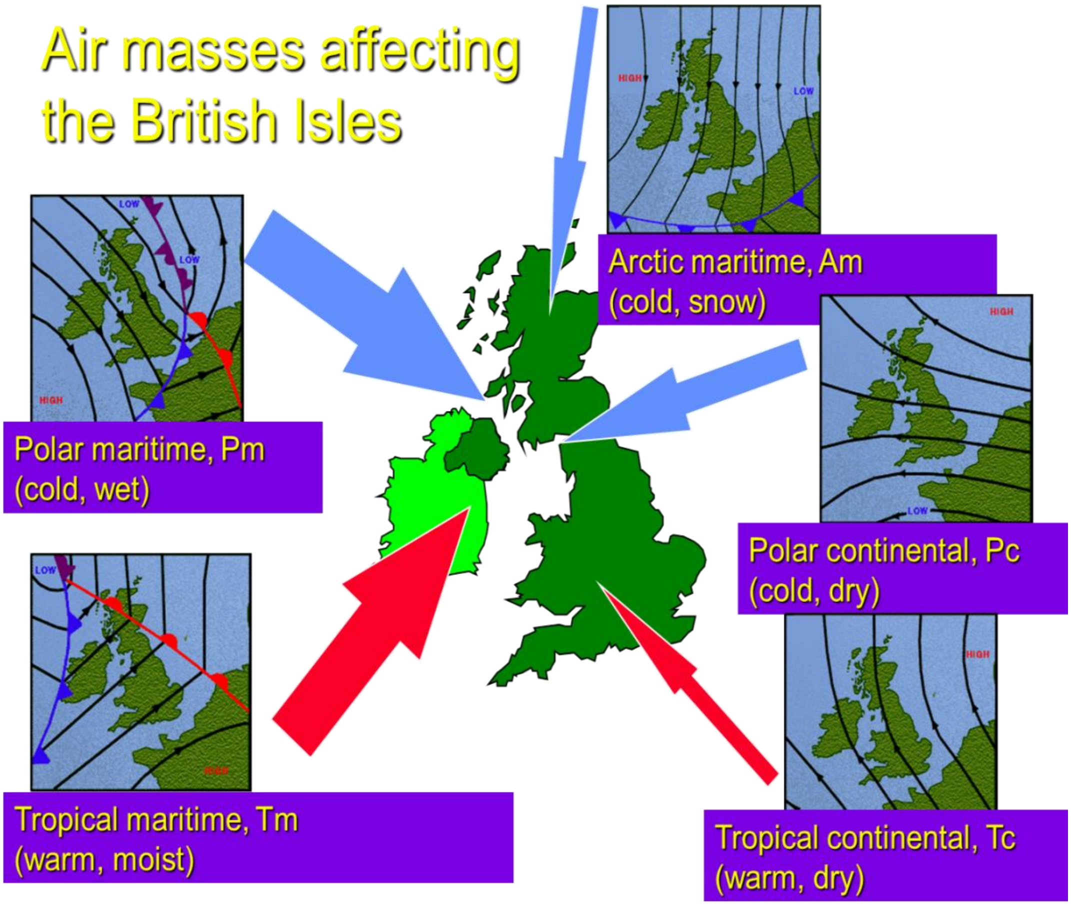


Figure 5.11 Air masses affecting the British Isles (adapted from Langmuir, 2013). The width of the arrows is in proportion to the frequency with which these air masses affect Britain.

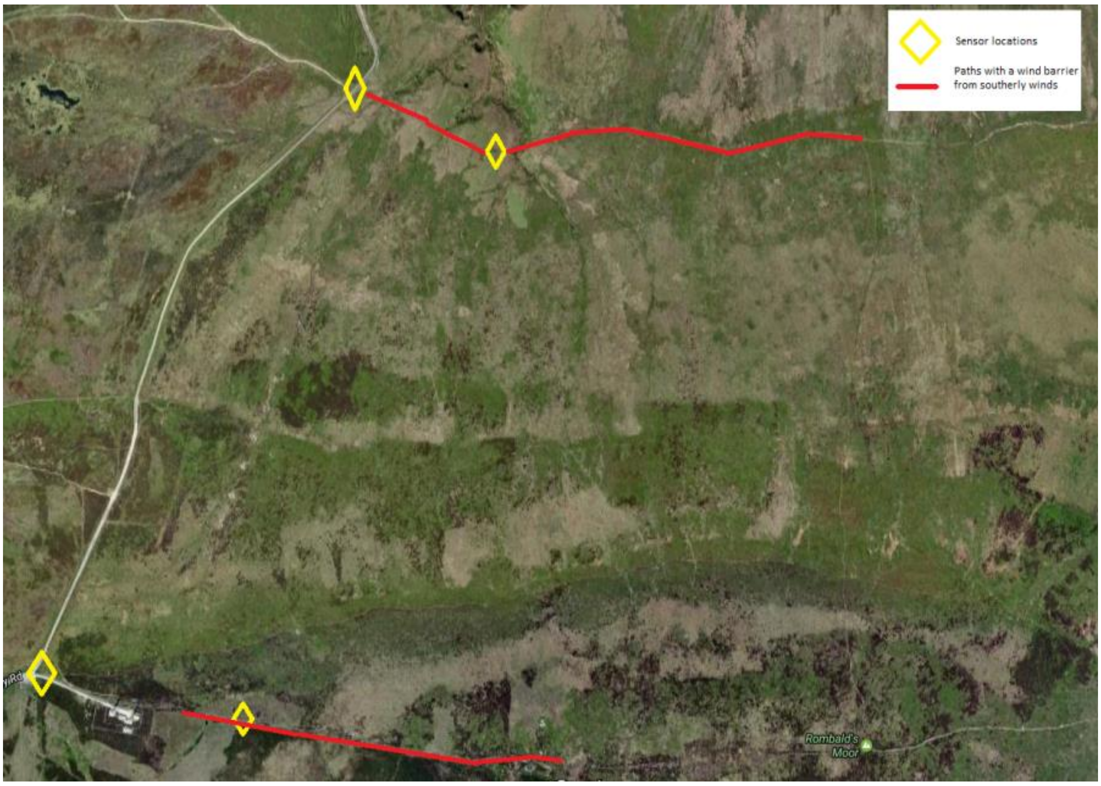


Figure 5.12 Areas of shelter and sensor locations in the survey area (Image: Google, 2017).

The survey area (Figure 5.12) is generally exposed as it is the highest part of the Rombold's Moor complex. There are two areas of shelter from the predominant south westerly winds: The top path has a wall running alongside it, and the bottom path is in the lee of the land. All other paths are exposed to a northerly aspect. These areas of shelter are marked in red on Figure 5.12.

Wind direction has been recorded at 21,361 data points across the whole collection period. The predominant wind has been from a westerly / south westerly angle, (Figure 5.13). In addition to the radar graph there were 1437 variable and 175 calm data points.

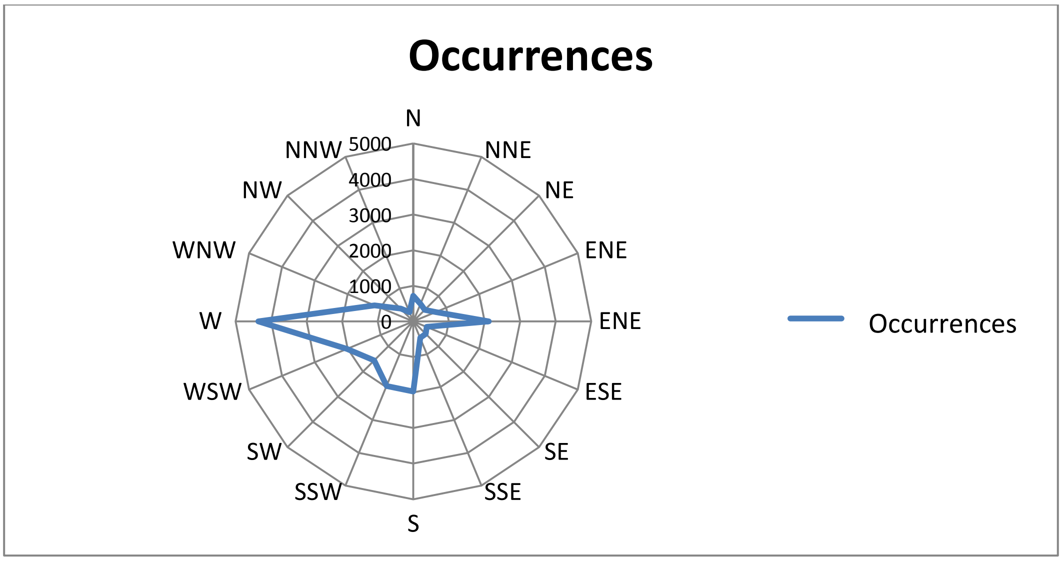


Figure 5.13 Number of occurrences of each wind direction. [In addition there were; 1437 variable and 175 calm readings].

Wind was reported in grouped data (by every 10 degrees). ANOVA analysis has been used to check if there is a significant difference in users based on wind direction (Table 5.5). Wind groups have been merged to form North, East, South, West, Calm and Variable.

Table 5.5 ANOVA, by wind direction.

	F value	P value
KR	6.690	P<0.001
WSG	8.420	P<0.001
TP	0.880	0.491
BP	4.150	0.011
KR(B)	1.080	0.368

ANOVA reported significant differences on Keighley Road and at Whetstone Gate (P<0.01) but there was no significance between wind direction and user on Top Path, Bottom Path or Keighley Road bottom at the P<0.01 level, however there is significance on the Bottom Path at P<0.05 level. This may have been because these are the more sheltered areas of the survey area (as shown in Figure 5.12, p.122) or this could be because the more remote sensors were only being triggered by more ardent users who are less perturbed by climatic conditions. A Tukey Post-Hoc test was completed to show where the significant differences occur, Table 5.6.

Table 5.6 Tukey post-hoc test to show differences in wind direction.

Wind directions that do not share a letter are significantly different			
	KR	WSG	BP
North	A	A	A
East	A	A B	A
South	**B**	**C**	**B**
West	A	B	A
Calm	A **B**	A B **C**	A B
Variable	A	A B	B

Table 5.6 shows that southerly winds had a significant impact on user numbers on KR, WSG and BP ($P<0.01$), whereas all other wind directions showed no significance. The fact that there is significance at KR and WSG sensors adds to the argument that there are two types of user on the moor. Less serious users who are easily influenced by climatic factors, but do not wander far onto the moor [just past KR and WSG sensors] and serious users who are less affected by weather and venture further out into the moor [triggering all sensors]. However, this argument is not supported by the fact that the more remote BP sensor shows significance at the $P<0.05$ level.

Average user counts by wind direction displayed as a percentage of the average count are shown in Table 5.7 (p.125). This shows fewer than average users when wind is coming from a southerly direction, or when there are calm conditions.

Table 5.7 Average users in each wind direction class as a percentage of the year (1st July 2014 - 30th June 2015 average).

	KR	WSG	TP	BP	KR(B)
North	109	114	104	111	94
East	106	110	101	99	105
South	91	89	95	84	98
West	104	101	103	98	103
Calm	88	77	96	92	96
Variable	102	108	101	116	105

Above average percentages are in red.

5.5.2: Wind Speed

Wind speed can be measured in metres per second (m/s), kilometres per hour (kph), miles per hour (mph), knots (1 knot = 1.15mph) or on the Beaufort wind force scale. Generally, METARs are recorded in metres per second (m/s). This has been converted into kph through the following formula:

Equation 1: metres per second to kilometers per hour wind speed calculation.

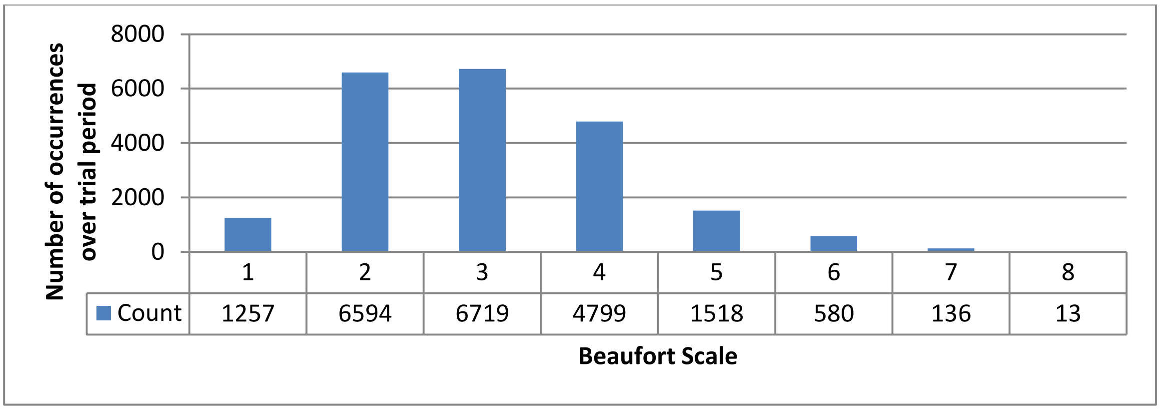
$$1\ m/sec\ = \frac{\frac{1}{1000}}{\frac{1}{3600}}\ km/hr\ = \frac{3600}{1000}\ km/hr\ = \frac{18}{5}\ km/hr$$

Table 5.8 gives a comparison of the different measurements of wind speed. Wind speed can impede user activities, although there is no definitive speed at which users might stop their activity as this is a personal judgement. Wind chill (Section 5.5.3, p.129) may have affected these personal decisions.

Table 5.8 Comparison of wind speed measurements (Beaufort, kph, mph and knots).

Beaufort number	**Beaufort wind description**	**kph**			**mph (1sf)**			**knots**		
0	Calm	1	to	1	1	to	1	1	to	1
1	Light Air	1	to	5	1	to	3	1	to	3
2	Light Breeze	6	to	11	4	to	7	4	to	6
3	Gentle Breeze	12	to	19	7	to	12	7	to	10
4	Moderate Breeze	20	to	28	12	to	17	11	to	16
5	Fresh Breeze	29	to	38	18	to	24	17	to	21
6	Strong Breeze	39	to	49	24	to	30	22	to	27
7	Moderate Gale	50	to	61	31	to	38	28	to	33
8	Fresh Gale	62	to	74	39	to	46	34	to	40
9	Strong Gale	75	to	88	47	to	55	41	to	47
10	Whole Gale	89	to	102	55	to	63	48	to	55
11	Storm	103	to	117	64	to	73	56	to	65
12 - 17	Hurricane	Above 117			Above 72.7			Above 65		

Wind speeds were taken at 21,616 points over the whole study period. Figure 5.14 (p.127) shows how these readings were distributed across a range of grouped wind speeds. These conditions ranged from light air movement to fresh gale (Beaufort scale 1 – 8).

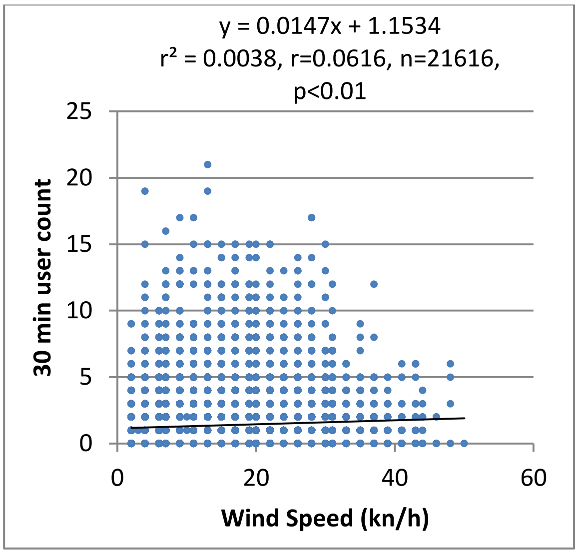


	1	2	3	4	5	6	7	8
🟦 Count	1257	6594	6719	4799	1518	580	136	13

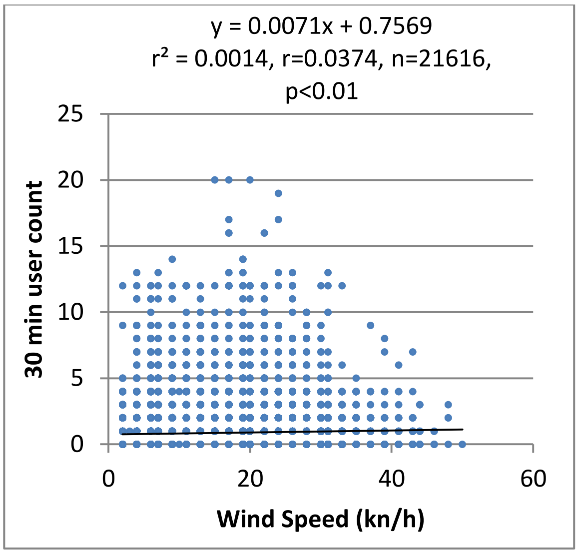
Figure 5.14 Number of counts per band.

There were very few occurrences of Beaufort conditions seven and eight, potentially leading to a skew for these conditions.

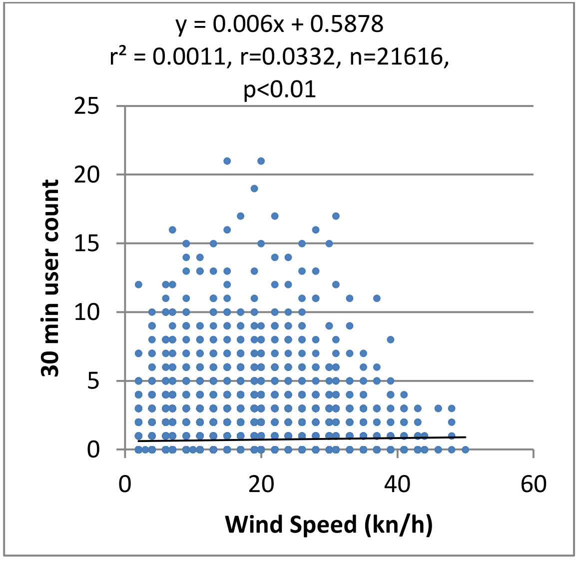
As wind speed was originally recorded in m/s (ratio data) scatter plots have been created between the two variables. These are shown in Figure 5.15 A-E (p.128).



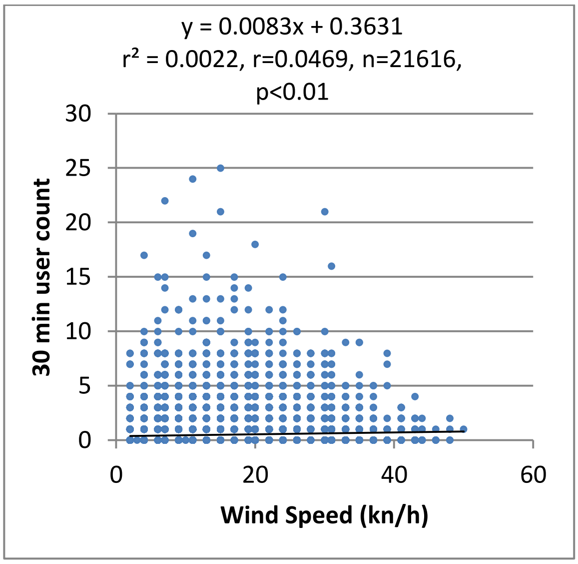
5.15A: Keighley Road



5.15B: Whetstone Gate



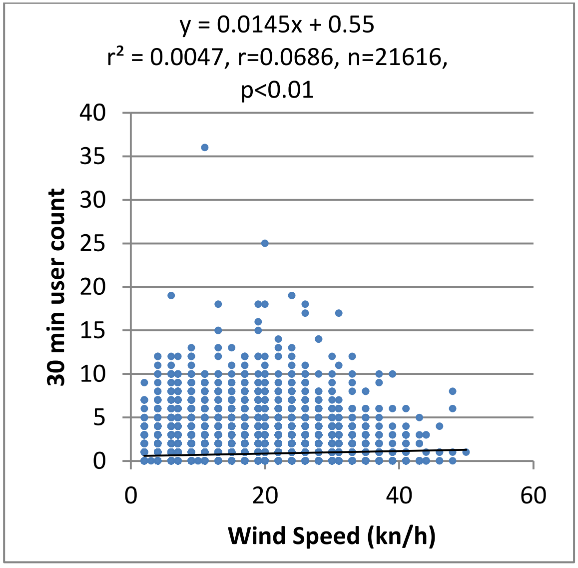
5.15C: Top Path



5.15D: Bottom Path

Summary of figure 5.53(a-e)

Sensor	r^2
KR (Keighley Road)	0.0038
WSG (Whetstone Gate)	0.0014
TP (Top Path)	0.0011
BP (Bottom Path)	0.0022
KR(b) (Keighley Road Bottom)	0.0047
Average R^2	0.0026



5.15E: Keighley Road (Bottom)

Figure 5.15 Scatter graphs for wind speed and user counts.

Correlations (Figure 5.15 A-E, p.128) showed a very weak, positive link between the two variables. Average user counts per band displayed as a percentage of the overall average show generally higher than average counts on Keighley Road between two and five on the Beaufort scale. Visitors passing the Keighley Road sensor are usually in vehicles; this would indicate that users in vehicles were usually less susceptible to the wind, but still decline to go out onto the moor at Beaufort scale six.

Table 5.9 Average users per wind band as a percentage of the overall average

Beaufort Scale	KR	WSG	TP	BP	kr(B)
1	98	68	53	34	51
2	106	68	54	37	56
3	114	69	54	39	63
4	126	80	62	48	75
5	123	72	62	47	82
6	95	65	51	39	68
7	88	46	45	45	49
8	51	13	0	6	45

Above average percentages are in red.

5.5.3 Wind Chill

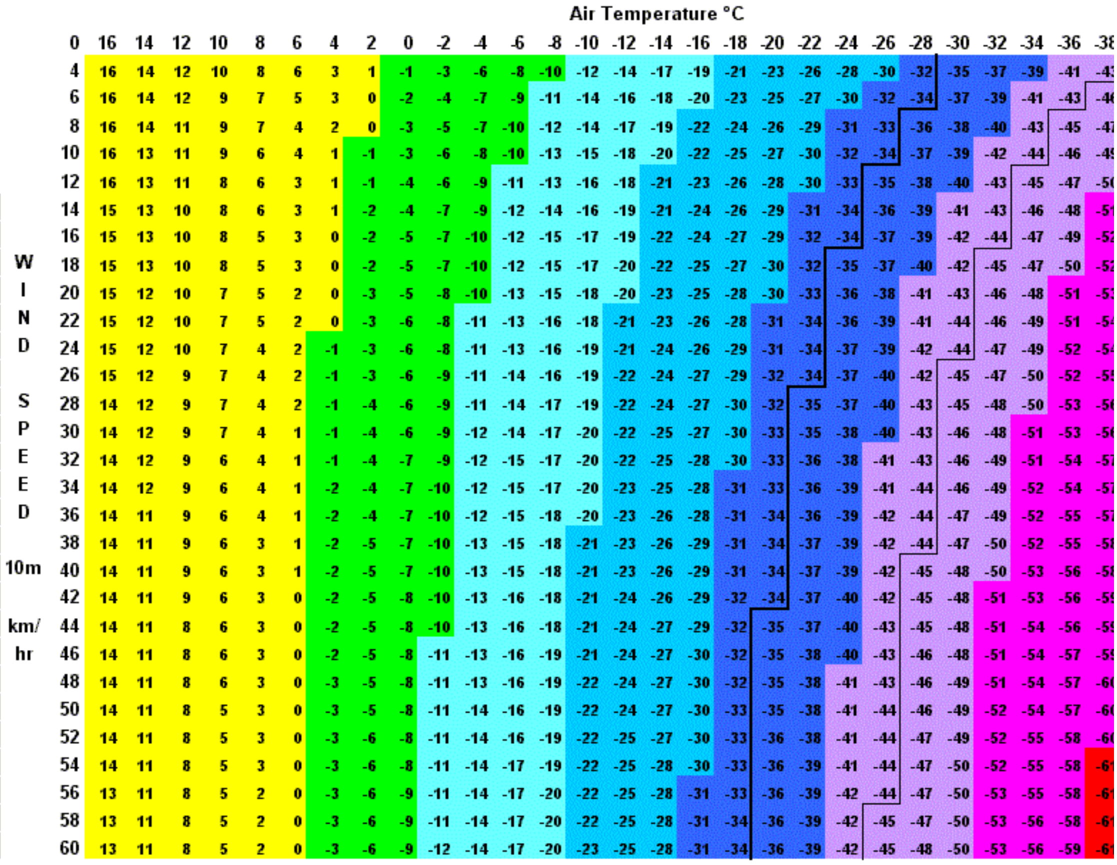
Wind chill is the perceived temperature caused by wind hitting a surface (e.g. skin). There are several calculations for wind chill; this study used the "UK New Wind Chill Calculation" as prescribed by the Joint Action Group for Temperature Indices (Met Office, 2016).

Equation 2 Wind chill calculation.

$$T_{\mathrm{wc}} = 13.12 + 0.6215T_{\mathrm{a}} - 11.37V^{+0.16} + 0.3965T_{\mathrm{a}}V^{+0.16}$$

Where T_{wc} = Wind Chill, T_a = Air Temperature (in ^{o}C) and V = Wind Speed in kph at 10 metre height.

Over the full study period 20,525 wind chill values have been calculated from the METAR data; 30 minute wind chill values (n=20,525; min: -8.9, max: 32.6). The average wind chill is 7.09^{o}C, with the modal value being -3.04^{o}C. Figure 5.16 (p.131) shows accepted discomfort levels at different wind-chill temperatures. Even at the minimum observed chill (-8.9) there was not a danger of frostbite, although at this temperature walking would still be uncomfortable, which may have had an impact on users.



Air Temperature °C

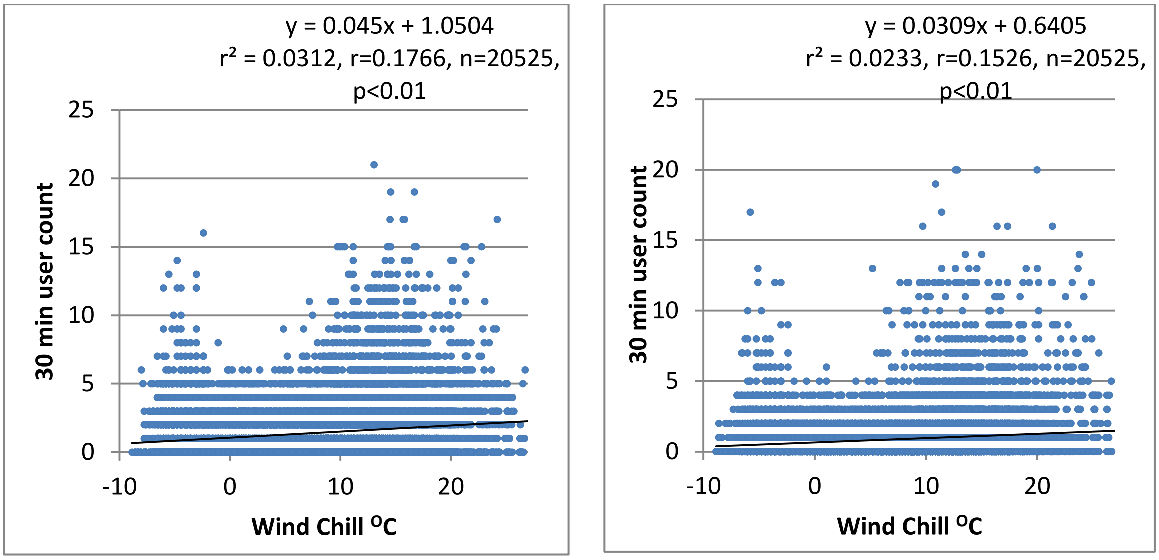
WIND SPEED 10m km/hr

0	16	14	12	10	8	6	4	2	0	-2	-4	-6	-8	-10	-12	-14	-16	-18	-20	-22	-24	-26	-28	-30	-32	-34	-36	-38
4	16	14	12	10	8	6	3	1	-1	-3	-6	-8	-10	-12	-14	-17	-19	-21	-23	-26	-28	-30	-32	-35	-37	-39	-41	-4
6	16	14	12	9	7	5	3	0	-2	-4	-7	-9	-11	-14	-16	-18	-20	-23	-25	-27	-30	-32	-34	-37	-39	-41	-43	-4
8	16	14	11	9	7	4	2	0	-3	-5	-7	-10	-12	-14	-17	-19	-22	-24	-26	-29	-31	-33	-36	-38	-40	-43	-45	-4
10	16	13	11	9	6	4	1	-1	-3	-6	-8	-10	-13	-15	-18	-20	-22	-25	-27	-30	-32	-34	-37	-39	-42	-44	-46	-4
12	16	13	11	8	6	3	1	-1	-4	-6	-9	-11	-13	-16	-18	-21	-23	-26	-28	-30	-33	-35	-38	-40	-43	-45	-47	-5
14	15	13	10	8	6	3	1	-2	-4	-7	-9	-12	-14	-16	-19	-21	-24	-26	-29	-31	-34	-36	-39	-41	-43	-46	-48	-5
16	15	13	10	8	5	3	0	-2	-5	-7	-10	-12	-15	-17	-19	-22	-24	-27	-29	-32	-34	-37	-39	-42	-44	-47	-49	-5
18	15	13	10	8	5	3	0	-2	-5	-7	-10	-12	-15	-17	-20	-22	-25	-27	-30	-32	-35	-37	-40	-42	-45	-47	-50	-5
20	15	12	10	7	5	2	0	-3	-5	-8	-10	-13	-15	-18	-20	-23	-25	-28	-30	-33	-36	-38	-41	-43	-46	-48	-51	-5
22	15	12	10	7	5	2	0	-3	-6	-8	-11	-13	-16	-18	-21	-23	-26	-28	-31	-34	-36	-39	-41	-44	-46	-49	-51	-5
24	15	12	10	7	4	2	-1	-3	-6	-8	-11	-13	-16	-19	-21	-24	-26	-29	-31	-34	-37	-39	-42	-44	-47	-49	-52	-5
26	15	12	9	7	4	2	-1	-3	-6	-9	-11	-14	-16	-19	-22	-24	-27	-29	-32	-34	-37	-40	-42	-45	-47	-50	-52	-5
28	14	12	9	7	4	2	-1	-4	-6	-9	-11	-14	-17	-19	-22	-24	-27	-30	-32	-35	-37	-40	-43	-45	-48	-50	-53	-5
30	14	12	9	7	4	1	-1	-4	-6	-9	-12	-14	-17	-20	-22	-25	-27	-30	-33	-35	-38	-40	-43	-46	-48	-51	-53	-5
32	14	12	9	6	4	1	-1	-4	-7	-9	-12	-15	-17	-20	-22	-25	-28	-30	-33	-36	-38	-41	-43	-46	-49	-51	-54	-5
34	14	12	9	6	4	1	-2	-4	-7	-10	-12	-15	-17	-20	-23	-25	-28	-31	-33	-36	-39	-41	-44	-46	-49	-52	-54	-5
36	14	11	9	6	4	1	-2	-4	-7	-10	-12	-15	-18	-20	-23	-26	-28	-31	-34	-36	-39	-42	-44	-47	-49	-52	-55	-5
38	14	11	9	6	3	1	-2	-5	-7	-10	-13	-15	-18	-21	-23	-26	-29	-31	-34	-37	-39	-42	-44	-47	-50	-52	-55	-5
40	14	11	9	6	3	1	-2	-5	-7	-10	-13	-15	-18	-21	-23	-26	-29	-31	-34	-37	-39	-42	-45	-48	-50	-53	-56	-5
42	14	11	9	6	3	0	-2	-5	-8	-10	-13	-16	-18	-21	-24	-26	-29	-32	-34	-37	-40	-42	-45	-48	-51	-53	-56	-5
44	14	11	8	6	3	0	-2	-5	-8	-10	-13	-16	-18	-21	-24	-27	-29	-32	-35	-37	-40	-43	-45	-48	-51	-54	-56	-5
46	14	11	8	6	3	0	-2	-5	-8	-11	-13	-16	-19	-21	-24	-27	-30	-32	-35	-38	-40	-43	-46	-48	-51	-54	-57	-5
48	14	11	8	6	3	0	-3	-5	-8	-11	-13	-16	-19	-22	-24	-27	-30	-32	-35	-38	-41	-43	-46	-49	-51	-54	-57	-6
50	14	11	8	5	3	0	-3	-5	-8	-11	-14	-16	-19	-22	-24	-27	-30	-33	-35	-38	-41	-44	-46	-49	-52	-54	-57	-6
52	14	11	8	5	3	0	-3	-6	-8	-11	-14	-16	-19	-22	-25	-27	-30	-33	-36	-38	-41	-44	-47	-49	-52	-55	-58	-6
54	14	11	8	5	3	0	-3	-6	-8	-11	-14	-17	-19	-22	-25	-28	-30	-33	-36	-39	-41	-44	-47	-50	-52	-55	-58	-6
56	13	11	8	5	2	0	-3	-6	-9	-11	-14	-17	-20	-22	-25	-28	-31	-33	-36	-39	-42	-44	-47	-50	-53	-55	-58	-6
58	13	11	8	5	2	0	-3	-6	-9	-11	-14	-17	-20	-22	-25	-28	-31	-34	-36	-39	-42	-45	-47	-50	-53	-56	-58	-6
60	13	11	8	5	2	0	-3	-6	-9	-12	-14	-17	-20	-23	-25	-28	-31	-34	-36	-39	-42	-45	-48	-50	-53	-56	-59	-6

From -25 to -34°: Frostbite likely after prolonged skin exposure to wind
From -35 to -60°: Frostbite possible in less than 10 minutes
Below -60°: Frostbite possible in less than 2 minutes

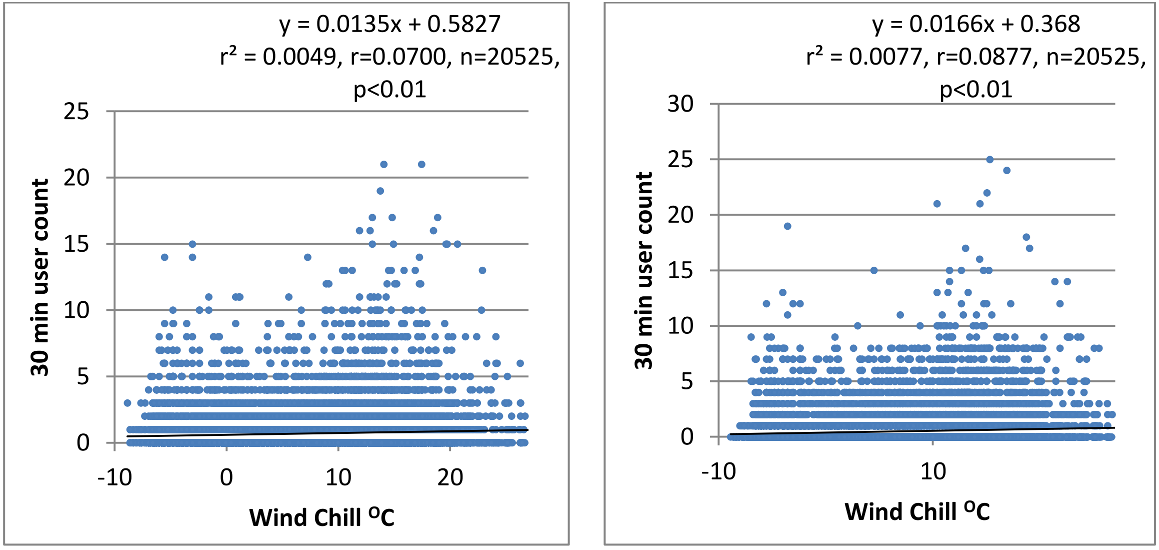
Figure 5.16 Wind chill and discomfort levels.

As wind chill is continuous data, correlations have been established to demonstrate the link between wind chill and user numbers (Figure 5.17, p.132).



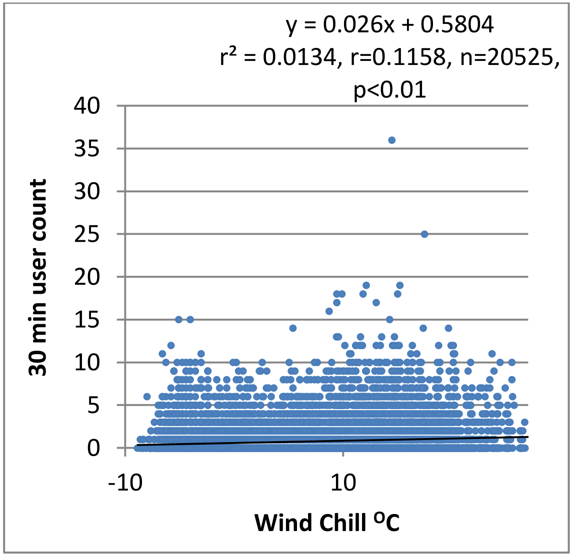
5.17A: Keighley Road

5.17B: Whetstone Gate



5.17C: Top Path

5.17D: Bottom Path



5.17E: Keighley Road (Bottom)

Figure 5.17 Scatter graphs for wind chill and user counts.

Summary of figure 5.45(a-e).

Sensor	r^2
KR (Keighley Road)	0.0312
WSG (Whetstone Gate)	0.0233
TP (Top Path)	0.0049
BP (Bottom Path)	0.0077
KR(B) (Keighley Road Bottom)	0.0134
Average R^2	0.0161

The correlations show a weak, positive link between wind chill and user counts that is slightly more apparent on Keighley Road.

5.6: Visibility

User counts were made at 17,384 30 minute periods between 1st July 2014 and 31st June 2015. Visibility was predominantly in the >10,000m category. Data was collected in 500m intervals up to >10,000m. Figure 5.18 shows the number of data points in each visibility group.

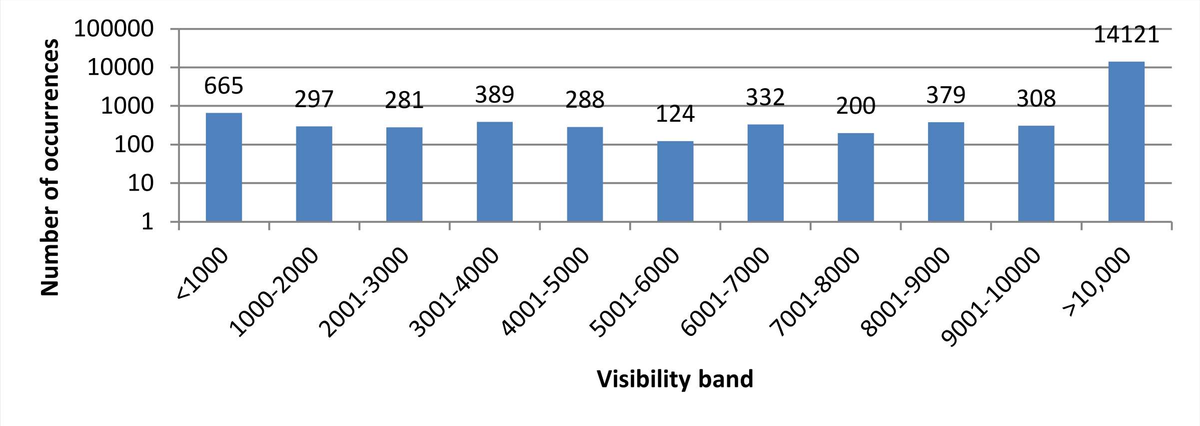


Figure 5.18 Number of counts per visibility band.

Comparing average user numbers and visibility produces a series of stochastic lines as can be seen in Figure 5.19 (p.133).

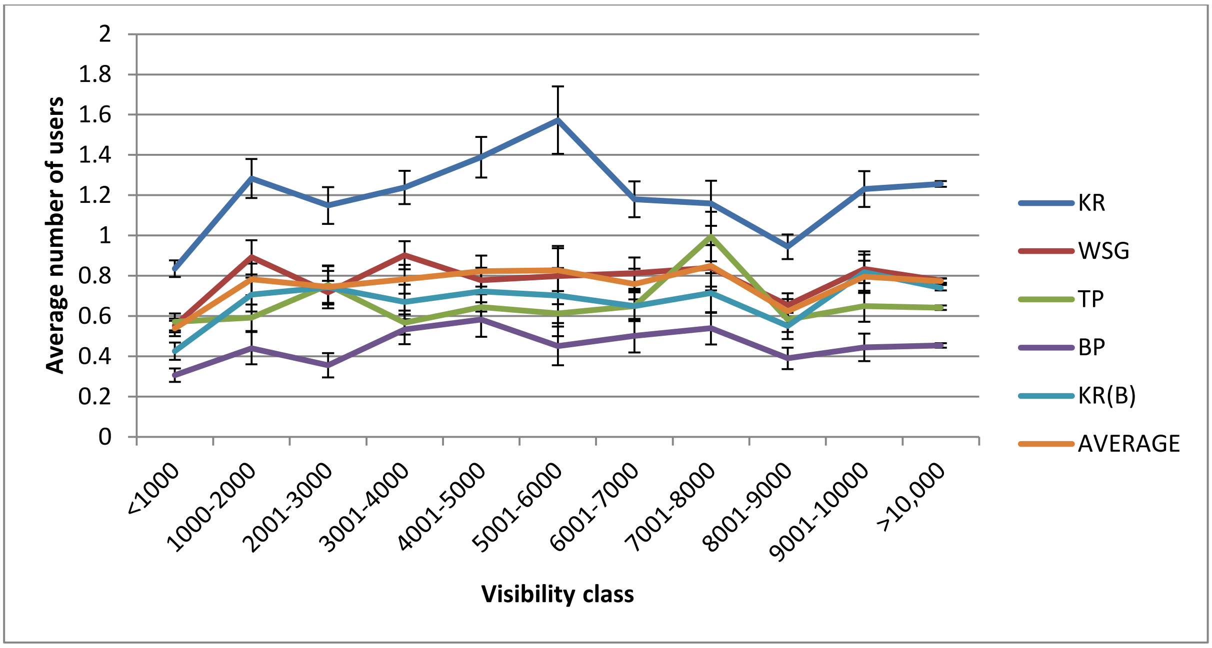
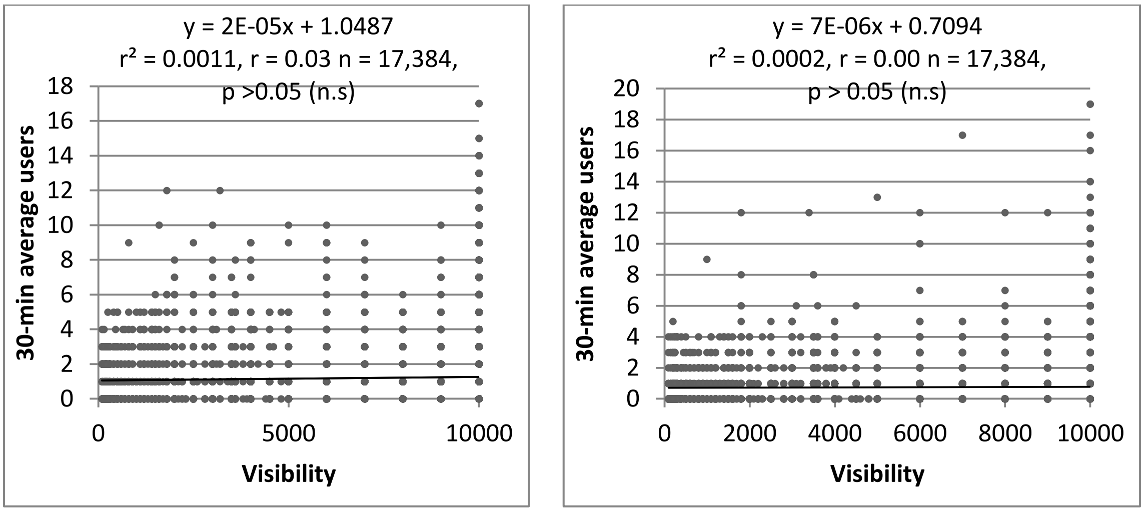


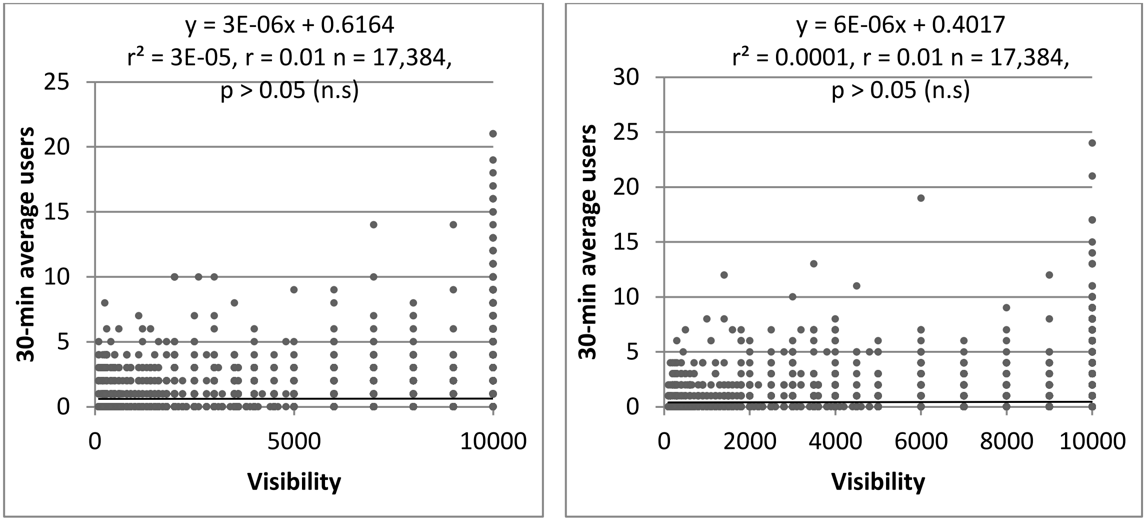
Figure 5.19 Average users by 1000m visibility class.

Original visibility data had 20 bands at 500m intervals (0 - >10,000), and this has been classified as interval data. Correlation analysis showed no significant (n.s) relationships between the two variables, as seen in Figure 5.20 A-E (p.135).



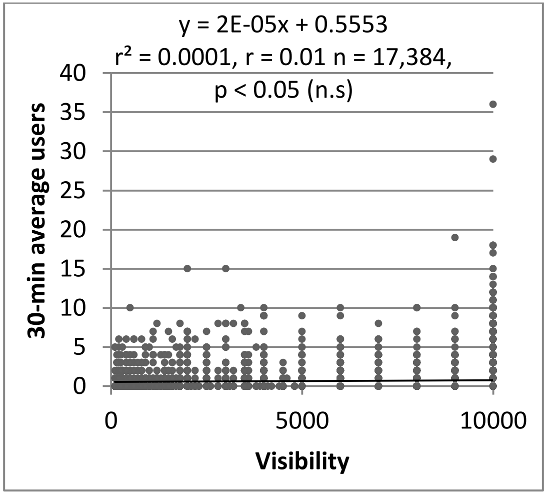
5.20A: Keighley Road

5.20B: Whetstone Gate



5.20C: Top Path

5.20D: Bottom Path



5.20E: Keighley Road (Bottom)

Figure 5.20 Scatter graphs for visibility and user counts.

Summary of Figure 5.63(a-e).

Sensor	r^2
Keighley Road	0.0011 (n.s)
Whetstone Gate	0.0002 (n.s)
Top Path	0.0000 (n.s)
Bottom Path	0.0001 (n.s)
Keighley Road Bottom	0.0001 (n.s)
Average R^2	0.0003

The correlations comparing visibility against users show no significant relationships (average $r^2 = 0.0003$). This may be because visibility was measured in intervals of 1000m, whereas a moorland user may have made their decision to use, or not use the survey area based on a considerably smaller visibility distance (i.e. 50m). Only 18% of the dataset are occurrences of <10,000m visibility.

5.7: Cloud

Cloud data have been extracted from the METAR reports and converted from a series of notes on observation to Oktas (as described in the Methods Chapter, p.72). Several METAR readings have been decoded as “Vertical Visibility (VV)”, this was usually followed by a measurement, indicating the area between ground and the first cloud. Some of the METAR reports for this location and time period have VV listed but no measurement. These VV have been ignored in this analysis. There are 16,673 data points used in this analysis over the period 01.07.2014 – 30.06.2015 (n=16,673).

Where two or more cloud conditions have been reported in one METAR report the highest Okta value has been taken and an extra one Okta added. For example: if the METAR report read FEW 1000[m], BKN, 5000[m] this would have been converted to seven Oktas, six for the BKN then an additional one to represent the FEW. The number of observations of each cloud condition varies between 27 – 4637 observations (Figure 5.21, p.137).

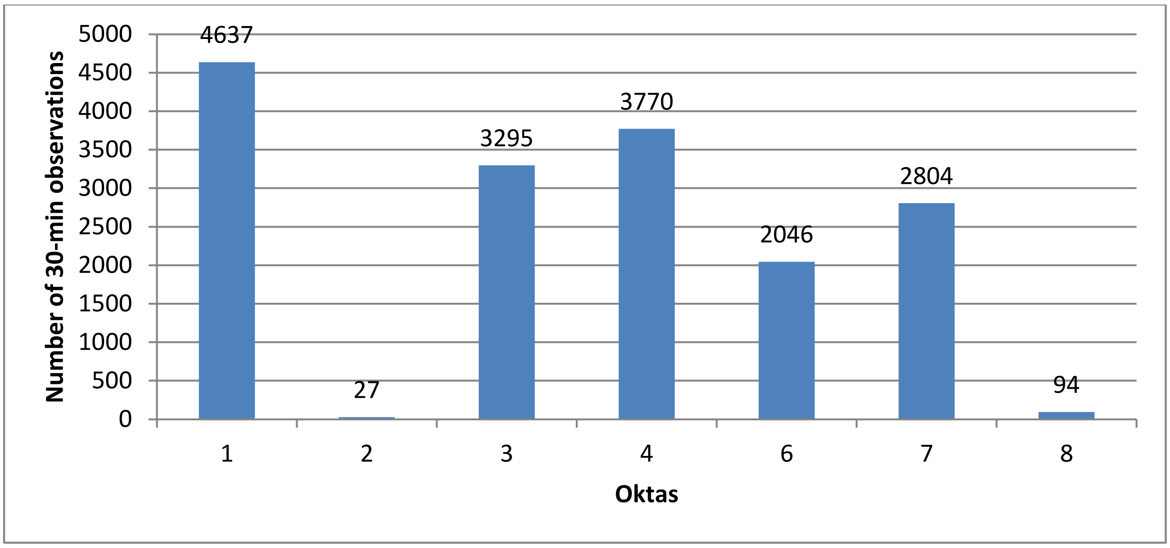


Figure 5.21 Sky condition count, by Okta.

As cloud data is grouped ANOVA analysis has been completed to determine if there is a significant difference in user numbers at different cloud conditions. The ANOVA statistics are reported in Table 5.10.

Table 5.10 ANOVA, by Okta.

	F value	P value
KR	42.71	P<0.001
WSG	18.42	P<0.001
TP	6.64	P<0.001
BP	17.91	P<0.001
KR(b)	27.45	P<0.001

As ANOVA showed a significant difference between the groups (P<0.01) a Tukey Post-hoc test was completed to see where the difference occurred, this can be seen in Table 5.11 (p.138).

Table 5.11 Tukey post-hoc test, by Okta.

Means that do not share a letter are significantly different					
	KR	WSG	TP	B	KR(b)
1	C	B	B	B D	B C
2*	A B C D	A B C	A B C	A B C D E	A B C D
3	B	B	A B	B	B
4	A	A	A	A	A
6	D	C	C	C E	D
7	B	A B	A B	B	A B
8	D	B C	A B C	A B C D E	C D
9	D	C	B C	D E	D

*The two Okta category (red) has very few data points [possibly due to the conversion method] so may be skewed (N =27).

The Tukey post-hoc test results showed some variation of users across the range of cloud groups. However, there is no pattern or link between higher levels of cloud and lower levels of use as the 7 Okta category shows high user numbers. This may be due to errors in the Okta conversion process (Table 3.8, p.72).

Table 5.12 Average users by Okta as an average of the total.

Oktas	**KR**	**WSG**	**TP**	**BP**	**KR(B)**
1	114	110	114	99	120
2*	83	91	71	143	74
3	126	116	116	113	130
4	143	133	132	142	155
6	81	81	93	62	70
7	127	122	118	114	136
8	55	68	60	60	44

Above average percentages are in red.

*The two Okta category has very few data points so may be skewed by other factors (N=27).

5.8: Rainfall

Rain conditions were measured over 17,520 points between 1st July 2014 – 31st June 2015. These counts are, no rain: 14,510, light rain: 2866, rain: 144. This represents rain falling on 17.2% of the 30 minute sample periods. As data was grouped an ANOVA test has been completed to check for significance between the categories (Table 5.13, p.140).

Table 5.13 ANOVA, by rain or no rain.

	F value	P value
KR	0.62	0.538
WSG	0.99	0.373
TP	3.03	0.048
BP	0.59	0.555
KR(b)	0.58	0.558

The ANOVA shows no significant difference at the P<0.01 level. However there is a significant difference at the P<0.05 level on Top Path. Tukey Post-hoc tests show, that the difference is between periods of rain (heavy and light) and no rain.

Table 5.14: Tukey post-hoc test, by rain.

Means that do not share a letter are significantly different.

	TP
Light Rain	A
Heavy Rain	A
No Rain	B

ANOVA and Tukey post-hoc tests only show differences in two of the five sensors across the moor. This may be partially due to the fact that rainfall is a localised condition, whereby at the time it was raining at the weather station (LBA) it may not have been raining at the study area (as shown in Figure 7.3, p.192). There is also a link between humidity and rainfall. Humidity ranged between 52% and 100% with the average humidity during rainfall being 91%. There is an auto-correlation between rainfall and relative humidity.

5.9: Sunlight data

Sunrise and sunset data have been obtained from Halesowen weather station, West Midlands, UK 106 km from the survey site. These data have been used as they give comprehensive sunrise and sunset times for the whole study period.

Each 30 minute weather block (01.07.2014 – 30.06.2015) was coded as “day” or “night”. Where the 30 minute period was over the interchange between day and night these data have been discarded, removing a maximum of two 30 minute periods per day. This left 8964 day counts and 8556 night counts. Average user counts showed a large difference between day and night (Figure 5.22).

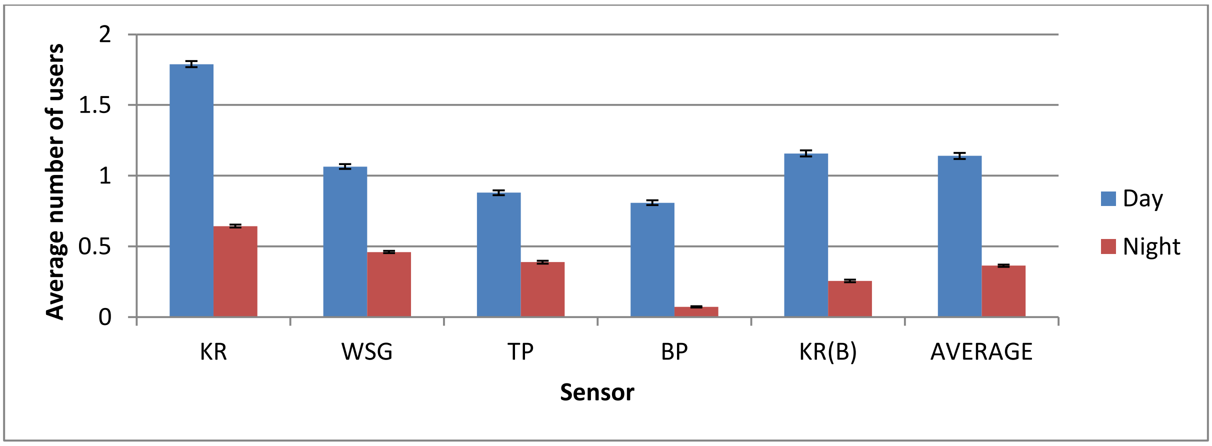


Figure 5.22 Comparison of user numbers by day and night.

As Figure 5.22 shows a large difference between daytime and evening users, ANOVA analysis has been used to compare the two variables. ANOVA data are reported in Table 5.15 (p.142).

Table 5.15 ANOVA, by sunlight or dark.

	F Value	P Value
KR	2350.61	P<0.001
WSG	1018.75	P<0.001
TP	559.06	P<0.001
BP	1610	P<0.001
KR(b)	1610.2	P<0.001

As the ANOVA tests show significance (P<0.01) between two variables it can be concluded that there was a significant difference in user counts between day and night. Post-hoc tests have not been completed as there are only two categories (day and night) indicating that the difference can only be between these two variables.

Summary of chapter

Of the nine variables that have been considered in this chapter, dew point was considered insignificant because of the high auto-correlation with temperature. Visibility was generally not considered significant at the 0.01 significance level. Factors that have been found to be significant are: Temperature, Wind Chill, Relative Humidity, Cloud and Sunlight. Wind speed was found to be significant at the p<0.01 level, but only displaying a very low relationship $R^2 = 0.00$ (2dp). Wind direction was considered significant on three of the five sensors. Rain was considered significant at TP at the p<0.05 level.

Table 5.16 Summary of Chapter Five findings.

	Keighley Road r^2	Whetstone Gate r^2	Top Path r^2	Bottom Path r^2	Keighley Road Bottom r^2
Temperature	0.05**	0.04**	0.01**	0.02**	0.03**
Relative Humidity	0.04**	0.02**	0.01**	0.03**	0.04**
Wind Direction[1]	S**	S**	S*	NS	NS
Wind Speed	0.00**	0.00**	0.00**	0.00**	0.00**
Wind Chill	0.03**	0.02**	0.00**	0.00**	0.01**
Visibility	0.03**	0.00	0.01	0.01	0.01
Cloud[1]	S**	S**	S**	S**	S**
Rain[1]	NS	NS	S*	NS	NS
Sunlight[1]	S**	S**	S**	S**	S**

[1] Where the data format has not allowed for correlations, ANOVA has been conducted, this is reported as S = Significant, NS = Not significant
No stars = Not significant at the 0.05 significance level
* = $p<0.05$; ** = $p<0.01$.

Chapter 6 Data modelling to predict user numbers

The results of this study have been discussed in Chapters Four (p.76) and Five (p.109). This chapter used two modelling approaches [regression and weighting factors] to assess whether a model can be built to predict future visitor numbers from time and weather variables.

6.1 Regression Based Approaches

Two regression based approaches were investigated: multiple and stepwise regression. Multiple regression was first trialled as this is the simpler of the two multivariate analyses. Multiple regression includes all variables presented to the equation. Once the multiple regression equations which explained the greatest variability were found, a stepwise regression was then trialled to investigate whether better predictions could be made through removing certain variables, or combinations of variables, from the calculation.

Note: In this chapter r^2 indicates a standard linear regression; R^2 indicates a multiple linear regression. Due to the large size of this dataset this chapter only uses one year of data: 1st July 2014 – 31st June 2015.

6.1.1 Dummy Variables

As one of the assumptions required in order to undertake multiple regression is for the data to be continuous, the categorical variables in this study (Day, Time, Month, Season, Cloud and Sunlight) have been regressed using dummy variables. Dummy variables allow the conversion of categorical variables into numeric variables by assigning the value one or zero. For example, Day can be converted to seven series of dummy variables with series one representing Mondays. All Monday data in this column is coded as a one, all Tuesday, Wednesday, Thursday, Friday, Saturday and Sunday data is coded as zero. Series two variables would represent Tuesdays. All Tuesday data in this column is coded as a one, all Monday, Wednesday, Thursday, Friday, Saturday and Sunday data is coded as the value zero. This is repeated for all days in the week.

6.2 Multiple Regression

The data collected were coded, prepared and regressed using SPSS as this allowed for more than 15 variables to be regressed at once (unlike Excel and Minitab). Dummy variables considerably increased the number of variables. Since a large amount of data was collected (n=21,000 when recorded at 30 minute intervals) test regressions were initially run on data from one day only to determine the optimum time interval. Mondays were selected as they saw the median use (high weekends, dropping to a low point on Thursdays (discussed in Chapter Four, p. 81), Monday gave an idea of baseline user data (Table 6.5, p.148).

The data intervals used were: 30 minutes, three, six and 12 hours, the results of which can be seen in Tables 6.1 (p.146) to 6.4 (p.148) and Figure 6.1 (p.150). User data per 30 minute period was added together to provide the different data intervals (i.e. three hours spans six 30 minute blocks). Weather data took the average condition in the time interval (i.e. the average weather condition in a three hour time interval would be the average of the six 30 minute observations).

It is noted that as the time intervals became larger accuracy would be lost in weather conditions, therefore the maximum time interval tested was 12 hours. All time intervals started at 00:20.

Initially regressions were tested at each interval for each variable to demonstrate which variables were the strongest predictors (Table 6.1 to 6.4). Then multiple regressions were tested to see which interval gave the strongest overall prediction of users (Table 6.5, p.148). Finally, in Figure 6.1 A-D (p.150), the regressions generated in Table 6.5 were plotted against the actual user counts on Keighley Road for the first 200 data points to test the fit of the regression model. These charts only show 200 data points as larger charts fail to show the fit of the model in enough detail.

The most significant r^2/R^2 value for each variable and location is shown in green; yellow indicates no change between time intervals.

Table 6.1 Regressions for variables by 30 minute interval.

		KR	**WSG**	**TP**	**BP**	**KR(B)**
Temperature	r^2	0.006	0.000	0.002	0.004	0.002
Relative Humidity	r^2	0.020	0.000	0.000	0.009	0.017
Wind Direction	R^2	0.020	0.020	0.016	0.009	0.003
Wind speed	R^2	0.001	0.003	0.004	0.012	0.007
Wind Chill	r^2	0.005	0.000	0.006	0.002	0.000
Visibility	r^2	0.000	0.000	0.002	0.000	0.001
Day/Night	R^2	0.12	0.050	0.027	0.081	0.089
Month	R^2	0.016	0.014	0.016	0.018	0.029
Cloud	R^2	0.000	0.000	0.000	0.000	0.000
Rain or no rain	R^2	0.000	0.000	0.000	0.000	0.000

Table 6.2 Regressions for variables by three hour interval.

		KR	WSG	TP	BP	KR(B)
Temperature	r^2	0.079	0.027	0.022	0.006	0.016
Relative Humidity	r^2	0.043	0.004	0.010	0.064	0.015
Wind Direction	R^2	0.013	0.000	-0.010	0.009	0.011
Wind Speed	r^2	0.013	0.018	0.009	0.046	0.020
Wind Chill	r^2	0.045	0.014	0.012	0.000	0.007
Visibility	r^2	0.000	0.004	0.004	0.000	0.004
Day/Night	R^2	0.302	0.173	0.167	0.259	0.237
Month	R^2	0.035	0.013	0.019	0.012	0.015
Cloud	R^2	-0.001	0.000	0.028	0.008	0.002
Rain or no rain	R^2	0.001	-0.010	0.000	0.006	0.004

Table 6.3 Regressions for variables by six hour interval.

		KR	WSG	TP	BP	KR(B)
Temperature	r^2	0.074	0.036	0.020	0.007	0.017
Relative Humidity	r^2	0.039	0.011	0.018	0.076	0.021
Wind Direction	R^2	-0.005	-0.022	-0.001	-0.031	-0.003
Wind Speed	r^2	0.004	0.012	0.017	0.03	0.013
Wind Chill	r^2	0.053	0.023	0.013	-0.005	0.008
Visibility	r^2	0.000	0.002	0.008	-0.003	0.003
Day/Night	R^2	0.315	0.239	0.209	0.387	0.362
Month	R^2	0.012	0.004	-0.002	-0.014	0.049
Cloud	R^2	-0.009	-0.01	0.025	0	-0.003
Rain or no rain	R^2	0.000	-0.014	-0.008	0.012	-0.004

Table 6.4 Regressions for variables by 12 hour interval.

		KR	WSG	TP	BP	KR(B)
Temperature	r^2	0.051	0.014	-0.004	-0.008	-0.010
Relative Humidity	r^2	-0.001	-0.010	-0.010	0.067	-0.009
Wind Direction	R^2	-0.041	-0.027	0.015	0.005	-0.042
Wind Speed	r^2	-0.010	-0.008	0.003	0.029	-0.008
Wind Chill	r^2	0.035	0.008	-0.005	0.022	-0.009
Visibility	r^2	0.000	0.007	0.023	0.025	0.010
Day/Night	R^2	0.012	0.000	0.018	-0.007	0.004
Month	R^2	0.089	0.034	0.017	0.05	0.035
Cloud	R^2	-0.026	-0.035	0.076	0.022	-0.010
Rain or no rain	R^2	0.000	-0.024	-0.016	0.033	-0.024

Table 6.5 Comparison of multiple regressions (all variables) over all time intervals (Mondays only).

	KR	WSG	TP	BP	KR(B)
0.5hr intervals adjusted R^2	0.164	0.098	0.074	0.115	0.158
3hr intervals adjusted R^2	0.362	0.176	0.170	0.350	0.324
6hr intervals adjusted R^2	0.361	0.224	0.235	0.481	0.421
12hr intervals adjusted R^2	0.049	0.067	0.152	0.078	0.025

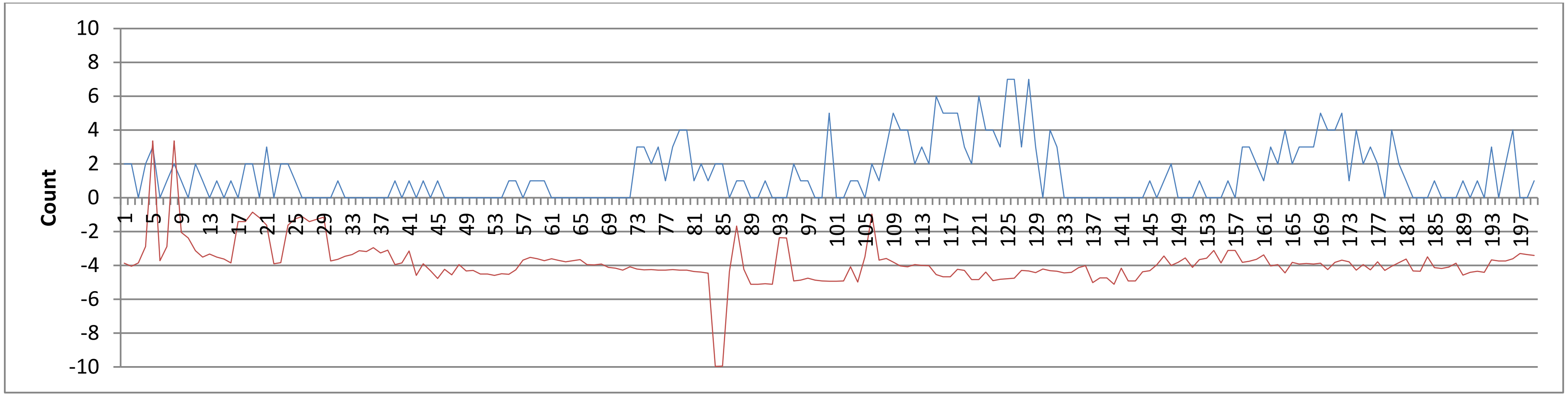


Figure 6.1a: By 30 minute interval

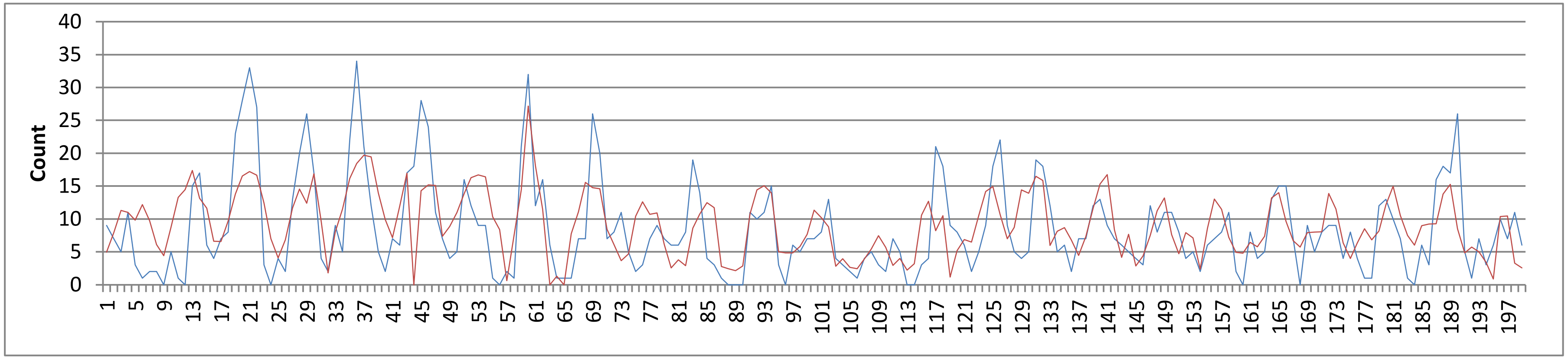


Figure 6.1b: By 3 hour interval

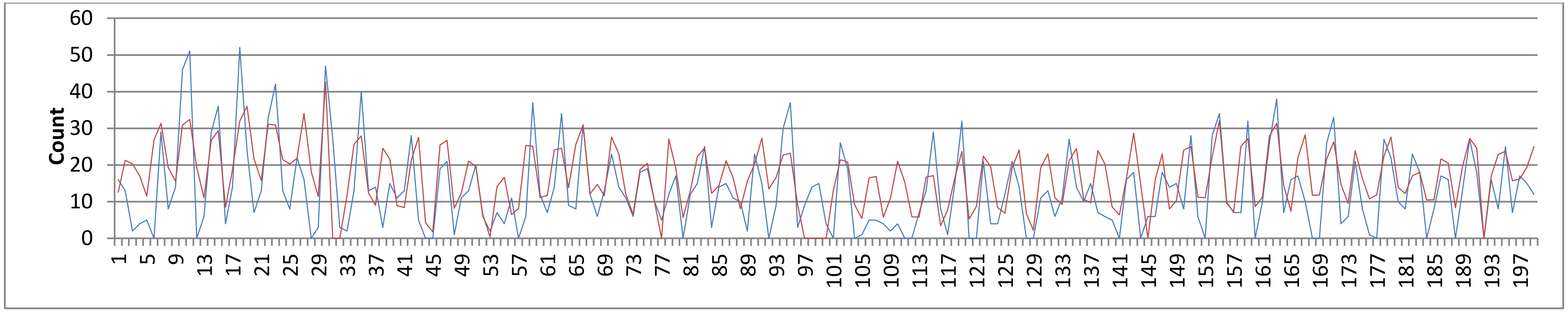


Figure 6.1c: By six hour interval

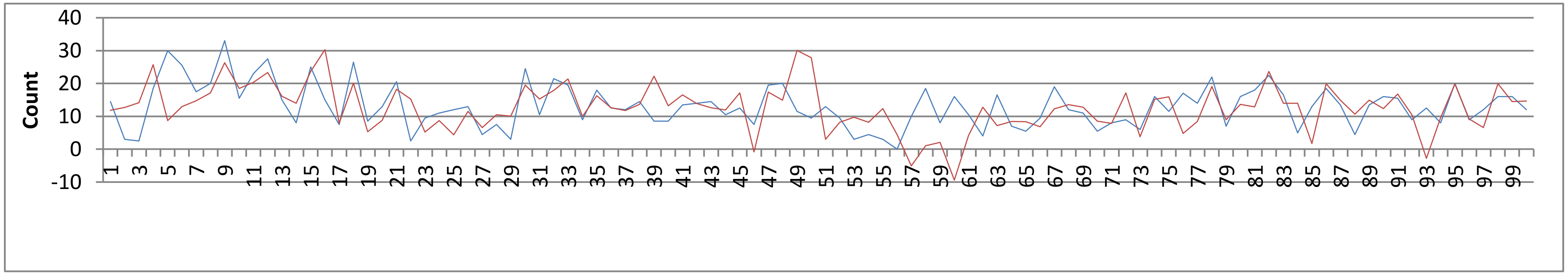


Figure 6.1d: By 12 hour interval (NOTE: Using 12 hourly blocks the full year only has 104 entries).

Figure 6.1 Line graphs to show fit of regression line for Keighley Road sensor (using the first 200 data points), Mondays only (Blue = actual counts, Red = Regression generated prediction).

The data shown in Figure 6.1 A-D (p.150) are the first 200 data points of the relative timespan, it is noted that the figures in Figure 6.1 show different time periods, as the first 200 data points at three hour intervals become 100 data points at six hour intervals and 50 data points at 12 hour intervals. As this represents Monday only data there are only 104 entries when viewed at 12 hour resolution.

The graphs in Figure 6.1 showed varying degrees of fit. Figure 6.1a showed no fit, with the prediction line only crossing the actual line between points three and nine. Figure 6.1b showed an improved fit but had a tendency to under and over predict in many places. Figure 6.1c had the best fit of the four charts however there was still a tendency to under and over predict. Figure 6.1d had a general fit but tended to have lost some accuracy when compared to Figure 6.1c.

As the six hour intervals returned the most meaningful data, (especially at multivariate level), and appeared to have the best fit line in Figure 6.1, this study used blocks of six hours for further analysis where appropriate.

Analysis of just Monday data (Table 6.5, p.148) showed a link between the variables and the sensor count (R^2=0.224 to R^2 0.481 at six hour intervals) multiple regressions were conducted on a daily basis to assess if certain days were easier to predict than others. This is reported in Table 6.6 (p.152).

Table 6.6 Comparison of R^2 values for all sensors across days of the week (all variables).

Day (n=120)	R2 value				
	KR	WSG	TP	BP	KR(B)
Monday	0.361	0.224	0.235	0.481	0.421
Tuesday	0.362	0.316	0.334	0.613	0.447
Wednesday	0.442	0.371	0.225	0.590	0.494
Thursday	0.367	0.448	0.270	0.448	0.511
Friday	0.544	0.419	0.164	0.458	0.389
Saturday	0.400	0.443	0.381	0.567	0.597
Sunday	0.516	0.577	0.315	0.571	0.528
1. Weekends* (n= 240)	*0.482*	*0.473*	*0.369*	*0.574*	*0.581*
All week days (n=840)	0.387	0.390	0.288	0.491	0.473

*Weekends comprises of all Saturday and Sunday data combined, then presented to the regression.

Table 6.6 shows that generally weekends are easier to predict than weekdays – this may indicate that weekends see higher patronage from visitors who were more susceptible to time and weather variables. Weekday users may have been less perturbed by these variables. Top path (TP, red on the Table) is generally harder to predict than the rest of the sensors, which may be due to its location or non-human traffic triggering the sensor [although the calibration exercises suggest against this]. The model worked best on Bottom Path (BP) data where it predicted 49.1% of the variability in user count data. Anecdotal evidence showed that this path was used more by regular walkers than irregular visitors [i.e. it is part of a fixed route for some walkers]. Further analysis was conducted to try to improve the accuracy of the prediction; this included analysis of daytime data only

(Tables 6.7 and 6.8, p.154) and summer data (Tables 6.9, p.155 and 6.10, p.155). Green background highlights show an increase in prediction accuracy. As the sample size (n) decreased in these analyses, regression coefficients have been calculated for both three and six hour intervals to demonstrate reliability.

Red text in Tables 6.7, 6.8, 6.9 and 6.10 indicates three hourly data.

Table 6.7 Comparison of R^2 values for daytime only data (using full year data, all days).

	KR	WSG	TP	BP	KR(B)
3hr data by daylight (n=807)	0.242	0.332	0.069	0.137	0.153
By all 3hr data	0.326	0.295	0.183	0.345	0.349
6hr data by daylight (n=397)	0.302	0.440	0.104	0.212	0.304
By all 6hr data	0.387	0.390	0.288	0.491	0.473

Although using daylight only data has only shown an increase in the regression coefficient for the WSG sensor (Table 6.7), Tables 6.1 (p.146) to 6.4 (p.148) show daylight as an important factor in predicting visitor numbers so further investigation has been conducted through daily analysis by using daylight only data. Daylight only data were separated out from the rest of the dataset as groups of three hours that had sunlight for the whole period. Table 6.8 (p.154) reports multiple regression coefficients using daylight data only, by day of the week.

It is not appropriate to run the daily multiple regressions on the six hour interval dataset as filtering by “daylight only” leaves daily datasets between 60 and 70 (n=60 – n=70). It is suggested that n=100 is a general guideline minimum for multiple regression (Dytham, 2003).

Table 6.8 Comparison of R^2 values for daytime only data at three hour intervals.

	N	KR	WSG	TP	BP	KR(B)
Monday	158	0.209	-0.051	0.041	0.018	0.045
Tuesday	159	0.188	0.423	0.156	0.186	-0.004
Wednesday	159	0.258	0.354	0.048	0.115	0.212
Thursday	160	0.166	0.341	0.126	-0.076	0.023
Friday	159	0.560	0.349	-0.026	0.118	0.108
Saturday	160	0.421	0.574	0.094	0.431	0.334
Sunday	158	0.492	0.353	0.143	0.196	0.351

The regression coefficients showed a variation by day of the week. When compared to the three hour interval figures given for Mondays in Table 6.5 (p.148) there is no benefit in classifying data by daytime as daytime only predictions are lower on every sensor. Therefore, filtering data by daylight has been ruled out.

Another consideration was to look specifically at the summer data (June, July and August). Again, due to the lower n values, data have been provided for three and six hour intervals in Table 6.9 (p.155). Table 6.10 (p.155) is restricted to three hour interval data as the six hour interval data at daily level provided sample sizes of 67 to 69 (n=67 – n=69). This sample size has been determined too small to provide a meaningful model. Green highlights an increase in prediction accuracy.

Table 6.9 Comparison of R^2 values for summer only data.

	N	KR	WSG	TP	BP	KR(B)
3hr summer only data	737	0.365	0.342	0.199	0.336	0.376
By all 3hr data		0.326	0.295	0.183	0.345	0.349
6hr summer only data	369	0.482	0.525	0.299	0.528	0.559
By all 6hr data		0.387	0.390	0.288	0.491	0.473

Table 6.10 Comparison of R^2 values for summer only data at three hour intervals at a daily level.

	N	KR	WSG	TP	BP	KR(B)
Monday	105	0.259	0.165	0.333	0.303	0.222
Tuesday	113	0.304	0.475	0.101	0.304	0.370
Wednesday	105	0.313	0.444	0.226	0.390	0.287
Thursday	105	0.407	0.460	-0.061	0.213	0.264
Friday	105	0.358	0.274	0.149	0.346	0.239
Saturday	105	0.288	0.452	0.102	0.556	0.318
Sunday	105	0.439	0.329	0.204	0.404	0.356

6.3 Stepwise regression

The multiple regressions showed that the highest accuracy was gained through using data for summer only, by six hour intervals (Table 6.9). When using all data the best predictions were also gained by using six hour interval data. These regression conditions were used for stepwise analysis. Stepwise multiple regression is the process of running the regression model several times and adding or taking away variables at each step until the best result is achieved.

6.31 Stepwise regression: summer and weekend data by six hour interval

Multiple regressions based on either summer only data (Table 6.9) or weekend only data (Table 6.8) showed higher predictability than weekdays combined. Weekends varied between 0.369 and 0.581 across the five sensors and summer varied between 0.299 and 0.599. If the lowest sensor value is removed (top path, in both instances) this is increased to 0.473 – 0.581 and 0.482 – 0.599 respectively.

When running weekend and summer data together in a model with 785 entries (n=785) R^2 values of KR=0.481, WSG: 0.502, TP: 0.353, BP: 0.561 and KR(B): 0.574 were achieved. This provided a basic model for predicting visitor numbers on weekends and summer holidays above the level of visitors during standard weekdays.

Using stepwise regression, the prediction for KR can be increased slightly to 0.492 (using the stepwise forward or backward method). Table 6.11 shows a comparison of the regression approaches for weekend and summer usage. The best fitting models are generated through the stepwise backward method.

Table 6.11 Various regression models for combined weekend and summer data at six hourly intervals.

	N	KR	WSG	TP	BP	KR(B)
Stepwise forward	785	0.492	0.502	0.354	0.563	0.576
Stepwise backward	785	0.492	0.512	0.360	0.567	0.579
Multiple Regression*	785	0.481	0.502	0.353	0.561	0.574

*Multiple regression used the enter method (i.e. all variables are regressed together).

6.32 Stepwise regression: all data using six hour time interval

Table 6.7 showed that six hourly intervals gave the best whole dataset for multiple regression modelling. These regressions have been recalculated using the forward and backward stepwise methods, shown in Table 6.12. These have been calculated using the whole dataset as just using the data not used in Table 6.11 (p.156) (i.e. weekdays in Autumn, Winter and Spring) gave a lower R^2 value for most sensors (KR: 0.347, WSG: 0.285, TP: 0.294, BP: 0.535 and KR(B): 0.473).

Table 6.12 Various regression models for all data at six hourly intervals.

	N	KR	WSG	TP	BP	KR(B)
Stepwise forward	1461	0.389	0.389	0.287	0.491	0.471
Stepwise backward	1461	0.394	0.396	0.296	0.497	0.479
Multiple Regression (Enter method)	1461	0.387	0.390	0.288	0.491	0.473

6.4 Final regressions

This work provides two sets of regression equations for consideration when predicting visitor numbers, one based on weekends and summer days (Table 6.14, p.159) and another based on all data (Table 6.13. p,158). Excluding the top path sensor (red in Tables 6.11 and 6.12) these models were able to predict between 40% and 58% of the variation in user count data. The best explanations were found on weekends and summer days at sensors closest to the main footpaths.

Table 6.13 Multiple regressions to predict user numbers through the year.

Equation 3 All year multiple regression (Keighley Road)

Y = 3.449*OCTA72+-1.030*OCTA9+1.251*JAN+6.369*FEB+4.610*MARCH+4.174*APRIL+-2.471*MAY+3.558*JUNE+6.306*AUGUST+0.827*SEPTEMBER+2.194*OCTOBER+9.441*NOVEMBER+8.352*DECEMBER+0.227*SAT+0.022*SUN+0.381*TEMP+7.609*RH+8.007*WINDDIR+-1.055*VARI+34.209*CALM+-0.322*NNE+13.263*ENE+9.552*ESE+9.509*SSE+-8.917*SSW+-2.744*WSW+-4.966*WNW+4.274*NNW+8.637*NE+19.940*SE+6.094*SW+-3.454*NW+2.217*N+0.130*E+0.286*S+2.196*WS+1.865*WC+2.042*VIS+-2.264*OCTA3+-15.150*RAIN+8.525

Equation 4 All year multiple regression (Whetstone Gate)

Y =-4.558*JAN+-3.990*FEB+-6.169*MARCH+-9.690*APRIL+-10.961*MAY+-11.072*JUNE+7.106*JULY+8.937*AUG+6.017*SEPT+-0.556*NOV+-0.924*DEC+0.045*TIME+0.314*MON+0.911*TUE+0.213*WED+2.065*FRI+4.082*SAT+3.388*SUN+0.144*TEMP+-0.018*RH+1.214*VARI+-0.616*CALM+0.545*NNE+-2.817*ENE+1.423*ESE+0.074*SSE+-1.142*SSW+-2.070*WSW+-0.913*WNW+-2.652*NNW+-1.830*NE+-1.696*SE+-2.438*SW+-1.370*NW+2.136*N+0.385*E+-1.130*S+-0.891*W+0.044*WS+-0.001*WC+0.022*OCTA1+1.025*OCTA3+0.835*OCTA6+-0.396*OCTA9+-1.904*RAIN+0.658*LIGHT RAIN+0.083*NORAIN+-8.826*NIGHT+4.630

Equation 5 All year multiple regression (Bottom Path)

Y =-1.988*JAN+-0.401*FEB+0.700*MAR+-3.109*APR+-3.046*MAY+-4.852*JUN+-1.726*JULY+-0.796*AUG+0.986*SEP+1.181*NOV+0.967*DEC+0.005*TIME+-0.018*MON+0.642*TUE+1.107*WED+0.311*FRI+2.732*SAT+3.070*SUN+0.184*TEMP+-0.014*RH+3.490*VARI+5.163*CALM+2.772*NNE+0.993*ENE+-0.597*ESE+1.824*SSE+-0.041*SSW+1.513*WSW+2.691*WNW+2.683*NNW+2.444*NE+1.996*SE+1.656*SW+1.899*NW+2.387*N+1.815*E+0.054*S+2.284*W+-0.037*WS+-0.108*WC+-0.598*OCTA1+-0.971*OCTA3+-0.495*OCTA6+0.530*OCTA9+-1.211*RAIN+0.863*LRAIN+1.439*NORAIN+-12.824*NIGHT+7.538

Equation 6 All year multiple regression (Keighley Road bottom)

=-6.882*JAN+-4.340*FEB+-10.895*MAR+-14.864*APR+-17.675*MAY+-18.310*JUN+2.668*JUL+3.711*AUG+3.470*SEPT+1.171*NOV+0.180*DEC+0.072*TIME+0.419*MON+0.470*TUE+-0.357*WED+0.429*FRI+4.308*SAT+3.415*SUN+0.129*TEMP+-0.043*RH+0.700*VARI+0.258*CALM+0.534*NNE+2.056*ENE+2.102*ESE+3.488*SSE+-1.616*SSW+-2.517*WSW+0.980*WNW+-7.161*NNW+-3.585*NE+-2.673*SE+-1.558*SW+-1.417*NW+0.610*N+-4.065*E+-0.286*S+0.040*W+0.07*WS+0.247*WC+0.077*OCTA1+-0.346*OCTA3+0.280*OCTA6+0.007*OCTA9+-4.834*RAIN+1.379*LRAIN+-4.185*NORAIN+-13.986*NIGHT+-3023.260

Table 6.14 Multiple regressions to predict user numbers during summer and weekends only.

Equation 7 Summer and weekend only multiple regression (Keighley Road)

=26.834*DAY+-0.027*TIME+16.702*SEPTEMBER+-15.682*WEDNESDAY+-15.203*THURSDAY+12.672*JUNE+-14.050*TUESDAY+-11.612*MONDAY+9.717*AUGUST+8.209*JULY+0.163*WINDSPEED+14.524*NORAIN+1112.907

Equation 8 Summer and weekend only multiple regression (Whetstone Gate)

=15.486*DAY+-1.684*N2+8.251*SEPTEMBER+5.396*WINDDIRECTION+6.908*SATURDAY+5.986*SUNDAY+0.422*TEMPARTURE+-4.986*JULY+-9400*SSE+5.389*NNE+-3.323*JUNE+-2.977*AUGUST+3384.848

Equation 9 Summer and weekend only multiple regression (Bottom Path)

=-17.5248*NIGHT+4.599*SEPTEMBER+7.929*SUNDAY+7.704*SATURDAY+-0.019*TIME+3.200*JUNE+-3.255*WEDNESDAY+-2.978*APRIL+813.083

Equation 10 Summer and weekend only multiple regression (Keighley Road bottom)

=-18.583*NIGHT+10.690*+SATURDAY+10.029*SUNDAY+0.600*TEMPERATURE+-4.387*JULY+-8.658*MAY+-6.576*OCTOBER+-5.909*MAY+-6.196*MARCH+-4.896*JANUARY+0.210*WINDSPEED+5.035*VARIABLE+3.425*SEPTEMBER+-3.446*OCTA7+8.647*NORAIN+-4.461

6.5 Weighting factor approach

An alternative to building the predictive model based on regression is to use a weighting factor approach. Each variable (time, date, wind speed etc.) was given a weighting factor (discussed in Chapters Four, p.76 and Five, p.109). The average number of visitors over the full year (for the sensor) was then multiplied by the various weighting factors of the variables observed at that time to produce an estimate of the number of visitors present on the moor at that time. The order of weighting multipliers does not affect the outcome of the prediction as shown in the example sums below:

1.5 x 3.2 x 4.5 x 0.2 = 4.32

1.5 x 0.2 x 3.2 x 4.5 = 4.32

If 1.5 in the sum above is the average user on the day, and subsequent numbers are multipliers, the same outcome (prediction) is achieved regardless of the order of the multipliers. A random example is given in Table 6.15.

Table 6.15 Weighting factors for Monday 6th April at 10:20.

	Average	Day	Month	Temp	Relative	Wind	Wind Chill	Beaufort	Oktas	Day /	Actual	Prediction
KR	1.2	0.879	0.790	0.749	1.260	1.111	0.650	1.260	1.26	1.471	2	3.79
WSG	0.8	0.835	0.672	0.578	0.690	0.679	0.570	0.800	1.16	1.396	0	0.33
TP	0.6	0.871	0.931	0.958	0.931	0.604	0.897	0.620	1.16	1.387	0	1.46
BP	0.4	0.811	0.845	0.958	2.270	0.386	0.626	0.480	1.16	1.387	6	1.72
KR(B)	0.7	0.893	0.845	0.778	0.600	0.691	0.598	0.750	1.268	1.836	2	0.96

This is one 30 minute period in the full study. Using all variables and all days, in an Excel spreadsheet, a correlation between predicted and actual counts gives the following: KR: 0.37, WSG:0.26, TP: 0.19, BP: 0.22 and KR(B): 0.24 (applied in Figure 6.2, p.163). Whilst these predictions do not show great promise, they do suggest that KR and WSG give the best explanations using this method; this may be due to these two sensors having less “no-count” gaps in the dataset. Other sensors (TP and BP) are further out on the moor and so are more likely to be triggered by regular users, who may be less susceptible to time and weather variations, but would also be likely to not be triggered at all in more of the 30 minute time periods then the busier sensors at KR and WSG.

Red = Prediction, Blue = Actual.

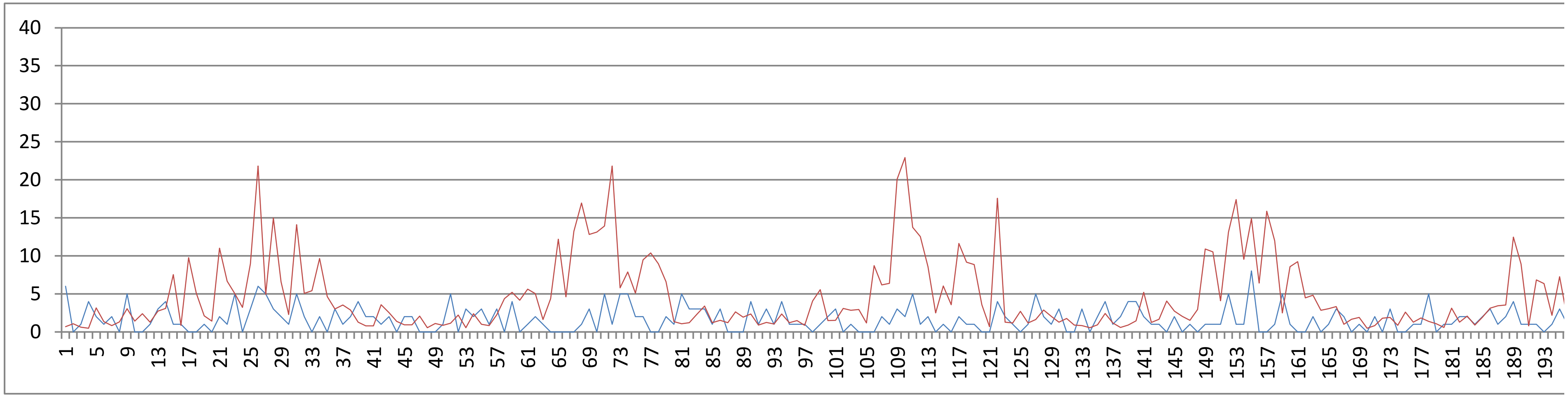


Figure 6.2a: Keighley Road Counts, Actual 337, Prediction 985.99.

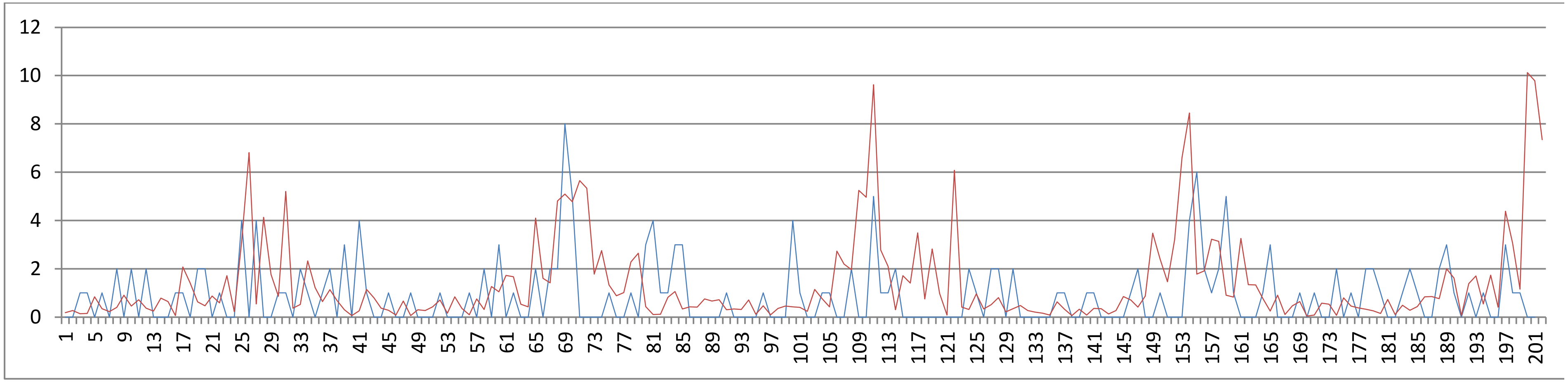


Figure 6.2b: Whetstone Gate counts, Actual 175, Prediction 269.57.

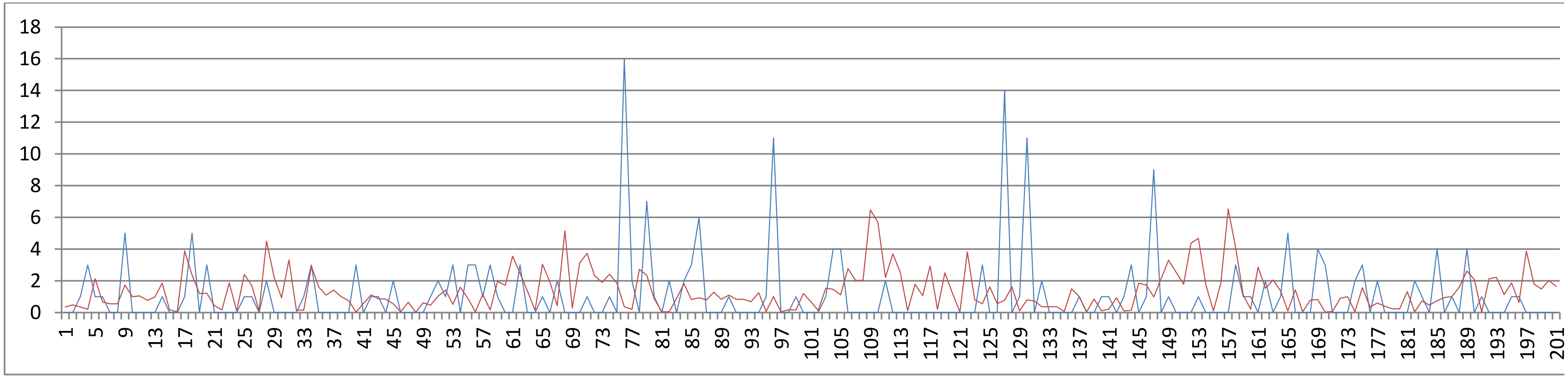


Figure 6.2c: Top Path Counts, Actual 218, Prediction 265.5.

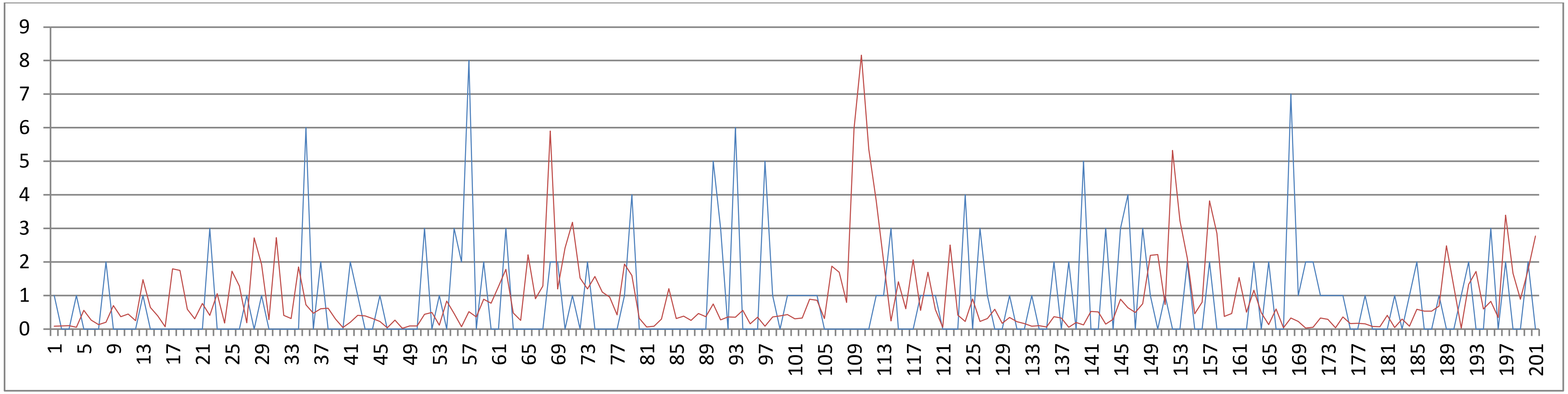


Figure 6.2d: Bottom Path Counts, Actual 163, Prediction 179.29.

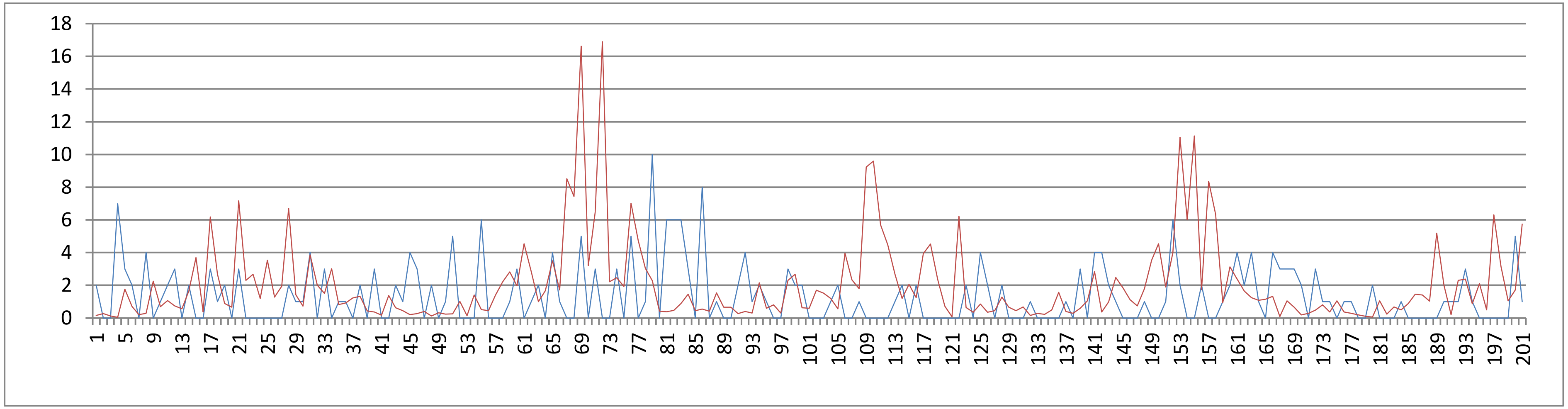


Figure 6.2e: Keighley Road Bottom counts, Actual 262, Prediction 411.11.

Figure 6.2 Predictions of users compared to actual figures for the first 200 data points (red = prediction, blue = actual).

All models shown in Figure 6.2 (p.163) tend to over predict user counts. Further testing was carried out to decrease the proportion of unexplained variation in user counts. This included using separate monthly and daytime only models to try to improve accuracy. However, both of these resulted in correlations of KR: 0.37, WSG: 0.19, TP: 0.11, BP: 0.25 and KR(B): 0.28. These were rejected as they were deemed not to be useful.

Further models were developed using various combinations of variables. The best combination excluded Relative Humidity, Beaufort scale and Wind Chill factors and achieved correlations of: KR: 0.46, WSG: 0.31, TP: 0.20, BP: 0.31 and KR(B): 0.34. This may be because there are auto correlations between Beaufort, Wind Chill, Relative Humidity and Temperature.

Further data manipulation was carried out through averaging data into larger time periods to establish a stronger link between the cause and effect. This yielded no overall improvement in the predictions (Table 6.16).

Table 6.16 Correlations between predicted and actual values using weighting factors.

	30 minute	**Two Hour**	**Four Hour**	**One Day**
Keighley Road	0.37	0.35	0.33	0.28
Whetstone Gate	0.26	0.26	0.27	0.25
Top Path	0.19	0.18	0.17	0.10
Bottom Path	0.22	0.22	0.26	0.15
Keighley Road (bottom)	0.24	0.25	0.22	0.14

6.6 Discussion of the approaches

An issue with the weighting analysis approach is that a linear relationship is assumed between the variables and all variables in the model are considered at all times. This may lead to autocorrelation and a simplification of complex relationships between some of the variables. For example, night time visitors on Keighley Road may not get out of their cars. Whilst daylight users who leave their cars are impacted by wind chill, night time visitors may not be impacted in the same manner.

This chapter proposes two sets of regression models for the prediction of future Ilkley Moor amenity moorland use. One set of models are generic offering an explanation of between 39% and 50% that can be applied across the whole year (Table 6.13 p.158). This is applied in Figure 6.3 A-D (p.167). These charts show 200 data points from 1st November 2014 as this model is designed to predict out of season use. The second set of models is designed to increase the accuracy of predictions at busier times on the moor (weekends and summer days). This model explained 49 to 58% of the variation in user counts, (Table 6.14, p.159) applied in Figure 6.4 A-D (p.170), which shows the first 200 data points collected (from 1st July 2014). All models use the stepwise backward formula as this formula gave the best fit line in all observations.

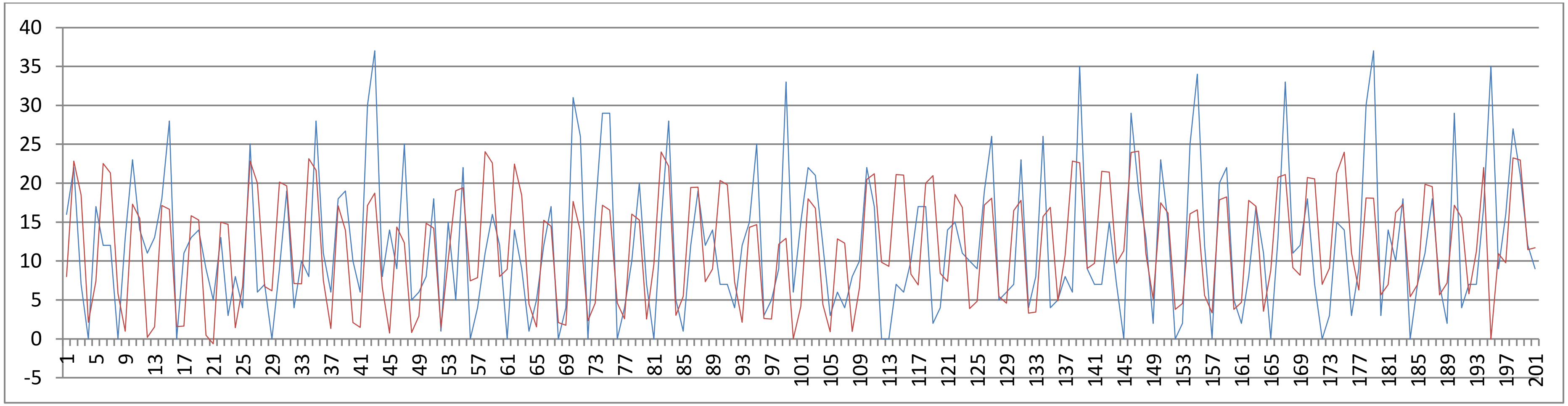


Figure 6.3a: Keighley Road

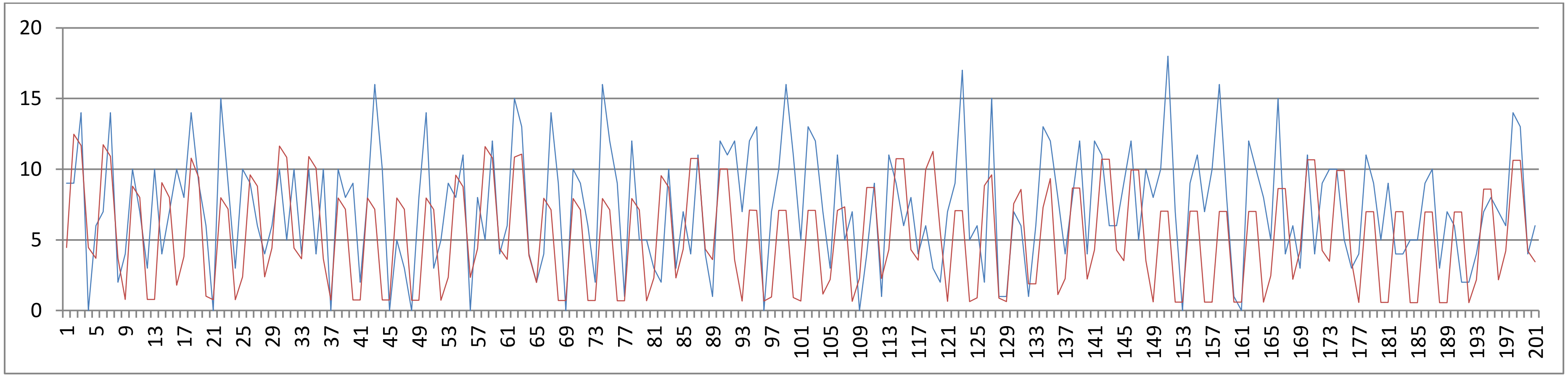


Figure 6.3b: Whetstone Gate

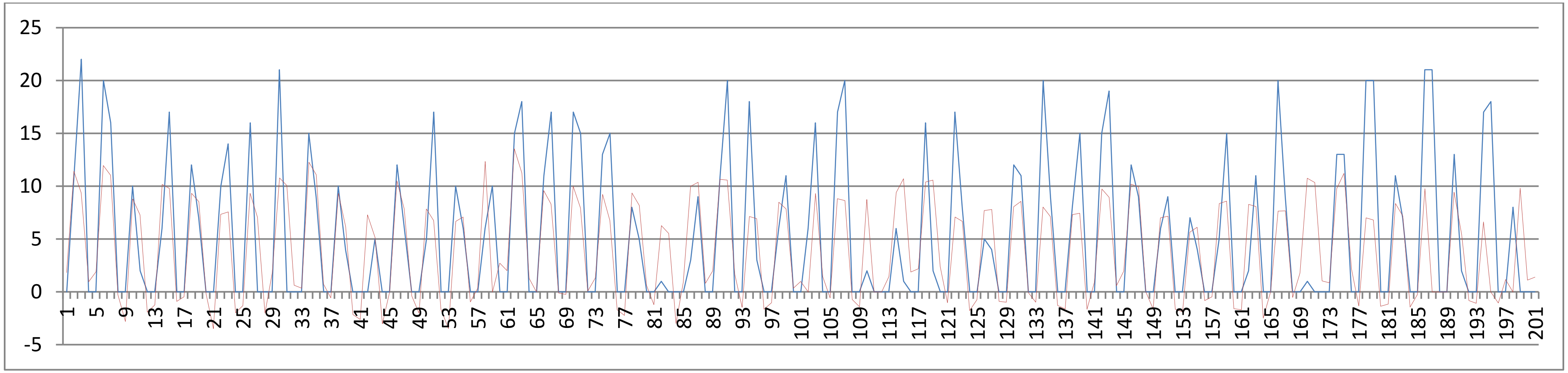


Figure 6.3c: Bottom Path

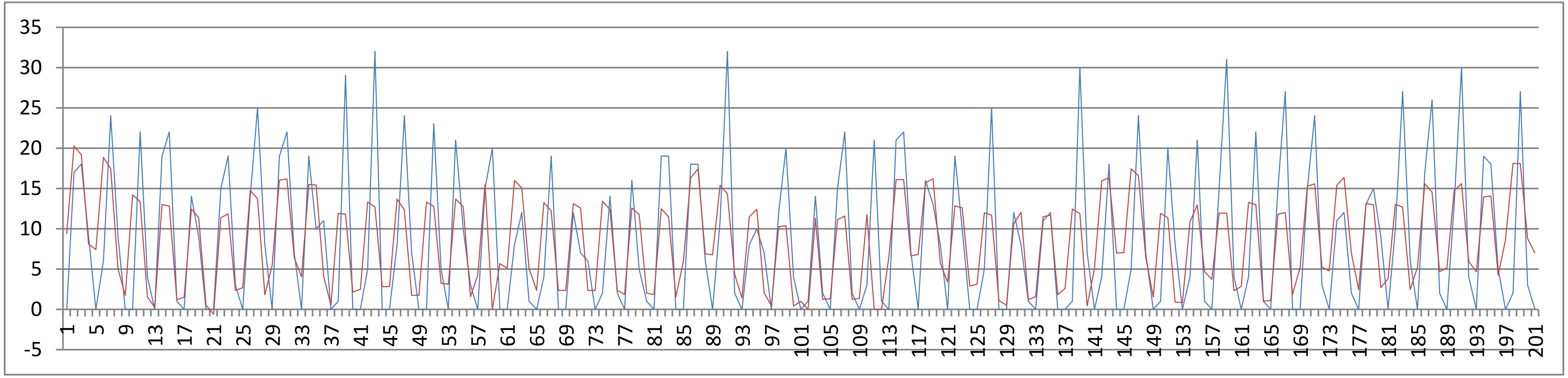


Figure 6.3d: Keighley Road Bottom

Figure 6.3 200 data points starting 1st November 2014, for sensors across the moor (excluding top path) using the full year prediction model. (Red = predicted, blue = actual).

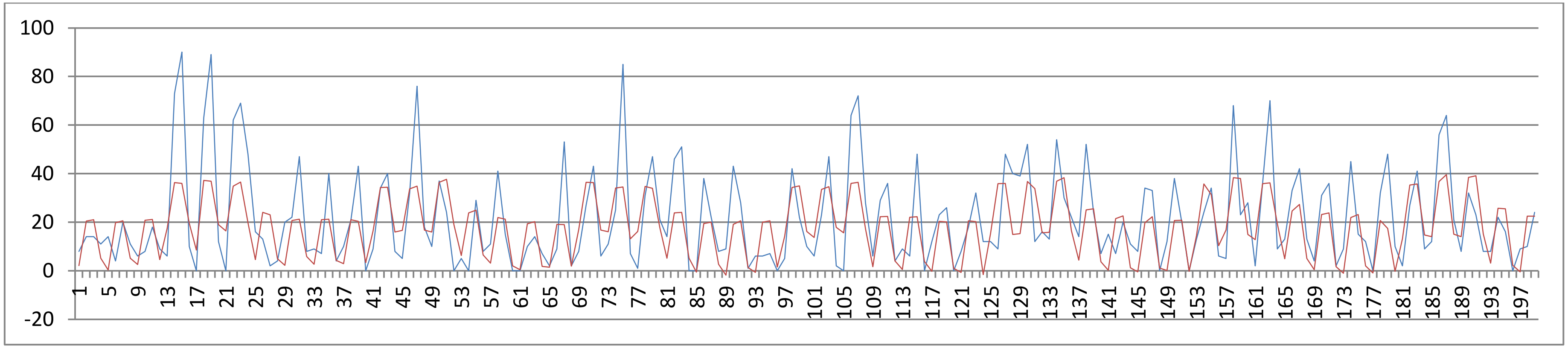


Figure 6.4a: Keighley Road

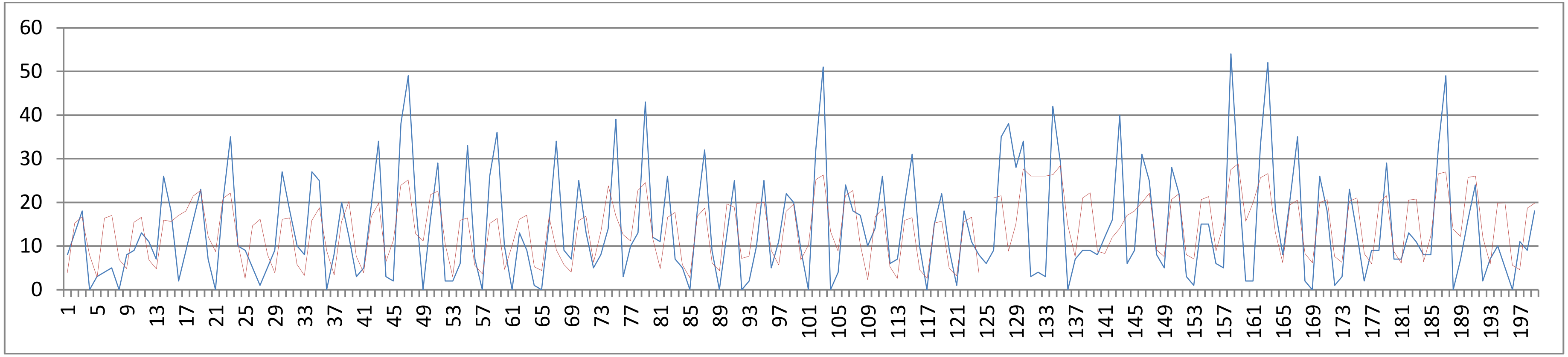


Figure 6.4b: Whetstone Gate

(Note: Six negative data points generated by the regression have been deleted and data have been interpolated on this graph, as it is impossible to have negative user numbers).

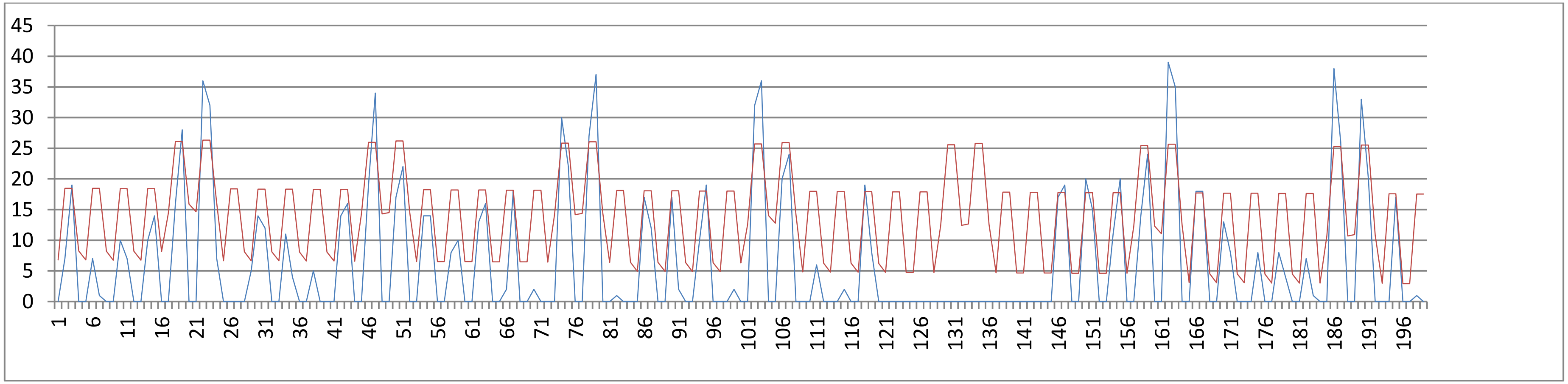


Figure 6.4ci: Bottom Path

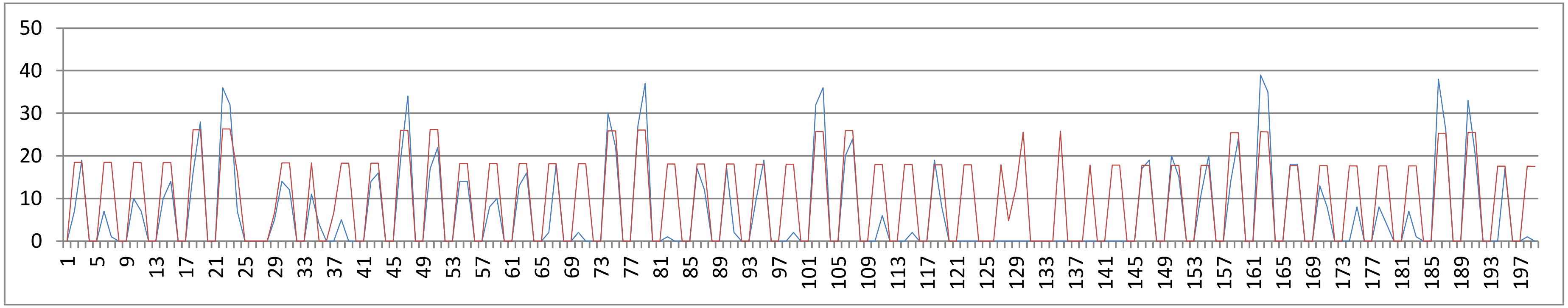


Figure 6.4cii: Bottom Path with night time regressions substituted with 0*

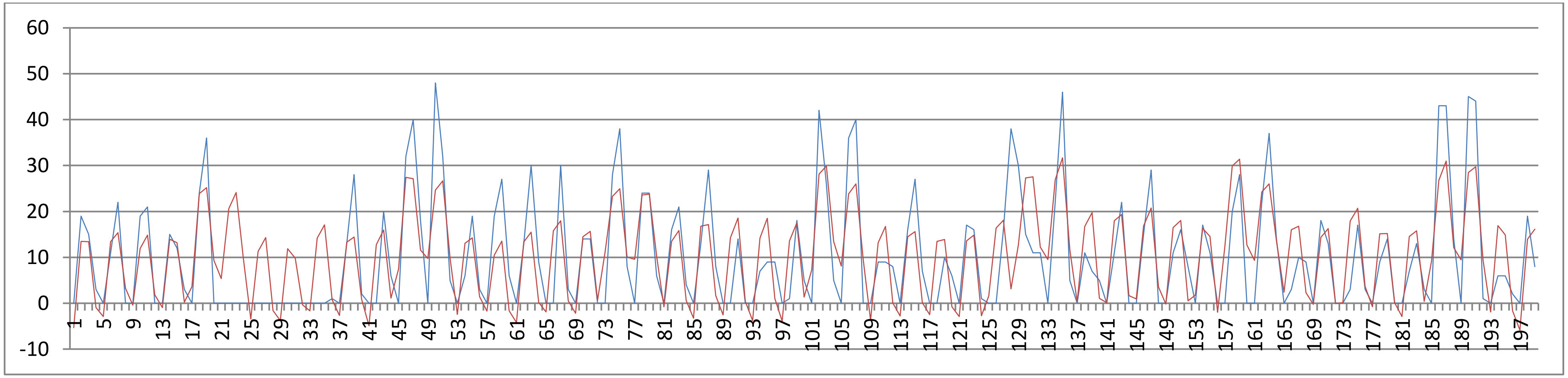


Figure 6.4d: Keighley Road Bottom

Figure 6.4 First 200 data points for sensors across the moor, excluding the top path using the summer and weekend prediction model (blue = predicted, red = actual).

*The regressions in Figure 6.4Ci predicted negative values. Logic would dictate that the minimum user numbers can only be 0. So Figure 6.4Cii substituted the negative values with the figure 0 on an evening and early morning, this pulled the line into a closer fit.

6.7 Summary.

While the weighting factor system is simplistic in its approach and is easily understood by a field operative, the regression models offer better predictive capability. Therefore, the weighting system has been deemed less useful than the multiple regression based modelling. These models explain at best only around 50% of the variability in user counts, showing that Pennine Amenity Moorland use is difficult to predict using these approaches.

Chapter 7 Discussion of the findings.

This chapter will take forward the results presented in Chapter Four (by time variable, p. 76), Chapter Five (by weather variable, p.109) and Chapter Six (data modelling to predict user numbers, p. 144). It is important to note that this study took an empirical approach so the results discussed here infer correlations between the two variables. All results in this assessment should acknowledge the potential existence of auto-correlation between factors for example: time of day and sunlight, or month of year and season.

As discussed in the Introduction, Literature Review and Methods chapters there was a lack of comparative moorland user data. Requests were made to a range of organisations, including the eight national parks that have significant areas of moorland (Snowdonia, Yorkshire Dales, Lake District, Northumberland, Peak District, Brecon Beacons, Dartmoor and Exmoor). Other organisations with moorland interests were also contacted for information (National Trust Marsden Moor Estate, Nidderdale Area of Outstanding Natural Beauty (AONB) and North Pennines AONB). Four national parks and three other organisations responded stating that they had no data about users on their moorlands (Alexander, 2017; James, 2017; Johnson, 2017; Pilkington, 2017; Proctor, 2017; Simmons, 2017; Welch, 2017. All Pers. Comm. Email communications with upland land managers) . Of the respondents four expressed interest in seeing this completed study. Moors For The Future partnership (Davies, 2006) provided a 2006 study looking into the demographics and social make up of their moorland users. Peak District National Park also provided a 2005 Peak District National Park visitor survey, which again focused on the demographics of their users.

Data have been compared with data from a range of other nature attractions and outdoor studies. The key studies used in this discussion are:

- CBMC (1988; 2013), unpublished short user attitudes surveys on Ilkley Moor.
- Brandenburg and Arnberger (2001), study of use of the Lower Danube National Park (an area of forest, near Vienna, Austria).
- Peak District National Park (2005) and Moors For The Future (Davies, 2006), user surveys in the Peak District, UK.
- Aylen *et al.* (2014), study of the effect of time and weather on visitors to Chester Zoo, UK.

With the exception of the CBMC studies it is important to note that although these other studies discuss users by time and or weather variable they may not be directly applicable to the user group on this Pennine moorland area.

7.1.1 Verification of the dataset

Year on year comparisons showed similar trends in data between the two comparative summers (2014 and 2015) (Figure 4.1, p. 80). ANOVA showed that like months (i.e. July 2014 and July 2015, August 2014 and August 2015, September 2014 and September 2015) were statistically similar. However, the very high data counts created very small P values which had potential to generate a false positive. When compared year on year (Figure 4.1b, p.80), similar spikes and falls are seen. While the two summers were statistically similar, and showed similar spikes and falls in the data (Figure 4.1b, p.80) there was an increase in footfall across all sensors [1.72% - 11.63%, average 5.89% increase] between summer 2014 and summer 2015 (Table, 7.1, p.174).

Table 7.1 Comparison of 30 minute average user counts year on year (July, August and September).

	KR	**WSG**	**TP**	**BP**	**KR(b)**	**Average**	**N**
2014	1.76	1.16	0.74	0.57	0.86	1.018	4452
2015	1.84	1.18	0.80	0.61	0.96	1.078	4275
% change	+4.55%	+1.72%	+8.11%	+7.02%	+11.63%	+5.89%	

This positive change between July/August/September 2014 and 2015 may be due to local factors, such as Friends of the Ilkley Moor group becoming more active and increasing awareness of the moor. Weather was considered to see if it was a driving factor in the increase in user numbers. Weather in summer 2015 was considered to be slightly worse than summer 2014, with slightly lower temperatures, higher humidity and slightly higher wind speeds (Table 7.2, p.174). As the changes in weather have only been slight and negative, weather has been ruled out as the reason for the increase in use.

Table 7.2 Weather summer on Summer (July, August and September).

Averages	**Temperature**	**Dew Point**	**Relative Humidity**	**Wind Speed**
2014	14.3 °C (n=3881)	10.9 °C (n=3881)	81% (n=3881)	13.2 km/h (n=4358)
2015	13.3 °C (n=3943)	10.4 °C (n=3943)	84% (n=3943)	13.9 km/h (n=4270)
% change	-1°C	-0.5°C	+3%	+0.7 km/h

The 5.89% average increase in users is broadly in line with increases shown in other studies. For example, Natural England (2015) detected an increase of 9.40% user numbers between March 2013 and February 2015. While this increase was detected before this study, it shows an overall trend toward increasing participation in outdoor recreation.

Schanger *et al.* (2017) claim that UK nature destinations received a mean user count of 7,638 per km^2, based on 30 sites over 170 observations. It is unclear whether this figure is quoted as a yearly mean or an ongoing mean. This survey area [$0.9km^2$] had counts between 7,868 and 21,548 [average: 13,338] across the survey area. Extrapolated to $1km^2$ for comparison with Schanger *et al.* (2017), this would be 14,820 users per km^2, based on an average of all sensors. The study area has nearly double the average number of users reported in Schanger *et al.* (2017). This is possibly because 16 of the 30 sites used in the Schanger *et al.* (2017) study were national parks with large areas of space enabling users to be more distributed across the site. This large increase in users at this study area offers evidence that this moorland is used in a different way, and should be managed in a different way to the more remote moorlands.

7.2 Variations in user over time

Chapter 4 (p. 76) presented the study results by time variable; these are discussed in this section.

7.2.1. Day of the week

The results presented show a clear difference in use by day of the week, with weekends displaying higher use than the rest of the week (Figure 4.2, p. 82). The Keighley Road sensor was unusual in having relatively more use on a Monday and Friday than the rest of the sensors. This may have been because Keighley Road received more evening use [i.e. Friday night, and Sunday night – into early Monday morning]. On average there was a general decline in use on Thursdays. The higher weekend use might be expected since a large proportion of the population may not have to attend work on weekends. However, the dip in use on Thursdays was unexpected. This may be of use in management planning (i.e. using Thursday as the key maintenance day would disrupt the fewest number of users). ANOVA showed that there was a significant difference in user counts between days of the week (Table 4.5, p.82). The error bars in Figure 4.2 (p.82) show that there is clearly a significant difference between user counts on weekends and on weekdays. However, error bars on some weekdays overlap with other weekdays. This may potentially be because weekday users are regular and weekends see the weekday users supplemented by additional ad-hoc users. Anecdotal evidence from observations while on the moor indicated that the area was being used often by dog walking businesses which need to walk the dogs on a daily basis and so presumably came back regularly.

Brandenburg and Arnberger (2001) also found that day of the week was the strongest time factor in their study of users in the Danube National Park, claiming that generally weekdays are pretty evenly used with a spike in weekend use. This is similar to what has been seen in this study. The Peak District National Park (2005) noted that weekend use was considerably higher than weekday use. Twenty percent of the survey population used the park on weekdays, whereas 80% used the park on weekends. This weekday/weekend split was seen in this study at Ilkley Moor, though it did not reflect the 80:20 ratio (Figure 4.2, p.82). This may indicate that users of this study area are characteristically different from the users of the more remote Peak District National Park.

7.2.2 Time of day

The main usage period for the moor ran from 04:51 – 18:50, which on average were daylight hours. Unexpectedly there was some use outside of these hours with only the period from 01:51-02:50 showing no use at all sensors. The KR sensor showed the highest counts, offering evidence that people are driving up to WSG car park but not always entering the moor, the road is fenced off and the only way to progress further is through WSG. The activity between 18:51 – 04:51 is generally confined to less than an average of 1 count per 30 minutes. Sensor errors may be responsible for some of this noise. It was not possible to test these sensors in the dark at the location. However, the researcher visited the moor after dark numerous times and on most visits users were observed in the Whetstone Gate car park with some people observed walking around on the moor (but within close proximity of the car park). There is a very small possibility that larger mammals such as deer (*Cervidae sp.*) have triggered some sensors across the area.

Further proof of use after dark could be gathered from mapping the dirt car park surface for tyre tracks and litter on an evening, then again the following morning, and comparing the observations in order to detect overnight use. Alternatively, a researcher could stay on the moor overnight to count use. However, the effect of an observer present could modify user behaviour. Night vision cameras could be used to detect and verify sensor accuracy but this would require consideration of ethics. A mobile phone application could be used to track users' movements across the car park and moor; however, this would require the consent of the user. It may be that certain user groups would refuse to participate with the application.

The CBMC (2013) survey indicated that 52% of moorland users had no preference for the time that they used the moor, 28% tried to use the moor in the morning only (of which 11% tried to use it before 09:00). A further 5% of the survey population said it was their first visit and the remaining 15% preferred the afternoons. In contrast, this study shows the highest number of users around the afternoon. CBMC calculated user times by asking people when they preferred to use the moor. Across the whole moor, this study has recorded when users actually use the high area of the moor, and so more confidence should be placed in the data collected in this study when assessing user numbers on the high moor as compared to the CBMC (2013) survey. The times at which CBMC conducted their survey are unclear. If their survey was predominantly conducted in the morning there is likely to be a bias toward the morning from their survey population, whereas this study made continuous 24/7 counts at five locations.

7.2.3 Month

As expected, data showed that the user counts peaked in the month of August in both years, with the quietest month being January (see the average line indicated on Figure 4.4, p.89). All counts dropped in January (this is likely due to the moor being inaccessible from snow cover for one week in January 2015, although there may be auto correlations here with season, weather and daylight). Again, ANOVA reports showed that the differences between months were statistically significant (Table 4.11, p.90). This may have been partially because of the sharp dip in users during January 2015. The Tukey post-hoc test (Table 4.12, p.91) showed, as may be expected, that the major difference was between January 2015 and the rest of the months. However, it also showed differences between other months. Brandenburg and Arnberger (2001) found May to be the highest frequented month in their study of the Lower Danube National Park. While May was not the least frequented it was also not the most frequented month in this study, perhaps further indicating a different type of user to the stereotypical user of a national park.

The Moors For The Future Partnership (Davies, 2006) conducted user surveys at 14 locations across the Peak District National Park in 2004/5. Using a mixed methods approach (some electronic counters and some face to face surveys) they produced data suggesting that generally users by month were erratic (Figure 7.1).

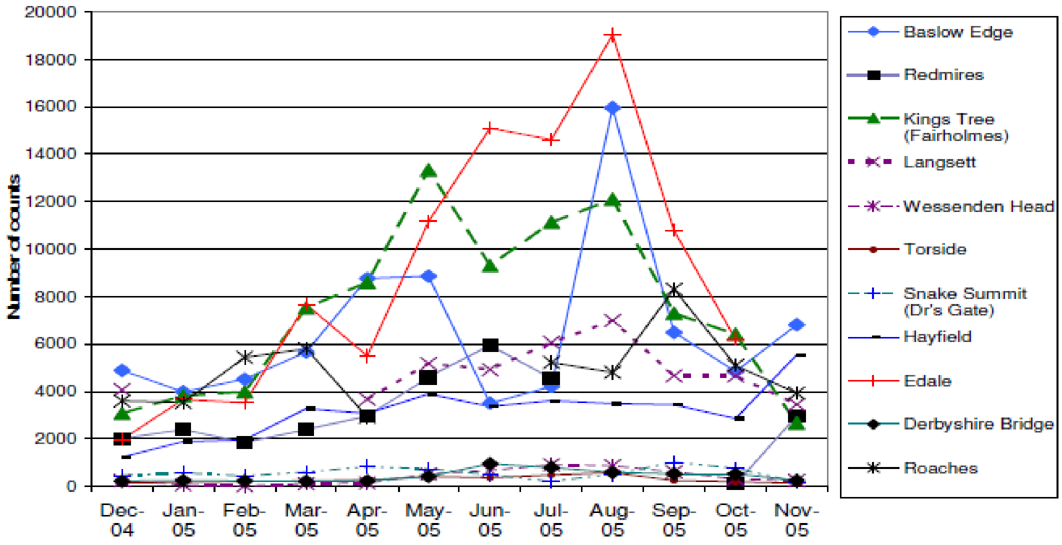


Figure 7.1 MOORS FOR THE FUTURE survey results by month (reproduced from "Recreation and Visitor Attitudes in the Peak District Moorlands (Davies, 2006, p.9).

The locations reported in Figure 7.1 varied across a range of Peak District environments. Langsett and Torside are potentially the most similar to Ilkley Moor in terms of accessibility, being within 30 minutes' drive of the centres of Sheffield and Manchester respectively, having car parking facilities and not being as remote as locations such as Snake Summit. Unfortunately, it is not possible to distinguish Torside's exact user counts in Figure 7.1. However, it can be seen that counts in these two areas did not spike to the extent of the more remote areas such as Edale, and Baslow Edge. Again, this fact potentially points to there being two different user groups.

Data have been taken from Figure 7.1 (p.179) for Langsett and compared with the average monthly data from this study (Figure 7.2) showing that generally there is a similarity across both sites.

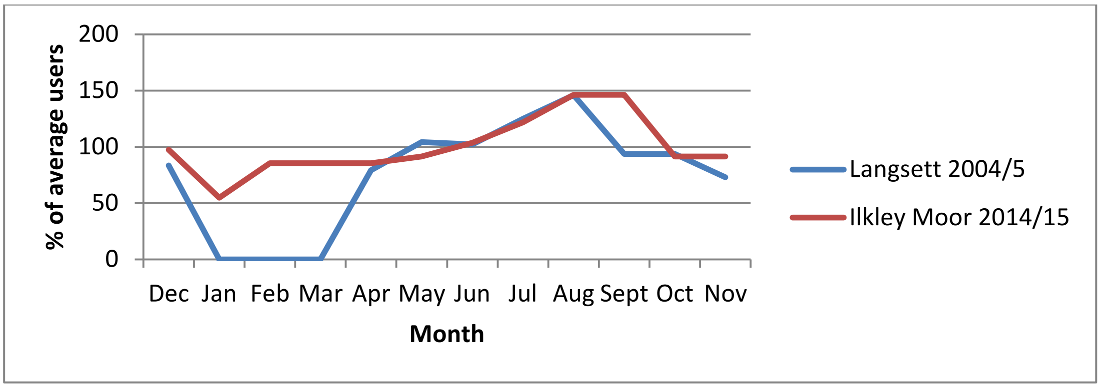


Figure 7.2 Comparison of data from this survey and MOORS FOR THE FUTURE results at Langsett (Adapted from: Davies, 2006).

However, it is important to note that this study reports in average users per 30 minute, whereas Davies (2006) reports total counts. Therefore, in order to compare the data from the two studies, Figure 7.2 presents the data by month as a percentage of the whole year. There is also missing data for Langsett during January, February and March which may have skewed the average calculation. This gives further evidence of the existence of a different group of moorland users because Figure 7.1 (p.179) indicates that the users that accessed Baslow Edge and the other more remote areas were highly impacted by seasonality or other auto-correlated factors, whereas the users who accessed Langsett and Torside and Ilkley Moor were less affected by seasonality. Brandenburg and Arnberger (2001) claim that certain users such as dog walkers and joggers are not seasonally affected as the dog generally requires walking regardless of the season and jogging may be part of an exercise regime that is independent of season. This could indicate the predominant type of user at Ilkley Moor.

In this study June, July, August and September showed higher than average counts across all sensors with the other months recording lower than average (Table 4.13, p.92). There is a distinct change around September / October and May / June. June – September could be grouped as “high season” and October – May grouped as “low season”. If significant management works were conducted in the low season months there would be less impact on visitors. The grouse (*Lagopus lagopus scotica*) shooting season in the UK runs from 12th August to 10th December. If an agreement could be negotiated to delay the start of grouse shooting from 12 August (known as “The Glorious Twelfth”), and shooting was confined to October, November and December, this would be highly likely to alleviate some of the stakeholder tensions on the moor.

7.2.4 Season

There is a very high auto correlation between season and month. As expected, Ilkley Moor saw higher use in summer, with lower use in winter. Spring and autumn appear to have similar use in Figure 4.5 (p. 93). The CBMC (2013) survey demonstrated that over 75% of the survey population had no seasonal preference. However, that study was conducted in summer on lower, potentially more sheltered ground. Keighley Road and Whetstone Gate tend to have proportionately higher use in summer when compared to the other sensors (Figure 4.5, p.93). The dip in winter use could have been partially caused by snow in January 2015 providing no access to the moor for a period of one week. However, daylight short days, temperature and a range of other factors could also have influenced this dip in use.

7.2.5 Holidays and local days of interest

Tables 4.17 (p.96) and 4.18 (p.97) compare bank holidays and local days of interest with similar days of the week. Of the 45 comparisons, 33 (73%) show over a 10% difference in user numbers. However, unexpectedly these differences generally show a decrease in user counts on bank holidays. This may add further weight to the argument that this moorland is an area for amenity use and not seen as a “holiday” or “day out” destination. The convenience of the moor may be traded by users for more distant countryside or other attractions on these bank holidays when they potentially have more time away from their other occupations. The CBMC (1988) survey indicated that over 75% of users lived within ten miles of the moor, further adding to the argument that many of the users frequent the moor because of its locality and convenience. If this is the case it may be appropriate to schedule management tasks and shooting on bank holidays. [Note: grouse shooting (*Lagopus lagopus scotica*) could only take place on the August bank holiday, as the other bank holidays are outside the shoot season].

Several key non-bank holiday dates have been picked out and compared with data from the rest of the study. These were: Whitsunday, Eid (2014 and 15), Yorkshire Day (2014 and 15) and the Glorious Twelfth (Table: 4.19 p.99). Whitsunday showed an average decrease in user counts, further adding to the idea that users may go away to other attractions on these days. Eid 2014 showed a large decrease in numbers, but this was then followed at Eid 2015 by a large increase in numbers. This may have been due to the fact that Eid uses the lunar calendar, which does not conform to the same day pattern as the Gregorian calendar that is generally used. Therefore, Eid would fall on different days and months each year, as Eid 2015 fell on a Saturday and Eid 2014 fell on a Tuesday there may be an autocorrelation effect here with day of the week.

Both Yorkshire days 2014 and 2015 showed an average decrease in user counts even though, some may argue, Ilkley Moor is considered to be the Yorkshire emblem. It may be reasonable to assume that the opposite would have happened here, perhaps users frequented other locations on Rombolds Moor and events at this time. The Glorious Twelfth (traditionally the first day of the grouse shooting season) showed a reduction in user counts in 2014 and an increase in 2015; again this could be due to autocorrelation with day or weather factors. It is of note that a protest was held on 12th August 2017 to demonstrate against grouse (*Lagopus lagopus scotica*) shooting on the moor (Quinn, 2017). Previous 12th August data would not have been able to predict this unusual event of course.

This study argues that bank holidays and other local holidays are too volatile to use for predictions as some have a positive impact while others have a negative impact. It is also unclear which auto-correlations are occurring with these days (i.e. falling on different days of the week or different weather conditions etc). The data collection strategy used compared the holiday with an average taken from a like day the week before, and one from the week after. For example, if the holiday was Wednesday 14th the comparison would be drawn from the average of Wednesday 7th and Wednesday 21st user numbers. Taking an average of just two days for the comparison could allow many other factors such as weather or other key events to skew the comparative data. However, taking more comparative data (such as all Wednesdays, or all August in the example above) would have potentially allowed day, month and seasonal factors to become auto correlators.

7.2.4 School holidays

Data show an increase in use over the school summer holiday (7%) and Easter holiday (6%) periods. The October and May school holidays were in line with term time data at either side of the holidays. The increase over these holidays could be due to auto correlation with season, month and weather factors. Similarly, the Christmas holiday reduction could be through auto correlation with weather and other time factors.

There was a decrease in user counts over the Christmas holiday (-13%) when compared with the previous term, but an increase when compared with the following term. This increase may be partially explained by noting that there was snow preventing access to the moor during one week in January 2015.

User counts in October and May half terms were in line with the data for the preceding and following terms. It may be expected that there would have been a decrease at Christmas and an increase in summer with no change at the half terms as this would fit in with the trends displayed in the monthly and seasonal data. Therefore, it could be concluded that school holidays had no impact on user counts. This could potentially indicate that users older than 18 dominate the Ilkley Moor users age profile.

7.3 Variation in user by weather condition

Weather data collected at the moor on observer visits showed a very small difference in weather recordings at Leeds-Bradford airport (LBA). Weather data collected at LBA is used in commercial aviation to assist pilots during take-off, flight and landing. This source of weather data is considered to be highly accurate. Other potential sources included the Environment Agency’s weather stations in Leeds or Bradford. These were not used as they are both at lower altitudes than LBA and only provided average daily readings, whereas LBA METAR data provided weather reports for every 30 minutes.

7.3.1 Temperature

A range of studies discussing the impact of climatic factors on tourism consider temperature to be the most significant predictor (Aylen *et al.* 2014; Bigano *et al.,* 2006; Lise and Tol, 2002; Maddison, 2001). However, this study found that while temperature was an influencing factor, it did not have as much impact as it did in other studies.

Agnew and Palutikof (2001) produced evidence to suggest that temperature was the main climatic factor behind a person's decision to participate in activities in the outdoors. They go on to suggest that the optimal "draw" temperature was 21^{O}C. This temperature is rarely achieved on Ilkley Moor. Their work is more aimed at tourism in general and perhaps not the specific user groups that are users of Ilkley Moor.

Temperature ranged from -3 to +27^{o}C across the whole study period. This variation in temperature would not have caused much discomfort to users that adaptions to clothing would not mitigate. Observing the data with over 50 occurrences (N>50), +1^{O}C to +16^{O}C, using a 5 point rolling average (Figure 5.3, p 112) shows, as expected, a general positive linear relationship between temperature and average user numbers. However, when tested through correlation, the relationship was weak (ranging from r^2 = 0.01 to 0.05).

Interestingly Limb and Spellman (2001) noted that respondents to their survey were concerned with the upper tolerable temperature limit, indicating that warm temperature was a problem rather than a draw factor. Many of their respondents cited concern about how children cope in warmer weathers. While this study shows a positive linear relationship between temperature and user numbers, there may be an upper threshold where people start to feel uncomfortable and user numbers decline, creating a non-linear relationship outside the reliably observed variables in this study (N<50). Nikolopoulou (2001) provides evidence that this threshold is around 25°C, suggesting that in her study of Greek public park usage, use tends to slow after this temperature. While her study was conducted in Greece, the local users of Ilkley Moor may find a lower tolerance limit based on their acclimatised preferences. Data presented in Figure 5.2 (p. 111) does start to show a decline in users at around 23°C [this is followed by an increase at around 27°C]. However, it should be noted that the higher temperatures have fewer count frequencies so the data is less reliable than for some of the more frequent temperature ranges. Aylen *et al. (*2014) look at the impact of weather on visitors to Chester Zoo (North West England), noting that 21°C tends to be the upper threshold at which point visitor numbers decline.

7.3.2 Relative humidity (RH)

The highest three humidity bands (71% - 100%) account for 83% of total humidity counts in this study, which is to be expected in this Pennine upland location on the British Isles which is surrounded by ocean. There are no counts between 0% and 20%; again, this is to be expected. There is a general negative relationship between relative humidity and average user counts (higher RH = lower user numbers, Figure 5.8, p.118). However, when using correlation only a very weak negative relationship was found (Figure: 5.10, p. 119 with r^2 ranging from 0.01 to 0.04). This relationship showed that humidity had minimal impact on user numbers. This may be as humidity, like rain, is a localised factor or users have become accustomed to the range of humidity levels displayed at the study area. Anecdotal evidence has been collected of a range of crimes in the area, from rubbish dumping to more serious crimes such as rape from McDermott (2017. Pers. Comm.) and the authors own observations. It may be that participants in criminal activity use certain weather conditions, such as fog, high relative humidity or darkness as a cover for their activity.

7.3.3 Wind direction

Generally, the wind travels from a South or Westerly orientation (Figure 5.13, p.123). These winds from the tropical maritime air mass usually bring warm but moist air (Figure 5.11, p.121) from the Gulf Stream of Mexico. ANOVA analysis reported a statistical significance between wind direction and user counts at KR, BP and WSG sensors.

If a user leaves WSG car park to access the moor, the prevailing wind will be behind the user, their face would not be directly exposed to the wind. This may provide a more comfortable outbound journey than when they turn around to come back to the car park, when the wind would be in their face and impeding progress. Further observation and interviews could be conducted to see whether wind direction has an impact on the user's choice of route around the survey area. Management should be aware of this effect and could possibly make efforts to raise awareness of the phenomenon among users.

Average users per wind direction class (Table 5.7, p.125), unexpectedly showed fewer than average user counts in the southerly direction class and in calm conditions. It may be reasonable to assume that the calm weather would have provided higher than average user counts and that southerly winds that bring in warmer air would also have been more pleasant than the colder northerly winds. One plausible explanation for this anomaly may be that on the other side of the Aire Valley, to the south of the moor there is a poultry waste disposal plant. Anecdotally the researcher has experienced faint ammonia smells that could potentially be attributed to this. It may be the case that if regular users found this smell unpleasant they may not visit the moor when the wind is from a southerly direction. However, further research would be required here to assess causality. Another consideration may be that the wind direction measured at LBA may not represent those in the survey area due to local conditions. However, this seems to be unlikely on a large scale across the whole of the study period of two years.

7.3.4 Wind speed

METAR code provided wind speed in metres per second. For the purpose of this study this has been converted into kph and Beaufort scale (Table 5.8, p. 126). Correlation between wind speed and user counts showed no relationship (Figure 5.7, p.117). When rounded to two decimal places the r^2 value is 0.00. Wind speeds of between two and four on the Beaufort scale dominate the dataset. The presence of light-moderate winds on the moor may have become the norm to the regular users who may have become acclimatised to the condition and prepared appropriately. Even at the upper end of Beaufort scale 4 the wind speed is still only 28kph which would not make walking too uncomfortable. However, this study does not consider gusts as these may have been localised at LBA and are recorded in a sporadic way. Gusts may have reduced the wind-chill factor to a more discomforting range. An example is given of Cairngorm summit in February 1950, wind speeds averaged 30 knots. Whereas gusts were recorded ranging between 40 and 95 during the same time period at the same location (Dybeck and Green, 1955). A study of gusts, and their impact on users would require an anemometer to be located within the study area.

Figure 5.12 (p. 122) shows how the moor is sheltered from prevailing winds, so that a south westerly wind at 28kph would hit the wall sheltering the top path and be diverted upward before reaching users on the top path. The survey area has a northerly aspect, so once the wind has been diverted by the wall running along the top of the survey area, the moor is still sheltered from the wind. This may allow users to go about their business without the full impact of direct winds. The car park is outside of this sheltered area which may account for the fact that wind direction has a more significant effect on user counts at the KR and WSG sensors.

7.3.5 Wind Chill

The correlation coefficient for the relationship between total sensor counts and wind chill is very low (r^2 = 0.01 to 0.03). This may be due to the sheltered aspect of the moor from the prevailing winds. Wind chill in this study ranged from -9 to +27^{o}C. At these exposures there is very little chance of getting frostbite. While only slight there is an improvement in the correlations at KR and WSG, which may give further indication of two types of user, one type that are prepared for the conditions and willing to progress to the more remote sensors and another type that are less willing to experience the colder and harsher weather conditions sometimes observed across the study area.

7.3.6 Visibility

Contrary to expectations, there was no relationship between visibility and user counts (Figure 5.20, p.135). This may be because visibility in METAR data is recorded in intervals of 1000m. Perhaps visibility needed to be less than 1000m to become a consideration for a moor user. At 1000m (1km) it would be possible to see from one side of the study area to the other. Users may require visibility to be reduced to around 10 metres to consider it unsafe to use the moor. There are also a very high proportion of visibility counts above

10,000m (N=14121. 83% of all data). As this is such a high percentage of the total study period, there is always the possibility that visibility conditions on the moor differed from those recorded at LBA.

7.3.7 Cloud

An ANOVA test found that cloud cover was a significant factor affecting user counts (Table 5.10, p.137). This could have been due to the extremely large dataset (resulting in a very low P value). Cloud had to be converted from METAR text data to Oktas for the analysis in this study. The method of conversion left only 27 counts of two oktas, and 94 counts of eight oktas. The very low frequency of 30 minute periods with two and eight oktas seems strange. These low counts at two or eight oktas may have caused bias in the ANOVA analysis. Brandenburg and Arnberger (2001) suggest that cloud cover in the previous seven days may have had more of an impact on the potential users decision to visit or not. As the 1988 CBMC survey suggests that generally only local people use the moor, the likelihood of users looking at forecasts seven days in advance may be low but it would be interesting to note the effect of cloud cover when the user decided to go on a journey to the moor, perhaps three hours before their visit. Further information could be gathered on causality though interviews and discussions with users about the factors behind their choice to use the area or not.

Cloud cover is localised and while cloud data are highly relevant for LBA, the distance between it and the moor could mean that cloud cover on Ilkley Moor could be different from that observed at LBA at any given time. Brandenburg and Arnbinger (2001) suggest that the brightness of the sky may have been a better measurement than cloud cover since this may have more of a psychological impact on the user. In the same study Brandenburg and Arnberger (2001) concluded that cloud cover only had a moderate impact on their user numbers. Morgan and Williams (1999) found that cloud cover had a link to the perceived aesthetic beauty of an area, and therefore cloud had an impact on attracting users to an area. The CBMC (2013) survey found that 55% of users listed “Scenery” as one of their reasons for visiting, so if Morgan and Williams’ findings are valid, it may have been assumed that cloud cover would have had more of an effect than demonstrated in this study.

7.3.8 Rainfall

Surprisingly this study showed no significant relationship between 30 minute rainfall and user counts at the $p<0.01$ level. However, Top Path showed some significance at the $p<0.05$ level. This may be due to the nature of rainfall being a rather localised factor. Potentially when rain was recorded at LBA it may not have been raining at the study site. Anecdotal observations at the site while collecting data have shown that rain is localised to the extent that it may be raining at one side of the study area and not at the other. Figure 7.3 (p.192) taken from Oxenhope Moor on the opposite side of the Aire Valley, shows the study area (highlighted in yellow) under an area of rain at the same time as other areas of Rombold’s Moor (red) are free from rain. Having said this, Scott and Jones (2007) did find that rainfall was an important variable in their study of golf course usage; they also found that rainfall in the morning affects user’s more than afternoon rainfall. While that study looked at golf, the same thought processes may be occurring in the minds of users of Ilkley Moor – potentially a morning rainfall could influence their decision of what to do that day.

Figure 7.3 Localised rainfall across Rombolds Moor (Image: Author).

While it may sound surprising that rainfall only had a partial effect (two of the five sensors, Table 5.13; Table 5.14 p.140) on user numbers in this study (perhaps due to the localisation of the rain, and the rain gauge being located some distance away from the area), Brandenburg and Arnberger (2001) also noted that precipitation only had a moderate effect on user numbers in their study of the users of the Lower Danube National Park. This may be due to the type of user. If people are progressing up Keighley Road to sit in their cars high up on the moor, rainfall or cloud would not affect their use unless their purpose was to take in the views. Also, joggers and dog walkers may not be influenced heavily by factors such as light rain or light cloud as their routine demands that they undertake the jogging or dog walking activity regardless of all but the most extreme weather conditions.

7.3.9 Sunlight

As may be expected, sunlight was the strongest factor in influencing user numbers. However, it can be assumed that there is a strong auto-correlation at play between sunlight and time. For example, there are some times throughout the year where darkness prevails (i.e. 0100hrs) and other times when light prevails (i.e. 1300hrs). However, there are other times, around dawn and dusk where sunlight and darkness change with the season. The discussion of the time variable gives some ideas around night time sensor triggers and potential errors.

7.4 General weather discussion

7.4.1 Weather reports

Some reference has already been made to the assessment of weather reports and their influence on users of survey areas. Brandenburg and Arnberger (2001) tried to consider the effect of perceived weather on users in their study. They suggested that there may even be a stronger link between perceived weather (weather reports) and user attendance than between actual weather and user attendance. However, their study was in a national park with a far larger survey area and potentially a different or far more diverse survey population. They suggested that observation of weather forecasts seven days in advance of the user deciding to use the area could be a useful predictor of visitor numbers. However, the CBMC (1988) survey showed that users generally only travel within one hour to use Ilkley Moor so perhaps monitoring of weather forecasts within a few hours of user activity would be more appropriate in this situation. However, this is a complex task because weather forecasts are now more available than ever before – while there are the traditional media forecasts (TV, Radio, Newspapers etc.) there are now also many other platforms for gaining detailed weather information on the internet and on mobile phone apps. Mobile apps such as Rain Today and the UK Met Office app now give users live radar rainfall data and satellite images of cloud cover for up to three hours.

Tourism experts generally agree that guests regularly fail to attend attractions when inclement weather is forecast (Brandenburg and Arnberger, 2001). However, they go on to note that weather forecasts play a less important role in user decisions when the user lives in close proximity to the attraction. It is of note that Ammer and Probstl (1991) offer evidence to back this up, claiming that weather forecasts only really influence people who travel over an hour to get to a tourism area. So potentially this may not affect many users of Ilkley Moor. Perry (2004) concluded that weather is a very subjective assessment and individuals make different value judgements on their activities.

7.4.2 Acclimatisation

If users of the survey area are frequent visitors they may have built up acclimatisation to the climatic conditions prevalent on the moor. Nikolopoulou (2001, p. 189) describes acclimatisation as “the organism’s response to repeated exposure to a stimulus”. Repeated exposure to wind, rain or a range of other climatic conditions may have unconsciously numbed the user’s senses to these weather conditions and partially explain why several weather factors showed no or poor correlations with user counts.

7.5 Who uses the moor?

Over the period of the MPhil study (2012-2013) 925 users were observed on the moor. Their activity was categorised and compared to data gathered from the CBMC (2013) survey data in Table 7.3 (p.196). It is inferred that Ilkley Moors users are loyal to the area; the CBMC (1988) survey suggested that users regularly make repeat visits to the moor (Table 7.4, p. 198). This is backed up with anecdotal evidence from the researcher seeing the same vehicles and speaking with the same people at the survey location on data collection trips. Activities such as dog walking and jogging tended to be observed at the moor. Brandenburg and Arnberger (2001) claim that users undertaking such activities tend to make frequent repeat visits to the same sites.

Table 7.3 Comparison of the MPhil, CBMC (2013) and Peak District National Park (2005) user activity surveys.

Activity	**MPhil study**	**CBMC 2013 survey**	**Peak District National Park (2005)**[4]
Walking (no dog)	43%	39%	80%[3] (27% < 2 miles, 53% > 2 miles.
Walking (with dog)	24%	39%	n.a
Running	20%	9%	n.a
Other	6%[1]	9%[2]	n.a
Cycling	7%	4%	7%
Hiking	Classed as walking	Classed as walking	9%
Climbing	Grouped as “other”	Grouped as “other”	3%
Picnic	Grouped as “other”	Grouped as “other”	20%
Sightseeing	Grouped as “other”	Grouped as “other”	27%
Photography	n.a	n.a	7%
Bird watching	n.a	n.a	8%
Visit an event	n.a	n.a	22%

1=Kite flying, Metal detecting and picnicking. 2=Picnicking, sightseeing, sitting in car, playing, rock climbing and reminiscing.

2= Peak District National Park do not differentiate between dog walking and just walking.

3= Peak District National Park method allowed users to select more than one option at once.

n.a = data not provided

CBMC surveys (1988; 2013) show that the majority of users will only travel one hour to reach the moor, whereas the Peak District National Park survey (Peak District National Park, 2005) showed that people generally travel greater distances to reach the park. Comparison of the user activities across Peak District National Park, this study and the CBMC (2013) study showed that generally people visit Ilkley Moor to go walking. While this is also a common activity in the Peak District National Park there were a range of other activities such as photography and visiting an event. These three surveys are difficult to accurately compare as they each listed different response options to their questions but it can be seen that generally there is a much greater variety of activities undertaken by users of the Peak District National Park than the Ilkley Moor users.

The data gathered from the CBMC (2013) survey showed differences when compared to the MPhil study. However, the MPhil study was based exclusively on the survey area whereas the CBMC study was based on a larger area which included the lower, more accessible land at Cow and Calf. Neither the results of the MPhil or the CBMC (2013) study relate particularly well to Brandenburg and Arnberger's (2001) study of the lower Danube National Park, which claimed that 58% of respondents were cyclists. This offers further proof that the users of Illkey Moor demonstrate different characteristics to the users of the wilder, larger national park areas. Another interesting factor is that the CBMC (2013) survey found that 88% of respondents admitted to letting their dog off the lead during their use of the area. This could cause a major stakeholder issue for shoot managers, as dogs off leads could cause disturbance to ground nesting birds and cause problems for the rearing of grouse.

Frequency of visits to Ilkley Moor was assessed through the CBMC (2013) survey (Table 7.4, p.198).

Table 7.4 Frequency of visits to moorlands.

Frequency	Ilkley Moor (CBMC, 2013 study).	Peak District National Park, 2005 study.
Daily	26%	8%
2-3 times per week	20%	(not an option)
Once per week	13%	16%
Once per month	9%	24%
Quarterly	(not an option)	25%
Yearly	0%	17%
Sporadic	22%	0%
First visit	9%	0%
Don't know/less than yearly	1%	10%

When compared with the Peak District National Park (2005) it can be seen that the users of this study area were far more frequent than visitors to the national park (Table: 7.4, p.198). This offers more evidence that the users on this moorland portray different characteristics to those using the more remote upland Peak District areas.

7.6 Can amenity use be predicted?

Chapter Six (p. 144) provided two alternative ways of predicting users based on the data collected. The chapter concluded with the regression based models being most accurate. The regression approach required time intervals larger than the 30 minute blocks in which the METAR weather data are reported (Table 6.5, p.148). Prediction down to 30 minute accuracy cannot be accurately achieved.

Correlation coefficients showed that generally the users of the moor were little affected by time and climatic factors which made predicting user numbers difficult. Using day of the week as a predictor showed that weekends were easier to predict than weekdays (Table 6.6, p.152). This reflects comments made by Aylen *et al.* (2014) and Brandenburg and Arnberger (2001) who also found weekends easier to predict than weekdays at their location.

Unfortunately, the weighting factor approach (p.159) did not provide any significant findings (highest explanations were between 22 and 37%, when removing the data from the least useful sensor). This method was investigated as it could have potentially provided predictions using a simplistic method that would have been easily understood by a field operative and potentially calculations could have been made on site from a list of weighting factors. The multiple regression modelling approach (p. 144) on the other hand required some fairly specialised programmes such as R or SPSS (note: Excel and Minitab could not regress this large number of variables all at once). The accuracy of the weighting factor model may have been improved through the use of further data collection and further refinement of the weighting factors. Chapter Six concluded that the most accurate prediction method was through the use of two sets of regression based models. One general model to predict user counts at any time (giving accuracies between 39% and 50% when removing the weakest predicting sensor) and another more focused model that could be applied to summer and weekends (giving accuracies between 49% and 58% when removing the weakest predicting sensor).

These results suggest that there are two distinct user groups on the moor:

- Group A are users who use the moor regularly throughout the week (and presumably the weekend) as highlighted in the CBMC (1988; 2013) surveys (users who use the moor daily or 2/3 times per week). In a way, users in this group are difficult to predict using time and weather variables because their use is steady and is little affected by weather, time of day, or day of the week. Perhaps they have become acclimatised to the moor and its prevalent conditions. Further research, through manual observation of repeat visitors, could determine a baseline number of “regular” users.

- Group B consists of users who use the moor on weekends and during summertime. It would appear from the data that there is a secondary group that supplement the first group’s use of the moor on weekends and in summer conditions. This user group is more predictable using time and weather factors as they are more prone to the influence of these factors.

At all times other than 01:50-02:50 there is evidence of activity in the study area. Average data show evening use (19:20-00:20) as 18% of daytime use (09:20-17:50), increased to 27% on average at Keighley Road. Sensor errors may be responsible for some of this off-peak count. However, the researcher visited the moor 23 times in periods of darkness across a range of weather conditions between 03:00-06:00 and 19:00-01:00. Users were observed in the car park at each visit. On four of these occasions users were also seen walking on the moor past Whetstone Gate. Evening use tends to be busiest on Fridays, whereas daytime use tends to be busiest on Saturdays. Evening use appears less erratic than daytime use. At Keighley Road there is an average 46% difference between the busiest and quietest evenings, compared to 63% between the busiest and quietest daytimes. These figures may be impacted by the lower number of evening users.

It is potentially beyond the scope of this study to understand activities these evening users were undertaking. However, it is important to raise these observations as a flag for managerial activities and further research. A note of caution is applied to further research in this area; consideration of ethics would be required, based on anecdotally observed actions of some users (fly-tipping and drug dealing, both reported to the police, car congregations [generally youths sitting around in modified cars] and evidence of sexual encounters). McDermott (2012; 2017. Pers. Comm.) notes similar observations, adding poaching.

Before demolition [2012] Bradford University owned a disused observatory near the car park, items related to drug abuse and rough sleeping were observed around the building. A news search for “Ilkley Moor” results in articles reporting rape (Parkin, 1987) [case withdrawn shortly after the article], murder (Meneaud, 2008; Wright, 2008) and UFO sightings (Clouston, 1990).

During this project, news of various dubious, bizarre and criminal acts in the wider collection of urban fringe areas appeared. From news articles relating to raves (Davidson, 2017), fly tipping (Atkinson, 2016; Case, 2018; Glover, 2016), paranormal activity (Ballinger, 2016; Clarke, 2011) and sexual encounters (Burnett, 2018; Hatton, 2018; McCully, 2017). Through to crimes such as rape (Connell, 2017; Hughes, 2017), and murder (Henderson, 2016; Whiteley, 1966).

These anecdotal observations and news reports provide evidence for a third user group (Group C, questionable use beyond fitness, dog walking and nature based escape), a group of users that may not be discouraged by poor climatic factors. Such users may even be seeking out certain adverse climatic factors such as fog to screen activity (although this was not detected in the data collected in this study). Generally however, research shows that there is a strong positive link between better climatic conditions and higher occurrences of crime (Field, 1992; Murtataya and Gutierrez, 2013; Ranson, 2014). Studies into crime tend to focus on a wide range of crimes in urban areas, whereas criminals at these urban-fringe locations may differ in their preferred climatic conditions.

A managerial consideration to this criminal element is user perceptions of safety. Maruthaveeran and Van Den Bosch (2014) highlight a psychological affect around crime. This is something that urban-fringe managers need to be aware of; if public perceptions of crime rise, regardless of actual crime levels, legitimate use may decrease. This may lead to a reduction in funding for areas and a negative spiral of decay. Maruthaveeran and Van Den Bosch (2014) note that familiarity with an area could reduce insecurity, suggesting that people feel comfortable knowing where the “escape routes“ are. The Friends of Ilkley Moor Group (2018) offer regular guided walks across the area, if people were encouraged to join in these activities familiarisation could take place in a safe and comfortable environment, leading to further trips by participants without the group. Alternatively, apps and maps could be produced labelling “safe” locations, such as the pubs at Whitewells and Riddlesden, the phone box at the end of Keighley Road (Riddlesden) and the game keepers cottages at Bingley Moor.

Physical incivilities play a part in user perceptions of areas. Users are often disturbed by the sight of graffiti, burned out cars and unkempt vegetation (Maruthaveeran and Van Den Bosch, 2014; Kuo *et al.* 1998). At present Ilkley Moor is well kept and generally free from physical incivilities. Anecdotal evidence by the researcher and McDermott (2017. Pers. Comm.) suggest that fly tipping is cleared up quickly. The researcher saw one burned out car in the car park during the study, this was removed within 24 hours of the observation [it cannot be stated how long it was there before the researcher observed it]. Vegetation provides an issue for the management of the area, with Kuo *et al.* (1998) suggesting that people feel safer in “kept” short vegetation. While there are no trees or large areas of bushes on the moor the CBMC (1998) management plan states that conservation should take priority over recreation, it would be unfeasible to trim all heather to a uniform short height. Until recently the disused Bradford University observatory could have been considered an eyesore, the structures were rusting and covered in graffiti. This could have tainted previous users' perceptions of the site. A marketing campaign around the theme "then and now" could be instigated by CBMC how the buildings have been removed and a heather re-colonisation programme has been installed. This may increase public confidence in the area.

Maruthaveeran and Van Den Bosch (2014) argue that people are generally more concerned about visiting open spaces where there are no staff patrols. It would be difficult to install a 24/7 managerial presence in current economic conditions. However, police patrols of Keighley Road could be made at key times such as dusk-01:50, with a focus on Friday evenings. Fisher and May (2009) found that the presence of officials had a negative effect on users, as users had not perceived there to be a danger at the site, then seeing a police presence they had thought about the potential for danger in the area.

Further research is required into Group A. If the size of this group could be ascertained, then the additional burden placed on the moor by Group B could be assessed and managed appropriately. It would be interesting to discover the overlap between Groups A and B. Does Group A diminish at the weekend at the expense of the increase in Group B? Is there crossover between Group A and B users, and Group C users? Do Groups A and B co-exist side by side? Or are there stakeholder conflicts? It would also be interesting to note what activities the two groups undertake. Where do Group A and B users come into conflict with Group C users? Brandenberg and Arnberger (2001) claim that their midweek users tended to be joggers and dog walkers who were little affected by weather; perhaps this is the case in this survey area. If Group A tends to consist of joggers and dog walkers, their routine would be systematic (i.e. the dog needs walking regardless of weather, or the jog is part of a health regime that the user feels is more important than climatic factors). Potentially then Group B could be people seeking release from their daily work and life, people coming up to the moor to sit and read newspapers, take in the views, picnic or stroll around and generally find escape. The evening traffic on weekends and summer days at WSG probably also heavily contributes to Group B's ease of prediction.

If this concept of Group A and B users is correct, consideration of Arnberger and Eders (2007) work into monitoring recreational activities in the forests near Vienna may assist in understanding the relationship between the two groups. They provide evidence to suggest that joggers tend to peak around June but then decline through the summer months, and dog walkers tend to also decline through the summer months (Figure 7.4, p.204). This may be because they go away on holidays at these times or have other commitments in the summer months. Conversely, Arnberger and Eder (2007) note an increase in Nordic walkers and cyclists in the summer months. These may be in the Group B of this study.

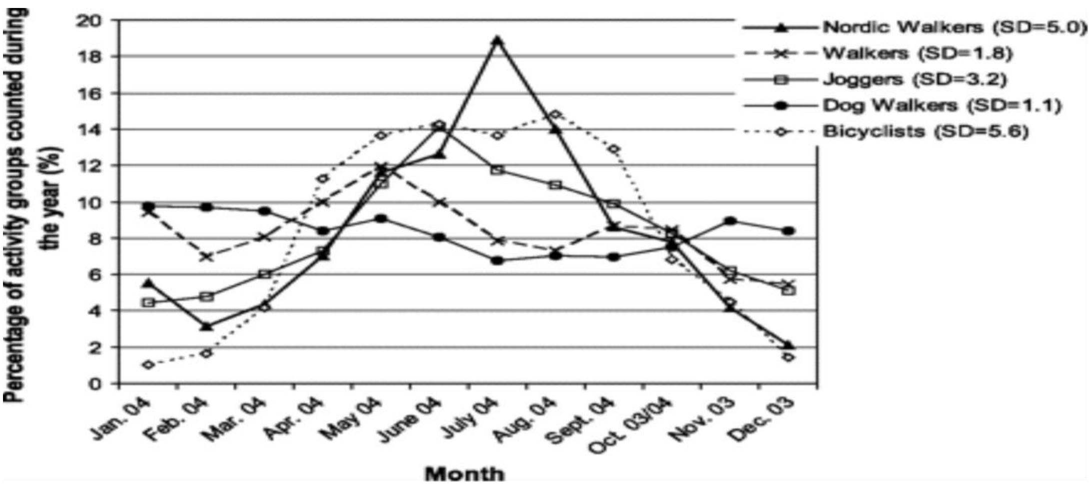


Figure 7.4 Yearly use patterns by activity type (reproduced from: Arnberger and Eder, 2007, p. 6).

If Arnberger and Eder's (2007) work is applicable to Ilkley Moor it may indicate that group A users decline over summer, but the survey shows increased summer users which could mean that this is taken up by an increase in Group B users. However, the MPhil study

(Appendix one, Figure 16. p.253) shows that faecal deposits which are left on the moor by dogs, peaked in August, which would indicate that dog walking on this survey area is most predominant in August.

Another approach to predicting moorland use may have been to develop separate models for different user groups (i.e. cyclists, walkers, joggers, dog walkers etc.) as each of these groups might respond to the time and weather variables differently. This is a potential avenue for further research.

Comparison with similar studies, such as that published by Ploner and Brandenburg (2003) showed that they were able to predict 86% of visitors to the Lower Danube National Park, Austria. The study carried out by Aylen *et al.* (2014) showed that they were able to accurately predict 70% of visitors to Chester Zoo. This study, with its highest prediction of 58%, perhaps seems disappointing. However, this lower prediction compared to these other studies may give further support to the claim that this area of "urban fringe" moorland has a different characteristic user to that of the more remote national parks and wilderness areas. Users in the Chester Zoo study were heavily influenced by school holidays and temperature which aided prediction, whereas users in this study are not influenced by school holidays, indicating a largely different type of user.

This study and model does not consider the "bounce back" factor. For example, Aylen *et al.* (2014) noted that visitors to Chester Zoo decreased on rainy days, but there was a subsequent increase on the next non-rainy day [i.e. visitors who were going to go to the zoo on a rainy day wait and go the next day when it is not raining]. During January 2014 the moor was inaccessible for a period of one week due to snow lying on the ground. However, the following week did not show any signs of increased use, when compared with data for the previous and following weeks. This would indicate that there is no "bounce back" factor at the moor [i.e. if a person cannot access, or is put off access they do not subsequently appear to make an extra trip to the moor to make up for their missed trip]. Unfortunately, there was only one winter period in the PhD data collection phase and only one period of total inaccessibility, further data would need to be collected to offer proof of the lack of a “bounce back factor”.

Another key issue is the link between users and satisfaction. While weather and time variables may influence a user’s decision to frequent the moor, there are also other factors playing on the user’s mind. Some works have considered “Psychological equivalent temperature” (Brandenburg and Arnberger, 2001) and its effect on users perceptions of the attraction. Other factors may include crime rates, previous experiences or encounters at the site or media influences (Tooke and Baker, 1996). For example, Wuthering Heights (IMDB, 2011) and Jane Eyre (BBC, 2016) have been produced and released within the last eight years, both including a significant area of moorland, close to this survey area. The broadcasting of such films could stimulate some extra people to consider visiting Ilkley moor.

Chapter 8 Conclusions, recommendations and contribution to knowledge

Brandenburg and Arnberger (2001) claim that knowledge of the user numbers on the days with highest user counts is essential for management of the physical resource (the land) and for prevention of stakeholder conflicts (the users). This study has shown that peak use is around July and August, with the peak use day being Saturday. Therefore, managers of the moor should aim to undertake restoration or improvement works outside of these times. It may also be worthwhile having a managerial presence in the area during these times.

In the Peak District National Park (2005) survey (N=29,151) over 50% of respondents suggested that self-guided leaflets would be a good improvement. Downloadable or app based guides could be produced for Ilkley Moor to enable certain user groups to guide themselves around the area. However, this may encourage more infrequent (perhaps Group B) users to the moor.

If the concept of two user groups (Groups A and B) is valid, each group may require a different managerial approach. Group A tend to be regular and frequent users. This group of people could be approached and used as a first line reporting system. Being regular users they will know the moor and they will be able to see and perhaps report changes on the moor quickly after they occur.

Another aspect of management is the avoidance of stakeholder conflict. The Literature Review highlights a range of stakeholder conflicts. Recently there has been conflict between amenity users and grouse (*Lagopus lagopus scoticus*) shooters (Quinn, 2017). Therefore, a plan has been constructed based on the outcomes of this study (Table 8.1, p.208).

This study recommends that grouse (*Lagopus lagopus scoticus*) shooting commences in October. While this would miss the traditional Glorious 12th in August and 49 other days of possible shooting, the CBMC and Bingley Moor agreement only allows shooting on six days per year (CBMC, 2016). A delayed start to the shoot would simply mean that these six days would have to take place in October, November and December. Major works on the moor could be conducted between January and March. This would avoid the peak amenity user period and the grouse shooting period. Major works would need to be completed before April since the months of April and May are the key grouse (*Lagopus lagopus scoticus*) nesting period. However, it is noted that due to the peat substrate and weather etc. it may not always be possible to conduct all major maintenance between January and March.

Table 8.1 Potential time framework for management activities.

Action	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Peak amenity use						🟨	🟨	🟨	🟨			
Potential grouse shooting										🟨	🟨	🟨
Grouse nesting season				🟨	🟨							
Potential heavy management work	🟨	🟨	🟨									

8.1 Wider implications

8.1.1 Climate Change

While the extent and rate of climate change is the subject of much debate, climate change is an acknowledged phenomenon by a wide range of academics. If the International Panel on Climate Change scenario A1FI occurs, this will lead to warmer and drier weather for the UK (Murphy *et al.,* 2009). This study shows that temperature and humidity is weakly linked to user numbers, while rainfall showed no significant correlations with user counts. Therefore, based on the observations in this study alone, it could be assumed that climate change would have minimal or no impact on user counts at this Pennine moorland location. However further analysis of the two groups may indicate that Group B are more susceptible to changes in weather, which may lead to an increase in their use.

While it would appear that users have become accustomed to, and accepting of conditions on the moor, UK Climate predictions show a potential temperature rise of 2.5-5.7^{O}C (Murphy *et al.* 2009) by 2100. This would lead to higher counts of the upper extreme temperature observations. During this study there were 290 30 minute observations over 16^{O}C. If the upper predicted increase (+5.7%) was applied that would be an additional 290 observations over 21^{O}C. Aylen *et al.* (2014) suggest that 21^{O}C is around the upper tolerable limit for users. Therefore, there are a potential 290 30 minute periods per year in the future when the moor could become uncomfortable to its users due to higher temperatures.

In the Chester Zoo study, Aylen *et al.* (2014) suggested that there was no evidence in their data (1970 – 2010) to suggest a long term change in use due to climate change, but rather there was a response to individual weather conditions on a daily basis. Considering that the snow in January 2014 did not produce a “bounce back” effect in this study, this may be an indication that climate change may result in lower moorland user counts at the higher end temperatures. People might be put off from using the moor in more extreme heat conditions but then may not make a subsequent additional trip to make up for the one that they missed. At the other end of the temperature scale users may be encouraged to use the moor more at the lower extremes of temperature. This levelling of seasonality could assist in management, as Butler (2001) claims that often visitor attractions have high infrastructural constraints in peak season and revenue shortfalls in low season. Anecdotal evidence from researcher trips has found that the car park at WSG has been full on several occasions during August.

8.1.2 Methods and applicability to other fringe areas

This study has been conducted on Ilkley Moor, an area of Pennine moorland fringe. However, the results of this study may be used in the management of other similar areas such as the area mentioned in the introduction at Norland Common, Calderdale. Using this study away from these Pennine upland environments may lead to a reduction in accuracy of the predictions. However, the data collection strategy gives a sound basis for user number data collection which, if carefully assessed, may be applicable to a range of similar urban fringe moors and attractions.

8.2 Recommendations for further work.

De Feritas (2003) suggested that climate and time variables were not a measure of satisfaction so may not be suitable for predicting repeat custom. Further work needs to be undertaken to assess users' motives and individual needs. Further study using a qualitative based approach could provide management with further data about the users' reasons for using the moor beyond time and weather variables, their needs, desires and impacts.

Some authors have attempted to assess the economic contribution of users to wilderness areas (e.g. Comley and Mackintosh, 2014). However, this study has shown that this moorland has a unique user profile. This may also be reflected in the spending habits of these users. The CBMC (1988; 2013) studies showed that predominantly users travelled less than one hour to reach the site. This means that they would not require local accommodation and may have eaten at home, therefore reducing their spending at the area. Further study is required to understand the nature of how these moorland users contribute to the local economy.

A cost-benefit analysis could be conducted into the continued municipal stewardship of Ilkley Moor, taking into account the overall cost of maintaining the moor (staff wages, resources, insurance, shooting income etc.), then assessing the benefits both in terms of immediate financial returns and longer term health and wellbeing benefits. Users average spend in local shops, public houses, hotels etc. could be ascertained then applied to the user predictions generated in this study to give a prediction of the immediate economic impact of users in the area. Other work could focus on the health and wellbeing benefits of this moor. A range of literature exists on nature therapy, green exercise and general health and wellbeing benefits gained from spending time in nature areas. The outcomes of these works could be applied to the user numbers predicted in this work to generate predictions of the health benefits of this particular area. Such a cost benefit analysis may be of use to moorland managers, council decision makers and financial controllers in planning for the future of this moorland.

Kajala *et al.* (2007) discussed a "paid for" access system in Nordic wilderness areas. This may be of use at Ilkley Moor. Research would be required to ascertain the perceived value to users, their willingness to pay and their preferences to what and how they are paying for (i.e. facilities, staff presence, conservation, membership schemes, donations etc.).

While this study has considered a range of time and weather factors, there are potentially many other factors that influence a user's decision to use or not use the moor. Qualitative analysis may discover and assess these factors, and then further quantitative study may produce data based on these variables.

This study has flagged up nocturnal use of the study area (Group C), especially around the KR and WSG area. Further data could be provided on these users, why they are using the moor and if their use is in conflict with daytime users of the moor. This information may be of use to moorland managers, police and other crime prevention agencies.

Peak District National Park (2005) and Moors For The Future (Davies, 2006) demonstrate that their users are generally an older demographic. They suggest that there are sustainability issues going forward as younger demographics are less prevalent in their park areas. Work could be undertaken on this moor to understand the demographic profiles of the user groups and potentially how the younger demographics could be encouraged to use the area. A note of caution must be applied here however, encouragement of the younger demographic should not be at the cost of the enjoyment of the older demographics.

The MPhil element of this study showed a stable litter volume on the moor (Appendix 1, p.252). The CBMC (1989 and 2013) surveys showed that over 40% of users asked for litter bins on the moor. Understanding different user groups and their needs may lead to data that could show where bins could be placed to remove the highest volumes of litter from the moor. Friends of Illkey Moor (Perham, 2013. Pers. Comm.) placed a bin liner on the fence at Whetstone Gate. Anecdotal evidence suggests that this has been emptied and replaced at points during this study (as the bin liner has changed from black to green bin liners on occasions). However, there are no records of the volume of litter collected. In the CBMC (1989) response to the 1988 study CBMC state that the problem with placing litter bins on the moor is emptying them. As they are in remote locations it would be difficult to add these to a bin collection round. They show concern that over full bins could potentially have a negative impact on users. Alternatively, further work could investigate the sources of litter and look into educating users about the need to remove their litter from the moor.

In the late 20th century a body of work was built up investigating vegetation on the moor by researchers such as Cotton and Hale (1989; 1994), Dalby *et al.* (1971) and Hale and Cotton (1988; 1993). Further work could repeat their studies and compare their data with up to date contemporary vegetation surveys, building up a picture of vegetation change on the moor over the period 1971 – present date.

8.3 Contribution of the thesis to knowledge

This research is valuable to a range of amenity moorland or other urban fringe stakeholders including academics who wish to further understand users and expand knowledge of this under acknowledged group. The study also meets the requirements and calls of land managers who have called for these data to be collected (McDermott, 2017. Pers. Comm. Perham, 2013. Pers. Comm.). In addition, this research is of use to wider funding, protection and crime prevention agencies. The Environment Agency and conservation organisations may wish to understand the time and climatic factors behind users’ decisions to use amenity land for recreation. Land owners, managers and curators may wish to use this knowledge in support of funding campaigns, and funders may wish to see this knowledge as part of funding applications to prove that the funding will bring value for money or meet any of their other criteria.

Unfortunately, these areas of “urban fringe” moorland are often the scenes of crimes, from small scale littering and breaking car windows through to more serious crimes. Data on the use of these moors could potentially help police and rescue organisations in their crime prevention, searches and other operations.

8.3.1 Specific contributions to knowledge

1. Provision of accurate user numbers for “urban fringe” areas: As previously discussed, both municipal land owners identified (CBMC and Calderdale Council) stated that they were unaware of any accurate or current 24/7 user data specifically focused on their moorland holdings. Both Perham (2013. Pers. Comm.) and McDermott (2017. Pers. Comm.) as local “urban fringe” moorland managers have called for these data. From an academic perspective there have been calls for more data on natural area land users by Ankre *et al.* (2016), Cessford and Muhar (2003), Jones and Ohsawa (2016), Kajala *et al.* (2007), Miller *et al.* (2017) and Schanger *et al.* (2017). In addition, Leung *et al.* (2015) and Smallwood *et al.* (2011) call particularly for more data on moorland users. This study has responded to these calls, by providing user data in a range of time and weather conditions.

2. Provision of data and a prediction method to assist managers in understanding their moorland use in a range of time and weather conditions: While contribution no.1 (above) provided an accurate guide to numbers using these areas of land it is also important to understand the time and weather factors affecting usage. Therefore, this study also provides regression models for predicting use of these areas going forward. These regression models may be further developed in future to include other variables such as weather forecasts.

3. Development, piloting and prototyping of a simple, inexpensive and accurate way of collecting user numbers: While there is a vast range of commercial equipment readily available to make visitor counts these often come at a considerable cost which may be beyond the budgets of many local, small scale projects. Many local authorities and organisations are currently in financial difficulty and cutting back on costs. This study has considered a range of options for collecting data (different sensors, human counts, cameras etc.) and focused on bringing set up costs down through home-made and user programmed microcomputer based sensors. The study has constructed its own sensors for under £20 each which is a vast saving on that of commercially available technology which might retail for more like £500-1000/sensor (Footfallcam.com, 2017).

4. Acknowledgement of an existence of a different group of moorland users: Reading around moorlands and the Literature Review of this work shows that there is a large amount of work focused on conservation, development of shooting and protection of moorlands (both in the UK and internationally). However, there is an apparent gap in literature that fails to really acknowledge that smaller areas of moorland around the "urban fringe" are in existence and require a different management style.

In the case of the larger moors, such as Saddleworth or the Peak District areas, the same moor may require two management standards: one for the remote areas of high moor promoting conservation, serious hikers and red grouse (*Lagopus lagopus scoticus*) shooting; and, another for those smaller areas of urban fringe, near roads and minor car parks where, Amblers may prevail over Scramblers (Edwards, 2007). This study contributes to this emergent area of moorland management.

Peak District National Park (2005) asked respondents to their questionnaire where else they had visited. The 225 responses included areas such as “Birmingham Park”, “Batley” and “Blackshaw Moor” but there are no recordings of Rombolds Moor or Ilkley Moor, indicating that people do not recognise this moor as a large scale visitor attraction.

Further to this acknowledgement of urban-fringe moorland users displaying different characteristics to those of the more remote national parks, there is also the acknowledgement of a potentially more sinister group of users. Toward the end of Chapter Seven (p.172) evidence and observations of criminal and dubious activity are discussed. These discoveries raise awkward questions for land managers and authorities. Land managers should consider how they monitor and police this aspect of urban fringe moorland use.

References.

Agnew, M.D. and Palutikof, J.P. (2001) Climate impacts on the demand for tourism. *Proceedings of the First Workshop on Climate, Tourism and Recreation, International Society of Biometeorology*, Halkidiki, 1st October V.1(1), pp.41-50
Available at: http://www.mif.uni-freiburg.de/isb/ws/report.htm
[Accessed: 3rd October 2017]

Altangerel, K. and Kull, C.A. (2013) The prescribed burning debate in Australia: Conflicts and compatibilities. *Journal of Environmental Planning and Management* [online], V.56(1), pp.103-120
DOI: 10.1080/09640568.2011.652831
[Accessed: 22nd January 2018]

Alzantot, M. and Youssef, M. (2012) UPTIME: Ubiquitous pedestrian tracking using mobile phones. *Wireless Communications and Networking Conference* [online] Shanghai, 2 April V.1(1) pp.34-37
DOI: 101109/WCNC.2012.6214359
[Accessed: 22nd January 2018]

Amin, I.J. Taylor, A.J. Junejo, F. Al-Habaibeh, A. and Parkin, R.M. (2008) Automated people counting by using low-resoloution infared and visual cameras. *Measurement.* [online], V. 41(1), pp.589-599
DOI: 10.1016/j.measurement.2007.02.010
[Accessed: 22nd January 2018]

Ammer, U. and Pröbstl, U. (1991) *Freizeit und Natur Verlag.* Hamburg: Paul Parey

Anderson, D.H. and Brown, P.J. (1984) The displacement process in recreation. *Journal of Leisure Research* [Online], V.16(1), pp.61-73
Available through ProQuest
[Accessed: 22nd January 2018]

Anderson, P. (1990) *Moorland recreation and wildlife in the Peak District.* Bakewell: Peak Park Joint Planning Board

Anderson, P. and Tallis, J.H. (1981) The nature and extent of soil and peat erosion in the Peak District. In: Phillips, J. Yalden, D. and Tallis, J. (Eds.) *Peak District Moorland Erosion Study: Phase One Report.* Bakewell: Peak Park Joint Planning Board pp.52-64

Ankre, R. Fredman, P. and Lindhagen, A. (2016) Managers' experiences of visitor monitoring in Swedish outdoor recreational areas. *Journal of Outdoor Recreation and Tourism* [online], V.14(1), pp 35-40
DOI: 10.1016/j.jort.2016.04.008
[Accessed: 22nd January 2018]

Arnberger, A. and Brandenburg, C. (2002) Visitor structure of a heavily used conservation area: The Danube Floodplains National Park, lower Austria. *Monitoring and Management of Visitor Flows in Recreational Protected Areas* [online] Tallinn, 20 August V.1 pp.7-13
Available at: http://mmv.boku.ac.at/refbase/files/arnberger_arne_bra-2002-visitor_structure_of.pdf
[Accessed: 22nd January 2018]

Arnberger, A. and Eder, R. (2007) Monitoring recreational activities in urban forests using long-term video observation. *Forestry* [online] V.80(1), pp.1-15
DOI: 10.1093/forestry/cpl043
[Accessed: 22nd January 2018]

Askham Bryan College (2016) *Farming in Yorkshire, Lancashire and Cheshire Benchmarking Data*. York: Askham Bryan College

Atkinson, N. (2016) Fly tipping anger as Kirklees Council discusses new charges. *The Huddersfield Daily Examiner* [online], 14th March 2016
Available at: https://www.examiner.co.uk/news/west-yorkshire-news/flytipping-anger-kirklees-council-discusses-11035733
[Accessed: 28th January 2018]

Augustine, D.J. and Milchunas, D.G. (2009) Vegetation responses to prescribed burning of greased shortgrass steppe. *Ecological Management* [Online], V.62(1) pp.89-97
DOI: 10.2111/08-135
[Accessed: 22nd January 2018]

Aylen, J. Albertson, J. and Cavan, G. (2014). The impact of weather and climate on tourist demand: the case of Chester Zoo. *Climatic Change* [online], V.127(2), pp.183-197
DOI: 10.1007/s10584-014-1261-6
[Accessed: 22nd January 2018]

Bain, C.G. Bonn, A. Stoneman, R. Chapman, S. Coupar, A. Evans, M. Gearey, B. Howat, M. Joosten, H. Keenleyside, C. and Labadz, J. (2011) *IUCN UK Commission of Inquiry on Peatlands* [online]
Available at: http://roar.uel.ac.uk/3591/
[Accessed: 22nd January 2018]

Ballinger, L. (2016) Mysterious “space poo” discovered on Huddersfield moorland – was it left by aliens? *The Huddersfield Daily Examiner* [online], 24th November 2016
Available at: https://www.examiner.co.uk/news/west-yorkshire-news/mysterious-space-poo-discovered-huddersfield-12225464
[Accessed: 28th January 2018]

Banister, J. (1985) *The vegetational and archaeological history of Rombolds Moor West Yorkshire*. Ph.D. thesis, University of Leeds

Bank of England (2017) *UK Inflation Calculator* [Online]
Available at:
http://www.bankofengland.co.uk/education/pages/inflationtools/calculator/default.aspx
[Accessed 26.08.2017]

Banks, P.B. and Bryant, J.V. (2007) Four-legged friend or foe? Dog walking displaces native birds from natural areas. *Biology letters* [online], V.3(6), pp.611-613
DOI: 10.1098/rsbl.2007.0374
[Accessed: 22nd January 2018]

Barret, P. (2017) RSPB logged 200 reports of crimes against birds of prey in 2015. *The Guardian* [online], 3rd February 1997
Available at: https://www.theguardian.com/environment/2017/feb/03/rspb-logged-200-reports-of-crimes-against-birds-of-prey-in-2015
[Accessed: 22nd January 2018]

Bateman, I.J. Day, B.H. Georgiou, S. and Lake, I. (2006) The aggregation of environment benefit values: Welfare measures, distance decay and total WTP. *Ecological Economics* [online], V.60(2), pp.450-460.
DOI: 10.1016/j.ecolecon.2006.04.003
[Accessed: 22nd January 2018]

Bathe, G. (2007) Political and social drivers for access to the countryside: the need for research on birds and recreational disturbance. *IBIS The International Journal for Avian Science* [online], 149, V.149(1), pp.3-8.
DOI: 10.1111/j.1474-919X.2007.00639.x
[Accessed: 22nd January 2018]

Battle, J. and Golliday, S.W. (2003) Prescribed fires impact on water quality of digressional wetlands in southwestern Georgia. *The Amreican Midland Naturalist* [online], V.150(1), pp.15-25.
DOI: 10.1674/0003-0031(2003)150[0015:PFIOWQ]2.0.CO;2
[Accessed: 22nd January 2018]

Bauer, D. Brandle, N. Seer, S. Ray, M. and Kitazawa, K. (2009) Measurement of Pedestrian Movements: A Comparative Study on Various Existing Systems. In: Timmermans, H. (Ed.) *Pedestrian behaviour.* Bingley: Emerald pp.325-344

BBC (2016) BBC – Jane Eyre – BBC Films [online]
Available at: http://www.bbc.co.uk/bbcfilms/film/jane_eyre
[Accessed: 22nd January 2018]

Bigano, A. Maddison, D. Hamilton, J.M. and Tol, R.S.J. (2006) The impact of climate on holiday destination choice. *Climate Change* [online], V.76(3), pp.389-406
DOI: 10.1007/s10584-005-9015-0
[Accessed: 22nd January 2018]

Bishop, I.D. Wherrett, J.R. and Miller, D.R. (2001) Assessment of path choices on a country walk using a virtual environment. *Landscape and urban planning* [online],V.52(4), pp.225-237
DOI: 10.1016/S0169-2046(00)118-3
[Accessed: 22nd January 2018]

Boer,M.M. Sadler,R.J. Wittkhun,R. McCaw,L. and Grierson,P.F. (2009) Long term impacts of prescribed burning on regional extent and incidence of wildfires – evidence from 50 years of active fire management in SW Australian forests. *Forest Ecology and Management* [online], V.259(1), pp.132-142.
DOI: 10.1016/j.foreco.2009.10.005
[Accessed: 22nd January 2018]

Bradford Ornithological Group (BOG) (No Date) *Birds on Rombolds Moor* [Information Leaflet]

Brandenburg, C. and Arnberger, A. (2001) The influence of weather upon recreation activities. *Proceedings of the First International Workshop on Climate, Tourism and Recreation* [online] Halkidiki, 5 October V.1(1) pp.122-132
Available at:
https://s3.amazonaws.com/academia.edu.documents/32414453/full_report.pdf?AWSAccessKeyId=AKIAIWOWYYGZ2Y53UL3A&Expires=1516713470&Signature=nTcIu4Rrd2SAAIMcAIBMDz5YwPU%3D&response-content-disposition=inline%3B%20filename%3DUsing_a_tourism_climate_index_to_examine.pdf
[Accessed: 22nd January 2018]

Brown, A.F. Shepherd, K.B. (1991) *Breeding birds of the south Pennine moors*. Joint Nature Conservation Committee (JNCC) Report No.7

Brown, R.W. and Sheaves, B.J. (1995) Densities of *Ixodes ricinus* ticks (Acari: Ixoidae) on moorland vegetation communities in the UK. *Experimental and Applied Acarology* [online], V.19(9), pp.489-497.
DOI: 10.1007/BF00052917
[Accessed: 22nd January 2018]

Brown, A.F. and Stillman, R.A. (1998) The return of the Merlin to the south Pennines. *Bird Study* [online], V.45(3), pp.293-301
DOI:10.1080/00063659809451100
[Accessed: 31st January 2018]

Bryant, C.R. Russwurm, L.J. and McLellan, A.G. (1982) *The City's Countryside. Land and its management in the rural-urban fringe*. London: Longman

Bu, F. Green-Rosel, R. Diogenes, M.C. and Ragland, D.R. (2007*). Estimating Pedestrian Accident Exposure: Automated Pedestrian Counting Devices Report*.
Available at: https://escholarship.org/uc/item/0p27154n
[Accessed: 22nd January 2018]

Burden, R.F. (1972) Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. *Journal of Applied Ecology* [online], V.9(2), pp.439 - 457
DOI: 10.2307/2402445
[Accessed: 22nd January 2018]
Burnett, T. (2018) Man performs sex act at Staffordshire fishing pool. *The Stoke Sentinel* [online], 25th January 2018
Available at: http://www.stokesentinel.co.uk/news/uk-world-news/man-performs-sex-act-staffordshire-1116113
[Accessed: 28th January 2018]

Burt, T.P. (2001) Integrated management of sensitive catchment systems. *Catena* [online], V.42(2), pp.275–290
DOI: 10.1016/S0341-8162(00)00141-7
[Accessed: 22nd January 2018]

Butler, R.W. (2001) Seasonality in Tourism: Issues and Implications. In: Baum, T. Lundtorp, S. (Eds.) *Seasonality in Tourism*. London: Routledge pp.332-339

Calladine, J. Critchley, C. Baker, D. Towers, J. and Thiel, A. (2014) Conservation management of moorland: a case study of the effectiveness of a combined suite of management prescriptions which aim to enhance breeding bird populations. *Bird Study* [online], V.61(1), pp.56-72
DOI: 10.1080/00063657.2013.876615
[Accessed: 22nd February 2018]

Case, P. (2018) Fly-tipping monstrosity leaves farmers with nowhere to turn. *The Farmers Weekly* [online], 12th January 2018
Available at: http://www.fwi.co.uk/news/fly-tipping-monstrosity-leaves-tenants-nowhere-turn.htm
[Accessed: 28th January 2018]

Cawson, J.G. Sheridan, G.J. Smith, H.G. and Lane, P.N.J. (2012) Surface runoff and erosion after prescribed burning and the effect of different fire regimes in forests and shrublands: a review. *International Journal of Wildland Fire* [online], V.21(7), pp.857-872
DOI: 10.1071/WF11160
[Accessed: 22nd February 2018]

CBMC (City of Bradford Metropolitan Council) (1977) *Biological data bank: Ilkley Moor report* [Unpublished]

CBMC (City of Bradford Metropolitan Council) (1988) *Recreation survey: Ilkley Moor* [Unpublished]

CBMC (City of Bradford Metropolitan Council) (1989) *Recreation impact assessment: Ilkley Moor* [Unpublished]

CBMC (City of Bradford Metropolitan Council) (1998) Yorkshire and the Humber rights of way and access group, Ilkley Moor: City of Bradford Metropolitan Council Management Plan [Unpublished]

CBMC (City of Bradford Metropolitan Council) (2012a) Scrutiny Review, Ilkley Moor Sporting Rights Deed [online]
Available at: https://www.bradford.gov.uk/media/2126/ilkleymoorsportingrightsdeed.pdf
[Accessed: 22nd January 2018]

CBMC (City of Bradford Metropolitan Council) (2012b) *Ilkley Moor NVC Classifications*, *Arcsoft map* [Unpublished]

CBMC (City of Bradford Metropolitan Council) (2013) Composite Surveys [Unpublished]

CBMC (City of Bradford Metropolitan Council) (2016) *Ilkley Moor Management Plan* [online]
Available at:
https://bradford.moderngov.co.uk/documents/s11701/Ilkley%20Moor%20Management%20Plan%20Final%20Consultation%20Draft.pdf
[Accessed: 22nd January 2018]

Cessford, G. Cockburn, S. and Douglas, M. (2002) Developing new visitor counters and their applications for management. *Monitoring and management of visitor flows in recreational and protected areas* [online] Vienna, 30 January V.1, pp.14-21
Available at: http://www.imba-uk.com/wp-content/uploads/perception_and_reality_of_conflict.pdf
[Accessed: 22nd January 2018]

Cessford, G. and Muhar, A. (2003) Monitoring options for visitor numbers in national parks and natural areas. *Journal for Nature Conservation* [online], V.11(4), pp.240-250.
DOI: 10.1078/1617-1381-00055
[Accessed: 22nd January 2018]

Chan, C.Y. and Bu, F. (2005) *Literature review of pedestrian detection technologies and sensor survey* [online]
Available at:
https://www.researchgate.net/publication/237367146_LITERATURE_REVIEW_OF_PEDESTRIAN_DETECTION_TECHNOLOGIES_AND_SENSOR_SURVEY_MidTerm_Report_for_Task_Order_5200_Experimental_Transit_Vehicle_Platform_for_Pedestrian_Detection
[Accessed: 22nd January 2018]

Change.org (2016) *End Grouse Shooting on Ilkley Moor* [online]
Available at: https://www.change.org/p/councillor-susan-hinchcliffe-end-grouse-shooting-on-ilkley-moor
[Accessed: 22nd January 2018]

Charman, D. (2002) *Peatlands and environmental change*. Chichester: John Wiley and sons

Clarke, D. (2011) *Longdendale Lights* [online]
Available at: https://drdavidclarke.co.uk/spooklights/longdendale-lights/
[Accessed: 28th January 2018]

Clouston, E. (1990) Cynics lose in close encounter with UFOphiles. *The Guardian,* 26th February 1990

Cohen, D.A. McKenzie, T.L. Sehgal, A. Williamson, S. Golinelli, D. and Lurie, N. (2007) Contribution of Public Parks to Physical Activity. *American Journal of Public Health* [online], V.97(3), pp.509-514
DOI: 10.2105/AJPH.2005.072447
[Accessed: 22nd January 2018]

Cole, D.N. and Daniel, T.C. (2003) The science of visitor management in parks and protected areas: from verbal reports to simulation models. *Journal for Nature Conservation* [online], V.11(4), pp.269-277
DOI: 10.1078/1617-1381-00058
[Accessed: 22nd January 2018]

Comley, V. and Mackintosh, C.I. (2014) *The Economic Impact of Outdoor Recreation in the UK: The Evidence* [online]
Available at: http://researchonline.ljmu.ac.uk/1579/1/Reconomics%20-%20The%20Evidence%20PDF%202014.pdf
[Accessed: 22nd January 2018]

Commons Hansard Debates [online], 6th September 2017, col 628-900627
Available at: https://hansard.parliament.uk/Commons/2017-09-06/debates/EEEE7766-2B15-4F55-B334-DF9DF6EE4910/OralAnswersToQuestions
[Accessed: 22nd January 2018]

Connel, J. (2017) Kulin Odedra, Kassim Multani and Bradley Tout appear at Worcester Magestrates Court for sexual offences against teenager. *Worcester News* [online], 31st August 2017
Available at: http://www.worcesternews.co.uk/news/15507309.Three_men_appear_in_court_for_sexual_offences_following_alleged_rape_of_teenage_girl_in_Worcester
[Accessed; 28th January 2018]

Cope, A. and Hill, T. (1997). Monitoring the Monitors: The use of visitor monitoring in England and Wales. *Countryside Recreation Network News.* V.5(1) pp.10-11

Cope, A. Doxford, D. and Probert, C. (2000) Monitoring visitors to UK countryside resources: The approaches of land and recreation resource management organisations to visitor monitoring. *Land Use Policy* [online], V.17(1), pp.59-66
DOI: 10.1016/S0264-8377(99)00035-6
[Accessed: 22nd January 2018]

Cotton, D.E. and Hale, W.H.G. (1989) Vegetation changes on Ilkley Moor 1964-1984. *Naturalist*. V.114(991), pp.104-114

Cotton, D.E. and Hale, W.H.G. (1994) Effectiveness of cutting as an alternative to burning in the management of Calluna vulgaris moorland: results of an experimental field trial. *Journal of Environmental Management* [online], V.40(2), pp.155-159
DOI: 10.1006/jema.1994.1011
[Accessed: 22nd January 2018]

Countryside and Rights of Way (CROW) Act 2000 [online]
Available at: http://www.legislation.gov.uk/ukpga/2000/37/part/I
[Accessed: 22nd January 2018]

Cowson, J.G. Sheridan, G.J. Smith, H.G. and Lane, P.N.G. (2012) Surface runoff and erosion after prescribed burning and the effect of different fire regimes in forests and shrub lands: a review. *International Journal of Wildland Fire* [online], V.21(7) pp.857-872
DOI: 10.1071/WF11160
[Accessed: 22nd January 2018]

Cumulus Consultants (2012) *Changing livestock numbers in the UK Less Favoured Areas – an analysis of likely biodiversity implications, for the Royal Society for the Protection of Birds (RSPB)* [Online]
Available at: http://www.rspb.org.uk/images/final_report_tcm9-340975.pdf
[Accessed: 22nd January 2018]

Dalby, M. Fidler, J.H. Fidler, A. and Duncan, J.E. (1971) The vegetative changes on Ilkley Moor. *Naturalist,* V.86(2), pp.37-40

Davidson, T. (2017) Cops 'pull the plug' on illegal rave in heart of Denbigh moors. *The Daily Post* [online], 7th January 2017
Available at: https://www.dailypost.co.uk/news/north-wales-news/cops-pull-plug-illegal-rave-12420385
[Accessed: 28th January 2018]

Davies, G.M. Ketteridge, N. Stoof, C.R. Gray,A. Ascoli, D. Fernandes, P.M. Marrs, R. Allen, K.A. Doerr, S.H. Clay, G.D. McMorrow, J. and Vandvik, V. (2016) The role of fire in UK peatland and moorland management: the need for informed, unbiased debate. *Philosophical transactions of the Royal Society* [online], V.371(1), pp.1-17
DOI: 10.1098/rstb.2015.0342
[Accessed: 22nd January 2018]

Davies, S. (2006) *Recreation and Visitor Attitudes in the Peak District Moorlands. Moors For The Future Partnership report no. 12* [online]
Available at:
http://www.moorsforthefuture.org.uk/sites/default/files/documents/MMF%20RR12%20Recreation%20and%20Visitor%20Attitudes%20in%20the%20Peak%20District%20Moorlands.pdf
[Accessed: 22nd January 2018]

De Freitas, C.R. (2003) Tourism Climatology: evaluating environmental information for decision making and business planning in the recreation and tourism sector. *International Journal of Biometerology* [online], V.48(1), pp.45-54
DOI: 10.1007/s00484-003-0177-z
[Accessed: 22nd January 2018]

DEFRA (2007) *The Heather and Grass Burning Code* [online]
Available at: http://www.fire.uni-freiburg.de/programmes/natcon/UK-DEFRA--Heather-Grass-Burning-Code-2007.pdf
Accessed: 22nd January 2018]

DEFRA (2010) *Farming in the Uplands. Written evidence submitted by Department for Environment, Food and Rural Affairs to Efra inquiry*.
Available at:
https://publications.parliament.uk/pa/cm201011/cmselect/cmenvfru/556/556vw.pdf
Accessed: 22nd January 2018]

Dharmarjru, R. Noyce, D.A. and Lehman, J.D. (2001) An evaluation of technologies for automated detection and classification of pedestrians and bicycles. *71st ITE annual meeting,* Chicago, V.1, pp.1-13

Dixon, G. and Hawes, M. (2015) A longitudinal multi-method study of recreational impacts in the Arthur Range, Tasmania, Australia. *Journal of Outdoor Recreation and Tourism* [online], V.9(1), pp.64-76
DOI: 10.1016/j.jort.2015.03.005
[Accessed: 22nd January 2018]

Donzelot, J. (1979) *The Policing of families.* London: Random House Incorporated

Douglas, D.J.T. Buchanan, G.M. Thompson, P. Amar, A. Fielding, D.A. Redpath, S.M. and Wilson, J.D. (2015) Vegetation burning for game management in the UK uplands is increasing and overlaps spatially with soil carbon and protected areas. *Biological Conservation* [online], V.191(1), pp.243-250
DOI: 10.1016/j.biocon.2015.06.014
[Accessed: 22nd January 2018]

Dustin, D. Bricker, K. and Schwab, K. (2010) People and Nature: Toward an ecological model of health promotion. *Leisure Sciences* [online], V.32(1), pp.3-14
DOI: 10.1080/014900903430772
[Accessed: 22nd January 2018]

Dwyer, J.C. Mills, J. Powell, J.R. Lewis, N. Gaskell, P. and Felton, J. (2015) *The State of Farming in Exmoor 2015* [online]
Available at: http://www.exmoor-nationalpark.gov.uk/__data/assets/pdf_file/0011/656174/Finalthe-state-of-farming-in-exmoor-2015-final-report_22-may.pdf
[Accessed: 22nd January 2018]

Dybeck, M. W. and Green, F. H. W. (1955) The Cairngorms weather survey, 1953. *Weather* [online], V.10(2), 41-48
10.1002/j.1477-8696.1955.tb00137.x
[Accessed: 22nd January 2018]

Dytham, C. (2003) *Choosing and using statistics, a biologist's guide*. 2nd ed. Oxford: Blackwell Publishing

Eagles, P.F.J. (2014) Research priorities in park tourism. *Journal of Sustainable Tourism*, V.22(4), pp.528-549

Edwards, T. (2007) *Results of the National Trail User Survey 2007* [online]
Available at: http://bankssolutions.co.uk/powys/wp-content/uploads/2013/05/CD-VATT-LAN-021-National-Trail-User-Survey-Results-2007-extracts.pdf
[Accessed: 22nd January 2018]

Facebook.com (2017) *Stop the shoot*
Available from: http://www.facebook.com/stoptheshoot
[Accessed: 22nd January 2018]

Fidler, J. H. Dalby, M. and Duncan, J. E. (1970) The plant communities of Ilkley Moor. *Naturalist*, V.95(1), pp.41-48

Field, S. (1992) The effect of temperature on crime. *The British Journal of Criminology* [online], V.32(3), pp.340-351
DOI: 10.1093/oxfordjournals.bjc.a048222
[Accessed: 28th January 2018]

Finney, S.K. Pearce-Higgins, J.W. and Yalden, D.W. (2005) The effect of recreational disturbance on an upland breeding bird, the Golden Plover *Pluvialis apricaria*. *Biological Conservation* [online], V.121(1) pp. 53-63
DOI: 10.1016/j.biocon.2004.04.009
[Accessed: 22nd January 2018]

Fisher, B.S. and May, D. (2009) College students' crime-related fear on campus: are fera-provoking cues gendered? *Journal of Contemporary Criminal Justice* [online], V.25(3), pp.300-321
DOI: 10.1177/1043986209335013
[Accessed: 28th January 2018]

Footfallcam.com (2017) *New Brochure* [Online]
Available at: http://www.footfallcam.com/Content/data/documents/New_Brochure.pdf
[Accessed: 22nd January 2018]

Friends of Ilkley Moor (2018) *Events and walks* [online]
Available at: http://www.ilkleymoor.org/Events/
[Accessed: 28th January 2018]

Fyfe, R.M. Giesecke, T. Davis, B. Brewer, S. Finsinger, W. Wolters, S. Blaauw, M. De Beaulieu, J.L. Binney, H. Gaillard, M.J. and Gil-Romera, G. (2014) Towards mapping the late Quaternary vegetation change of Europe. *Vegetation History and Archaeobotany* [online], V.23(1), pp.75-86
DOI: 10.1007/s00334-012-0390-y
[Accessed: 22nd January 2018]

Gliptis, S. (1995) Recreation and the environment: challenging and changing relationships. In: Leslie, D. (Ed.) *Tourism and Leisure: Towards the millennium: vol. 1: Culture, Heritage and participation.* Leisure Studies Association: Eastbourne

Glover, C. (2016) Marsden Moor beauty spot struck by fly tipping. *The Huddersfield Daily Examiner* [online], 26th April 2018

Available at: https://www.examiner.co.uk/news/west-yorkshire-news/marsden-moor-beauty-spot-struck-11238790
[Accessed: 28th January 2018]

Golik, A. and Gertner, Y. (1992) Litter on the Israeli coastline. *Marine Environmental Research* [online], V.33(1), pp.1-15
DOI: 10.1016/0141-1136(92)90002-4
[Accessed: 22nd January 2018]

Google (2017) *Rombolds Moor – Google Maps* [Online]
Available at: https://www.google.co.uk/maps/place/Rombald's+Moor/@53.8997376,-1.8227432,661m/data=!3m1!1e3!4m5!3m4!1s0x487bfad6ad684955:0xfb1069c797fbd60d!8m2!3d53.9030833!4d-1.8269166
[Accessed: 22nd January 2018]

Grant, M.C. Mollord, J. Stephen, L. and Thompson, P.S. (2012) *The costs and benefits of grouse moor management to biodiversity and aspects of the wider environment: a review* [online]
Available at:
http://ww2.rspb.org.uk/Images/grant_mallord_stephen_thompson_2012_tcm9-318973.pdf
[Accessed: 22nd January 2018]

Gutzwiller, K.J. (1991) Assessing the recreational impacts on wildlife: The value and design of experiments. *56th North American Wildlife and Natural Resources Conference* [online], Edmondton, 17 March V.1, pp.249-255
Available at: https://wildlife-management-institute.myshopify.com/products/transactions-of-the-56th-north-american-wildlife-and-natural-resources-conference
[Accessed: 22nd January 2018]

Hadwen, W.L. Hill, W and Pickering, C.M. (2007) Icons under threat: why monitoring visitors and their ecological impacts in protected areas matters. *Ecological Management and Restoration* [online], V.8(3), pp.177-181
DOI: 10.111/j.1442-8903.2007.00364.x
[Accessed 22nd January 2018]

Hale, W.G.H. and Cotton, D.E. (1988) The management of vegetation change on Ilkley Moor. *Aspects of Applied Biology*, V.16(2), pp.311-316

Hale, W.G.H. and Cotton, D.E. (1993) Vegetation changes in Ilkley Moor between 1964 and 1984, and possible environmental causes. *Naturalist*, V.118(1), pp.123-134

Hatton, B. (2018) A dog found pink knickers and sex toy after a stargazer was propositioned in Ashdown Forest. *Kent Live* [online], 24th January 2018
Available at: http://www.kentlive.news/news/kent-news/dog-found-pink-knickers-sex-1114059
[Accessed: 28th January 2018]

Heathwaite, A.L. (1993) Disappearing peat – regenerating peat? The impact of climate change on British peatlands. *The Geographical Journal* [online], V.159(2), pp.203-208
DOI: 10.2307/3451411
[Accessed: 22nd January 2018]

Henderson, E. (2016) Britain's most haunted site in murder probe after man's body found near ghost hunting tours. *The Mirror* [online], 25th August 2016
Available at: https://www.mirror.co.uk/news/uk-news/britains-most-haunted-site-murder-8700870
[Accessed: 28th January 2018]

Higgs, E.S. (1976) The History of European Agriculture--The Uplands. *Philosophical Transactions of the Royal Society of London* [online], V.275(936), pp.159-173
DOI:10.1098/rstb.1976.0078
[Accessed: 22nd January 2018]

Hines, R.K. (2017) Review of literature: Potential benefits of urban nature exposure and stream corridor based recreation. *Illuminare* [online], V.15(1), 35-46
Available through Indiana University
[Accessed: 22nd January 2018]

Holden, J. Brown, L.E. and Palmer, S.M. (2016) Moorland vegetation burning debates should avoid contextomy and anachronism: a comment on Davies *et al*. (2016). *Philosophical Transactions of the Royal Society* [online], V.371(1708), pp.107-108
DOI: 10.1098/rstb.2016.0432
[Accessed: 22nd January 2018]

Holden, J. Shotbolt, L. Bonn, A. Burt, T.P. Chapmann, P. Dougill, A.J. Fraser, E.D.G, Hubacek, K. Irvine, B. Kirkby, M.J. Reed, M.S. Prell, C. Stagl, S. Stringer, L.C. Turner, A. and Worrall, F. (2007) Environmental change in moorland landscapes. *Earth Science Reviews* [online], V.82(2), pp.75-100
DOI: 10.1016/j.earscirev.2007.01.003
[Accessed: 22nd January 2018]

Honold, J. Lakes, T. Beyer, R. and Van der Meer, E. (2015) Nature views from home, greenways and public parks. *Environment and Behaviour* [online], V.48(6), pp.796-825
DOI: 10.1177/0013916514568556
[Accessed: 22nd January 2018]

Howarth, P.F. and Thompson, D.B.A. (1990) Factors associated with the breeding distribution of upland birds in the south Pennines, England. *Journal of Applied Ecology* [online], V.27(2), pp.562-577
DOI: 10.2307/2404302
[Accessed: 22nd January 2018]

Hughes, L. (2017) Extra police at Wirral beauty spot where woman was raped. *Echo* [online], 29th August 2017
Available at: https://www.liverpoolecho.co.uk/news/liverpool-news/extra-police-wirral-beauty-spot-13544102
[Accessed: 28th January 2018]

IMDB (2011) *Wuthering Heights 2011 – IMDB* [online]
Available at: http://www.imdb.com/title/tt1181614/
[Accessed: 22nd January 2018]

Innies, M.W. Stanbury A.J. Tomanknova, I. and Douglas, D.J.T. (2016) Changes in moorland and heathland bird abundance in south west England in relation to environmental change. *Bird Study* [online], V.63(4), pp.543-553
DOI: 10.1080/00063657.2016.1241755
[Accessed: 22nd January 2018]

Ilkley Urban District Council [defunct] (1952) *Correspondence between Ilkley Urban District Council and Ministry for Agriculture Forestry and Fishing (MAFF)* [defunct] Unpublished.

Jackson, D. (1995) *Report to the head of transportation and planning, Grouse shooting licence: Ilkley Moor* [Unpublished]

Jones, A. Bateman, I.J. and Wright, J. (2003) *Estimating arrival numbers and values for informal recreational use in British woodlands* [online]
Available at: https://www.forestry.gov.uk/pdf/batemanf2.pdf/$FILE/batemanf2.pdf
[Accessed: 22nd January 2018]

Jones, T. and Ohsawa, T. (2016) Monitoring nature-based tourism trends in Japan's national parks: Mixed messages from domestic and inbound visitors. *Parks* [online], V.22(1), pp.25-36
DOI: 10.2305/IUCN.CH.2016.PARKS-22-1TJ.en
[Accessed: 22nd January 2018]

Kajala, L. Almik, A. Dahl, R. Diksate, L. Erikkonen, J. Fredman, P. Jensen, F. Sendergaard, A. karoles, K, Sielvnen, T. Skov-Peterson, H. Vistad, O.I. Wallsten, P. (2007) *Visitor monitoring in nature areas – a manual based on experiences from the Nordic and Baltic countries*. Stockholm: Termanord

Khan, J. Powell, T. (2010) *Land Use in the UK* [online]
Available at: http://www.ons.gov.uk/ons/guide-method/user-guidance/well-being/publications/land-use-in-the-uk.pdf
[Accessed: 22nd January 2018]

Kilburg, E.L. Moorman, C.E. DePerno, C.S. Cobb, D. and Harper, C.A. (2015) Wild turkey pre-nesting resource selection in a landscape managed with frequent prescribed fire. *Southeastern Nationalist* 14. [online], V.14(1), pp.137-146
DOI: 10.1656/058.014.0114
[Accessed: 22nd January 2018]

Korpella, K. Borodulin, M. Neuvonen, M. Paronen, O and Tyrvainen, L. (2014) Analyzing the mediators between nature-based outdoor recreation and emotional well-being. *Journal of Environmental Psychology* [online], V.37(1), pp.1-7
DOI: 10.1016/j.jenvp.2013.11.003
[Accessed: 22nd January 2018]

Kuo, F.E. Bacaicoa, M. and Sullivan, W.C. (1998) Transforming inner-city landscapes: Trees, sense of safety and preference. *Environment and Behaviour* [online], V.30(1), pp.28-59
DOI: 10.1177/0013916598301002
[Accessed: 28th January 2018]

Kutti, J. (2012) *A test setup for comparison of people flow sensors*. Licentiate thesis, Aalto University
Available at: http://lib.tkk.fi/Lic/2012/urn100598.pdf
[Accessed 22nd January 2018]

Labadz, J.C. Burt, T.P. and Potter, A.W.R. (1991) Sediment yield and deliver in the blanket peat moorlands of the southern Pennines. *Earth surface processes and landforms* [online], V.16(3), pp.255-271
DOI: 10.1002/ESP.3290160306
[Accessed: 22nd January 2018]

Langan, P. (1997) Fury as council bans grouse shooting. *Wharfedale Reporter*. 25th February, p.9

Langmuir, E. (2013) *Mountaincraft and Leadership.* 4th ed. England: Mountain Leader Training England (MLTE)

Larson, L.R. Jennings, V. and Cloutier, S.A. (2016) Public parks and wellbeing in urban areas of the United States. *PLOS One* [online], V.11(4), pp.1-19
DOI: 10.1371/journal.pone.0153211
[Accessed: 22nd January 2018]

Leung, Y. Walden-Schreiner, C. Conlon, K. and Miller, A.B. (2015) A simple method for monitoring dog leash compliance behaviour in national parks and natural areas. *Journal of Outdoor Recreation and Tourism* [online], V.9(1), pp.11-16
DOI: 10.1016/j.jort.2015.03.001
[Accessed: 22nd January 2018]

Liddle, M. (1997) *Recreation Ecology*. London: Chapman and Hall

Limb, M. and Spellman, G. (2001) Evaluating domestic tourist's attitudes to British weather. A qualitative approach. *Proceedings of the First Workshop on Climate, Tourism and Recreation, International Society of Biometeorology* [online], Halkidiki, 5 October V.1(1), pp.21-35
Available from:
https://www.researchgate.net/profile/Andreas_Matzarakis/publication/233758777_Proceedings_of_the_First_International_Workshopon_Climate_Tourism_and_Recreation/links/09e4150b490da0ac00000000.pdf#page=24
[Accessed: 22nd January 2018]

Lindsay, R.M. and Charman, D.J. Everingham, F. O'Riley, R.M. Palmer, M.A. Rowel, T.A. and Stroud, D.A. (1998). *The flow country. Peatlands of Caithness and Southerland* [online]
Available at: http://jncc.defra.gov.uk/page-4281
[Accessed: 22nd January 2018]

Lise, W. and Tol, R.S.J. (2002) Impact of climate change on tourist demand. *Climate Change* [online], V.55(4), pp.429-449
DOI:10.1023/A:102072802
[Accessed: 22nd January 2018]

Littlewood, N.A. Evans, D.M. Villar, N. Pakeman, R.J. Evans, S.A. Dennis, P. Skartveit, J. and Redpath, S.M. (2014) The cascading impacts of livestock grazing in upland ecosystems: a 10-year experiment. *Ecosphere* [online], V.6(3), pp.1-15
DOI: 10.1890/ES14-00316.1
[Accessed: 22nd January 2018]

Local Government Act 1976 [online]
Available at: http://www.legislation.gov.uk/ukpga/1976/57
[Accessed: 22nd January 2018]

Lupp, G. Forster, B. Kantelberg, V. Markmann, T. Naumann, J. Honert, C. Koch, M and Pauleit, S. (2016) Assessing the recreation value of urban woodland using the ecosystem service approach in two forests in the Munich metropolitan region. *Sustainability* [online], V.8(11), pp. 1156-1163
DOI: 10.3390/SU8111156
[Accessed: 22nd January 2018]

MacEwan, A. and MacEwen, M. (1982) *National Parks, Conservation of Cosmetics?* London: Alien and Unwin.

Mackintosh, C.I. Zehndorfer, E. and Darko, N. (2016) *Outdoor recreation as a potential lever for health improvement: A review of the health benefits, barriers and opportunities for the sector* [online]
Available at: https://e space.mmu.ac.uk/617906/1/MMU%20literature%20review%20health%20benefits%20of%20OR.pdf
[Accessed: 22nd January 2018]

Maddison, D.J. (2001) In search of warmer climates? The impact of climate change on flows of British tourists. *Climate Change* [online], V.49(2), pp.193-208
DOI: 10.1023/A:101074251
[Accessed: 22nd January 2018]

Maes, J. Teller, A. Erhard, N. Liquete, C . Braat,L. Bery,P. and Egoh, B. (2013) *Mapping and assessment of ecosystems and their services: analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020* [online]
Available at:
http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf
[Accessed: 22nd January 2018]

Maruthaveeran, S. and Van Den Bosch, C.C.K. (2014) A socio-ecological exploration of fear of crime in urban green spaces – A systematic review. *Urban Forestry and Urban Greening* [online], V13(1), pp.1-18
DOI: 10.1016/j.ufug.2013.11.006
[Accessed: 28th Janaury 2018]

Matthews, E. and Poigne, A. (2009) Evaluation of a “smart” pedestrian counting system based on echo state networks. *EURASIP Journal on Embedded Systems – Challenges on complexity and connectivity in embedded systems* [online], V.8(1), pp.1-9
DOI: 10.1155/2009/352172
[Accessed: 22nd January 2018]

McCully, G. (2017) Camera plan to curb Lancashire beauty spot sex acts. *Lancashire Post* [online], 18th October 2017
Available at: https://www.lep.co.uk/news/crime/camera-plan-to-curb-lancashire-beauty-spot-sex-acts-1-8811175
[Accessed: 28th January 2018]

Meneaud, M. (2008) Moor sex attack suspect is arrested. *Lancashire Telegraph* [online], 1st July 2008
Available at:
http://www.lancashiretelegraph.co.uk/news/3188806.Moor_sex_attack_suspect_is_arrested/
[Accessed: 28th January 2018]

Merrell, T.R. (1984) A decade of change in nets and plastic litter from fisheries off Alaska. *Marine Pollution Bulletin* [online], V.15(10), pp.378-384
DOI: 10.1016/0025-326X(84)90172-3
[Accessed: 22nd January 2018]

Met Office (2016) *Wind chill factor* [online]
Available at: http://www.metoffice.gov.uk/learning/wind/wind-chill-factor
[Accessed 22nd January 2018]

Miller, A.B. Leung, Y-F. and Kays, R. (2017) Coupling visitor and wildlife monitoring in protected areas using camera traps. *Journal of Outdoor Recreation and Tourism* [online], V.17(1), pp.44-53
DOI: 10.1016/j.jort.2016.09.007
[Accessed: 22nd January 2018]

Millhausler, A. Anderwald, P. Haeni, M. and Haller, R.M. (2016) Publicity, economics and weather – Changes in visitor numbers to a European National Park over 8 years. *Journal of Outdoor Recreation and Tourism* [online], V.16(5), pp.50-57
DOI: 10.1016/j.jort.2016.09.005
[Accessed: 22nd January 2018]

Milligan, G. Rose, R.J. and Marrs, R.H. (2015) Winners and losers in a long-term study of vegetation change at Moor House NNR: Effects of sheep-grazing and its removal on British upland vegetation. *Ecological Indicators* [online], V.69(1), pp.89-101
DOI: 10.1016/j.ecolind.2015.10.053
[Accessed: 22nd January 2018]

Monbiot, G. (2016a) *Bonfire of the Verities* [online]
Available at: http://www.monbiot.com/2016/03/10/bonfire-of-the-verities
[accessed 22nd January 2018]

Monibot, G. (2016b) Meet the conservationists who believe that burning is good for wildlife. *The Guardian*, 14th January, p.43

Ministry of Agriculture Forestry and Fishing [defunct] (1952) *Correspondence between MAFF and Ilkley Urban District Council [defunct]* Unpublished

Moorland Association (2006) *The Moorland Association – Economics of Grouse Moors* [online]
Available at: Http://www.moorlandassociation.org/economics3.asp
[Accessed: 15th June 2017]

Morgan, R. and Williams, A.T. (1999) Video panorama assessment of beach landscape aesthetics on the coast of Wales. *Journal of Coast Conservation* [online], V.5(1), pp.13-22
DOI: 10.1007/BF02802735
[Accessed: 22nd January 2018]

Muhar, A. Schauppenlehner, T. Brandenburg, C. and Arnberger, A. (2007) Alpine summer tourism: the mountaineers' perspective and consequences for tourism strategies in Austria. *Forest Snow and Landscape Research*, V.81(1), pp.7-17

Murphy, J.M. Sexton, D.M.H. Jenkins, G.J. Boorman, P.M. Booth, B.B.B. Brown, C.C. Clark, R.T. Collins, M. Harris, G.R. Kendon, E.J. and Betts, R.A. (2009) *UK Climate Projections Science Report: Climate Change Projections* [online]
Available at: http://ukclimateprojections.metoffice.gov.uk/media.jsp?mediaid=87893
[Accessed: 22nd January 2018]

Murtataya, R. and Gutierrez, D.R. (2013) Effects of Weather on Crime. *International Journal of Humanities and Social Science.* V.3(10), pp.71-75

National Parks and Access to the Countryside Act (1949) [online]
Available at: http://www.legislation.gov.uk/ukpga/Geo6/12-13-14/97
[Accessed: 22nd January 2018]

Natural England (2015) *Monitor Engagement with the Natural Environment: Annual report from the 2013-2014 survey (JP009)* [online]
Available at: http://publications.naturalengland.org.uk/publication/6579788732956672
[Accessed: 22nd January 2018]

Neary, D.G. Klopatek, C.C. DeBano, L.F. and Ffolliott, P.F. (1999) Fire effects on belowground sustainability: a review and synthesis. *Forest Ecology and Management* [online], V.122(1), pp.51-71
DOI: 10.1016/S0378-1127(99)00032-8
[Accessed: 22nd January 2018]

NFU Hill and Upland Farming Group (2014) *Our Commitment to the Hills and Uplands* [online]
Available at: https://www.nfuonline.com/assets/4815
[Accessed: 22nd January 2018]

Nikolopoulou, M. (2001) The effect of climate on the use of open spaces in the urban environment: Relation to tourism. *Proceedings of the First International Workshop on Climate, Tourism and Recreation* [online] Halkidiki, 5 October V.1(1), pp.185-195
Available at:
https://www.researchgate.net/profile/Andreas_Matzarakis/publication/233758777_Proceedings_of_the_First_International_Workshopon_Climate_Tourism_and_Recreation/links/09e4150b490da0ac00000000.pdf#page=24
[Accessed: 22nd January 2018]

North Yorkshire Moors National Park (NYMNP) (2014). *The English Uplands as a Natural Resource* [Education leaflet]

Orellana, D. Bregt, A.K. Ligtenberg, A. and Wachowicz, M. (2011) Exploring visitor movement patterns in natural recreational areas. *Tourism Management* [online], V.33(3), pp.672-682
DOI: 10.1016/j.tourman.2011.07.010
[Accessed: 22nd January 2018]

Parkin, M. (1987) UK News in Bief: Woman made up rape story. *The Guardian,* 25th June 1987, p.10

Pattinson, V.A. Butcher, D.P. and Labadz, J.C. (1994) The management of water colour in peatland catchments. *Water and Environment Journal* [online], V.8(3), pp.298-307
DOI: 10.1111/j.1747-6593.1994.tb01108.x
[Accessed: 22nd January 2018]

Peak District National Park (2005) *Peak District National Park Visitor Survey, 2005* [online]
Available at:
http://www.peakdistrict.gov.uk/__data/assets/pdf_file/0020/162281/visitorsurvey2005.pdf
[Accessed: 22nd January 2018]

Pearce-Higgins, J.W. and Grant, M.C. (2006) Relationships between bird abundance and the composition and structure of moorland vegetation. *Bird Study* [online], V.53(2), pp.112-125
DOI: 10.1080/0006365069461424
[Accessed: 22nd January 2018]

Perry, A.H. (2004) Sports tourism and climate variability. *Proceedings of the Second International Workshop on Climate, Tourism and Recreation*, Crete, 8 June V.2(6), pp.21-31

Ploner, A. and Brandenberg, C. (2003) Modelling visitor attendance levels subject to day of week and weather: a comparison between linear regression models and regression trees. *Journal for Nature Conservation* [online], V.11(4), pp.297-308
DOI: 10.1078/1617-1381-00061
[Accessed: 22nd January 2018]

Quinn, B. (2017) Glorious twelfth under fresh fire from protesters on moors and streets. *The Guardian* [online], 13th August
Available at: https://www.theguardian.com/uk-news/2017/aug/12/glorious-twelfth-anti-hunting-protests
[Accessed: 22nd January 2018]

Ranson, M. (2014) Crime, Weather and Climate Change. *Journal of Environmental Economics and Management* [online], V.67(3), pp.274-302
DOI: 10.1016/j.jeem.2013.11.008
[Accessed: 28th Janaury 2018]

Ratcliffe, D.A. and Thompson, D.B.A. (1988) The British uplands: their ecological character and international significance. *Ecological Change in the Uplands*, V.1(1), pp.9-36

Ravenscroft, N.O.M. (1995) The conservation of *Carterocephalus palaemon* in Scotland. In: Pullin, A.S. (Ed.) *Ecology and Conservation of Butterflies*. Netherlands: Springer pp. 165-179

Ritson, J. (1988) Ilkley Moor shows signs of wear and tear. *The Independent.* 25th February, p.21

Ritson, J. (1997) Moor could see the end of grouse shooting tradition. *Wharfedale Reporter*. 10th October, p.14

Ritson, J. (1998) Parish Council wants control of the Moor. *Ilkley Gazette*. 8th January, p.23

Saayman, M. and Viljoen, A. (2016) Who are wild enough to hike a wilderness trail? *Journal of Outdoor Recreation and Tourism* [online], V.14(1), pp.41-51
DOI: 10.1016/j.jort.2016.04.004
[Accessed: 22nd January 2018]

Sah, J.P. Ross, M.S. Snyder, J.R. Koptur, S. and Cooley, H.C. (2006) Fuel loads, fire regimes, and post-fire fuel dynamics in Florida Keys pine forests. *International Journal of Wildland Fire* [online], V.15(4), pp.463-478
DOI: 10.1071/WF05100
[Accessed: 22nd January 2018]

Schanger, J.P. Maes, J. Brander, L. Paracchini, M.L. Volkmar, H. and Dubois, G. (2017) Monitoring recreation across European nature areas: A geo-database of visitor counts, a review of literature and a call for a visitor counting reporting standard. *Journal of Outdoor Recreation and Tourism* [online], V.18(1), pp.44-55
DOI: 10.1016/j.jort.2017.02.004
[Accessed: 22nd January 2018]

Scott, D. and Jones, B. (2007) A regional comparison of the implications of climate change on the golf industry in Canada. *Canadian Geography* [online], V.51(2), pp.219-232
DOI: 10.1111/j.1541-0064.2007.00175.x
[Accessed: 22nd January 2018]

Shaw, P.J.A. Lankey,K. and Hollingham,S.A. (1995) Impacts of trampling and dog fowling on vegetation and soil conditions on Headley Heath. *London Naturalist,* V. 74(1), pp.77-83

Smallwood, C.B. Beckley, L.E. Moore, S.A. and Kobryn, H.T. (2011) Assessing patterns of recreational use in large marine parks: A case study from Ningaloo Marine Park, Australia. *Ocean and Coastal Management* [online], V.54(4), pp.330-340
DOI: 10.1016/j.oceanman.2010.11.007
[Accessed: 22nd January 2018]

Smith, W.G. and Rankin, W.M. (1903) Geographical distribution of vegetation in Yorkshire part 2 Harrogate and Skipton district. *Geographical Journal* [online], V.22(2), pp.149-178
DOI: 10.2307/1775607
[Accessed: 22nd January 2018]

Sterl, P. Brandenburg, C. and Arnberger, A. (2008) Visitors' awareness and assessment of recreational disturbance of wildlife in the Donau-Auen National Park. *Journal for Nature Conservation* [online], V.16(3), pp.135-145
DOI: 10.1016/j.jnc.2008.06.001
[Accessed: 22nd January 2018]

Suarez, E.R. and Medina, G. (2001) Vegetation structure and soil properties in Ecuadorian paramo grasslands with different histories of burning and grazing. *Arctic, Antarctic, and Alpine Research* [online], V.33(2), pp.158-164
DOI: 10.2307/1552216
[Accessed: 22nd January 2018]

Taczanowska, K. Brandenburg, C. Muhar, A. Hat-Pawlikowska, K. Ziobrowski, S. Chlipała, B. Grocholski, S. Krzeptowski, J. Jodłowski, M. Bielański, M. and Witkowski, Z. (2014) Who is hiking in the Tatra National Park, Poland? A socio-demographic portrait of visitors. *Proceedings of the 7th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas (MMV)* [online], Tallinn. 20 August V.1(1), pp.27-29

Tallis, J.H. (1997) Peat erosion in the Pennines: The bad lands of Britain. *Biologist*, V.44(1), pp.277-279

Taylor, J.A. (1983) The peat lands of Great Britain. In: GORE, A. J, p. (Ed.) *Ecosystems of the world 4b: Mires: Swamp, Bog, Fen and Moor.* New York: Elseveier

Taylor,K. Anderson, P. Taylor,R. Longden,K. and Fisher,P. (2005) *Dogs, Access and Nature Conservation* [online]
Available at: publications.naturalengland.org.uk/file/70026
[Accessed: 22nd January 2018]

The Countryside Recreation Network (2016) *A countryside for health and wellbeing: The physical and mental health benefits of green exercise* [online]
Available at: http://www.docs.hss.ed.ac.uk/education/outdoored/health_wellbeing.pdf
[Accessed: 22nd January 2018]

Thearme, A.P. Green, R.E. Baines, D. Bainbridge, I.P. and O'Brien, M. (2001) The effect of management for red grouse shooting on the population density of breeding birds on heather –dominated moorland. *British Ecological Survey* [online], V.38(2), pp.439-457
DOI: 10.1046/j.1365-2664.2001.00597.x
[Accessed: 22nd January 2018]

Thompson, R. (2009) Sustainability of hill sheep flocks in England. *Small Ruminant Research* [online], V.86(3), pp.71-73
DOI: 10.1016/j.smallrumres.2009.09.021
[Accessed: 22nd January 2018]

Tian, D. Wang, Y. Bergin, M. Hu, Y. Liu, Y. and Russel, A.G. (2008) Air quality impacts from prescribed forest fires under different management practices. *Environment, Science and Technology* [online], V.42(8), pp.2767-2772
DOI: 10.1021/es0711213
[Accessed: 22nd January 2018]

Tooke, N. and Baker, M. (1996) Seeing is believing: the effect of film on visitor numbers to screened locations. *Tourism Management* [online], V.17(2), pp.87-94
DOI: 10.1016/0261-5177(95)00111-5
[Accessed: 22nd January 2018]

Upper Wharfedale Fell Rescue Association (UWFRA) (2013) *Home – Upper Wharfedale Fell Rescue Association* [online]
Available at: http://www.uwfra.org.uk/
[Accessed: 22nd January 2018]

Velander, K.A. and Mocogini, M. (1999) Beach litter sampling strategies: is there a best method? *Marine Pollution Bulletin* [online], V.38(12), pp.1134-1140
DOI: 10.1016/S0025-326X(99)00143-5
[Accessed: 22nd January 2018]

Velander, K.A. and Mocogni, M. (1998) Maritime Litter and Sewage Contamination at Cramond Beach Edinburgh -- a Comparative Study. *Marine Pollution Bulletin* [online], V.36(5), pp.385-389
DOI: 10.1016/S0025-326X(97)00204-X
[Accessed: 22nd January 2018]

Wainright, M. (2012) Grouse shooting in Bradford – A gift for George Galloway. *The Guardian* [online], 20th March 2012
Available at: https://www.theguardian.com/uk/the-northerner/2012/mar/20/georgegalloway-charlottebronte-grouse-ilkley-moor-bradford
[Accessed: 22nd January 2018]

Watson, A. (1982) *Effects of human impact on Ptarmigan and Red Grouse near ski lifts in Scotland*. Annual report of Institute of Terrestrial Ecology p.51

Watson, A. (1991) *Critique of report 'Moorland recreation and wildlife in the Peak District' by Penny Anderson.* London: Ramblers Association

West Riding County Council (WRCC) (1953) *Maps and proposals submitted to WRCC planning board for gas exploration on Ilkley Moor*. [Unpublished]

Wharfedale Naturalists Society (1993) *Birds of Ilkley Moor* [Information Leaflet]

Whiteley, G. (1966) Life sentences for Brady and Hindley. *The Guardian* [online], 7th May 1966
Available at: https://www.theguardian.com/century/1960-1969/Story/0,,106456,00.html
[Accessed: 28th January 2018]

Williams, B.E. Bradstock, R.A. Boer, M.M. Cary, G.J. Price, O.F. Barret, D. Cook, G. Gill, A.M. Hutley, L.B.W. Keith, H. Maier, S.W. Mayer, M. Roxburgh, S.H. and Russel-Smith, J. (2012) Modelling the potential for prescribed burning to mitigate carbon emissions from wildfires in fire-prone forest of Australia. *International Journal of Wildland Fire* [online], V.21(6), pp.629-639
DOI: 10.1071/WF11023
[Accessed: 22nd January 2018]

Willoughby, N.G. Sangkoyo, H. and Lakaseru, B.O. (1997) Beach Litter: an increasing and changing problem for Indonesia. *Marine Pollution Bulletin* [online] V.34(6), pp.469-478
DOI: 10.1016/S0025-326X(99)00141-5
[Accessed: 22nd January 2018]

Woo, S. Jeong, S. Mok, E. Xia, L. Changsu, C. Muwook, P. and Heo, J. (2010) Application of a WiFi-based indoor positioning system for labour tracking at construction sites: A case study in Guangzhou MTR. *Automation in construction* [online], V.20(1), pp.3-30
DOI: 10.1016/j.autcon.2010.07.009
[Accessed: 22nd January 2018]

Woodhead, T.W. (1929) The history of the vegetation of the southern Pennines. *Journal of Ecology* [online], V.17(1), pp.1-34
DOI: 10.2307/2255912
[Accessed: 22nd January 2018]

Wright, S. (2008) Dad-of-four admits moor rape and murder bid. *Telegraph and Argus* [online], 6th October 2008
Available at:
http://www.thetelegraphandargus.co.uk/news/local/localbrad/3732044.Dad_of_four_admits_moor_rape_and_murder_bid/
[Accessed: 28th Janaury 2018]

Yalden, D. W. (1981) Loss of other wildlife and amenity. In: Phillips, J. Yalden, D. and Tallis, J.H. (Eds.) *Peak District Moorland Erosion Study: Phase One Report.* Bakewell: Peak District National Park Authority

Yalden, D.W. and Yalden, P.E. (1989) The sensitivity of breeding Golden Plovers to human intruders. *Bird Study* [online], V.36(1), pp.49-55
DOI: 10.1080/00063658909477002
[Accessed: 22nd January 2018]

Yao, J. and Odobez, J.M. (2007) Multi-layer background subtraction based on colour and texture. *Computer vision and pattern recognition, 2007* [online] Minneapolis, 17th June V.1(1), pp.1-8
DOI: 10.1109/CVPR.2007.383497
[Accessed: 22nd January 2018]

Yorkshire Dales National Park Authority (2004) *Dales farming*
[Presentation given at Craven College, 7th November 2004]

Xu, H. Lv, P. and Meng, L. (2010) A people counting system based on head-shoulder detection and tracking in surveillance video. *Computer Design and Applications* [online] Qinhuangdao, 25th June V.1(1), p.394
DOI: 10.1109/ICCDA.2010.5540833
[Accessed: 22nd January 2018]

Appendix 1: MPhil transfer report (Methods and Results).

Methods.

This work uses a mixed methods approach. Each study uses an appropriate method. The water, vegetation, litter, faeces and erosion studies use natural science methods (quantitative data from repeat observations). Bird surveys use naturalistic observation (unobtrusively observing the animals in their natural habitats). User surveys follow qualitative observation Methods.

Visitors

Cessford and Muhar (2003) note that visitors can be recorded through four methods, Observations, Counting devices, registrations or inferred counting (Table 1).

Table 1: Four methods of visitor monitoring.

Method	Comment
Observation	• Costly (In terms of man hours).
Registrations	• Will people register? What percentage of patrons will pre-register? Accurate Figures cannot be provided. May obtain qualitative data though.
Inferred counting	• Requires data to be collected on other variables (i.e. rubbish) then relies on the comparators developed in other work (on other sites).
Counting devices	• Often expensive equipment. How tamper proof is the equipment? Certain equipment needs electricity; none is available on the moor.

McIntyre (1990) discusses methods of predicting visitor numbers by counting cars, but this does not give a full indication as people may have accessed the moor on foot or parked in other locations. This approach does not account for the idea that there may be between 1 and 7 people travelling in one car. Observations of users allow the researcher to record visitor numbers, time, behaviours and trends. Other methodologies tend to only record visitor numbers. There is also a cost element, observations are free whereas count devices such as piezo mats or broken beam systems are often expensive, measure one entrance or exit and are prone to calibration errors (Cope *et al.*, 2000). Visitor registrations rely on members of the public to voluntarily register. As the moor is an urban common (Urban Commons Act 1925) there is no legal precedent for the public to register their interest before or after using the moor. In any case, if people were voluntarily asked to register, there would be no way of determining, with accuracy, the percentage registering as a percentage of the whole.

Vegetation

Vegetation change can be recorded in a number of ways, for example: Abundance, Density, Frequency, Cover, Richness and Biomass. Table 2 discusses methods of surveying vegetation.

Table 2: Vegetation sampling methods.

Method	Comment
Line transect	In-depth reading, ideal for measuring bare ground between plants.
Random quadrants	Not comparable to the previous months readings.
Whittaker Method	Complex and time consuming.
Fixed belt transect	Shows a build-up of data for the same area.
Robel Pole	Collect data in circular bands around a fixed point.

Recording scales.

Hale and Cotton (1993) use a unique 10 point scale whereas the CBMC (2010) Use the National Vegetation Classification (NVC) (Dayton *et al.*, 2001). There is also the DAFOR (Dominant, Abundant, Frequent, Occasional, Rare) scale, however this scale is subjective and would need clear guidelines as to the different categories.

Pilot experiments have been carried out to look at the use of cameras to take images of vegetation for analysis by computer. These experiments concluded that accurate data could not be collected as the camera was unable to detect under-story species and recognise leaves/shades of green in enough detail to analyse accurately. It is noted that bigger images may have allowed this but this project does not have access to cameras or computer space able to analyse such large files.

Erosion

Initially erosion was to be studied using repeat photography, however this proved very complex and demanded many hours to perfect the images. Time was not available so other methods were considered, such as comparison of aerial photographs, comparison of previous vegetation works, comparison of previous images and measurement of areas of bare ground. Internet based satellite images of the moor were contrasted to measure changes in eroded areas, but unfortunately images could not be scaled enough to provide accurate measurements and the skills required were beyond the expertise of the researcher and project team.

Birdlife

There are two common methodologies for counting birdlife, the Common Bird Census (CBC) and the Breeding Bird Survey (BBS) (British Trust for Ornithology (BTO), 2013). In addition, birds could be counted on a tally basis (simple counts of species). It was decided not to follow the CBS (Common Bird Survey) Methods as the BTO abandoned this Methods in favour of BBS (BTO, 2013). Other methodologies were considered such as; simple sighting of birds in a set time period, but this was considered speculative, limited bird sightings to one particular area of the moor and would give more accurate recordings for the area nearest the observer. Pearce-Higgins and Grant (2006) and Tharme *et al. (*2001) provide sampling strategies based on squares. This method was not chosen as it would leave incomparable data for this particular moor.

Litter and Canine faeces

Velander and Mocogni (1999) discuss different sampling strategies (stand lines, random quadrats, vegetation lines and belt transects). At the southern edge of the survey area there are three radio masts, images have been obtained from 20m, 40m and 60m up these masts – the camera was unable to detect rubbish and issues were found with obtaining permission to regularly climb these towers.

Hydrology

Water quality could be sampled by looking at suspended sediment, pH, nitrate and phosphate content. As rainfall could affect these samples frequent sampling would be needed, this could be through the use of an automatic sampler. The samples would then have to be transported to a laboratory for analysis, all of which was deemed to be too time consuming and costly.

Methods

The work is split into a series of studies. Each study relies on the exact same location(s) being found on every visit. A system has been developed where each location has a peg at or near the South Western corner, a measurement and bearing are taken from this point to another corner of the plot, allowing the researcher to re-locate the same sample plot every time. A grid reference is taken for the peg. The researcher locates the general area by GPS then finds the peg by using a magnet attached to a piece of string (shown in Figure 2).

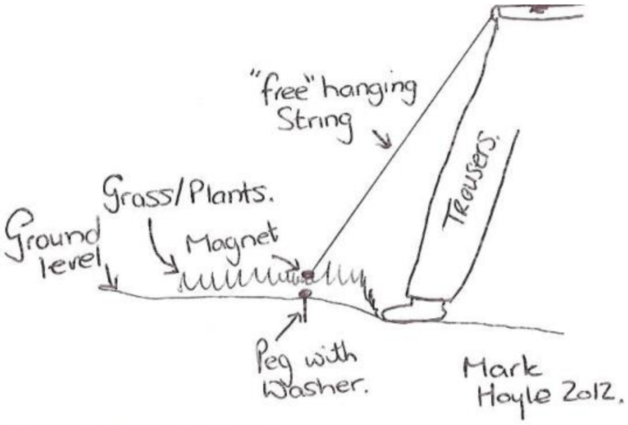


Figure 2: Method of locating pegs.

User Surveys

To review the impact of humans on the moor, information needed to be collected regarding visitors to the moor. Bradford Council does not have accurate data on the usage of the moor (Perham, 2013, *Pers. Comm.*).

Visitor counts are conducted on the final Saturday of every month, from the points illustrated in Figure 3, for three hours over three fixed locations.

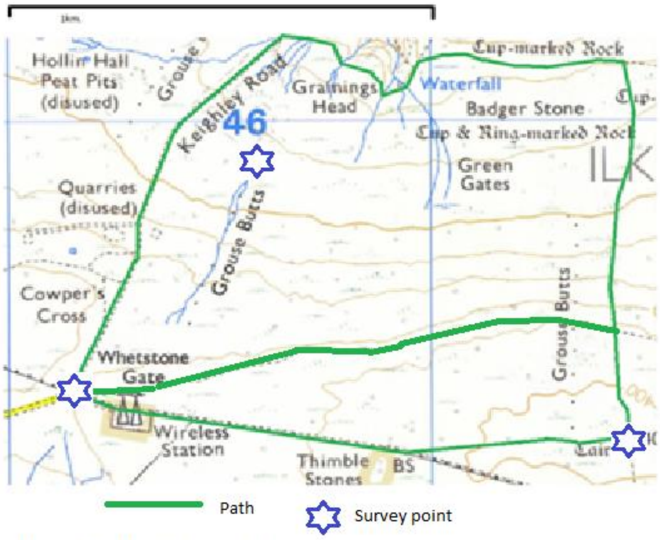


Figure 3: Visitor survey locations.

To calculate weekday usage, data has been collected using the same method for seven consecutive half days on two occasions (June and Oct 2012) and seven consecutive full days (January 2013). This data allowed a weighting factor to be developed which can be used to predict what usage the moor will receive on particular days. The results of this are shown in Table 3.

Users were counted and categorised by activity in a tally chart format. During preliminary analysis it became apparent that data were also needed on where people went on the moor, from July 2012 the study also recorded visitor origins and destinations along with whether they stuck to the path or left the pathways. This was recorded using a series of code (Appendix 1).

Vegetation

The following section details how vegetation was surveyed across the trial area (results of the vegetation transects are contained in Appendix 2).

Whole moor vegetation map

CBMC (2010) provide a map of vegetation by NVC category. This map was checked using Google Earth and field observations. 88 locations were visited on the moor (88 peg locations) these points were checked against the CBMC (2010) vegetation map each point was considered accurate. These points are spread across a wide area of the moor, it was decided that the CBMC (2010) map is accurate.

Mapping the moor using Hale and Cotton's (1993) 10 point scale was considered, but as accurate maps are already available of the plant communities it was considered inefficient. A whole moor map using the DAFOR scale was considered, however it would have been far too time consuming to catalogue all the plants on the moor.

Control and experimental sites

Certain sites have been noted as highly frequented by visitors. A 10m x 1m transect of the vegetation in five of these sites has been taken (experimental). This has been compared to similar transects (control) to show the difference between areas of high and low recreational use (Figure 4). This method is derived from that of Job and Taylor (1981) who conducted similar experiments at Plynlimon.

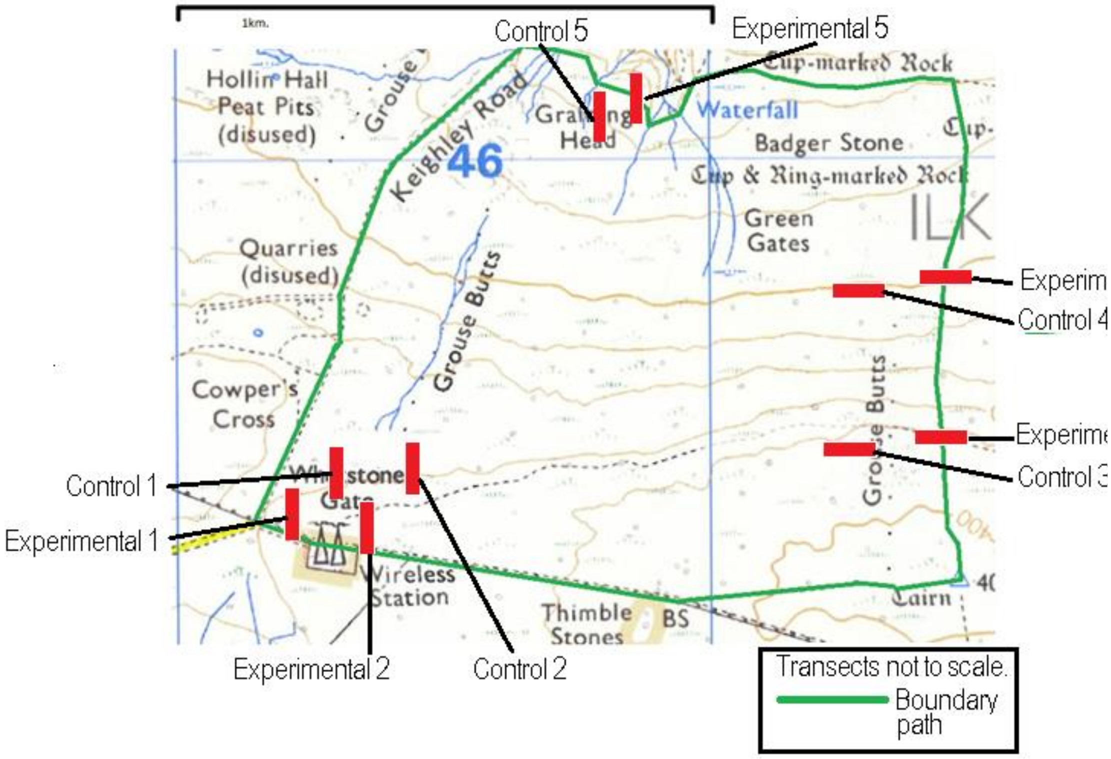


Figure 4: Vegetation survey locations.

The control and experimental sites, seen in Figure 4, have been selected to ensure as much parity as possible. Each control and its experimental transect share the same altitude, geology, aspect, slope and are within 50m of the partner site. The sites were located and a 10x1m net placed over the site with 20cm^2 boxes created from the netting. The vegetation in each 20cm^2 square was recorded using the Hale and Cotton (1993) 10 point scale, as this survey also wanted to look at bare ground an 11th point was added to the scale: 50% or more bare ground. This scale is designed for the plant communities of this particular moor so may allow for possible comparison with their earlier data.

Litter and faeces

Eighteen sites have been surveyed on a monthly basis for litter and faeces, 1.5 hours was allocated to this task (5 minutes per transect) Most transect locations are common with another survey so locating time is not required. Figure 5 shows the locations of the litter and faeces surveys.

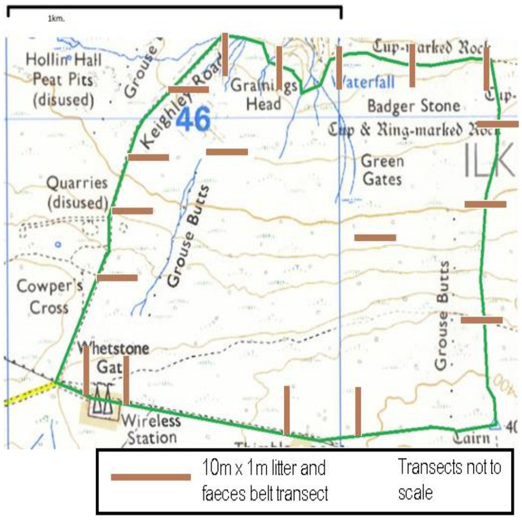


Figure 5: location of litter and faeces surveys.

The 10mx1m net was used as the researcher was already carrying the net. This gives an area surveyed regularly for litter and faeces 180m^2 (0.02% of the overall area). Litter is recorded as small (up to 10cm, medium 10-30cm and large, over 30 cm).

Birdlife

Bird counts have been made on a monthly basis, following the BBS Methods (BTO, 2013). Following these methods makes for possible comparison with BTO data in the analysis stage of this project.

The bird surveys were always conducted between 0700 and 0900 to give fair comparison between months and BTO statistics. Following two 1 km lines across the moor (yellow in Figure 6), birds are recorded as sighted or heard in ether 0-25m, 25-100m or over 100m ranges.

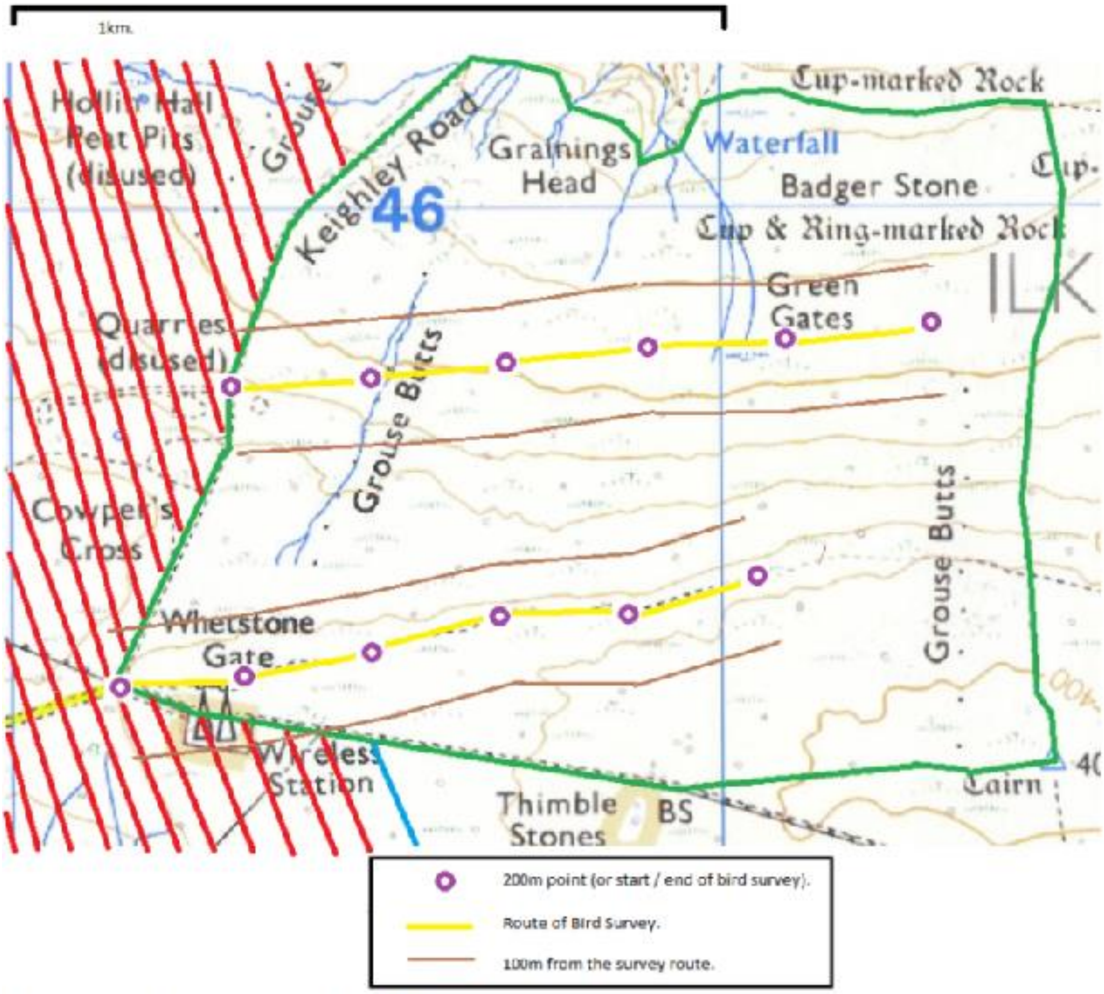


Figure 6: Bird survey locations.

Birds are listed as in flight, grounded or heard and by BTO code for example ML3*f*2*h*1*g* would indicate that in one section 6 Merlin were noted, (3 in flight, 2 heard and 1 seen grounded).

Water quality

Given the holistic nature of this study, it was decided that in order to be able to take useful observations of any potential changes in water quality which might be attributable to recreational visitors, it would be too time consuming and costly in terms of automatic field samplers and laboratory testing equipment, water quality was deemed to be beyond the scope of this project. A number of studies have embraced moorland water quality issues and transport of faecal coliforms in upland streams (e.g. Silsbee *et al.*, 1976; Hunter *et al.*, 1999; Kay *et al.,* 2008).

Erosion

Erosion was monitored by taking measurements of the width of footpaths and bare ground at certain points every month. From the data that were collected a picture could be built up of how fast paths or bare ground expand or contracted. Figure 7 shows how erosion was measured.

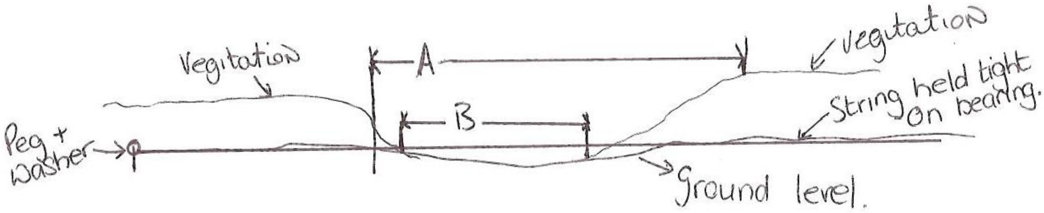


Figure 7: Erosion measurement.

A peg was located in the ground near a path or bare ground area, a piece of string was attached and held at a bearing across the path or bare ground. Two measurements were taken along the string, the area of visible erosion (A) and the area of bare ground (B). Figure 7 shows the bare ground and path measurement technique.

Results

The work has yielded some positive results, the results are discussed below.

Users

The user survey shows data in three elements, number of visitors (Figure 8), activities undertaken (Figure 9) and areas of the moor used (Figure 10) User Figures are given as the 9 hours that they were observed for. To estimate Figures for the full day multiply these Figures by 1.3 (estimate based on an equinox day 12hrs day/12hrs night).

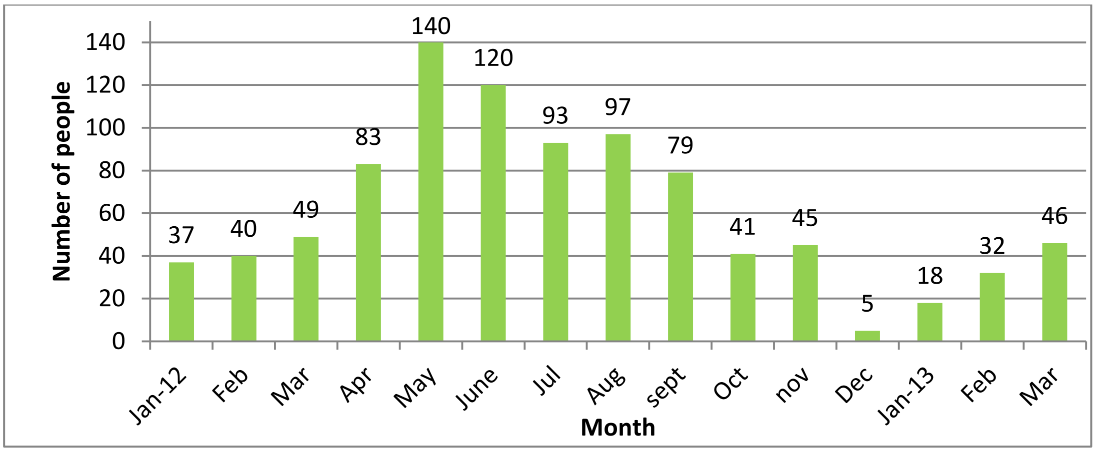


Figure 8: Users by month.

On average the moor was used by 62 people per survey day, with a standard deviation of 38.5.

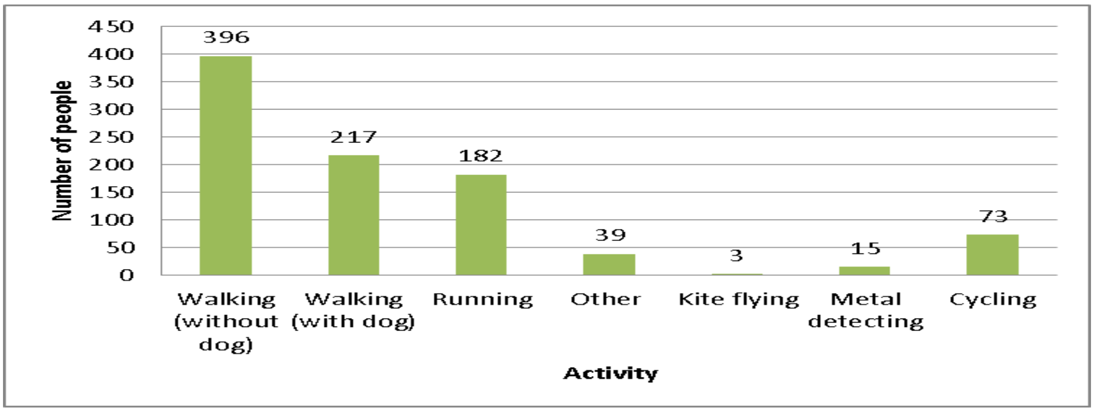
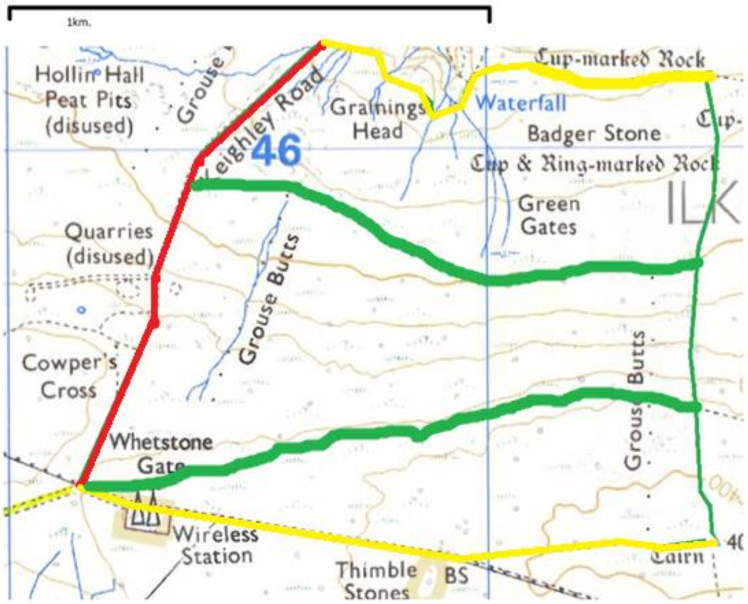


Figure 9: By user, by activity.



Path	Trips	%
Top path	327	19.20%
Eastern Path	134	7.87%
bottom Path	248	14.56%
Keighley Road	980	57.55%
Southern Cross	9	0.53%
Northern Cross	5	0.29%
Total	1703	100.00%

% of trips.	
🟥	50-100%
🟦	20-50%
🟨	10-20%
🟩	0-10%

Figure 10: By area visited.

Some people took more than one path so the percentage is worked out as % taking individual paths against number of paths taken. If someone was to walk all the way around the perimeters of the survey area they would have taken 4 paths (but been classed as one visitor).

It is of note that no one ventured away from paths on the moor.

The location was observed for three periods of 7 days to give an indication of the amount of people who used the moor (this data can be seen in Table 3).

Table 3: Day weightings.

Day	June	October	January	Average	Percentage	weighting
Monday	51	30	17	32.7	54.8%	0.55
Tuesday	48	36	12	32	53.7%	0.54
Wednesday	57	28	8	31	51.9%	0.52
Thursday	43	42	1	28.7	48.0%	0.48
Friday	45	17	10	24	40.2%	0.40
Saturday	120	41	18	59.7	100.0%	1.00
Sunday	113	40	19	57.3	96.1%	0.96
Total	477	234	85	265.3		

Percentage is as a percentage of the Saturday counts. (The October PM and June AM counts have been multiplied by 2 to give a full day data.)

Example; if one Saturday there are 100 people on the moor, it would be fair to assume that the following Sunday there will be 96 people on the moor (100 x 0.96).

Data were collected over dates in June, October and January as this allowed for an average based on weather conditions, holidays, seasons and recreational pursuits. The accuracy of these data would be improved by adding more full observation weeks.

Note: The moor has been observed in several weather conditions, by the end of the project it is anticipated that observations will have been made in all weather conditions; weather multipliers can then be created.

Table 4 shows where people entered and exited the moor.

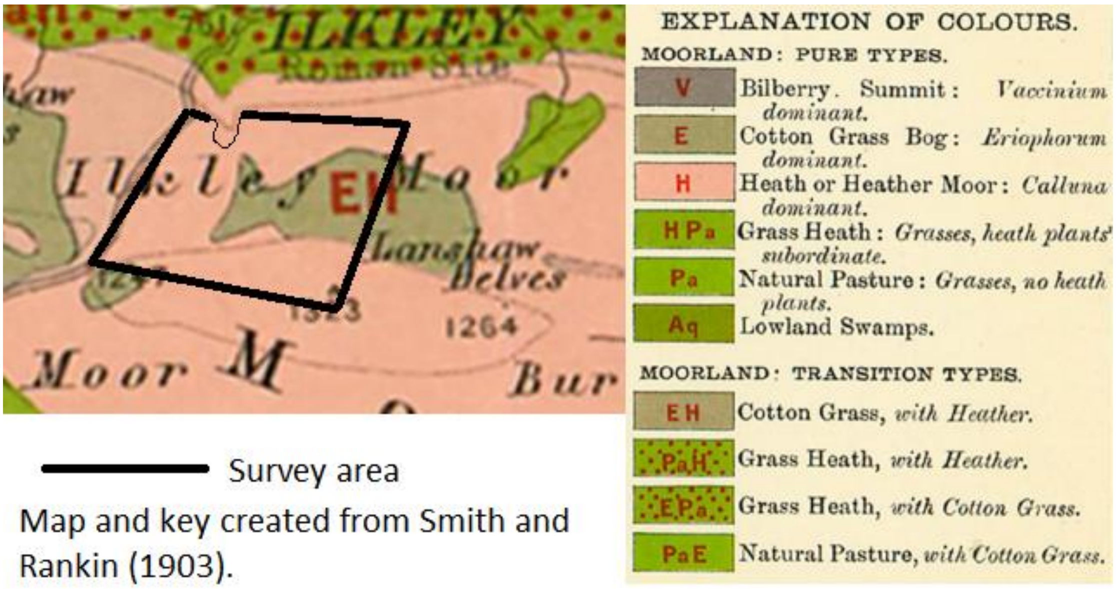
Table 4: Entry and exit points

Entry	Count	%	Exit	Count	%
Whetstone gate	401	43.35%	Whetstone gate	491	53.08%
Cairn	129	13.95%	Cairn	102	11.03%
X or Y	0	0.00%	X or Y	0	0.00%
North East Corner	82	8.86%	North East Corner	100	10.81%
Grainings Head	311	33.62%	Grainings Head	220	23.78%
Other	2	0.22%	Other	12	1.30%
Total	925	100.00%	Total	925	100.00%

Data collected from August – March then multiplied by 1.61 to generate the missing data, as 61% of traffic was in January –July.

Vegetation

Several vegetation maps have been provided, Smith and Rankin (p. 175, 1903) were the first to survey the moor in 1903 (Figure 11).



Map and key created from Smith and Rankin (1903).

Figure 11: 1903 vegetation map [The survey area has been drawn in black] (Smith and Rankin, 1903).

In the Smith and Rankin (1903) ecological survey of Yorkshire (Figure 11), the survey area (Outlined) is predominantly Heather Moor (*Calluna vulgaris)* dominant. With a section of Cotton Grass *(Eriophorum)* and Heather *(Calluna)* mix on the central plateau area. There are also maps available by Cotton and Hale (1989) and Wharfedale Naturalists (1971). It is not the remit of this work to provide in-depth discussion of vegetation changes. Therefore only the Smith and Rankin (1903) and CBMC (2010) maps (Figures 11 and 12) are presented in this work.

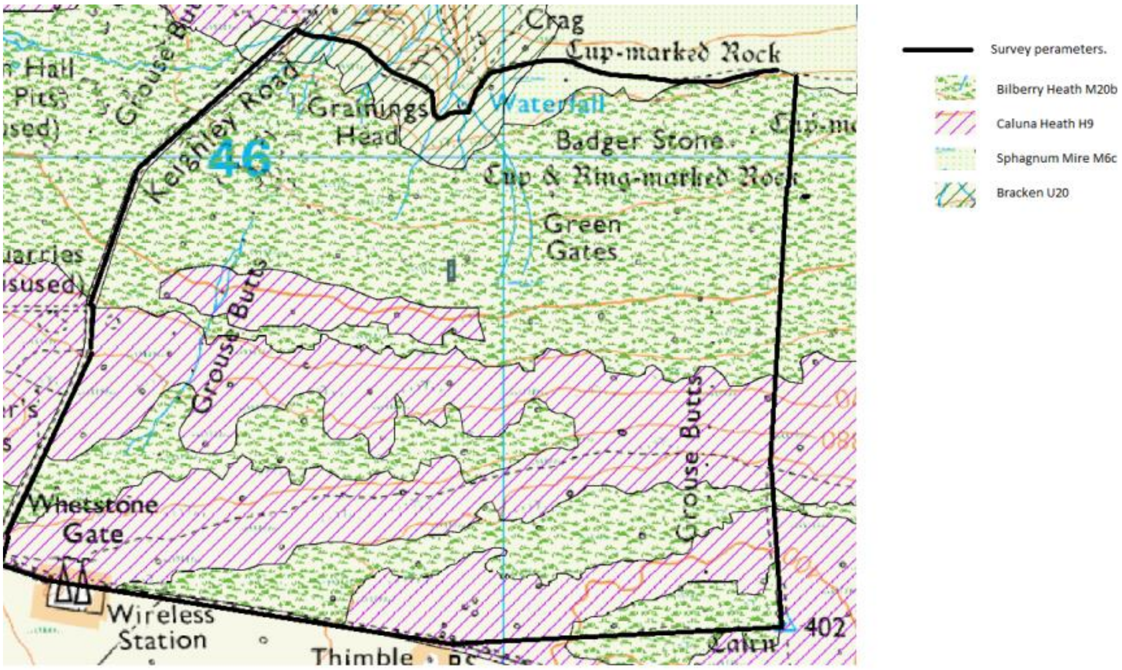


Figure 12: CBMC Vegetation map (Ilkley High Moor) (CBMC, 2010).

Control and experimental plots

The control and experimental plots showed no change over the 14 months that they were surveyed (see Appendix 2). This may be due to vegetation not changing at a fast enough pace to be recorded, or the data collection method may not have been sensitive enough.

The control and experimental plots show that there is an impact from recreation, as each of the experimental plots show gaps in the traditional plant communities where the path has cut through. The experimental plots in heather also show that the edges of paths generally grow back with grasses and crowberry rather than the original heather.

Vegetation change has been an on-going process. Hale and Cotton (2012, *Pers. Comm.*) and Banister (1985) point out that vegetation is constantly changing they suggest that the area has seen, forest, early agriculture, and the current vegetation. Comparison of the

Smith and Rankin (1903) and CBMC (2010) maps show a change in vegetation over the past century (Figures 11 and 12).

This could be from sources other than amenity use. Holden *et al. (*2007) and Charman (2002) suggest vegetation change factors (discussed in literature review). It would be appropriate not to continue with the vegetation surveys as literature proves that change is an on-going process and the cause cannot be confined to amenity use.

Litter

Over the 14 months that this survey has been operating 3035 pieces of litter have been recorded (202.3/month).

Figure 13 shows that litter deposits have remained constant over the period of study. With the exception of August; it is of note that a litter sweep was carried out during August. However, by September the litter had reached the standard level again. This suggests that litter is frequently entering the moor. As there is not a significant rise month on month from January 2012 to March 2013 litter must also be leaving the moor.

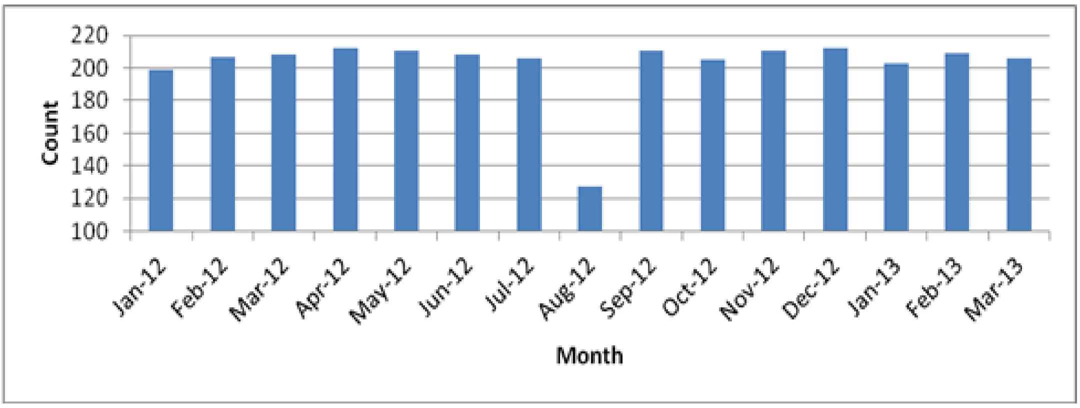


Figure 13: Litter by month.

Six transects dissected pathways, litter very rarely stayed on the path surface (4 times in 3035) Litter tended to disperse up to 4m from the southern path (path width: 2m) and up to 2m from Keighley Road (path width 4m). This could be due to vegetation type, wind or exposure.

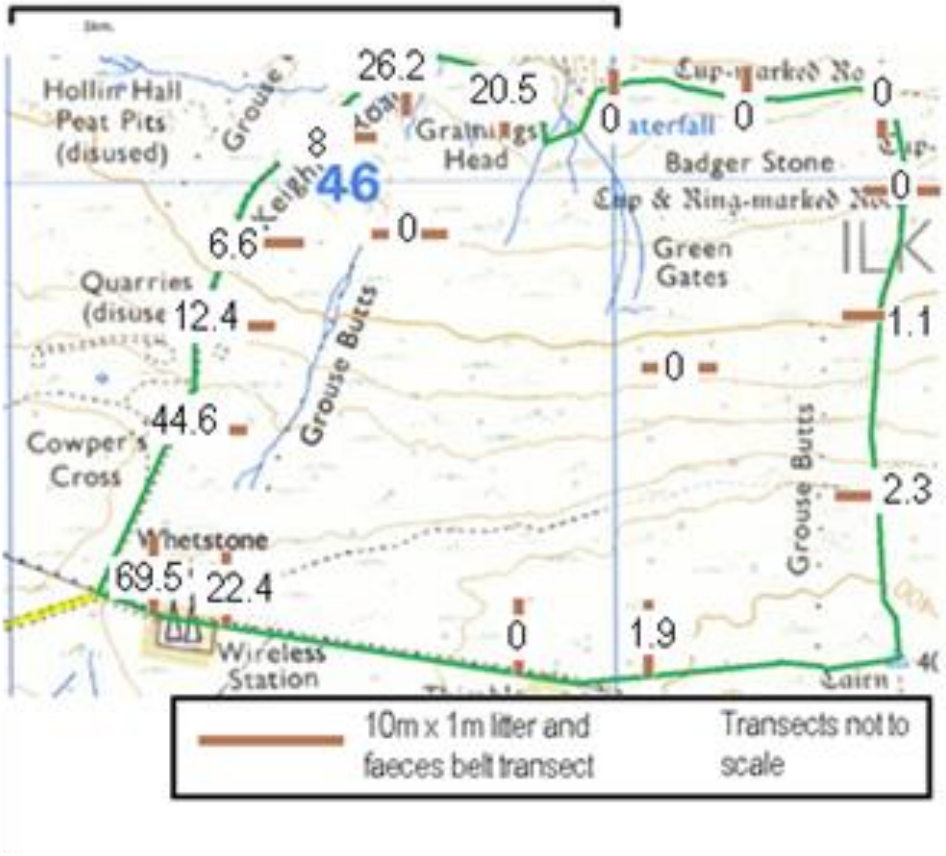


Figure 14: Litter distribution across the survey area.

Figure 14 shows that litter occurs in highest frequencies along Keighley Road (highest frequency toward Whetstone Gate) and in a mixture of vegetation communities.

When compared with the user map (Figure 10) it shows that litter is highest concentrated in the areas that people visit. The two control plots (Grouse Butt and end of Bird survey) show no litter. This shows that litter is not travelling through the centre of the moor.

The 20.5 on the bottom path is possibly as at this point there is a very sharp drop from Keighley Road, and the road cambers around to the East, it is plausible that rubbish is falling from Keighley Road down to Grainings head (26.2 to 20.5 in Figure 13).

Canine faeces

Over the 14 months of the survey 1467 canine faecal deposits have been logged. Figure 16 shows canine faecal recordings by month. It has been noted that not all deposits may have had canine origins. The researcher has made every effort to ensure that the deposits are canine through observing various types of faecal deposits at Askham Bryan Agricultural College. Figure 15 shows the differences between canine and grouse deposits.

Figure 15: Faecal deposits (left (A) Canine deposits, right (B) Grouse deposits).

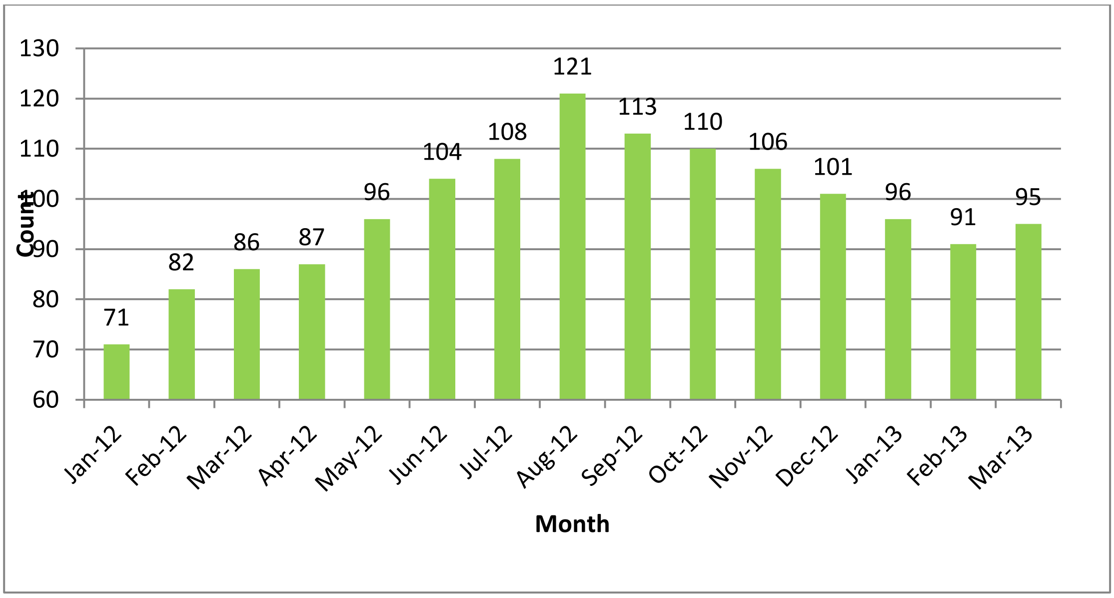
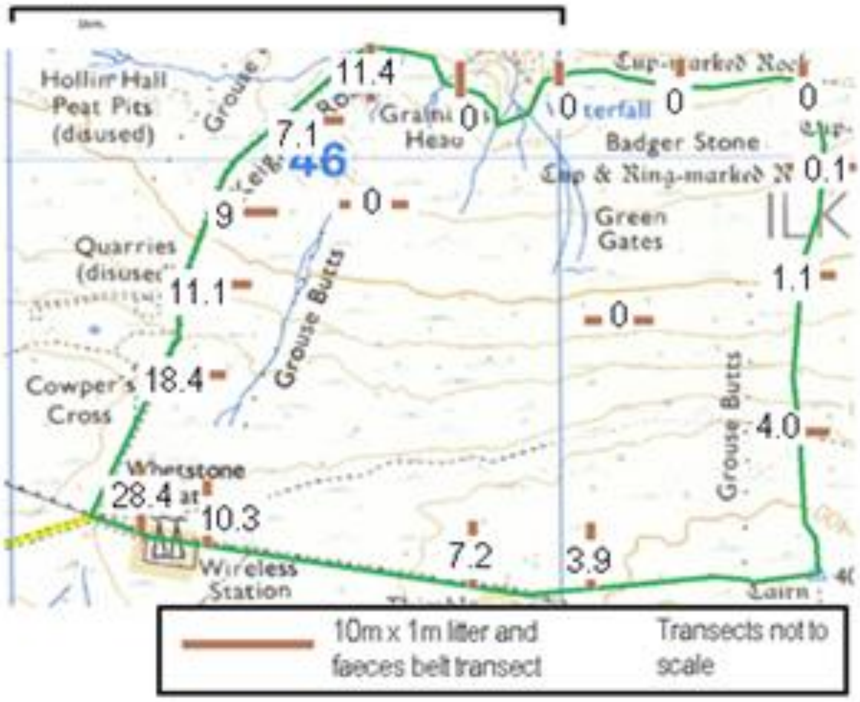


Figure 16: Faecal deposits, by month.

Figure 16 shows that there must be a movement of faeces (on and off) the moor, as faecal deposits are recorded as increasing (Jan – Aug) and decreasing (Aug – Feb 2013). The chart also demonstrates that the moor has gone over the saturation point. It is shown that

January 2013 is 25 counts higher than January 2012, Suggesting that a further 25 deposits are left on the moor per year (further observations will confirm/disprove this).



Map showing average canine faeces per transect (over 14 months).

Figure 17: Faecal distribution

Canine faeces are at their highest concentration in the Whetstone Gate/Keighley Road area, as indicated on the map. Perham (2013*, Pers. Comm.*) notes that this is not the worst place on the moor for deposits; he claims that the worst places are around Whitewells.

The highest faecal counts are along Keighley Road, a strong correlation with the highest user counts (Figure 10). Unlike litter there are higher faecal counts all the way along the top path to the Cairn. The researcher has observed several dog walking companies use the path between Whetstone Gate and Cairn, this may explain the high faecal count and lower litter counts. Evidence is still required to prove these as the source.

Birdlife

Historic documents show an abundance of birdlife on the moor. Unfortunately none of these studies is confined to the same survey area as this work. BTO are currently unable to provide data for this particular community.

This survey sighted 283 birds over 14 visits. As can be seen in Figure 18 these are all common moorland birds.

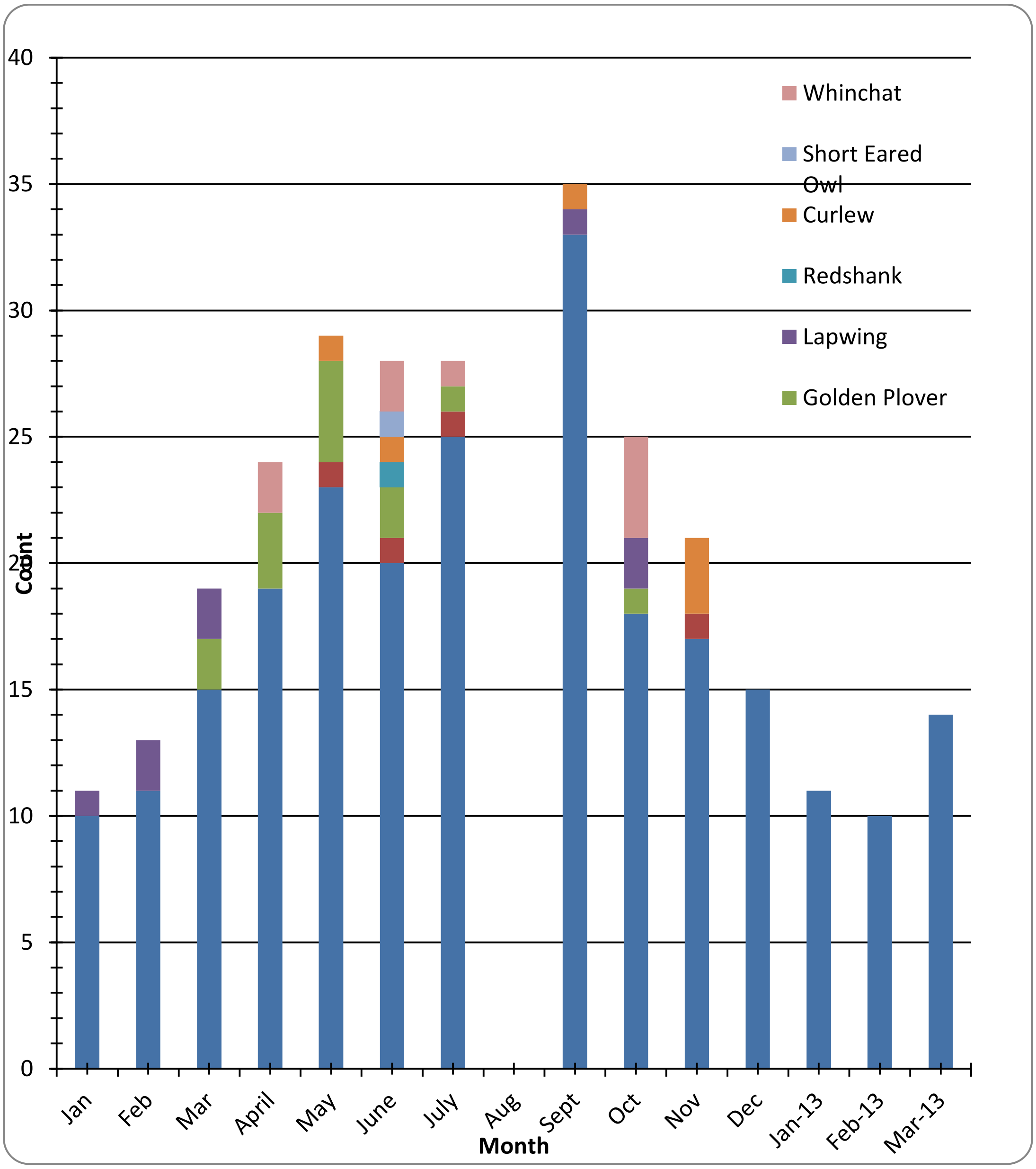


Figure 18: Birds by type.

The moor is predominantly managed for grouse shooting; explaining the high Red Grouse (*Lagopus lagopus* scoticus) populations (Figure 19 shows bird sightings excluding red grouse). The survey in August 2012 was undertaken at the same time as several people were using model aircraft, no birds were recorded.

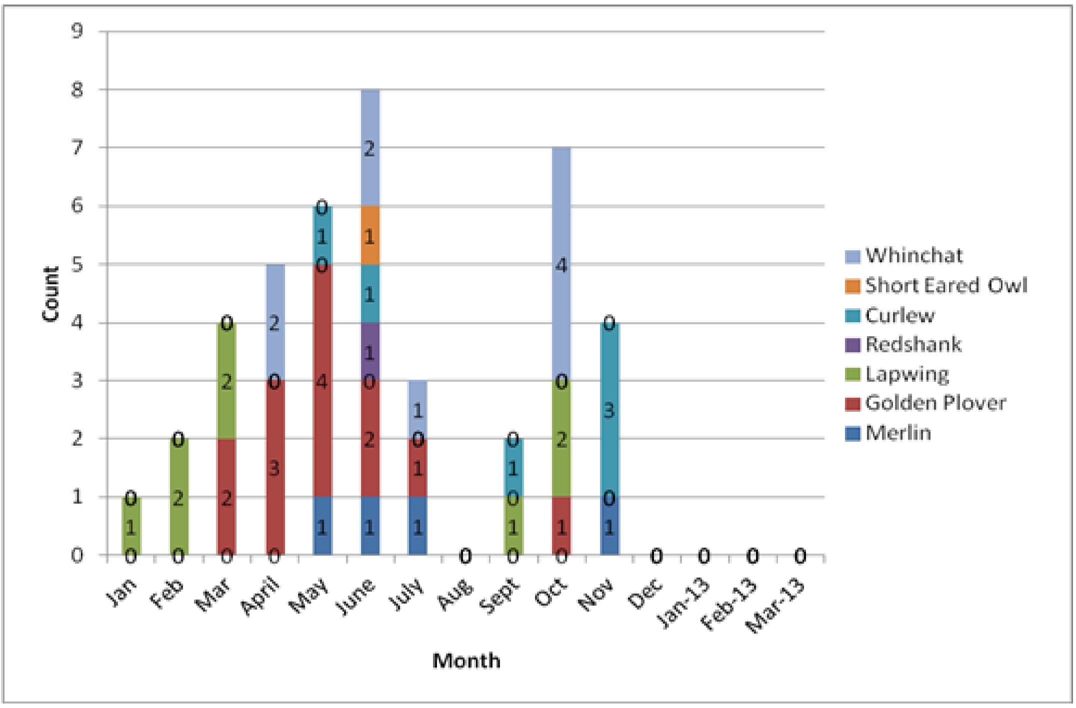


Figure 19: By type, excluding red grouse.

During the first part of the year (January-July) the birds were fairly evenly spread across both lines in Figure 6. During the shooting season (August – November) all except 5 sightings were made along line 2. This may be as line 1 is close to the boundary of Bingley Moor (kept and shot for grouse) whereas line 2 is closer to Ilkey (centre of population) and distant from the shooting.

Erosion.

Erosion was measured on the moor by repeat measuring footpath widths and measuring patches of bare earth. The wooden boardwalks, flagstones and Keighley Road did not change size, and vegetation wear to the sides of these stayed the same. The gravel paths did not change width. Only the bare peat paths did change size over the course of the study.

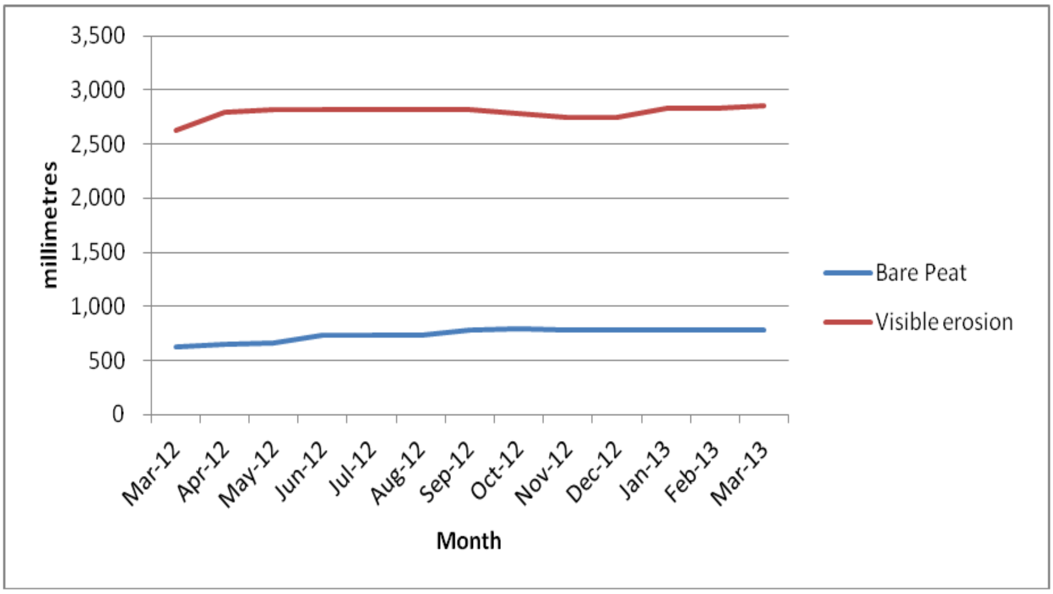


Figure 20: Erosion in peat paths.

Areas of bare peat increased over the period of the study, by 149mm on average over 17 survey points. The accuracy of these measurements could be disputed as each measurement relied on collecting information from the exact same location every month. It is possible that measurements could have been mistakenly noted or provided on slightly wrong bearings. These results should be taken as a notional indicator of peat erosion, rather than exact measurements.

Areas of bare ground were surveyed but no change was found in any of the observations thus far. This may be because the ground is not changing size or because the survey Methods was not able to pick up minor changes in the spread/contraction. As this study has provided data of a questionable nature it will not be continued past the MPhil stage.

Contribution to knowledge/findings

1. How can usage estimates be provided for a remote area?
    Who uses the moorland? For what purpose? Where do people go? What is the temporal and spatial distribution of use?
2. Is there a significant impact on plant and animal life on moorland that is used for public amenity?
3. Is there a significant threat from erosion on moorlands from amenity use?
4. Is there a significant threat from litter on the moorland?

How can usage estimates be provided for a remote area?

This work to date has given an estimate of moorland usage. At this stage it is difficult to make comparisons as there are no other recent data about usage of this particular moor. The literature review indicated that this approach would be the simplest and cheapest form of data collection. By adding extra visits to work out weightings, this report will provide a framework for estimating user numbers.

The work has provided a template for projections of users by day, projections could be provided of users by day, activity, month and weather condition these have not been provided here as there is, thus far, only 14 months' worth of data – to provide more accurate projections at-least two years data would be needed.

Further work:

The user surveys will continue, but through electronic or manual 24/7 count methods. To allow data to be collected based on a range of time and weather factors. Time and weather data will be sought to compare and develop a model of use over a range of time and weather conditions.

Is there a significant impact on plant and animal life on moorland that is used for public amenity?

The surveys have shown that there is not normally an impact on the bird population from amenity use as the birds are generally spread across the survey area, except in the instance of August when model aircraft were present on the moor. McDermott (2012, *Pers. Comm.*) , a local game keeper explains this by suggesting that the birds may have assumed this large avian was a Peregrine Falcon *(Falco peregrinus)* (predator) and sent the smaller bird population into hiding.

The survey proves that shooting (on nearby sites) has an impact on birdlife. Birdlife is recorded as moving to the opposite side of the survey area to the sound of gunshots. It is noted that perhaps this survey area is too small to scientifically analyse the impact on bird populations as birds are highly mobile and cannot be confined to a 0.9km^2 plot. The work shows that there has been an impact on vegetation; the experimental plots have pathways through them, in the heather predominant areas the edges of the path are growing back with grasses rather than the incumbent heather. Unfortunately the data collected so far does not go into enough detail to note whether vegetation is growing back faster than it is being destroyed.

This study agrees with Dalby (1973), Cotton and Hale (1989) Hale and Cotton (1993 and 2012 *Pers. Comm.*) and Perham (2013 *Pers. Comm.*) who all claim that Bracken (*Pteridium*) and Crowberry *(Epp nigrum)* are colonising the moor. All these sources are in agreement that the moor is drying out and cite this as the reason for vegetation change – without investigating why the moor is drying out it would be inappropriate to cite amenity use as a significant cause of vegetation change.

Figure 12, the 2010 CBMC vegetation survey shows a change to M20b (Mire with cotton grass (*Eriophorum vaginatum)* and Crowberry *(Empetrum nigrum)* occurring frequently) Dayton *et al.*, (2001).

Whilst there are changes in animal behaviour from some amenity use (model aircraft) and changes in vegetation (footpath edges) there has been a process of change over the last century, (Figures 11 and 12) This work cannot currently define how much of this is amenity use and how much of this is other factors (e.g. climate change).

Comparison of the CBMC (2010) vegetation map and user survey map shows no direct correlation between usage and vegetation communities; paths with all levels of usage cross each vegetation zone. There are no clear corridors of vegetation linked to footpaths.

Is there a significant threat from erosion on moorlands from amenity use?

Visitors do not stray from the paths; therefore they can only directly cause erosion on the paths themselves. A note of caution may be observed here, is this the Hawthorne effect? (Mayo, 1933) the observed modify behaviours as they know they are being observed (saw the researcher watching and decided to stay to footpaths).

The bare ground surveys show that there is no change in the areas of bare ground on the moor. Perham (2013) (*Pers. Comm.*), Hale and Cotton (2012) and the Friends of Ilkley Moor (2012) note that there has previously been work to reseed the moor, and that in the past there has been extensive bare ground. It could be assumed that this has contributed to the covering of bare ground. If this is the case then naturally bare ground may have expanded, but re-seeding and other conservation works have counterbalanced this.

Dalby (1973); Hale and Cotton (2012) (*Pers. Comm.*) and Perham (2013) (*Pers. Comm.*) all note that the moor is drying out. This drying process creates a stronger peat surface that is not as erodible as wet peat; this could also be a contributory factor to the longer term contraction of bare peat areas. The peat pathways are eroding, 149mm over the course of this survey, however Perham (2013) (*Pers. Comm.*) notes that money is being spent installing path surfaces (such surfaces have not eroded in this survey).

The report concludes that at present Ilkley Moor is suffering from erosion on the bare peat pathways around the moor; As the moor is used for amenity, groups have pushed for considerable investment to be made on the moor (reseeding, pathways etc) Hale and Cotton, (2012) (*Pers. Comm.*) and Perham (2013) (*Pers. Comm.*).

Is there a significant threat from litter on the moorland?

Most litter and canine faeces accumulate on the Keighley Road/Whetstone Gate area of the survey. It was noted during surveys that identifiable pieces of litter have been picked up in different transects, showing that litter is moving along Keighley Road.

The study found that there was a fairly constant litter count on the moor (195-205 pieces) in any month, except August (127 pieces) after a litter sweep. This suggests that in the average month 63 pieces of litter are deposited on the survey area, but to keep this number, 63 pieces of litter must leave the moor every month. This suggests that the litter sweep removed litter that was going to remove itself anyway. However this litter would have inevitably caused a problem elsewhere.

There is a strong link between users, litter and canine faeces. Comparison of Figures 14, 16 and 19 show that litter and faecal deposits remain where users visited, indicating that litter and faeces cause a significant impact.

References [Transfer report].

Banister, J. (1985) The vegetational and archaeological history of Rombolds Moor West Yorkshire. Ph.D. thesis. Unversity of Leeds.

British Trust for Ornithology, (2013) Breeding Bird Survey [online] Available at: http://www.bto.org/volunteer-surveys/bbs [Accessed 8th April 2013].

City of Bradford Metropolitan Council (CBMC) (1989) Recreation impact assessment: Ilkley Moor. Bradford: CBMC [Unpublished].

City of Bradford Metropolitan Council (CBMC) (1998) Yorkshire and the Humber rights of way and access group, Ilkley Moor: City of Bradford Metropolitan Council Countryside Service. Bradford: CBMC.

City of Bradford Metropolitan Council (CBMC) (2010) Ilkley Moor NVC Classifications, Arcsoft map. Bradford: CBMC [Unpublished].

Cessford,G. Muhar,A. (2003) Monitoring options for visitor numbers in national parks and natural areas. *Journal for Nature Conservation*. 11, 240-250.

Charman, D. (2002) *Peatlands and environmental change*. 1st ed. Chichester: John Wiley and sons.

Cope, A. Doxford, D. Probert, C. (2000) Monitoring visitors to UK countryside resources The approaches of land and recreation resource management organisations to visitor monitoring. *Land Use Policy.* 17, 59-66.

Cotton, D.E. Hale, W.H.G. (1989) Vegetation changes on Ilkley Moor 1964 – 1984. *The Naturalist.* 114. 109-114.Cotton, D.E. Hale, W.H.G. (1994) Effectiveness of cutting as an alternative to burning in the management of *Calluna vulgaris* moorland: results of an experimental field trial. *Journal of Environmental Management.* 40. 155-159.

Dayton, N. Elkington, T. Jackson, D.L. Strachan, I.M. (2001) *National Vegetation Classification: Field guide to mires and heaths,* 1st ed. Peterborough: JNCC.

Dalby, M. (1973) Bryological observations on some of the bogs and flushes of Ilkley Moor. *The Naturalist.* 6. 133-135.

Friends of Ilkley Moor (http://www.ilkleymoor.org/, accessed 19-4-12).

Hale, W.G.H. Cotton, D.E. (1993) Vegetation changes in Ilkley Moor between 1964 and 1984, and possible environmental causes. *Naturalist.* 118, 123-134

Hale, W.G.H. Cotton, D.E. (2012) Interview by author, Bradford 10th October.

Holden, J. Shotbolt, L. Bonn, A. Burt, T.P. Chapmann, P. Dougill, A.J. Fraser, E.D.G, Hubacek, K. Irvine, B. Kirkby, M.J. Reed, M.S. Prell, C. Stagl, S. Stringer, L.C. Turner, A. Worrall, F. (2007) Environmental change in moorland landscapes *Earth Science Reviews*, 82, (1), 75-100.

Hunter C., Perkins J., Tranter J. Gunn J. (1999). Agricultural land-use effects on the indicator bacterial quality of an upland stream in the Derbyshire Peak District in the U.K. *Water Research,* 33, 17, 3577-3586.

Job, D.A. Taylor, J. A. (1981) The production, utilization and management of upland grazing's on Plynlimon, North Wales. *Journal of Biogeography.* 5, 2, 173-191.

Kay D., Crowther J., Stapleton C.M., Wyer M.D., Fewtrell L., Anthony S., Bradford M., Edwards A., Francis C.A., Hopkins M., Kay C., McDonald A.T., Watkins J., Wilkinson J. (2008). Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research*, 42, 2649 – 2661.

Mayo, E. (1933) *The human problems of an industrial civilization.* New York: MacMillan.

McIntyre, N. (1990) Recreation involvement: The personal meaning of participation. Thesis. Australia: University of New England.

Pearce-Higgins, J.W. and Grant, M.C. (2006) Relationships between bird abundance and the composition and structure of moorland vegetation. *Bird Study.* 53, 112-125.

Perham, R. (2013) Personal Communication - Interview by author, Bradford 1st March.

Silsbee, D. Plastas, L.A. Plastas, H.J. (1976). A survey of backcountry water quality in Great Smokey Mountains National Park. *Management Report No. 10.* Uplands Field Research Laboratory, Gatlinburg. TN.

Smith, W.G. Rankin, W.M. (1903) Geographical distribution of vegetation in Yorkshire part 2 Harrogate and Skipton district. *Geographical Journal.* 22. 149-178.

Thearme, A.P., Green, R.E., Baines, D., Bainbridge, I.P. O'Brien, M. (2001) the effect of management for red grouse shooting on the population density of breeding birds on heather –dominated moorland. *British Ecological Survey.* 38. 439-457.

Urban Commons Act (1925) London: HMSO.

Velander, k. Mocogini, M. (1999) Beach litter sampling strategies: is there a best method? *Marine Pollution Bulletin.* 38. (12). 1134-1140.

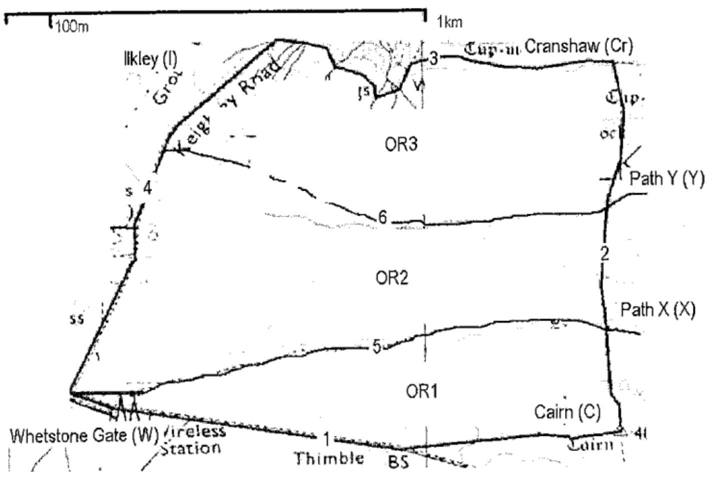
Wharfedale Naturalists Society (1993) Birds of Ilkley Moor. Cullingworth: Wharfedale Naturalists Society.

MPhil Appendix 1: Visitor surveys.

All routes and activities are coded; users and their movements are then recorded as a series of code.

For example 2W2DW would indicate that two people came onto the moor from Whetstone Gate, took Keighley Road, they were driving and they also left through Whetstone Gate.

Visitor surveys (August 2012 onward as amended).

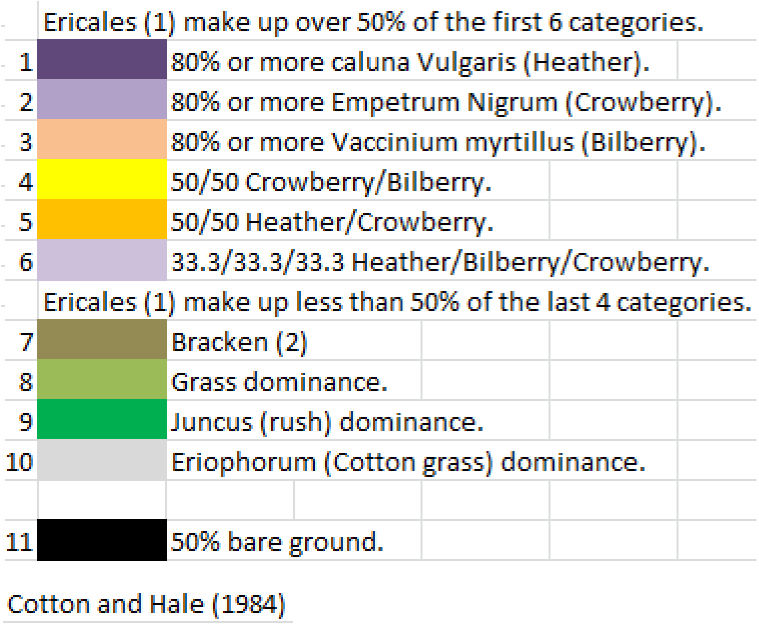


Rules of the visitor survey.

Using the map (above) record every visitor sighted on the table.

- Origin / Destination, use ether or W, C, X, Y, Cr, I (Whetstone Gate, Cairn, Path X, Path Y, Cranshaw or Ilkley).
- Chart the visitor(s) route by using ether (or a combination of) 1,2,3,4,5 or 6.
- Use the following abbreviations to demark hobbies:
  - C – climbing.
  - K – Kite flying.
  - M – Metal detecting.
  - R – Running.
  - S – Shooting (Grouse, organised).
  - Si – Shooting (Illegally).
  - D – Driving.
  - W – walking.
  - WD –Walking (with dog).
- If the visitor stays on the track (or within 5m of the track no further notes are needed).
- If the visitor goes off the track; use the code OR1, OR2, or OR3 depending on off road area.
  - 25 - less than 25m.
  - 100 - 25 to 100m.
  - 101 - Over 100m.

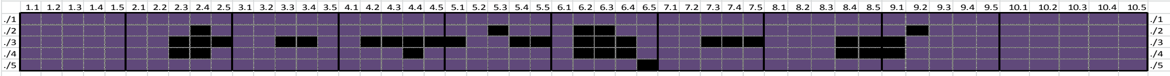
MPhil Appendix 2: Vegetation transects.



	Ericales (1) make up over 50% of the first 6 categories.	
1	🟪	80% or more caluna Vulgaris (Heather).
2	🟪	80% or more Empetrum Nigrum (Crowberry).
3	🟧	80% or more Vaccinium myrtillus (Bilberry).
4	🟨	50/50 Crowberry/Bilberry.
5	🟧	50/50 Heather/Crowberry.
6	🟪	33.3/33.3/33.3 Heather/Bilberry/Crowberry.
	Ericales (1) make up less than 50% of the last 4 categories.	
7	🟫	Bracken (2)
8	🟩	Grass dominance.
9	🟩	Juncus (rush) dominance.
10	⬜	Eriophorum (Cotton grass) dominance.
11	⬛	50% bare ground.

Cotton and Hale (1984)

Control 1.



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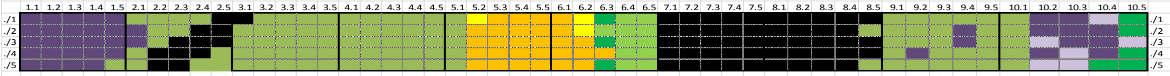

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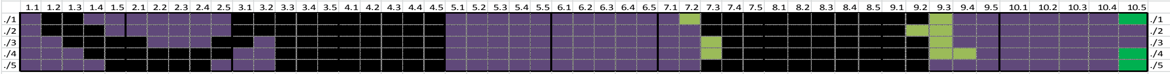

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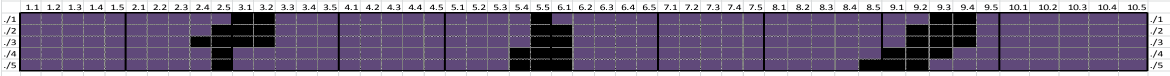

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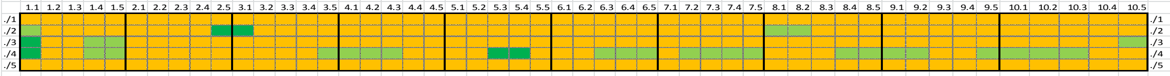

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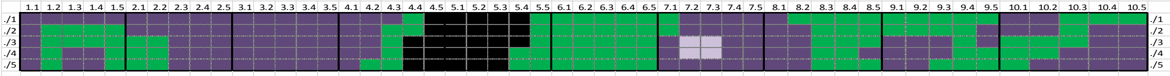

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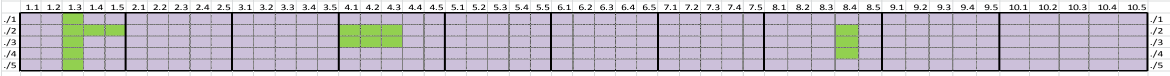

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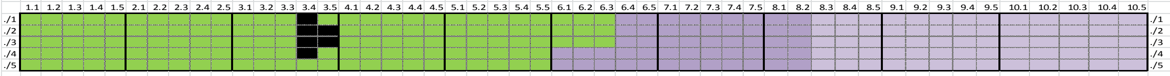

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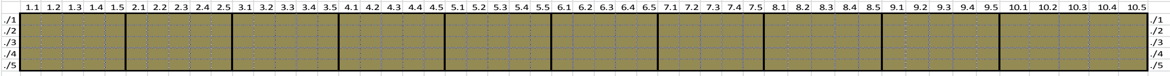

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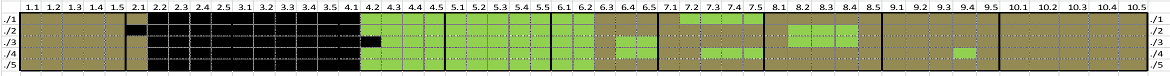
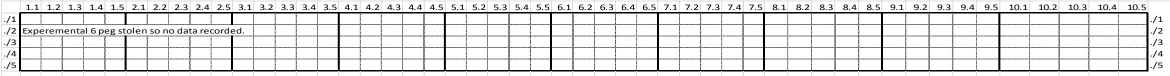


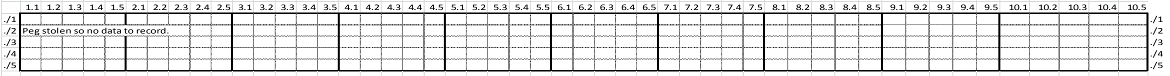
*In cells 1.1 to 2.1 (/1 to /5) Bracken has been sprayed off so there is now a mixture of Bracken shoots and Mosses.

Control 6.



Experemental 6 peg stolen so no data recorded.

Experimental 6 (Peg Stolen).



Peg stolen so no data to record.