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HOP!: a PGIS and citizen science approach to monitoring the condition of upland paths

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Abstract

This research project was inspired by the increase in popularity of hillwalking and the problem of the lack of monitoring and maintenance of upland paths which may lead to serious deterioration of those paths. Wicklow Mountains National Park (WMNP), just south of Dublin City in Ireland, has a large network of mostly informal upland paths. A comprehensive baseline survey of many of these paths was carried out by a professional in 2002/3, but they have not been surveyed since.

The aim of the research is to design an app to collect data on the condition of hiking paths in WMNP using a PGIS approach combined with citizen science, and to compare the current condition with that recorded in 2002/3 surveys.

The PGIS approach to collecting data on path condition involved consultations with the District Conservation Officer of WMNP and hillwalkers, which were held at a number of stages during the project. These consultations informed the design of the path condition survey, the app, and the format of the presentation of the results in GIS. They also resulted in the recruitment of citizen scientists to carry out the surveys.

An app called HOP! (which stands for How's Our Path!) was developed in PhoneGap and runs on iOS and Android mobile devices. The app prompts the user to record path condition indicators, including path width, depth and braiding, and to take photographs at pre-set target points along a chosen hiking path. Eight of the twenty four WMNP paths surveyed in 2002/3 were successfully surveyed in 2016/17 with the HOP! app by five hillwalkers, acting as volunteer data collectors. The 2002/3 path condition data was converted into a structured format in order to display it in ArcGIS and in the app, and to compare the current condition with that recorded in 2002/3.

The HOP! app was found to be easy to use and effective, and geolocated photographs, including a hiking pole to assist in judging scale, were found to be very valuable in recording the path condition. While 60% of the locations surveyed showed some improvement or no change in overall path condition, 71% of these locations had deteriorated in some way – path widening, deepening or braiding. The overall condition of six of the eight paths was found to have disimproved since they were surveyed in 2002/3. It is concluded that valuable path condition data can be collected by volunteers using the HOP! app.

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Abbreviations

Abbreviation	Meaning
amsl	Above mean sea level
AS	Amber Survey
JS	JavaScript
JQ	JQuery
JQM	JQuery Mobile
ME	Maulin East path
MI	Mountaineering Ireland
MM	Mountain Meitheal
MT	Maulin-Tonduff path
OS	Oldbridge-Scarr path
PGIS	Participatory GIS
PWS	Prince William's Seat path
SK	Scarr-Kanturk path
TR	Three Rock path
TRF	Three Rock-Fairy Castle path
VGI	Volunteered Geographic Information
WhDj	White Hill-Djouce path
WMNP	Wicklow Mountains National Park

Chapter 1 Introduction

1.1 Hillwalking

Hillwalking is a popular and growing activity in Ireland, where we have many large areas of relatively unspoilt and beautiful hills and mountains with abundant flora and fauna. People are encouraged to explore and enjoy the landscape, because it is a very healthy and rewarding pastime. Although hiking can have some damaging results on the environment, its negative effects can be minimised through good management, to the benefit of all.

1.2 Impacts of hiking on natural areas and the importance of monitoring

Visitors to natural areas impact on the environment they explore. Hillwalking results in the vegetation being trampled on and soil being compacted. Repeated walking on a path may result in erosion and ecosystem disturbance.

Newsome et al. (2013), in their review of natural area tourism, look at how to achieve a balance between keeping these areas in as good a state as possible and, at the same time, enabling people to explore and experience natural areas. When discussing hillwalking, they point out that the “condition of hiking trails in natural areas is…a major management consideration”. They further state that monitoring is an essential part of management, and regret that it is often neglected. Up to date information on the condition of hiking paths is essential for their good management and conservation.

Monitoring is defined by Newsome et al. as “systematic gathering and analysis of data over time”. There are a number of ways of assessing the condition of trails, and this is usually done by trained professionals carrying out surveys (Marion and Leung, 2001, Tomczyk and Ewertowski, 2011). Such surveys are expensive and time-consuming, and lack of funding means they are often not carried out as regularly as required, if at all.

1.3 Wicklow Mountains National Park

There are many paths in upland areas in Ireland along which hillwalkers regularly hike. Most of these paths have evolved over time, and some are now way-marked, in an effort to actively encourage people to get out into the countryside. Many of these paths are on either privately owned lands or on commonages (lands shared between a number of owners) (MI, 2013). However, some of the uplands are state-owned, and these are managed by the National Parks and Wildlife Service (NPWS) (2015). NPWS manages six National Parks in Ireland. These National Parks abide by the criteria and standards for National Parks specified by the International Union for the Conservation of Nature (IUCN), which states that the primary objective of a National Park is “To protect natural biodiversity along with its underlying ecological structure and supporting environmental processes, and to promote education and recreation” (IUCN, 2017).

One of the National Parks managed by NPWS is Wicklow Mountains National Park (WMNP) (2015). This park is situated just south of the capital city, Dublin, and comprises over 20,000 hectares in the Wicklow and Dublin Mountains, including the historic site of Glendalough. Figure 1-1 shows the boundary of the park in 2009. Since then, additional lands have been purchased and added to the park, and it is hoped that the park will continue to grow in size.

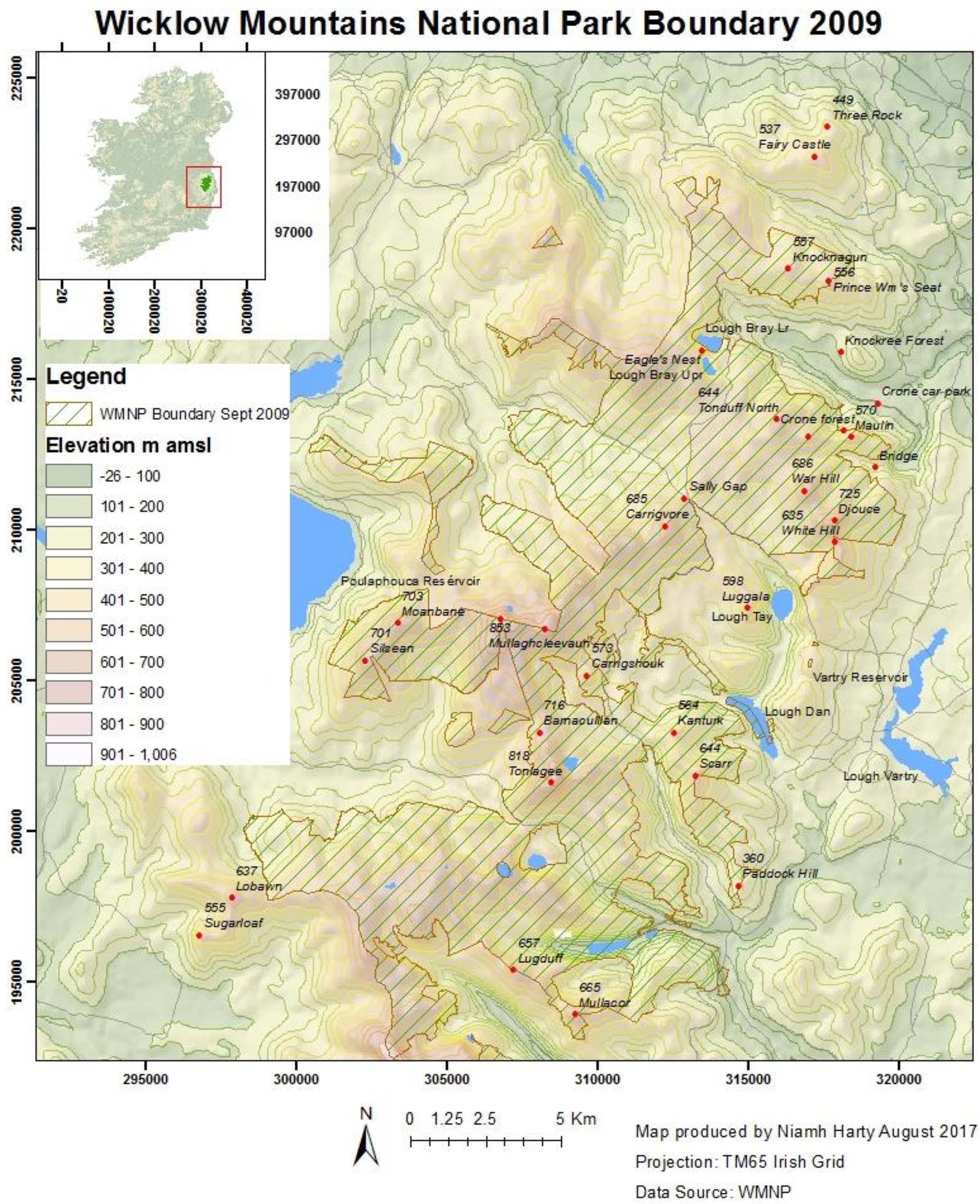

Figure 1-1 Boundary of Wicklow Mountains National Park in 2009

As part of the recreation role of WMNP, the 2005-2009 Management Plan for the park (NPWS, 2005) describes the many types of activities of visitors to the park as follows:

> "WMNP is an important recreational resource for a large catchment area including Dublin, and also attracts considerable numbers of visitors from further afield. Active recreational activities include walking, sight-seeing, cycling, fishing, rock climbing, orienteering and horse riding. Other recreational activities, such as painting, photography, bird watching and historical interests are also important."

The park has a large network of mostly informal upland paths. Some of these are in poor condition, due to the high volume of walkers using them. Djouce Mountain, at 725m elevation, is one of the highest mountains in the north east section of the park (seen in the map in Figure 1-1). It is close to Dublin, and is very popular with walkers of all ages. The path erosion caused by hillwalkers on the path on the eastern slope of the mountain is visible from a long distance away, as seen in the photograph in Figure 1-2 which was taken 4km from the summit.

Figure 1-2 Erosion on Djouce, WMNP, as seen from a point 4km from the summit (Photo by Niamh Harty July 2017)

A comprehensive baseline survey of many of the WMNP upland paths was conducted in 2002/2003 as part of a survey of all the hiking paths in Wicklow. This survey was a joint project between WMNP and Mountain Meitheal (MM) (2014). MM is an organisation of volunteers who build and maintain paths in Ireland's mountains and forests. They "promote sustainable recreation by encouraging personal responsibility and awareness". The Wicklow path surveys have not been repeated, and the District Conservation Officer at the park stated that it would be very useful to the park management if the paths in the park were re-surveyed to find out their current condition (Mullen, 2015). Due to lack of resources, the park cannot undertake this task itself.

1.4 Mobile technology

Advances in mobile technology, together with widespread access to GPS, make it possible for anyone with a smartphone to record spatially referenced photographs, and many hillwalkers are already familiar with using GPS to track their walks and, in some cases, to guide them. Several multimedia apps have been developed to allow non-professionals to record and submit data on research projects. For example, the app on the MoM-NOCS project enables users to record nature observations (Skevakis et al., 2014). Open source software is available to allow developers to produce apps which can run on most smartphones.

1.5 PGIS and citizen science

GIS is widely used in many areas today, to display and to analyse spatial data. Participatory GIS (PGIS) (Quan et al., 2001) is a GIS in which the knowledge of local experts and stakeholders is a key element of the information contained. The objective of PGIS is to create a GIS which is "context- and issue-driven rather than technology-led, and seek[s] to emphasize community involvement in the production and/or use of geographical information" (Dunn, 2007). Using a "bottom-up" approach, the GIS produced is directly useful and relevant to those who help to create it.

Citizen science (Thornton and Leahy, 2012, Dickinson et al., 2012) is the name given to an increasingly popular scientific method in which non-professionals collect scientific data for research projects or other purposes. It is a specific type of crowdsourcing.

A citizen science approach was initiated by Mountaineering Ireland (MI) in 2014 to assist in the gathering of information about the condition of the hill paths in Ireland. As part of the "Helping the Hills" initiative, a survey was organised in which walkers and climbers were encouraged to submit survey reports together with photographs of any erosion they observed while out walking (Hills, 2014). The response to the MI survey was disappointing. A possible reason for this was that the survey reports had to be manually recorded, photographs taken, and both had to be emailed or posted later.

Despite the lack of success experienced with the MI survey, the author has experienced a culture of both volunteering and caring for the environment among many hillwalkers, so a different approach to the "Helping the Hills" survey may prove to be successful.

1.6 Aim and Research Objectives

This research project is prompted by the increase in popularity of hillwalking and the problem of the lack of monitoring and maintenance of upland paths which may lead to serious deterioration of those paths.

The aim of the research is to design an app to collect data on the condition of hiking paths in WMNP using a PGIS approach combined with citizen science, and to compare the current condition with that recorded in 2002/3 surveys.

The Research Objectives of the project are:

RO 1: To develop an app to collect data on hiking path conditions in WMNP, based on a PGIS and citizen science approach.

RO 2: To compare the path condition data collected using PGIS and citizen science with that collected by a professional surveyor in 2002/3.

RO 3: To convert the path condition surveys of 2002/3 into a format that can be used for comparison with the current condition.

RO 4: To determine the condition of the WMNP hiking paths today, and to compare it with the condition in 2002/3.

1.7 Outline of thesis

Details on current research and expertise on monitoring path condition, mobile technology, PGIS and citizen science are outlined in Chapter 2. Chapter 3 describes the methodology used to achieve the research objectives, and the results are presented in Chapter 4. These results are discussed in Chapter 5, and the conclusions are presented in Chapter 6.

Chapter 2 Background

In this chapter, current practice in the assessment of the condition of hiking paths is reviewed, with a view to selecting the method of assessment to be used in this project. In order to inform the design of the app and the approach to getting volunteers, current developments in mobile technology, PGIS and citizen science are reviewed.

2.1 Path condition assessment

In order to be able to decide exactly how hillwalkers (as non-professional surveyors) could carry out a path condition survey, and to find out what information they should be asked to record, the impacts of hillwalkers on paths are first outlined, and then current path condition assessment practice is reviewed.

2.1.1 Impacts of hillwalkers in natural areas

Hillwalkers have an impact on the area through which they walk, because they cause a "disturbance" to the environment. Newsome et al. (2013) describe "disturbance" as the alteration of the structure or function of an ecosystem. Hillwalkers may cause disturbance in the following three elements of a natural area, resulting in an upset to the delicate balance of the natural ecosystem:

i. Wildlife

Hillwalkers may cause disturbance to wildlife just by their presence, if they prevent the wildlife from living in their natural way. They may frighten the animals, or make the animals go to a different area to avoid them. The paths created by hillwalkers, or paths constructed to facilitate them, may affect the natural movement of animals. The usual rest areas of animals may be disturbed or rendered useless. In these ways, hillwalkers may cause stress in animals.

However, unlike "ordinary" tourists in other natural areas, hillwalkers are unlikely to lure the animals to them with food, which would interfere with the normal life of the animals in their ecosystem. Nor is it likely that hillwalkers would add noise and pollution to an area.

ii. Vegetation

Hillwalkers damage vegetation by trampling on it. This may result in a loss of plant cover because sensitive plants which are trampled on may not survive. There may be a reduction in the height of the vegetation because trampling flattens the plants. Different types of vegetation respond in different ways, with some more resilient than others. This can result in a change in the composition of the vegetation, because the delicate plants die and the more hardy species thrive and take over. Quick growing plants can recover but slow growing ones often cannot. Tree seedlings may be carried away on boots, or may be rendered useless.

iii. Physical environment

When people walk on soil, pressure is applied to it, and this results in compaction of the soil. A result of compaction is that there are less voids between the soil particles, and so less space for water to flow through the soil. This can cause water logging which affects the vegetation. It also reduces the water available to the plants.

There is often serious danger of erosion of soil as a result of trampling – particularly if the vegetation which protects the soils has been damaged or destroyed. If vegetation has been removed, the soil may also be in danger of being blown away by wind, or brought downhill by rain, leaving gullies behind.

Compaction and erosion may seriously impact mature trees – the exposure of their roots may result in damage to them, and the reduced availability of water will affect the survival of the trees.

2.1.2 Hiking paths and degradation problems

This section focuses on the specific impacts on the paths walked on by hillwalkers.

Marion, Wimpey and Park (2011) coin the phrases "trail science" in the area of "recreation ecology". They identify soil loss on trails as the most significant and irreversible form of trail impact. They point to the problems on steep ground where water rushing down the trail can increase erosion, and on flat boggy ground where walkers widen the impacted area by walking around the wet sections. Both of these impacts are to be seen on many of the paths in WMNP.

Degradation of hiking paths is a world-wide problem. In the late 1980's, Lance et al. (1989) reported on the network of paths in the Cairngorms in Scotland which had evolved since the 1940's. Monitoring of these paths, which started in the 1960's, showed that paths were widening, and soil erosion and damage to vegetation was increasing. In their study of changes in path widths, Lance et al. saw "a general trend of development, beginning with the simple widening of a single track….., proceeding to erosion and the occurrence of secondary tracks…., thence to the widening and merging of these… and the further creation of others…. Eventually, the path becomes a braided, eroding web…"

Lance et al. concluded that the main cause of widening was the amount of traffic on the paths. Subsequent research by others has found that, as well as the level and type of traffic (walking, horse-riding, cycling, etc.), the rainfall, geology, steepness and roughness of slope, soil type, and vegetation type are all key factors in the nature and seriousness of path damage (Newsome et al., 2013).

In summary, as paths are used, they get wider and deeper, gullies form, water flows down gullies causing even more erosion. Paths get wet and muddy causing walkers to walk on one side or the other, widening the path and/or creating new parallel paths (braiding). By observing and measuring these problems over time, one can monitor the paths and assess damage.

2.1.3 Terminology – formal/informal paths/trails/tracks

When a route followed by a hillwalker can be seen on the ground, it may be called a "path", "trail", or "track" in the literature. In Ireland, "path" and "trail" have specific meanings, as defined by MI in its document on "Principles to guide the management of path erosion in Ireland's upland areas" (MI, 2013). MI states that "a 'path' means a line that is visible on the ground, which may be manmade, but in most cases has evolved through repeated footfall. This is distinct from developed walking routes that have directional marking, that are often referred to as trails and are typically at lower levels." Scottish literature uses the term "upland path" (Hunt et al., 2016) and this refers to paths which are similar to those in WMNP. Researchers from most other parts of the world usually use the term "trail" (and sometimes "track") to apply to any visible hiking route. They use the classifications of "formal" and "informal" to distinguish between different types of route. In order to be able to identify which findings presented in the literature may apply to this project, it is important to determine which term applies to the paths in the WMNP.

Marion and Leung (2011) define three categories of trail in protected areas: **surfaced and un-surfaced formal trails** are planned trails provided by the protected area management, and **informal trails** are user-created and therefore unplanned. Marion and Leung identify typical trail problems, and indicate which ones are common for each of the three different types of trail. In particular, they say that un-surfaced formal trails commonly have problems of trail widening, muddiness and soil loss, while these are uncommon for informal trails, and conversely informal trails commonly have problems of trail proliferation and landscape fragmentation while un-surfaced formal trails do not. A key feature which distinguishes a formal trail from an informal one is that a formal trail is usually monitored and (ideally) maintained.

Marion and Leung's categorisation does not directly apply in many parts of Ireland and Scotland, where most of the networks of upland paths have evolved informally (i.e. they were unplanned and user-created) but they have become so well-used that they have the traffic, and associated damage, which Marion and Leung associate with an un-surfaced formal trail. These hiking paths therefore would correspond to a new category of **unplanned user-created un-surfaced formal trails**, which are similar to Marion and Leung's un-surfaced formal trails, but have additional problems related to the fact that they were user-created and unplanned. Therefore, most of the findings relating to un-surfaced formal trails presented in the literature are taken to be applicable to the paths studied in this research, together with some of the findings relating to informal trails.

Most paths in WMNP correspond to unplanned user-created un-surfaced formal trails, but there are a few which have been turned into way-marked partly-surfaced formal trails, with board-walks, cross-drains, steps and bridges along certain sections. The Wicklow Way is one such trail, together with other way-marked trails around Glendalough.

2.1.4 Management and monitoring of hiking paths

In order to maintain hiking paths in good condition, regular monitoring is an essential part of the management plan for the paths. If regular monitoring is carried out (with follow-up maintenance where required), hillwalkers can continue to use and enjoy the trails, and as much of the land as possible is unaffected by their activity.

Work on paths can range from "light touch" to "fully engineered" solutions (Hunt et al., 2015). "Light touch" work includes re-alignment and braid blocking, and if problems are caught early enough, this can be sufficient to prevent serious deterioration. The work carried out must encourage walkers to stay on the path and not create new paths. The photograph in Figure 2-1 was taken on the Maulin East path in one of the 2002/3 surveys and shows one of the problems which face those who plan work on paths. It shows that, if walkers have an option, they will walk on soft peat instead of hard stone. The path in the photograph will continue to widen because of this behaviour, so any pathwork done must aim to address this.

Figure 2-1 Maulin East 2002/3: Walkers walking on peat and not on stone

Recently, the seriousness of the problem of erosion on Irish uplands due to hillwalking activity has been recognised, and some major studies have been carried out. In Donegal, in the northwest of the country, the Errigal Stakeholders Committee was formed in 2012 to investigate the serious erosion on Errigal Mountain. A study was commissioned, and Walking the Talk produced a report advising on "the long term sustainable management" of Errigal (York, 2015). The report states that "Experience from other mountain areas shows that lack of maintenance is the biggest cause of path failure". It states that an "important decision-making tool for the path manager is monitoring data. This can be done with a combination of trained individuals inspecting the path on a frequent basis (e.g. volunteers) and a competent person to assess the outcomes of the inspections."

With similar problems of worsening path erosion on the MacGillycuddy Reeks in Kerry in southwest Ireland, the MacGillycuddy Reeks Mountain Access Forum was formed in 2014 to "develop a plan of action for the sustainable management" of the Reeks. A path audit was commissioned in 2015 and the resulting report was produced by the Cairngorms Outdoor Access Trust (COAT, 2015). The audit was "designed to capture objective baseline data on the condition of the path network, to prioritise paths and sections of paths where management is required, and to obtain indicative costings and recommendations on repair and maintenance works needed". Monitoring of the paths was an essential part of the recommendations in the report, in which the authors expressed the optimistic view that, on many sections of path, minor work “will provide a ‘stitch in time’ to prevent decline requiring exponentially higher levels of expenditure in future years to reverse what looks to be inevitable decline.”

2.1.5 Principal path condition assessment methods

The assessment of trail condition is one of three different types of trail survey, which can be used in the management of trails, identified by Marion et al. (2011). The three types are shown in Table 2-1.

Table 2-1 Types of trail survey identified by Marion et al. (2011)

Trail survey type	Information produced
Trail attribute inventory	A map of the trail network, together with details such as hiking difficulty, type of use, and trail signage
Trail condition assessment	Type, severity, and location of trail impacts such as erosion, path widening or muddiness
Trail prescriptive management assessment	Details of maintenance or new work which should be done on sections of trails

All three are important for trail management, and trail condition assessment is the type of survey to be carried out in this research project.

There are many ways to approach the assessment of path condition. Marion et al. (2011) identify three main approaches, point sampling, problem assessment, and condition class, and these are summarised in Table 2-2.

Table 2-2 Trail condition assessment approaches - Marion et al. (2011)

Trail condition assessment approach	Details
Point sampling survey	Data is recorded at fixed intervals along a trail
Problem assessment survey	Details of every pre-defined trail impact problem are recorded where they are observed
Condition class survey	The trail is divided into sections within which the trail condition is homogeneous. Each section is assigned a classification under one or more headings

Each of these methods has a different outcome, and different data (“indicators” or “impact variables”) are recorded in each. Marion et al. recommend that management should select indicators to suit the trail network and requirements, and they advise that it is better to have measurable indicators than subjective assessments. Each of these survey approaches produces data which can be used as baseline data with which to compare future survey results. Thus, for example, one can monitor how the width of a path increases over time at a particular point or section along a path.

Each method is described in more detail below.

a) Point sampling survey

The point sampling survey method records data at pre-determined points along the path, and results in a detailed report of the condition of a trail at intervals along its length. Examples of studies which used this method are presented in Table 2-3.

Table 2-3 Examples of point sampling surveys

Researchers	Location of study	Purpose of study	Data recorded
Marion and Leung (2001)	Part of the Appalachian Trail in Great Smoky Mountains National Park, on the Tennessee-North Carolina state border, USA	Comparison of different assessment techniques	Trail width, depth, number of informal trails, and the percentage of exposed soil/rock/muddy soil etc. in the tread
Svajda et al. (2016)	Rocky Mountain National Park, Colorado, USA	To study how abiotic factors, such as grade, elevation, surface type and trail slope alignment, together with type and level of use, influence the condition of trails	Trail width, depth, number of informal trails, and the percentage of exposed soil/rock/muddy soil etc. in the tread
Wimpey and Marion (2010)	Acadia National Park, Maine, USA	A study of factors which influence trail width	Trail width and percentage of exposed soil/rock/muddy soil etc. in the tread
Lance et al. (1989)	The Cairngorms, Scotland	To study the widening of paths and to propose a method for monitoring changes	Path width, and the number of paths
Hill and Pickering (2009a)	Three protected areas in New South Wales, Australia	Comparison of different trail condition assessment methods	Width of track which was bare of vegetation, the total width impacted by trampling, and track erosion (maximum incision)

In addition to path width, the number of paths, and, in most surveys, the path depth, some of the surveys also estimated "condition characteristics" in the path at each point by recording the percentage exposed soil/rock/muddy soil (Marion and Leung, 2001, Svajda et al., 2016, Wimpey and Marion, 2010). This percentage composition indicates the level of degradation of the trail.

Points are generally equally spaced and may be located by a trail measuring wheel (Marion and Leung, 2001) or using GPS (points having been identified prior to survey using GIS) (Wimpey and Marion, 2010, Svajda et al., 2016). Lance et al. (1989) calculated the intervals at which readings were to be taken in order to give statistically valid results for detecting changes in mean width.

The point sampling method is good for providing baseline data which can then be used to monitor changes over time, if the same measurements are taken at the same locations at regular intervals of time. It is also quite objective, because the measurements taken require little subjective judgement. It is, however, possible that some problem areas along the trail might be missed because the sampling point is not at a problem area, but this can be catered for, either by increasing the sampling frequency, or by allowing surveyors to record additional data at extra points if they wish.

b) Problem assessment survey

Also known as a problem-focused rapid survey, the problem assessment survey approach only looks for damage along the trail. Two published studies in which this method was used are summarised in Table 2-4.

Table 2-4 Examples of problem assessment surveys

Researchers	Location of study	Purpose of study	Data recorded
Marion and Leung (2001)	Part of the Appalachian Trail in Great Smoky Mountains National Park, on the Tennessee-North Carolina state border, USA	Comparison of different assessment techniques	Soil erosion, excessive root exposure, excessive trail width, wet soil, running water on trails, and multiple trails
Hill and Pickering (2009a)	Three protected areas in New South Wales, Australia	Comparison of different trail condition assessment methods	Track depth (incision), root exposure, excessive width of track, wet boggy soil, multiple tracks, excessive grade, and informal tracks

This method gives trail managers immediately useful information about problems on the trails, and could subsequently be used to monitor these problems. However, the data produced may be subjective, because it relies on pre-definition of impact problems and lineal extent limits. For example, if the surveyor is asked to record any sections of trail longer than 10m with width greater than 5m, he/she would not record a section of width 20m but only 5m long. An excellent comparison of the point sampling method and the problem assessment method is given by Marion and Leung (2001).

c) Condition class survey

This method involves the classification of each homogeneous section along the trail in terms of various trail impacts, and/or classification of each section in terms of overall condition. Four or five classes are typically defined which describe the condition of a section and they range from 0 or 1 (very good) to 4 or 5 (very bad). If trail impacts are assessed as well as overall condition, impacts such as trail width and depth are first measured, and then classified (e.g. width may be classified so that any width less than 0.5m has classification 1, widths between 0.51m and 1.0m have value 2, etc., up to trail width greater than 5m having a value of 5). Three studies in which this method was used are shown in Table 2-5.

Table 2-5 Examples of condition class surveys

Researchers	Location of study	Purpose of study	Data recorded
Tomczyk and Ewertowski (2011)	Gorce National Park, Poland	To study visitor impacts on trails	Trail width, trail depth (incision), muddy sections, number of braided informal trails, number of old abandoned sections, type of use (hiking and/or biking and/or motorised) and level of use
Nepal and Nepal (2004)	Sagarmatha National Park, Nepal	To study visitor impacts on trails	Trail width, multiple treads, incision, exposed soil and rock, root exposure, landslides, slope failure, muddiness, and running water on the trail
Hill and Pickering (2009a)	Three protected areas in New South Wales, Australia	Comparison of different trail condition assessment methods	Trail width, trail depth, grade/slope, overall condition, degree of track development, muddiness and running water, and rate of deterioration

Tomczyk and Ewertowski (2011) recorded trail data at thousands of sections along 55.1 km of trails. The mean section length was 11m. Nepal and Nepal (2004) also produced an overall condition classification system in which each section was assigned a value between 1 and 4 (little damage to severe damage).

Hill and Pickering (2009a) interpret the condition class method in a different way to that used by others. Instead of having a single condition value per section for each of a number of impacts, they take quite long sections and assess the proportion of the section with different levels of impact. This means that they know if there is poor condition on a track, and what proportion of the trail has that condition, but they do not necessarily know where it is. They identified six impacts, the level of which was to be assessed in each track section. The impacts are visibility of track, average width of track, average slope, track depth, muddiness, and rate of deterioration. They specified a range of categories for each impact. For each track section and for each impact type, they recorded the proportion of the section which fell into each level. They also defined five overall condition classes and recorded the percentage of track section which was in each class.

The main advantage of the condition class method is that it is designed to be very quick to complete, particularly if only an overall condition classification is recorded for each section. The main disadvantage is that this can be very subjective – for example a location judged to have "excessive muddiness" by one surveyor may be judged as having "moderate muddiness" by another. In surveys which include measurements in addition to assessments, these can be stored and used as baseline data for future monitoring. Nepal and Nepal (2004) stored their survey data in a database for this purpose.

2.1.6 Combined methods and other assessment methods

The three principal assessment methods described in the previous section have advantages and disadvantages, and a number of researchers have adapted them. Some of these are shown in Table 2-6 and are described in this section.

Table 2-6 Examples of combined survey methods

Researchers	Location of study	Purpose of study	Data recorded
Marion and Leung (2011)	Zion National Park, Utah, USA	To develop protocols for assessment of visitor impacts on trails	Trail width, trail depth, % composition of trail width, excessive erosion and multiple treads
Ólafsdóttir and Runnström (2013)	Southern highlands in Iceland	To map trail condition and to examine its relationship to physical properties of the location	Trail width, depth, soil erosion, impact on vegetation
Dixon et al. (2004)	Tasmania, Australia	Long term monitoring of unimproved hiking paths	Trail width (bare and total), trail depth, drainage, path surface

Marion and Leung (2011) combined the point sampling and problem assessment approaches in their condition survey of un-surfaced formal trails in Zion National Park, Utah, USA. They measured trail width, depth and % composition of trail width – roots/mud/rock/veg/soil – as in the standard point sampling method. They also recorded details of excessive erosion and multiple treads whenever these were observed, as in the problem assessment method.

Ólafsdóttir and Runnström (2013), in their study of hiking trail conditions in two areas in the southern highlands of Iceland, combined the point sampling and condition class approaches. Every 100m along each trail, they measured trail width and depth, and they also made a visual assessment of the severity of soil erosion and the impact on the vegetation, assigning values ranging from 0 to 3. From the four elements of data recorded at each point, they calculated a condition class (a value between 0 (very good) and 4 (very bad)). In this way, their overall condition class was a combination of objective measured data together with subjective assessed data.

A very different type of condition assessment survey is reported by Dixon et al. (2004). They describe a long-term (eight years) monitoring programme of mostly unplanned, unimproved tracks in Western Tasmania. Instead of attempting to survey all the tracks, they monitor a few indicators in a relatively small number of fixed sites in different "types" of location, and use the results to model the whole track network using predictions based on the "type" of location.

2.1.7 Path condition assessment in Ireland and the UK

Important and useful practical work on upland path condition assessment is currently being carried out in Ireland and the UK, but details are not, at present, in any published peer-reviewed journal. The study described by Lance et al. (1989) is the most recent journal publication I have found on path condition assessment in either Ireland or the UK. Current activity is described in this section.

a) Amber Surveys

The Upland Path Advisory Group (UPAG) in Scotland has produced two manuals which have been published by Scottish Natural Heritage (SNH). They are the Upland Path Management Manual (Hunt et al., 2016) and the Upland Pathwork Manual (Hunt et al., 2015). In these manuals, path surveys at three levels of detail are recommended. They are named using a traffic light analogy, and are shown in Table 2-7.

Table 2-7 Types of path survey adopted by UPAG (Hunt et al., 2016)

Survey Type	Description
Green	A mainly desk-based initial survey of a path network, and includes inventory-type information such as routes, land ownership, and any information already know about condition
Amber	A more detailed survey of the entire path network under consideration, and includes detailed measurements, condition assessment, and pathwork management requirements.
Red	A very detailed survey of sections of paths which require work, and includes a specification for, and sketches of, work required, and time and cost estimates.

An Amber Survey is the type of survey aimed at in this research. In format, it is very similar to a condition class survey as described above. Each path is divided into homogeneous sections and both quantitative and qualitative information are recorded at each section, as shown in Table 2-8.

Table 2-8 Data recorded in an Amber Survey (Hunt et al., 2016)

Type of Data Recorded	Data recorded	
General information	• Path location • Date	• Weather • Surveyor
Descriptive data (for each section)	• Location of start of section and its length • Vegetation	• Path type • Path surface
Physical Measurements (for each section)	• Number of paths and braids • Path width – bare and trampled • Eroded depth	• Long gradient • Cross-gradient
Assessment of path condition (for each section). These are recorded as indices ranging from 1 to 5, where 1 is most damaged and 5 is least damaged	• Roughness • Drainage • Erosion	• Dynamism • Condition
Path management (for each section)	• Work urgency • Prescription • Walk-in times	• Comments • Photographs

An Amber Survey results in data which is very detailed for each section, and because the same information is recorded in a systematic way for all sections, it is very suitable for representation, exploration, and comparison in a GIS. This means that different paths can be compared to each other and surveys of a path done at different times can show changes in condition. UPAG recommends that surveys are carried out by experienced personnel, ideally on as wet a day as possible, or just after a wet spell, because that is when one can see the path at its worst. They recommend to avoid winter when snow or other bad weather conditions may hamper the survey and the surveyor may get too cold. They estimate that a full Amber Survey of 6km takes one day to complete. They advise that the survey is done going uphill.

The Amber Survey method was used recently in Ireland in the studies of the paths on Errigal (York, 2015) and the MacGillycuddy Reeks (COAT, 2015). The resulting overall condition map for the network of paths on Errigal is shown in Figure 2-2. The conditions of different sections of path are mapped using a scale ranging from minimal damage to severe damage. No GIS maps were included in the MacGillycuddy Reeks report.

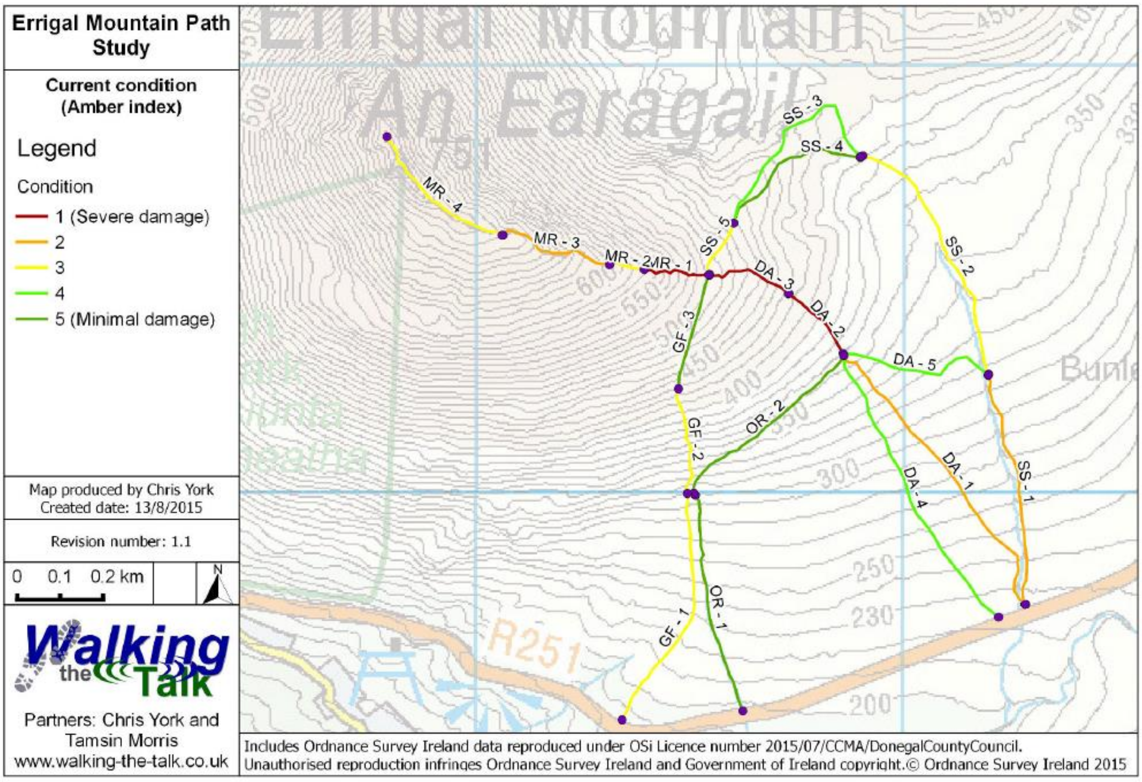

Figure 2-2 Path Condition Map of Errigal (York, 2015)

b) Wicklow Path surveys 2002/3

Surveys of thirty eight Wicklow hiking paths were conducted in 2002/3 in a joint project between WMNP and Mountain Meitheal (MM). WMNP funded the surveys in the park, and MM obtained a grant from The Heritage Council (HC, 2017) to survey the paths outside the park. A professional surveyor was employed to conduct the surveys, assisted by volunteers.

The reports of twenty four[1] of these surveys were supplied to me in MS Word format by WMNP. In order to illustrate the format of these survey reports, parts of the first two pages of the Maulin to Tonduff survey are shown in Figure 2-3. Three full pages of this survey are shown in Appendix A. As can be seen from the extracts, the data recorded in the 2002/3 surveys was quite unstructured – i.e. different types of information were recorded at different points. This reflected the expertise of the surveyor, who knew what the relevant information was at each point, but it makes it difficult to represent the survey data in digital format.

These surveys used a combination of the problem assessment method together with the condition class method. Problem areas were reported when observed, and sections of path in good condition were reported also.

The twenty four paths are shown in the map in Figure 2-4. Two of the paths are parts of the way-marked Wicklow Way (“WWay” in Figure 2-4), and one is a separate way-marked route St Kevin’s Path. The other twenty one paths are unmarked, but most are well used and clearly

[1] The reports of the other fourteen surveys (together with nine of the twenty four I received) are available in pdf format on the Mountain Meitheal website (MM, 2014)

defined. The paths in the north east area of the park are the most highly used because of their proximity to Dublin.

The type of soil on which the paths are located affects their resistance to the effects of trampling. Most of the Wicklow paths are on peaty soil, which is very soft to walk on, and very popular with hillwalkers. It is however also very prone to erosion due to trampling and water damage. A map of the paths and the type of soil on which they are located is in Appendix B.

Wicklow Mountains Path Survey

Maulin Tonduff	
Start to Finish:	O 18186 13289 to O 1595 1367
Altitude (lowest – highest):	500m - 644m
Weather:	Wet morning, windy and overcast
Access:	Crone forest car park
Surveyed by:	John Monaghan, 30 / 7 / 02.

No	**Pos Irish Grid O**	**Comments / Photographs**
1	18186 13289	Top of Crone forest, at stile
2		follow 3m wide grass / stony track contouring to the right (WSW) around Maulin towards the saddle between Maulin and Tonduff
3	17903 13120	At stone wall a minor path goes straight on towards col between M and T; I followed the main path turning left (SW) up onto Maulin  pic57 looking back down to stone wall shows island in centre of path; tape = 0.5m
4	50m on up	a 50cms gully in the peat; path width average 1m; path surface of loose stones and peat

Figure 2-3 Parts of first two pages of 2002/3 survey report on the Maulin to Tonduff path

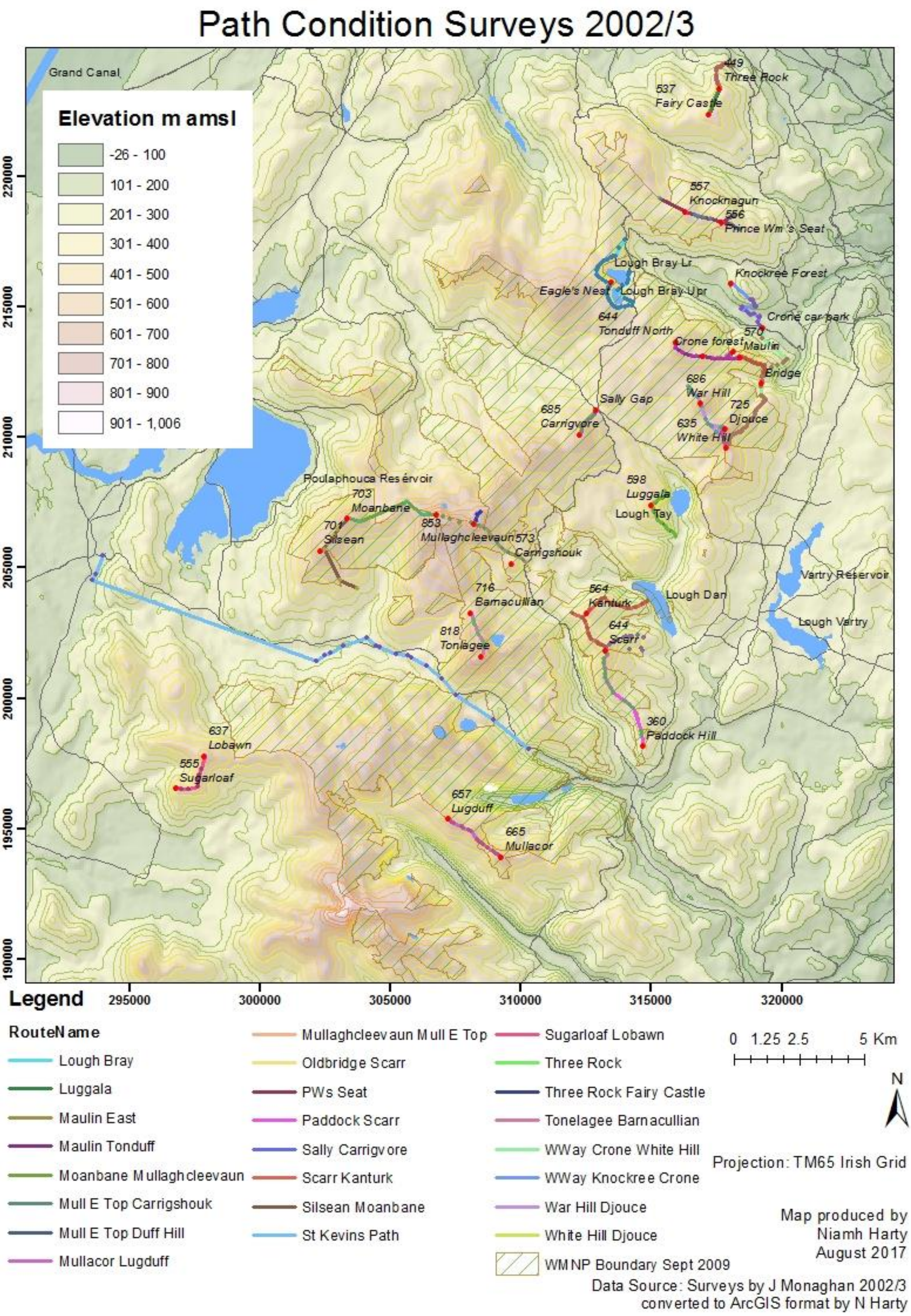

Figure 2-4 Routes surveyed in 2002/3

c) National Trails Office

The National Trails Office (NTO) (2016b) was established in Ireland in 2007 to "coordinate and drive the implementation of an Irish Trails Strategy, and to promote the use of recreational trails in Ireland." The paths which the NTO coordinates are way-marked paths, mostly at low elevations. One of their paths, the Wicklow Way, passes through WMNP. The NTO publishes standards for trails (NTO, 2008b, NTO, 2008a), and also conducts inspections of trails (NTO, 2010). In its assessment of trail quality, the NTO is interested in much more than path condition, and uses a form of the trail attribute inventory survey method defined in Table 2-1. "Erosion of pathway and very wet trail sections" is only one of five issues it takes into account when judging trail quality. The other factors include percentage of trail on road, poor way-marking, trail furnishings in poor condition, and poor information for trail users. Because the types of paths the NTO is involved with are, for the most part, quite different to those on WMNP, their views on trail monitoring have limited applicability to this project.

2.1.8 Measurements, equipment and personnel

Most path condition surveys record descriptive data, physical measurements, and overall assessments of path condition. In order to enable surveyors to carry out reliable surveys, survey manuals, such as those written by Hunt et al. (2016), Hill and Pickering (2009b), Marion and Hockett (2008), are often produced. These set out exactly how to conduct survey, giving details of the equipment required and detailed instructions of what to record and how. The National Park Service in the US (NPS, 2008) produced an excellent manual for recording the condition of informal trails in Yosemite National Park.

a) Measuring path width

In many studies, path width (referred to as "tread width" by many researchers) is measured as the total distance across the path between the most obvious outer boundary of trampling-related disturbance (Marion and Leung, 2001, Wimpey and Marion, 2010, Marion and Leung, 2011, Svajda et al., 2016). It is the distance between boundaries defined by "pronounced changes in ground vegetation height, cover, composition or organic litter" (Marion and Leung, 2001). These researchers also recorded the "tread condition characteristics" of this total path width in the format of the percentage exposed soil / organic litter / vegetation cover / rock / mud / gravel / exposed roots / water / other in the tread.

Tomczyk and Ewertowski (2011) measured trail width as the sum of the width of bare soil (i.e. where vegetation cover was completely destroyed) and disturbed vegetation cover (i.e. trampled, broken plants), and did not record tread condition characteristics.

Lance et al. (1989) measured trail width using two measurements: width of bare ground and overall width of path which is the sum of the width of bare soil and the trampled ground either side of it. They also measured the total width of any secondary tracks at a point.

Ólafsdóttir and Runnström (2013) measured trail width, and devised a formula for calculating trail width in cases where there were extra parallel trails or the trail area widened significantly because of walkers spreading out. This allowed them to include multiple treads in a single trail width value.

In an Amber Survey, path width is recorded in terms of the “bare width” which is the total width of bare ground, and the “trampled width” which is the additional width of the path where vegetation has been disturbed.

b) Measuring trail depth

Marion and Leung (2001) recorded two measurements for trail depth – one was the maximum incision relative to the current tread and the second was the maximum incision relative to the estimated original level of the path. Svajda et al. (2016) used the variable Cross-Sectional Area (CSA) method described by Olive and Marion (2009) to obtain a very accurate estimate of trail erosion at each location. This involves taking several depth measurements across the tread. In Zion National Park, Marion and Leung (2011) recorded both the maximum incision and the CSA of soil loss. Ólafsdóttir and Runnström (2013) and Tomczyk and Ewertowski (2011) measured the maximum incision. In an Amber Survey, the depth is the distance of the lowest point of the path below the surrounding ground.

c) Equipment

In professional surveys, the use of GPS equipment to record locations of survey points is now very common. Tomczyk and Ewertowski (2011) used a laser rangefinder to measure trail width and depth. Svajda et al. (2016) used a tape rule to measure trail width. The use of remote sensing and Lidar to produce maps of trails and their condition is growing, but this is very expensive (Newsome et al., 2013) and has not been investigated as part of this research. Photographs of paths with a hiking pole of known length across the path is a good way of estimating the path width, when exact measurements are not essential.

d) Personnel

The surveys reviewed in this section were carried out by professionals or other trained personnel. An understanding of trail impact problems, the chosen survey method, and the objectives of the survey are important for a successful trail condition assessment survey. In particular, subjective data such as recording indices of trail impacts (e.g. assigning a rating value between 1 and 5 to the amount of muddiness at a point along a trail) require considerable expertise and judgement.

2.1.9 Conclusions relating to path condition assessment

This review of professional path condition surveys has shown that they are very detailed and time-consuming, and that the professional surveyor requires a considerable amount of experience to be able to provide a comprehensive report on the condition of a hiking path. However, some elements of a survey do not require the same amount of judgement as others - for example measuring path width and depth at specified points, and also taking photographs.

2.2 Mobile technology

Apps can be readily developed to use the functionality in a smartphone (geolocation, camera, email, etc.) and to enable users to record data and take photographs. Apps are regularly used in research projects. The app used by volunteers to record the condition of public paths in England and Wales in the "Big Pathwatch" project (Ramblers, 2016) was professionally produced, and was extremely simple to use. Hylander (2015) developed an Android app to evaluate Cultural Ecosystem Services from people's own perceptions in a specific ecosystem. Users record on the app their positive feelings when looking at a particular ecosystem. Kangas et al. (2015) produced an app, Tienoo, to allow people to express opinions about a forest area in Finland. Skevakis et al. (2014) produced a system, MoM-NOCS, which includes an app to allow users to record nature observations and send them to a central system. All these apps have simple user interfaces, and in all of them geolocation is a key item of data. Data is recorded and submitted to be used later in research. Screenshots of these apps are shown in Appendix C.

The usability of an app is very important. Much has been written on this topic, and Ekstedt and Endoff (2012) considered it in great detail in their report. One of the many opinions on usability which they cited was the set of usability goals for any product set out by Preece. These are shown in the diagram in Figure 2-5, taken from Ekstedt and Endoff's report.

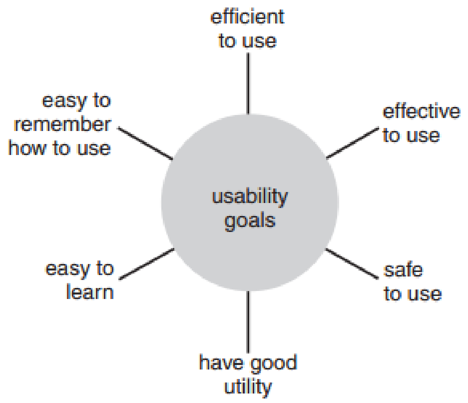

Figure 2-5 Usability goals (Preece, cited in Ekstedt and Endoff, 2012)

Harrison et al. (2013) reviewed the usability of mobile apps specifically. They list the following issues which need to be addressed:

- Mobile context
- Connectivity
- Small screen size
- Resolution
- Limited processing power
- Different data entry methods

They recommend that, when developing an app, one should take into account the end user, the task to be carried out, and the context in which the app will be used. They identified seven attributes which reflect the usability of the app, most of which are in the criteria identified by Preece. The additional attributes are:

- Errors – the app should be developed so that typical errors made by users are minimised
- Cognitive load – the app should be developed with the expectation that the users will probably be multi-tasking while using it

2.3 PGIS and citizen science

GIS software is regularly used today to display and manipulate the data recorded on path condition surveys. For example, Ólafsdóttir and Runnström (2013) mapped the results of their path surveys in Iceland using a GIS, and the results of the survey of Errigal were also presented in a GIS.

The monitoring of path condition is a key requirement in the management of hiking paths, and scarcity of resources makes it difficult to carry out as regularly as desirable. Professional surveys are time-consuming and costly, so any possibility of obtaining useful “free” data is worth investigating. This is where Participatory GIS (PGIS) and citizen science may be useful.

2.3.1 PGIS

PGIS emerged in the mid 1990’s as a result of an aspiration to “democratise” GIS (Brown and Kyttä, 2014, Dunn, 2007, Pánek, 2016). It was designed to address criticisms of GIS such as “[the] use of the [GIS] technology lends the illusion of control over decision making when actual control remains within the governing class.” (Sieber, 2006). PGIS was defined as “a variety of approaches to make GIS and other spatial decision-making tools available and accessible to all those with a stake in official decisions” (Schroeder, 1996, cited in Sieber, 2006, p.492).

The term PGIS in this thesis refers to both Participatory GIS (PGIS) and Public Participation GIS (PPGIS). The main difference between the two types of PGIS is the sphere in which they operate: PGIS usually refers to projects in developing countries which give a voice and empowerment to marginalised communities, while PPGIS projects generally facilitate the inclusion of citizens’ views in policy making in developed countries (Brown and Kyttä, 2014, Kar et al., 2016).

PGIS is an approach to creating a GIS which contains the knowledge and data of local experts and stakeholders, and their direct participation in this community-based GIS is a key factor in its success. Stakeholders include both the community and the administrative institutions/bodies who will use the PGIS. The level of participation in a PGIS project varies from project to project. Quan et al. (2001) list several PGIS projects in natural resource management and the level of stakeholder participation varies from “low” to “high”. Many PGIS projects focus on marginalised and under-represented populations, but not all PGIS do. There are ongoing debates about the actual level of empowerment achieved, the degree of democratisation of GIS reached, and the ethics related to use of the data gathered in the production of the PGIS (Corbett et al., 2016, Dunn, 2007).

The major advances in ICT, including GPS, geolocation technologies, and Web 2.0 (Batty et al., 2010, Kar et al., 2016, Rinner et al., 2008), which led to the emergence of the "geospatial web" (GeoWeb) in the start of the 21st century, had a significant impact on PGIS. The GeoWeb enabled people to easily share geospatial information online. As well as facilitating traditional PGIS, this has resulted in a new, and quite different, type of participation process, often termed "geoparticipation" (Pánek, 2016), producing data called Volunteered Geographic Information (VGI). There are global VGI platforms such as Ushahidi (2018), which enables crowdsourcing for social activism, and OpenStreetMap (2018), and there are also local VGI projects which use geospatial technology to support local citizen participation in various ways, such as FixMyStreet (2018). FixMyStreet is an online platform where citizens can log, with locations on a map, problems such as dumping, graffiti, or potholes, and the reports are passed on to the local council responsible for maintenance. It started in the UK in 2007, and is now widely used in Europe, and in some other countries around the world.

While there are many common features shared by PGIS and VGI, including the collection of local spatial knowledge, the inclusion of citizens in the GIS process, and gathering more information for less cost, there are also important differences between the two approaches (Verplanke et al., 2016). In PGIS, the GIS data is gathered painstakingly from the people in a community and it is analysed before it is uploaded into the GIS. The PGIS process is "slow, small and intense" but the data is "rich, culturally sensitive and situated local spatial knowledge". On the other hand, VGI is data contributed via the GeoWeb by many people who may or may not be part of the same community. There are few controls on it, quality may be questionable, and a huge amount of data can be generated very quickly. The data collected must be analysed/aggregated at the destination. The collaboration, internal validation and acceptance, which are inherent in PGIS, are absent in the VGI approach.

Development of a PGIS may be through various participatory research methods including perceptual maps produced by locals, interviews, focus groups, and field visits, and the data gathered may be quantitative and/or qualitative. Interviews and focus groups are the methods relevant to this research.

Interviews are often used in research to gather information which cannot be obtained using a rigidly structured questionnaire. They are conversations which are usually unstructured or semi-structured (Valentine, 2005). In a structured interview, a fixed set of questions is asked in a fixed order, and so it is quite similar to a questionnaire. In an unstructured interview, only the main topic is identified, and the conversation may go in any direction. In a semi-structured interview, the interviewer has a set of open-ended questions or "themes" to be addressed, and the interviewee is allowed to respond to each question/theme in his/her own way in any order. Issues may be brought up which had not been anticipated by the interviewer, and the flow of the conversation may be directed by the interviewee. The material collected in a good interview is "rich, detailed and multi-layered". The interviewer requires skill in posing questions which encourage the interviewee to talk, and must also be skilled in listening and responding to the interviewee in a way which keeps the conversation on track and the information flowing.

A **focus group** is "a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of research" (Conradson, 2005). The two main aims of a focus group are to gain insight into "the spectrum of views that the individuals hold", and "the nature of their interaction and dialogue". In other words, it is useful to see the way the participants discuss, justify, and argue their views, which may throw light on reasons or causes for people having particular viewpoints. Focus groups are especially useful in studies where the complexity of the issues means that one would not be able to design a questionnaire to adequately allow respondents to correctly and fully give their views and the reasons for them, and where important additional knowledge is expressed through the interaction between participants, which may not emerge in one-to-one interviews. Quan et al. (2001) recommend that "care is required over the composition [of the focus group] so that as many as possible feel free to express their opinions".

Focus groups may be useful at the start of a research project when the researcher wants to ensure that he/she is aware of all possible aspects of an issue, and the results of the focus groups could then be used to direct the design of further research, using some other methodology. In their "Manual for Focus Groups", Dawson et al. (1993) say that focus groups may be used in exploratory studies, testing ideas, solving specific problems, and evaluating projects. They recommend that the moderator's characteristics should include adequate knowledge of the issues, listening skills, leadership skills, a good relationship with the participants, and good observation skills.

Quan et al. (2001) identify some of the key factors needed to achieve a successful implementation of a PGIS. Those which are important for this research project are as follows:

- There should be acknowledgement by all stakeholders that a GIS will be useful in the issues being addressed. If this is agreed, then there is more likelihood of all the relevant parties participating as fully as required.
- The GIS developer must have an ability to communicate with the stakeholders. On a student project, the student must make all efforts to relate to the locals in a non-technical way, without jargon, and to talk in the language of the locals, and to "translate" later, as required, into GIS terminology.
- Accurate GPS will be required if stakeholders will be providing field data. In most parts of the world, this is probably not difficult today.
- Regular feedback to the stakeholders will greatly assist the progress of the project. It will allow for errors to be corrected quickly, and for data to be validated.
- The careful and accurate phasing of the steps in the process of creating the GIS is very important. For example, one should get perceptual maps and opinions first, before doing detailed surveying.
- One should ensure that all data is up to date and accurate. Any data in the GIS which is found to be incorrect will reduce faith in the project.

Appleton and Lovett (2005) recommend that feedback should be provided in clear maps, and that visualisation must be realistic and as accurate as possible.

Barndt (2002), cited by Dunn (2007), outlines three guidelines for the evaluation of PGIS projects:

- Assess the value of the results in terms of providing appropriate and timely information upon which organizations can usefully act.
- Assess the management of the project to see if it is sustainable and properly integrated into the activities of the relevant organizations.
- Assess the achievement of a consensus to support a local working system with appropriate community capacity building in the context of wider, and tangible, development strategy plans.

A wide variety of PGIS applications have been developed in fields such as land-use planning, soil mapping, natural resource management, conservation and environmental management (Brown and Kyttä, 2014, Dunn, 2007, Quan et al., 2001). In the field of natural area tourism, Wolf et al. (2018) used PPGIS to explore conflicts between the different users, including mountain bikers and horse riders, on trails in national parks in northern Sydney, Australia. They used paper and online surveys to get the users to report their use of trails and any conflicts they had experienced, with incident sites located on a map. No reports of PGIS in the area of hiking path management were found in the literature search for this project.

2.3.2 Citizen science

Citizen science uses the opportunities provided by the GeoWeb to gather scientific data in a focused and controlled way. In contrast to much VGI, the citizens collect the required data in a very structured format, and often receive some training to maximise the quality of the data they collect.

There is a tradition among many hillwalkers of wanting to give back to the environment which gives so much enjoyment. A spirit of sustainable recreation is expressed in the vision statement of Mountain Meitheal (MM) whose volunteers give back to the uplands in a very practical way. The MM volunteering model is based on the volunteer organisation which maintains the Appalachian Trail in the US. In addition to regular work on path maintenance, MM also assisted in many of the path surveys conducted in Wicklow in 2002/3.

Mountaineering Ireland (MI) shares this vision of sustainable recreation. Most hillwalking clubs are affiliated to MI, whose mission statement (MI, 2017) is :

> "Mountaineering Ireland exists to represent and support the walkers and climbers of Ireland and to be a voice for the sustainable use of Ireland's mountains and hills and all the places (coastline, crags, forests) we use."

Its vision is "… that Ireland's mountain landscapes will be valued and protected as environmental, cultural and recreational assets."

In its document on “Principles to guide the management of path erosion in Ireland’s upland areas”, MI (2013) asserts that it “…commits to engaging with members to promote responsible and sustainable enjoyment of Ireland’s uplands, to build understanding of upland path issues and to encourage members’ involvement in efforts to address this and other recreation management issues.”

Even though the 2014 survey on path erosion which was part of the “Helping the Hills” initiative was not successful, there is potential to involve the hillwalking community in information gathering in the future.

Successful projects in the UK which use the citizen science approach to obtain information on the condition of paths include “Adopt a Path” in Scotland (COAT, 2017) and the “Big Pathwatch” in England and Wales (Ramblers, 2016). “Adopt a Path” is an ongoing initiative in Scotland in which a person “adopts” a path and records its condition on a regular basis. Details of each survey are recorded manually on the path, and written up and submitted online later. The “Big Pathwatch” was a campaign to review the condition of footpaths, bridleways and byways throughout England and Wales. Three thousand citizen surveyors used an app during the last six months of 2015 to record problems and positive aspects related to the condition of public paths. Over half the total area of England and Wales was covered in the survey. Unlike the “Adopt a Path” program which regularly runs training days and in which much of the data recorded is measurable, it is unclear if any training was provided on the “Big Pathwatch” project, and much of the data collected appears to have been quite subjective.

A study by the James Hutton Institute (2014) assessed “the viability, practicality and utility of using a citizen science project to assess soil erosion in Scotland.” They concluded “that citizens could be involved in recording observations of soil erosion and that where there is access to the appropriate technology these observations could be spatially referenced using GPS.” Among their recommendations, they advised that “[a] website and mobile device application (app) for both iOS (Apple) and Android devices [should be developed] as these technologies will provide access to the majority of the population”.

The lessons learnt from these projects and report could be taken into account to implement a successful citizen science-based path survey in Ireland.

Chapter 3 Methodology

An important element of the methodology adopted in this project is a **participatory approach** to the research. This was inspired by the recommendation of Kesby et al. (2005) to "explore how participation might be built into, and indeed improve, some aspects of your [research] project". This chapter outlines the steps carried out to achieve each of the four research objectives of the project, and the participatory approach particularly influenced the methodology for objectives 1 and 2, and, to a lesser extent, 4.

3.1 Methodology – RO 1: *To develop an app to collect data on hiking path conditions in WMNP, based on a PGIS and citizen science approach*

3.1.1 RO 1 – PGIS and citizen science

The requirements for the app were determined using a PGIS approach in consultations with both hiking path managers and hillwalkers.

PGIS consultations

The participatory research techniques of interviews and focus groups were used to gather information from the stakeholders throughout this project.

A number of interviews were conducted with the District Conservation Officer (DCO) of WMNP in her offices. The interviews were informal and semi-structured. Before each meeting, a set of questions, together with results of work to date, were prepared. These were used as the basis and focus of the discussion, but the conversation was not restricted to them. The DCO was always very enthusiastic about the project and had many ideas and suggestions to contribute at each meeting. Hand-written notes were taken during each interview, and more detailed notes were written immediately afterwards, while the discussion was still fresh in my mind. If clarification was needed on any issue, a follow-up query could have been sent via email, but this was never required.

The consultations with hillwalkers took the format of informal semi-structured focus group discussions. As for the interviews with the DCO, a set of questions was prepared in advance, together with examples of project progress to date. It is recommended that, in a focus group, there should usually be between four and ten participants who "have enough in common to allow the development of a productive conversational dynamic" (Conradson, 2005). There were six participants in each of the two focus group discussions for this project, and they were all members of this researcher's hillwalking club. As moderator in the focus group, my role was to guide the discussion and to ensure that the conversation stayed on track. I had to be careful to just interview the participants, and not to take over the session. All participants know me and each other well, and we are all friends, so there was no need for the usual preliminaries of ice-breaking in the focus group, nor was there a need to ensure that all participants were comfortable and felt able to talk and voice their opinions. The discussions were very fruitful, with many thoughtful suggestions and ideas put forward, which may not have emerged in individual one to one interviews.

Consultations with WMNP District Conservation Officer

The main expert in path management in the project was WMNP District Conservation Officer (DCO) Enda Mullen, who advised on the basic requirements of the app. She knows the park, the terrain, and the requirements for management and conservation. She is aware of the need to obtain up to date information on path condition in WMNP, and she is also familiar with the 2002/3 surveys of the paths in WMNP.

It has been found that the success of a PGIS relies, in part, on the stakeholders recognising the benefits of the project to them (Quan et al., 2001). Therefore, it was essential to identify what kind of an app WMNP would see as helpful to them. At the first interview, the DCO rejected an initial idea of an app like FixMyStreet for the paths in the park, because users of such an app, who reported poor conditions on a hiking path, might expect immediate action by WMNP to “fix” it, and the park would not be able to respond in that way. Instead, she suggested that an organised re-survey of the paths surveyed in 2002/3 would be very beneficial, and that the 2002/3 survey reports should form the basis for the new surveys which could be conducted by non-professionals using the app. In this way, citizen science would be used in the collection of data, and not VGI.

Having thus identified the desired function of the app, the incorporation of the DCO’s expertise (and indirectly that of the other park officers) should ensure that the survey app will enable volunteers to record data which will be useful for the park.

After the first four surveys of upland paths, the results were shown to the DCO and her colleagues to get their views and suggestions for modifications. A final consultation with the DCO was held at the end of the project in order to obtain her opinion of the work done.

Consultations with other path managers

On the advice of the DCO, discussions with staff of the National Trails Office (NTO) were held early in the project. The proposed app was explained to them and they were asked for their comments. Based on their experience with the regular inventory surveys carried out on their way-marked trails, they observed that an app which prompts the user when he/she has arrived at a point at which to record data would be very useful, and that the ability to conduct a survey on a single mobile device, and not requiring a separate GPS unit and camera, would be very desirable.

A meeting with Mountain Meitheal volunteers also took place at end of the project.

Consultations with hillwalkers

The advice of hillwalkers was another essential element in the project. This group of people regularly use the hiking paths, are stakeholders who are interested in the preservation of the upland paths, and were the source of the volunteer data collectors (citizen scientists) to carry out the surveys.

At the first meeting with a group of six hillwalkers to discuss the project, the idea and aim of the app and the research were outlined, a map showing the paths which had been surveyed in 2002/3 was distributed, and an early paper mock-up of the app was presented. The group was asked for initial thoughts and observations. They were enthusiastic about the idea, and said they would be willing to contribute to this effort to help the environment. They clearly understood the plan and saw its potential. On the practical side, they suggested that the battery life of a mobile device should be taken into account when using the app on the hills. All the issues raised at the meeting are presented in Appendix D.

A second meeting with another group of six hillwalkers (some of whom had attended the first meeting) was held after the first four surveys had been conducted and the app was considered stable. A map of all the paths yet to be surveyed was shown, together with sample results from one of the initial surveys. Volunteers were asked to select the path they would like to survey. The app with the data for that path was sent to those who volunteered, together with a brief manual and the 2002/3 survey report for that path. Towards the end of the project, an email was sent to another hillwalking club requesting volunteers, and one member of that club carried out a survey.

Each volunteer was asked for comments and feedback after completing their survey. Where feasible, the feedback received was taken into account in the app and subsequent surveys.

3.1.2 RO 1 – The app

Selection of software and platforms

Apps can either be developed for a specific type of mobile device – e.g. iOS or Android – using their own “native” code, or they can be developed using a multi-platform tool and deployed on a variety of devices.

It was decided that the app for this project should work on both iPhones and Androids, because these are the most popular phones in Ireland, accounting for over 98% of the Irish mobile phone market (details are presented in Appendix E). The multi-platform tool Adobe PhoneGap (PhoneGap, 2015a) was recommended to me for the development of the app. It was an attractive option because only JavaScript (JS), HTML, and CSS are required to build apps in PhoneGap and I have experience with these languages. PhoneGap is free and open source software with a large community of developers and users, and a considerable amount of documentation, both formal and informal. It is made available under Apache License, Version 2.0 (ASF, 2004), and may be used to develop “mobile applications that are free, commercial, open source, or any combination of these” (PhoneGap, 2015a). After successful initial tests, it was adopted as the development tool.

Getting started

A number of sample apps were developed using PhoneGap to see how to implement the key functionalities anticipated to be required in the app for this project, such as the use of the geolocation, camera, email, and maps.

These samples were based on articles by Traeg (2014) and Coenraets (2012, 2014), and on a demo on the JQuery Mobile website (JQuery, 2015). In his sample app, Traeg used the JQuery Mobile (JQM) framework, which is a specialised version of the JQuery (JQ) framework specifically geared to mobile devices. JQ and JQM are open source JS libraries which are designed to allow programmers to "write less, do more" in apps written in JS. In order to distribute an app developed with PhoneGap, the cloud-based PhoneGap Build option (PhoneGap, 2015b) was selected. Further details on the sample apps developed and PhoneGap Build are presented in Appendix F.

Design of the app

Following the consultations with the DCO, path managers in the NTO, and hillwalkers, it was determined that the core functionality required in the app was to enable the user to:

- See their current location on a map, together with the path they were to follow and the points at which they were to record the condition.
- Record their walk.
- Record path condition at selected points.
- Email the results when they are finished.

A mock-up of the user interface of the app was produced in Visio (Microsoft, 2017). This is shown in Appendix G. Feedback from hillwalkers and a graphic design professional were incorporated into the final design of the app.

Development of the app

The app was developed in PhoneGap and runs on iOS and Android mobile devices. It was initially developed and tested on iOS, and the first two surveys were carried out on that version of the app. Because many potential volunteers had Android phones, it was decided to test the app on Android, and only three very small code changes had to be made to get it to work on the Android (as well as iOS).

Almost all coding problems encountered were resolved by using Google search. Forums were particularly good, with Stack Overflow (SO, 2017) always providing the best information.

Some of the principles of the Agile software development methodology (VersionOne, 2015), including incremental development, early delivery, and continuous improvement were used. This methodology allowed for the WMNP DCO and the volunteer data collectors to be able to see the app as it evolved and to comment on it at each stage. In accordance with the participatory nature of the project, the participants' opinions and views were taken on board as much as possible.

PhoneGap on its own is very basic, and plugins had to be included to add specific functionality. Some of these were standard plugins such as those that enable file management and control over the status bar. Others were custom-built plugins which address particular issues on particular devices. For example, the standard plugin to get access to the camera on the device does not provide details of the latitude and longitude of the location (Exif data) at which the photograph was taken. Because it was thought that this would be useful information, a plugin, written by another developer, was used so that this extra data for each photograph could be recorded.

Page navigation, buttons, sliders, radio buttons and choice lists were created using JQM. An SQLite database (2018) was used for data storage. Google Maps JavaScript API (2018) was used to display the map showing the user's location and the path to be followed. A new email address was set up for the project, and the SQLite database and photos are sent to it when the user has completed his/her survey. Because the full-size photos are very large (between 5MB and 10MB each), small versions were created and it is these which are emailed on completion of the survey. The full-size photos are transferred manually later. Some extracts of code are provided in Appendix H.

3.2 Methodology – RO 2: *To compare the path condition data collected using PGIS and citizen science with that collected by a professional surveyor in 2002/3*

3.2.1 RO 2 – PGIS and citizen science

The path condition data to be collected by volunteer surveyors using the app was determined through consultations with the DCO, studies of current monitoring and survey practice, and reviews of the 2002/3 survey reports. The app was developed and used to collect current path condition data, and this data was then compared to the data collected in 2002/3.

At the first meeting, the WMNP DCO recommended that the surveyors (as citizen scientists) should record, as far as possible, the same type of data that was recorded in the 2002/3 surveys. She recommended that the app should be kept as simple as possible, advising that it will not replace a professional survey. She also advised that geolocated photos would be very useful to park management; path condition could be assessed from the photos, particularly if they include a hiking pole of known length from which scale can be inferred; photographs could be used to verify any other data recorded at a point.

3.2.2 RO 2 – Path condition data

The surveys to be conducted in this project are intended to form part of a monitoring programme in WMNP. Therefore, many of the seven steps to be followed in the development of a monitoring programme recommended by Newsome et al. (2013) were carried out. The steps are reproduced in Table 3-1, and each step is discussed in this section. Step 3 is the most important for this research objective, because it is the one in which the data to be recorded is identified, while the other steps put the decisions made in Step 3 in context.

The **need for the survey and its overall aim** (step 1) were set out in Chapter 1. The detailed objectives were determined to be as follows:

- To collect the most important and most useful data which non-professionals can record.

- To collect data similar to that collected in 2002/3 so that 2002/3 data can be used as baseline data.
- To highlight areas in which there has been deterioration since 2002/3.
- To carry out a partial survey, rather than a full professional survey.

Table 3-1 Steps in development of a monitoring programme

	Step
1	Evaluate need for the monitoring programme and determine its objectives
2	Review existing approaches to monitoring used in this location and elsewhere
3	Develop monitoring procedures and identify what data should be recorded
4	Document monitoring protocols and provide training
5	Conduct monitoring fieldwork
6	Develop analysis and reporting procedures
7	Apply monitoring data to management

Existing approaches to surveys (step 2) were reviewed in Chapter 2. The different types of path monitoring surveys used internationally, and the surveys of paths in WMNP in 2002/3, were examined.

When **developing the monitoring procedures** (step 3), decisions had to be made on two key issues: the type of survey, and the impact data to be recorded.

In relation to the type of survey to be adopted, it was decided to use the point sampling method with pre-determined points. The surveyor will record the path condition at the same points as it was recorded in the 2002/3 surveys. This will mean that changes in condition may be identified as easily as possible. Newsome et al. (2013) define monitoring as the "systematic gathering and analysis of data *over time*". If the condition is recorded at the same points as used in the 2002/3 surveys, that essential "*over time*" element in monitoring will be satisfied. Therefore, the 2002/3 survey will be used as a baseline as much as possible. Another benefit of using the same points as in 2002/3 is that there will then be no need for the volunteer surveyor to have the expertise to recognise where data should be recorded, and a non-professional should be able to carry out the survey.

In relation to what data to collect at each point, the digital nature of an app makes it ideal for the recording of a structured set of data at each point. The use of the Amber Survey (AS) format on two recent major path condition surveys in Ireland indicates that this Scottish method is applicable in this country. Based on the WMNP DCO's recommendation, a subset of the AS data will form the majority of the data to be input by the user. However, instead of recording the data for a section of path, as in an AS, the survey in this project will record that data at specific points only, as was done in the 2002/3 surveys.

The data recorded in a full AS is reproduced in the middle column of Table 3-2, and the subset chosen to be recorded on the app is shown in the right hand column. Some of the data can be automatically recorded by the app (location, date and surveyor ID), while a few measurements will be taken/estimated by the surveyor – path width and depth. The surveyor will also record if the path is braided or not, the path type, and the path surface (from the choice lists used on an AS), and one or two photographs will be taken at each point. The qualitative assessment of path condition recorded in an AS is very complex for a non-professional to understand, because so many of the items are inter-related (e.g. drainage and erosion), and it would be inappropriate to ask an amateur to assess these. Therefore, it was decided instead to ask the surveyor to record muddiness and water flow in a simple format, using the terminology used in many of the 2002/3 surveys. Muddiness will be recorded as "dry", "wet", or "very wet"; water flow will be recorded as "no water flow", "low water flow along path", "high water flow along path". The equipment required to record this small set of data will consist of a mobile device (running the app) and a hiking pole (to estimate lengths and to be placed in photographs for scale).

Table 3-2 Data to be recorded on app, with data recorded in Amber Survey for comparison

Type of Data	Data recorded in Amber Survey	Data to be recorded on app
General information	Path location Date Weather Surveyor	Path location[1] Date[1] Weather Surveyor[1]
Descriptive data (for each section)	Location of start of section and its length Vegetation Path type Path surface	 Path type Path surface
Physical Measurements (for each section)	Number of paths and braids Bare path width Trampled path width Eroded depth Long gradient Cross-gradient	Single or braided path Bare path width Trampled path width Eroded depth
Assessment of path condition (for each section).	Roughness Drainage Erosion Dynamism Condition	Muddiness - dry, wet, or very wet Water flow - no water flow, low water flow along path, or high water flow along path
Path management (for each section)	Work urgency Prescription Walk-in times Comments Photographs	 Comments Photographs
Notes: [1] Automatically recorded on app		

The data chosen to be recorded in the app was also recorded in the 2002/3 surveys, albeit in a less structured way, and not at every point. Comparison of the current condition with that in 2002/3 should be possible.

Limited **monitoring protocols and training** (step 4) were included in this project, and they are included in Appendix H. **Monitoring fieldwork** (step 5) was carried out by volunteers recruited through consultations with hillwalkers, and the results are presented in the next chapter. **Analysis and reporting procedures** (step 6) were developed as described in the sections of this report relating to research objective 4. The **application of monitoring data to management** (step 7) was not part of this project (which may be regarded as a pilot study), but the results were presented to WMNP management for assessment, and this is described in Sections 4.2 and 4.4.

3.2.3 RO 2 – Error analysis

The app will record the location of the surveyor using the GPS facility on the user's mobile device. In order to obtain an estimate of the GPS error in the location recorded, a test was devised to study the difference in the locations recorded on different devices when physically in the same place at the same time. A section of a path up the eastern side of Djouce (not one of the paths in the Wicklow Survey) was recorded by me on two phones at the same time - an iPhone 6 and a Samsung Galaxy Note 3. The path on this side is very wide, and is shown in the photograph in Figure 1-2.

Another possible method of assessing the GPS location error is to look at the error estimate provided by the mobile device itself. When the latitude and longitude of the location are provided by the mobile device, a field called the "accuracy level" is also returned. This is a value in meters, and is the device's estimate of the accuracy of the location. The lower the value, the better the accuracy. For example, an "accuracy level" value of 10m means that the device estimates that the location it specifies is correct to within 10m. While the user is recording a walk with HOP!, the app records the location all along the path at regular intervals, not just at the points at which the condition is recorded. This record of the full path includes the "accuracy level" field at each point, and this was examined for all paths surveyed to see if the "accuracy level" field could be used in error estimation.

3.3 Methodology – RO 3: *To convert the path condition surveys of 2002/3 into a format that can be used for comparison with the current condition*

The 2002/3 path condition data was converted into a structured format in order to display it in ArcGIS (esri, 2018) and in the app, and to compare it with the current condition.

The text in the MS Word survey reports was first imported into Excel. It was then manipulated in Excel so that the coordinates of each survey point were identified, with estimates required in some cases. The notes recorded at each point were interpreted, together with any corresponding photographs, to obtain the path condition in terms of the same measurements as used in the app (path width, depth, braiding, muddiness, etc.). Much of the condition data had to be estimated either from photographs or from the condition recorded at points close by, because of the descriptive format of the original reports and because path width, depth and braiding were not noted at each survey point. Further details of the data conversion process are given in Appendix I.

The locations of all survey points on all paths, and the condition data for some paths, were loaded from an Excel file into ArcGIS. Because extracting the path condition from the survey reports was very time-consuming, condition data was only extracted for those paths that volunteers surveyed in 2016/17.

For each path surveyed in 2016/17, target points at which the condition was to be recorded using the app were selected from the points surveyed in 2002/3.

3.4 Methodology – RO 4: *To determine the condition of the WMNP hiking paths today, and to compare it with the condition in 2002/3*

The data recorded with the app by the volunteers was input into ArcGIS and saved as shapefiles. These were then used to create maps showing the current condition compared to 2002/3. The final format of these maps was worked out in consultation with the DCO and other experts in path management when the surveys were complete.

The transfer of the data collected on the app into ArcGIS was relatively straightforward. The data was exported from the SQLite database to CSV files, which were then added to an ArcGIS map. The map was in the Irish National Grid (TM65) coordinate system, because this is the system which the WMNP staff always use. The Irish National Grid is described in Appendix I. The WGS84 latitude and longitude of the survey points, saved by the app, were transformed by ArcGIS into TM65 (x, y) coordinates.

The overall path condition at each point was displayed using a scoring system similar to that used by Ólafsdóttir and Runnström (2013). The score is calculated by assigning individual scores for each of the five impact variables (path width, depth, braiding, muddiness and water flow) and adding these together to give an overall score, ranging from "0 - Very Good" to "4 - Very Poor". Details of how the scores are calculated are given in Table 3-3.

The change in overall condition from 2002/3 to 2016/17 was calculated by subtracting the overall condition score for 2002/3 from that for 2016/17 and assigning values ranging from "Major Improvement" through to "Major Disimprovement", as shown in Table 3-4.

This score for the change in overall condition may "hide" locations at which one, or more, of the impact variables has deteriorated. Therefore, a second method of displaying the change in condition was devised. It highlights locations at which any one of the individual impact variable scores has deteriorated. A point is assigned a value of 1 if any of the five impact variable scores is worse in 2016/17 than in 2002/3 – path width, path depth, braiding, muddiness, and water flow. The value is 0 if there has been no deterioration.

Table 3-3 Scoring system for path condition

Impact Variable	Score	Description
Path width (bare and trampled) (m)	0	width < 1m
	1	1m <= width < 3m
	2	3m <= width < 6m
	3	width >= 6m
Braiding of path	0	single path
	1.5	multiple paths
Path depth (m)	0	depth = 0
	1	0 < depth < 0.25
	2	0.25 <= depth < 0.5
	3	depth >= 0.5
Muddiness	0	dry
	1.5	wet
	3	very wet
Water flow	0	no water flow
	1.5	low water flow
	3	high water flow
Overall Condition Score	0 - Very good	total < 2
	1 - Good	2 <= total < 4
	2 - Fair	4 <= total < 6
	3 - Poor	6 <= total < 8
	4 - Very Poor	total >= 8

Table 3-4 Scoring system for change in overall condition

Change in Overall Condition	Score 2016/17 - Score 2002/3
Major improvement	-3 or -4
Improvement	-2
Minor improvement	-1
No change	0
Minor disimprovement	1
Disimprovement	2
Major disimprovement	3 or 4

Chapter 4 Results

The results for each research objective are presented in this chapter.

4.1 Results – RO 1: *To develop an app to collect data on hiking path conditions in WMNP, based on a PGIS and citizen science approach*

4.1.1 RO 1 – The app

The app developed in this project is called HOP! which stands for How's Our Path! It prompts the user to record the path condition and to take photographs at pre-set target points along a chosen hiking path in WMNP. These target points are locations at which the condition was recorded in the 2002/3 surveys. The user may also record the condition at other locations along the path, if desired. The app also records and saves the full path hiked by the user. Full details of the functionality of the app, together with sample screenshots, are provided Appendix H.

The app was generally stable, but the following issues occurred. On one survey, the app did not work on two mobile devices because of lack of access to the internet and Google Maps. Fortunately, a third mobile device was available which did have access, and the survey was carried out using it. On a number of path surveys, the email of the data from the app did not work, and the data and photographs were retrieved later directly from the mobile devices. On the final survey, a technical issue caused the app to crash repeatedly, resulting in the loss of almost all data recorded by the volunteer.

4.1.2 RO 1 – PGIS and citizen science

The participation and feedback of the stakeholders - the hillwalkers who were the citizen scientists, and the DCO who was the expert – reported here.

Responses and feedback from hillwalkers as citizen scientists

Many hillwalkers liked the concept of the project, because it will help to sustain the upland paths they enjoy and share. Several of them offered to help by using the app to collect data, and four of these followed through on their offers. Five others, who offered to assist, did not come back to me when I sent them the choice of routes to survey, but I did not pursue them because I did not require too many people for this pilot study, and I did not want to pressurise anyone. A number of other hillwalkers expressed initial interest in assisting, but I did not follow them up either because they were not needed.

Three of the path surveys were carried out by me, and four volunteer surveyors carried out the other five path surveys. Two of these volunteers were accompanied and advised by me on their surveys, and the other two did their surveys alone. All reported that they had a positive experience doing the survey. One of the volunteers who surveyed alone willingly did a second survey, and would have done many more if the time had been available. This volunteer is the most technically experienced of all the volunteers (he has an IT background and regularly records his walks on a GPS device), and he had no unsurmountable problems during his surveys. The other volunteer who collected data alone did a preliminary survey of his path to check that everything worked, and it did. Regrettably, on his full survey he lost almost all the data he carefully recorded, due to technical problems.

The app was found to be very easy to use by all volunteers. The following is a brief summary of the points made by the data collectors after their surveys:

- The app is easy to use
- The surveys must be done on special dedicated walks – they cannot be done while out on a club hike
- The target points should not be too close together
- One should not survey on a short day in winter
- One should remember to bring a battery pack and walking pole
- It can be difficult to enter data on a phone in bright sunshine

Some volunteers said that the notifications with bird sounds produced by HOP! when they were close to a target point were very useful, but the app was used without attention to these notifications by others.

Details of the feedback received from the data collectors are in Appendix J.

Feedback from District Conservation Officer (DCO)

At the final meeting with the DCO, a number of her colleagues in WMNP attended also. They were all very impressed with the HOP! app and the results obtained. They said that the app would be very useful in the monitoring of the hiking paths in WMNP. They proposed that it could also be used by park staff on their own monitoring projects.

4.2 Results – RO 2: *To compare the path condition data collected using PGIS and citizen science with that collected by a professional surveyor in 2002/3*

4.2.1 RO 2 – Path condition data

In this section, the condition data collected in 2016/17 using the HOP! app is described and compared to the data collected in 2002/3. A summary of the comparison is presented in Table 4-1.

HOP! uses the point sampling survey method with pre-selected target points on a path. The volunteer surveyor is prompted to record the condition at each of the targets, which are points surveyed on that path in 2002/3. The volunteers took one or two photographs at each point, most of them recorded path width and depth measurements also, and one also recorded detailed notes. Path width was recorded to the nearest 0.1m by the surveyor using his/her hiking pole, which is approximately 1m in length. Path depths were also recorded to the nearest 0.1m, based on judgement by eye. Some surveyors also recorded the condition at extra points at which they thought the condition was poor.

Table 4-1 Comparison of 2016/17 path condition data with 2002/3 data

	2016/17 Surveys using HOP!	2002/3 Surveys
Survey design	• Designed using PGIS approach	• Designed by professional surveyor
Qualifications of surveyor	• Amateur volunteer surveyors as citizen scientists	• Professional surveyor
Type of survey	• Point sampling at pre-determined points	• Combined problem assessment method with condition class method
Completeness of survey	• Partial condition survey • Measurable indicators only • No assessment or subjective data	• Complete survey including recommendations for pathwork and predictions of deterioration
Digital vs analogue	• 100% digital • Tabular format • Same data at each point • Consistent format at each point • Directly importable into GIS	• Analogue descriptive report with photographs • Different types of data at each point • Different data format at each point • Difficult to import into GIS
Quantity of recorded data	• 1 or 2 photographs taken at every point • Path width, depth and braiding recorded not always recorded • Additional notes recorded rarely	• Path width and depth not always recorded • Photographs taken at approximately 50% of survey points
Data quality	• GPS location recorded automatically on mobile device • Path width estimated to nearest 0.1m • Path depth estimated to nearest 0.1m	• GPS locations at various levels of precision – nearest 1m, 10m, or 100m • Tape measure used to measure path width, recorded to nearest 0.5m or 1m • Tape measure used to measure path depth, recorded to nearest 0.1m

As an example of the survey data collected using the app, all of the data recorded at the first point on the Prince William's Seat path in December 2016 is shown in Table 4-2, with the accompanying photograph in Figure 4-1. The section of the survey for the same point recorded in 2002 is in Table 4-3.

All of the 2016/17 data is saved in a table, with pointers to associated photographs. Some data is saved automatically by the app and other data is recorded by the volunteer surveyor. For each point, the path details, surveyor ID number, point ID number, and the number of that point in the 2002/3 survey are automatically saved, together with the latitude and longitude of the point, and the date and time the recording was made. The volunteer surveyor records the weather conditions, may take one or two photographs and add captions for the photographs, and may record the other data (path type, surface, width, depth, etc.) as shown in the sample in Table 4-2.

The 2002 data is in text format with a number of associated photographs (varying from none to four). The data recorded is not of a consistent format. For example, the path width shown in Table 4-3 is recorded as "1 – 2m". At other points on other surveys, the width is recorded in other ways such as "average 1m", "width <= 2m", and "today (dry day, but after a wet June) you need to go out 20m or so on either side to get around the wettest part". At many points, the path width is not recorded at all, but in some cases can be interpreted from the photographs which include a hiking pole of specified length. In almost all surveys, the path width, when recorded at all, is expressed to the nearest 0.5m or 1m. The path depths recorded are expressed to the nearest 0.1m.

The expertise of the surveyor is evident in many notes recorded, such as the comment “will get wider in wet weather” in Table 4-3. Some similar notes contain advice on pathwork required. For example, another survey includes the note “[the photo] …… shows another very wet patch which needs bridging”.

The GPS coordinates in the 2002/3 survey reports are expressed in Irish National Grid coordinates, which are described in Appendix I. The coordinates were recorded with a level of precision which varied from coordinates expressed to the nearest meter, to coordinates expressed to the nearest 100m. For example, the location of the summit of Djouce is recorded in the White Hill – Djouce survey report to the nearest 100m. The coordinates are recorded as O 179 103, which becomes (317900, 210300) when converted to National Grid coordinates. This point is about 40m from the actual summit whose correct coordinates are, with extra precision, (317861.9, 210345.7).

Table 4-2 Data recorded at the first point on the Prince William’s Seat path in 2016

PathID	30
Path_Name	Prince William's Seat
HikerID	10
SurveyID	2
PointID	1
HistPointID	I2
Lat	53.19978063
Lng	-6.231018137
Weather	Cold, cloudy, dry
Date	04/12/2016
Time	12:50:36
Photo1	Photo1_1_2
Photo1Capt	Ref pic 24
Photo2	
Photo2Capt	
NotesPt1	Appears to be a previously used/infrequently used trail
NotesPt2	
PathType	Evolved slope
PathSurface	Heather/other vegetation, Stone, Peat
BareWidth	2.5
TrmpldWidth	0
Depth	0
Braiding	Single Path
Muddiness	Wet
WaterFlow	No water flow

Figure 4-1 Photo1_1_2 taken at first point on Prince William's Seat survey in 2016 – caption "ref pic24"

Table 4-3 Data recorded at the first point on the Prince William's Seat path in 2002

No.	Pos Irish Grid O	Comments	Photographs
2	182_{60} 180_{30}	pic24 looking back towards start of path; pw 1 – 2m; on soft peat; will get wider in wet weather.	
3	same	pic25 looking ahead towards Prince William's Seat	

As an example of photographs taken of the same path section in 2016/17 and 2002/3, Figure 4-2 shows photographs taken at approximately the same point on the White Hill-Djouce path. The 2016/17 photo is on the left, and the 2002/3 photo is on the right. The same eroded area is highlighted in the two photos. In 2003, the path width was recorded as 3m, and in 2017 it was recorded as 4.5m. The trampled area to the right in 2017 is where the width has increased. Both surveys were carried out in the month of June, so the growth of vegetation was comparable.

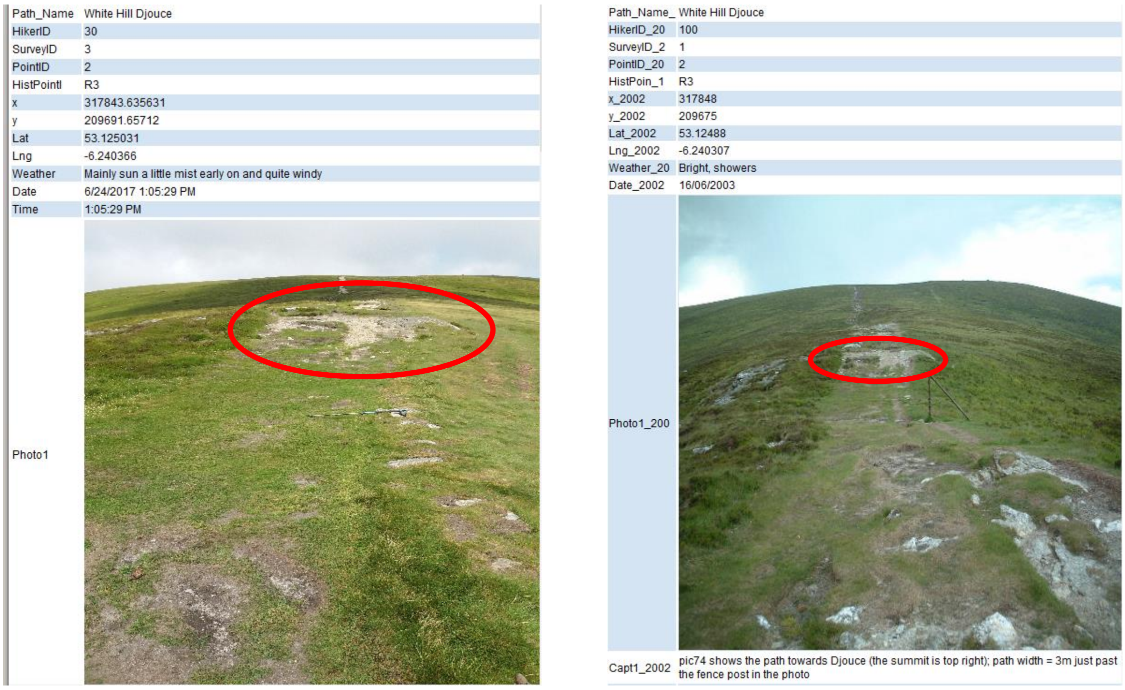

Figure 4-2 Photos taken at same point on White Hill-Djouce path: 2017 on left and 2003 on right

4.2.2 RO 2 – PGIS and citizen science

When reviewing the data collected in the 2016/17 surveys, as part of the participatory approach in this project, the District Conservation Officer observed that path width, path depth and braiding on their own give a very good indication of the state of a path, and she advised that the assessment of muddiness and water flow is useful but not essential. She also said that the lack of professional judgement in the surveys did not detract from their overall value which is significant for the park management.

Before carrying out their surveys, very few of the volunteers read the manual provided, nor did they read the 2002/3 survey report. However, after carrying out their survey, many of them said that some brief training would have been useful – in particular how to locate points and where to take photographs. There is a facility in HOP! to allow the user to look at the photographs taken in 2002/3 at the same spot in order to decide what to photograph on their own survey, but only one of the volunteers used this. Some of the volunteers said that the choice lists presented by the app were very long (for example, the list of path surface types provided).

Even though HOP! is designed to collect only a subset of the full data recorded on an Amber Survey, the volunteers did not always record even this relatively small amount of data. The data recorded on each survey varied from a minimal survey with photographs only to a complete survey in which every single item was recorded and extra notes were added.

After conducting their surveys, the data collectors said that they found that recording data at each point is time-consuming. The length of time to record data at a point was briefly studied. The full path followed by the surveyor is recorded in HOP! and it includes a timestamp at each point. This enables one to see how long the person spent around a point at which he/she was recording data on HOP! The timestamps on the path on the White Hill-Djouce survey show that, at point R4 where the condition was recorded with two photographs, path type, path surface, bare width, trampled width, braiding and muddiness, and no notes or captions, the recording took three and a half minutes. At point G25 on the Oldbridge-Scarr survey, carried out by a different volunteer, the time spent recording the same amount of data, was also about three and a half minutes.

4.2.3 RO 2 – Error analysis

The paths recorded simultaneously on an iPhone and an Android phone in the GPS error estimation test are shown in the map in Figure 4-3. The points recorded by each device were converted into lines representing the paths.

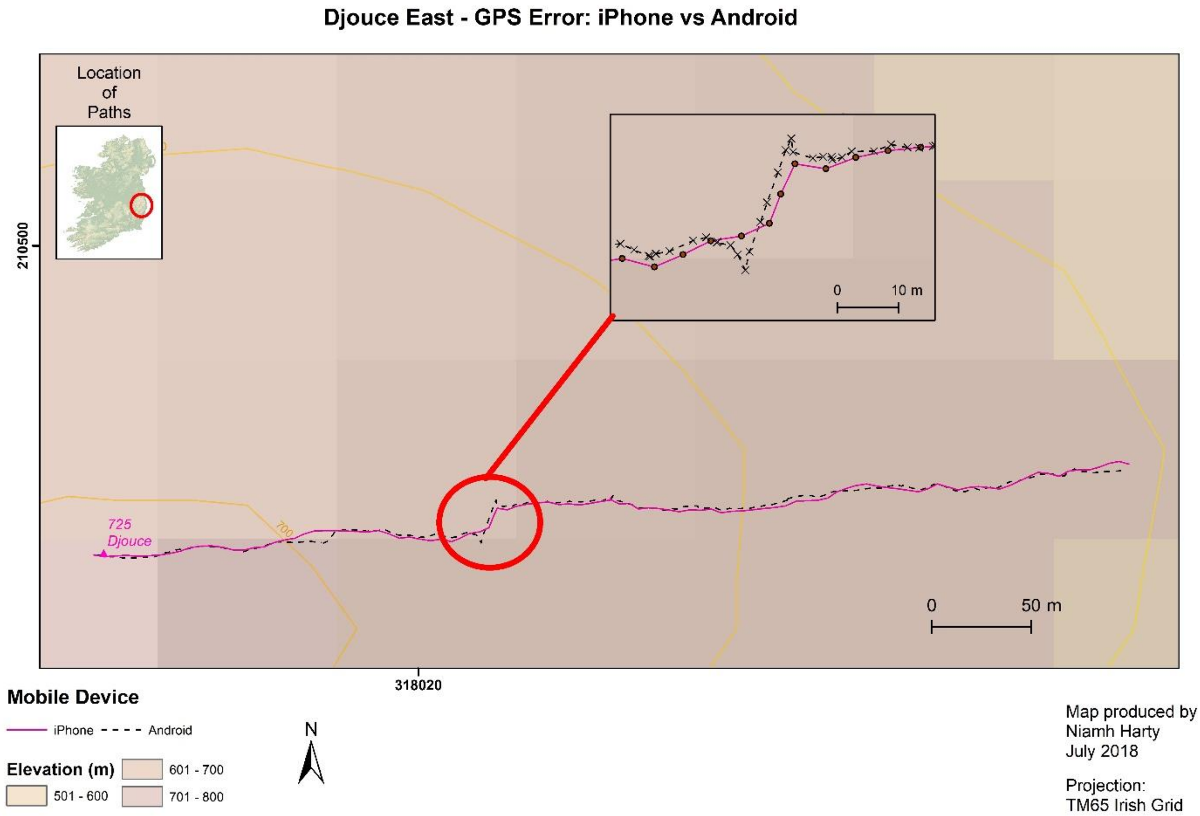

Figure 4-3 Djouce East - Paths recorded simultaneously on iPhone and Android phone

The two paths can be seen to be very similar, but not exactly the same. The full path recorded on the iPhone is 545m in length, and that on the Android is 560m. Most points along one line are within 2m of the corresponding point on the other line, though at one section the distance between the two lines is about 5m.

The Root Mean Square error (RMSE) (ITC, 2001), which is often used in GIS to calculate the difference between two sets of data points for the same location, was calculated for the two paths. A regular grid, at an angle parallel to the general direction of the two paths, was used to sample points on the paths at regular intervals, as shown in Figure 4-4. The x,y coordinates of the n sample points were used to find the vector difference between corresponding points on the two paths. At each point i, the vector has components δx_i and δy_i. The RMSE values for the x and y components for the full path, m_x and m_y, and the total RMSE value m_{total} were calculated using the following formulae:

$$m_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n} \delta x_i^2} \quad \text{and} \quad m_y = \sqrt{\frac{1}{n}\sum_{i=1}^{n} \delta y_i^2}$$

$$m_{total} = \sqrt{m_x^2 + m_y^2}$$

These calculations were carried out for three different grid widths – 1m, 2.5m and 5m. The results are presented in Table 4-4. A conservative estimate of RMSE is 1.7m, based on the three values calculated (1.61m, 1.64m, and 1.65m).

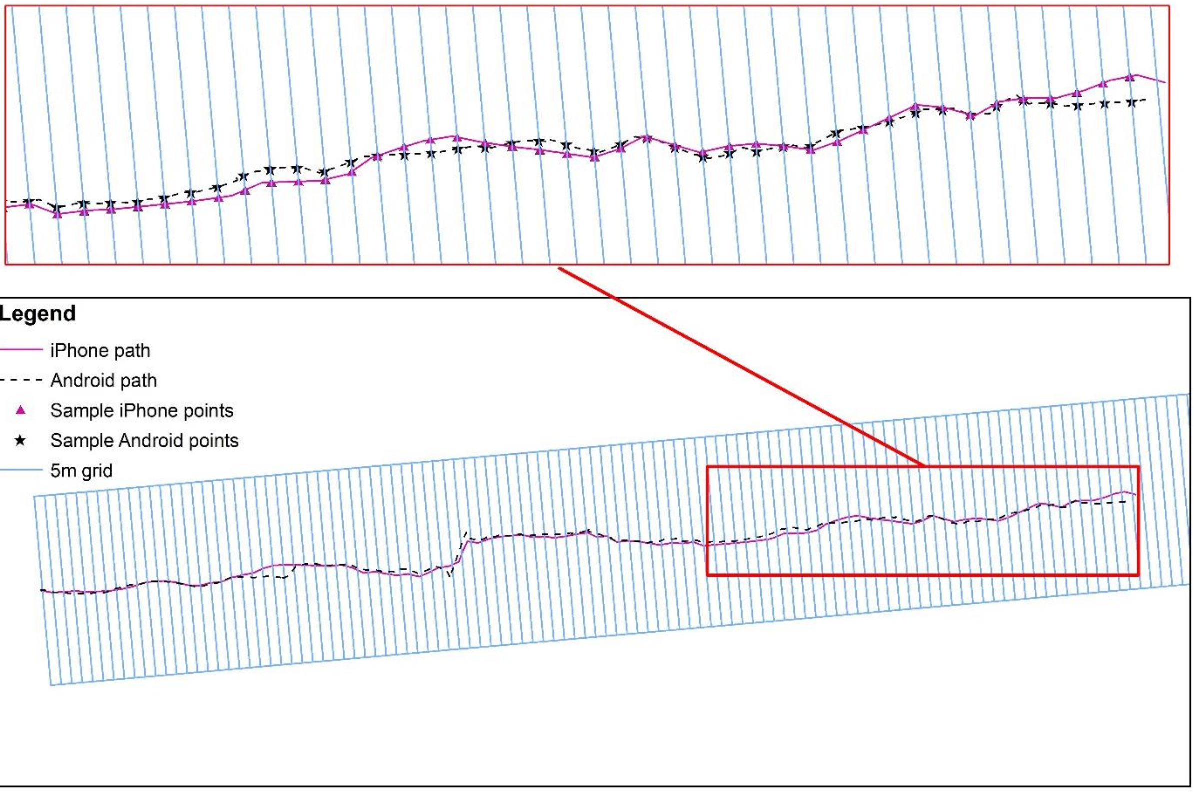

Figure 4-4 Calculation of RMSE for iPhone and Android paths

The inset in Figure 4-3 shows a section at which the path width is very large, where I tried to use the two phones to measure the width by walking from one side of the path to the other. This is shown by the diagonal lines going approximately from northeast to southwest. The width “measured” on the iPhone is 11m, and that on the Android is 23m. It was noticed in this location that the seven points recorded on the Android are seven separate points as they appear in the inset. However, the three points on the iPhone line across the path are in fact twelve points – five at one point, three at another and four at the third.

Table 4-4 RMSE values for GPS paths on Djouce East for varying grid widths

Grid width	Number of sample points on paths	RMSE x (m)	RMSE y (m)	Total RMSE (m)
5m	104	0.14	1.61	1.61
2.5m	208	0.15	1.64	1.64
1m	519	0.15	1.64	1.65

A summary of the study of the "accuracy level" field, returned by each mobile device with each GPS location on the full paths walked by the surveyors, is presented in Table 4-5.

Table 4-5 "Accuracy level" field of GPS location recorded by the mobile device [1]

Path Name	Device	No. of points with "accuracy level" <= 5m	No. of points with "accuracy level" > 5m	% of points with "accuracy level" of 5m or less	Minimum "accuracy level" value (m)	Maximum "accuracy level" value (m)	Notes
Three Rock and Three Rock Fairy Castle	iPhone6	522	1	99.81%	5.0	10	2
Maulin East - iPhone	iPhone6	2121	1	99.95%	5.0	10	2
Maulin East - Android	Android Samsung Galaxy Note 3	256	23	91.76%	3.9	54	3
PWs Seat	iPhone6	20933	1	100.00%	5.0	10	2
Oldbridge Scarr	Android_a	832	78	91.43%	3.0	522	4
White Hill Djouce	Android_b	330	4	98.80%	3.0	400	5
Maulin Tonduff	Android_a	12863	10	99.92%	3.0	1190	6
Scarr Kanturk	iPhone4	6326	330	95.04%	5.0	1238	7

Notes:

1. The mobile device records an "accuracy level" of X when it estimates that the GPS location recorded is correct to within Xm
2. Only one point with "accuracy level" of 10m - all others had 5m
3. Points with high "accuracy level" values were at the start and the end of the path.
4. The "accuracy level" value was highest at the top of Scarr (522m). The next highest values were 42m or below.
5. The "accuracy level" value was highest at one point in the middle of the walk (400m). The next highest values were 12m or below.
6. High "accuracy level" values of 1190m, 1058m, 954m, 192m, 121m, 74m, 44m and 10m were all at first location where the surveyor started recording data.
7. High "accuracy level" values of between 1238m and 274m were recorded at 19 points. High "accuracy level" values of between 50m and 10m were recorded at 311 points

Overall, the "accuracy level" was consistent on the iPhone6, with over 99.5% of points on three walks having an "accuracy level" of 5m, and the maximum "accuracy level" value was 10m. The iPhone4, used on Scarr-Kanturk, had an "accuracy level" value of 5m or less on 95% of the points, rising to an "accuracy level" value of 1.2km at one point.

The model types of two of the three Android phones used in the surveys were not recorded, so they have been designated as “Android_a” and “Android_b”. The “accuracy level” values returned on all Android phones varied across a wide range, all having a lowest “accuracy level” value of 3m and rising to highest values of 54m, 522m, 400m, and 1190m on the four paths. These phones had “accuracy level” values of 5m or less on between 91.4% and 99.9% of points on paths.

In only one instance were very clearly incorrect GPS coordinates returned for a point. The coordinates recorded were of a point about 9km away from where the surveyor actually was. The screenshot in Figure 4-5 shows the path recorded from White Hill to Djouce. Three points recorded one after the other are highlighted. Two are on the correct path, and one is on the top right of the screenshot. The “accuracy level” reported for the incorrect point was 400m.

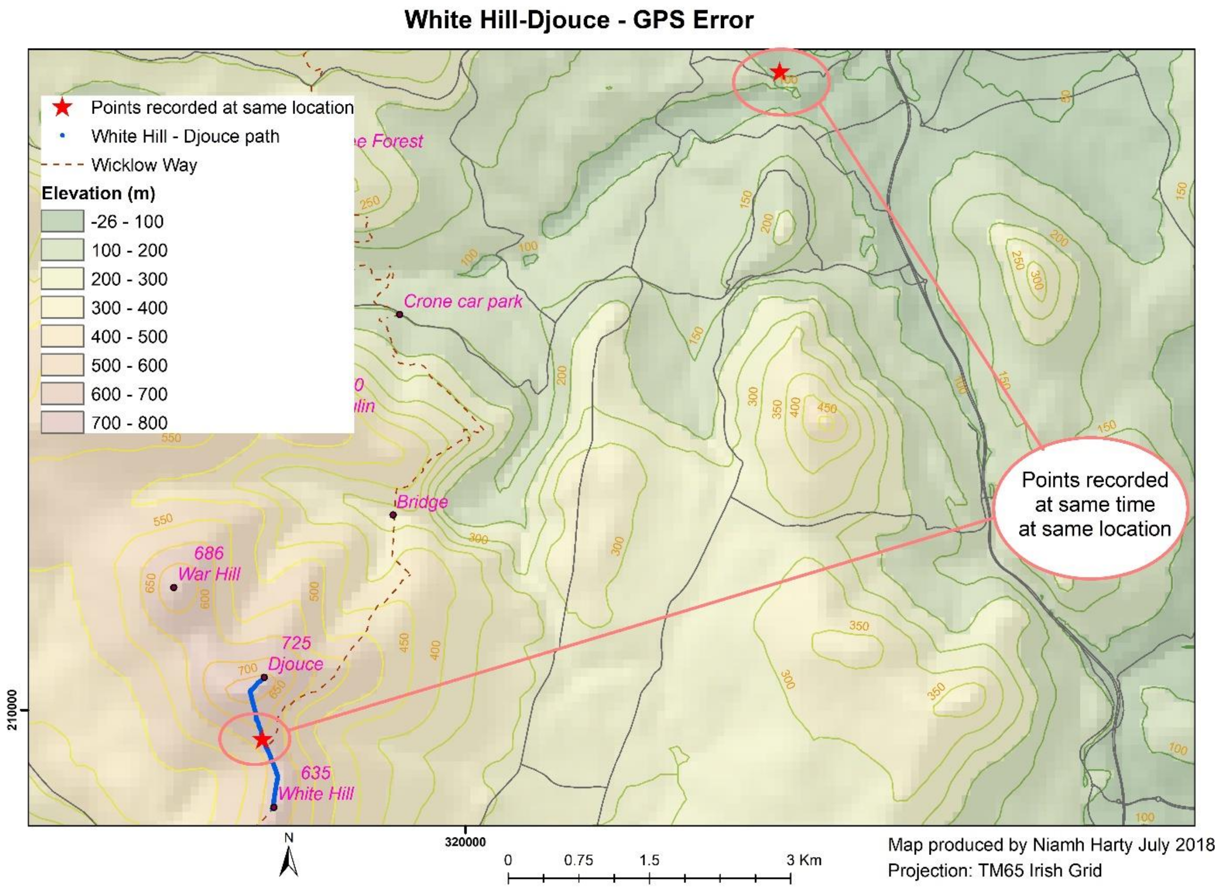

Figure 4-5 White Hill-Djouce Survey Point with Incorrect Geolocation

All other points with high “accuracy level” values had locations which were within at least 10m or 20m of the expected position (assessed by visual inspection only).

4.3 Results – RO 3: *To convert the path condition surveys of 2002/3 into a format that can be used for comparison with the current condition*

The points surveyed on twenty four paths in 2002/3 are shown in the map in Figure 2-4.

The 2002/3 path condition data was imported into ArcGIS for the eight paths surveyed in 2016/17. As an example, the condition of one point on the Maulin-Tonduff path survey report of 2002/3 is shown in Table 4-6, and the tabular data extracted for that point is shown in Table 4-7.

The data in the first six rows is administrative data which was created for the project and was not part of the 2002/3 survey report. The x,y Irish National Grid coordinates were obtained from the survey report and converted to WGS84 latitude and longitude in ArcGIS. The weather and date were obtained from the start of the survey report. The photo details refer to where the photograph is stored on the computer, and the caption and notes were taken directly from the survey report. The fields from “path type” to “water flow” were derived from the photograph (because none of this information was explicitly recorded at this point), and expressed in the same format as in HOP!. The last field is the number of the target point, indicating that this point is to be used as a target in the HOP! survey.

Further details of the conversion of the Maulin-Tonduff path condition in 2002/3 are presented in Appendix K.

Table 4-6 Maulin-Tonduff path survey 2002/3 - point 3

No	Pos Irish Grid O	Comments	Photographs
3	17903 13120	At stone wall a minor path goes straight on towards col between M and T; I followed the main path turning left (SW) up onto Maulin pic57 looking back down to stone wall shows island in centre of path; tape = 0.5m	

Table 4-7 Maulin-Tonduff path survey 2002/3 - point 3 data converted to tabular format

PathID_2002	60
Path Name_2002	Maulin Tonduff
HikerID_2002	100
SurveyID_2002	1
PointID_2002	3
HistPointID_2002	D3
x_2002	317903
y_2002	213120
Lat_2002	53.15581
Lng_2002	-6.23822
Weather_2002	Wet morning, windy and overcast
Date_2002	30/07/2002
Photo1_2002	
Capt1_2002	pic57 looking back down to stone wall shows island in centre of path; tape = 0.5m
Photo2_2002	
Capt2_2002	
Photo3_2002	
Capt3_2002	
NotesPt1_2002	At stone wall a minor path goes straight on towards col between M and T; I followed the main path turning left (SW) up onto Maulin;
NotesPt2_2002	pic57 looking back down to stone wall shows island in centre of path; tape = 0.5m
PathType_2002	Evolved line
PathSurface_2002	Grass / Stone
BareWidth_2002	1.5
TrmpldWidth_2002	0
Depth_2002	0
Braiding_2002	Single Path
Muddiness_2002	Dry
WaterFlow_2002	No water flow
Target in HOP	1

4.4 Results - RO 4: *To determine the condition of the WMNP hiking paths today, and to compare it with the condition in 2002/3*

Eight of the twenty four paths surveyed in 2002/3 were surveyed with the HOP! app by five data collectors in 2016/17. The overall condition of these paths, recorded with the app, is shown in the maps in Figure 4-6, the change in overall condition since 2002/3 is shown in the maps in Figure 4-7, and points at which one or more of the impact variables has deteriorated since 2002/3 are shown in the maps in Figure 4-8. Detailed maps and descriptions for all surveys are presented in Appendix L. A summary of the path conditions is presented in the form of descriptive statistics in Table 4-8. The overall quality of each path is presented in Table 4-9, and Table 4-10 summarises the average path width and path depth.

Table 4-8 shows the number of points surveyed on each of the eight paths, and summarises the overall condition in 2016/17, changes (if any) in overall condition since 2002/3, and deterioration in any indicator (if any) since 2002/3. These are based on the scoring systems and assessment methods described in Section 3.4.

In total, 100 points were surveyed. 84% of these had an overall condition score in 2016/17 which was “fair” or better, while 16% had an overall condition score which was “poor” or “very poor”. While 60% of the locations surveyed showed some improvement or no change in overall condition since 2002/3, 40% had a disimprovement. 71% of the points surveyed had deteriorated in some way – path widening, deepening, braiding, muddiness, or water flow.

Table 4-9 provides an estimate of the overall quality of each path. It shows the average overall condition score of each path as measured in 2016/17 and 2002/3, together with the change between 2002/3 and 2016/17. The standard deviations are also included. The table also shows the number of points per kilometre which were surveyed in 2016/17.

Six of the eight paths showed a disimprovement in overall path quality since 2002/3, with the scores increasing by values ranging from 0.15 to 1.20. In 2002/3, the path quality values ranged from 0.50 to 1.89 with four of the eight paths having a value less than 1.00. In 2016/17 the values ranged from 0.50 to 2.00, with only one path having a value less than 1.00. The path from Three Rock to Fairy Castle has the best overall quality in 2016/17 (0.50) and has improved since 2002/3 when it had an overall score of 1.33. However, the standard deviation of 0.76 in 2016/17 shows that the quality is not consistent along the path. The overall quality of one other path also improved, but by a smaller amount – the Prince William's Seat path improved from 1.89 to 1.78, and the standard deviation of 1.23 in 2016/17 shows significant variation in quality along the path. Maulin to Tonduff has the worst overall quality (2.00) and has disimproved since 2002/3 when it had a score of 1.23. The standard deviation in 2016/17 of 1.24 indicates large variation in quality along the path.

The average values of path width and depth, together with standard deviations, are shown for each path in Table 4-10. The values in 2016/17 and 2002/3, and the change since 2002/3 are presented.

Four of the eight paths had an average path width in 2016/17 of 4m or more, with standard deviations ranging between 1.77m and 3.17m. For three of these paths, there has been a disimprovement since 2002/3, with the average path width increasing by 1.35m, 1.76m, and 1.98m. The average depth of all paths was between 0.00m and 0.47m in 2016/17, with standard deviation ranging between 0.00m and 0.60m. Seven of the eight paths had an increase in average path depth since 2002/3, with increases ranging from 0.02m to 0.41m.

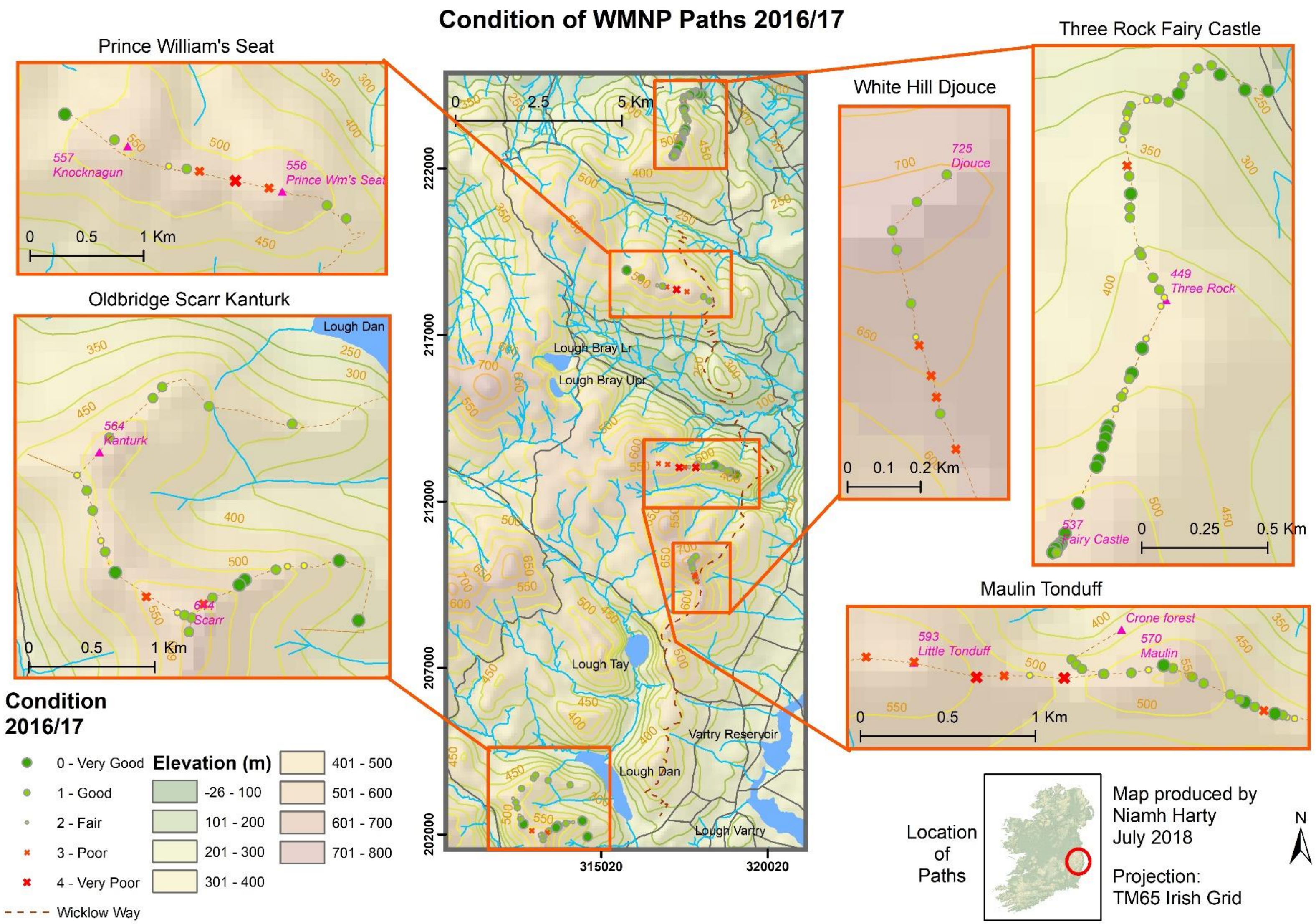

Figure 4-6 Path Condition in WMNP in 2016/17 as recorded with the HOP! app

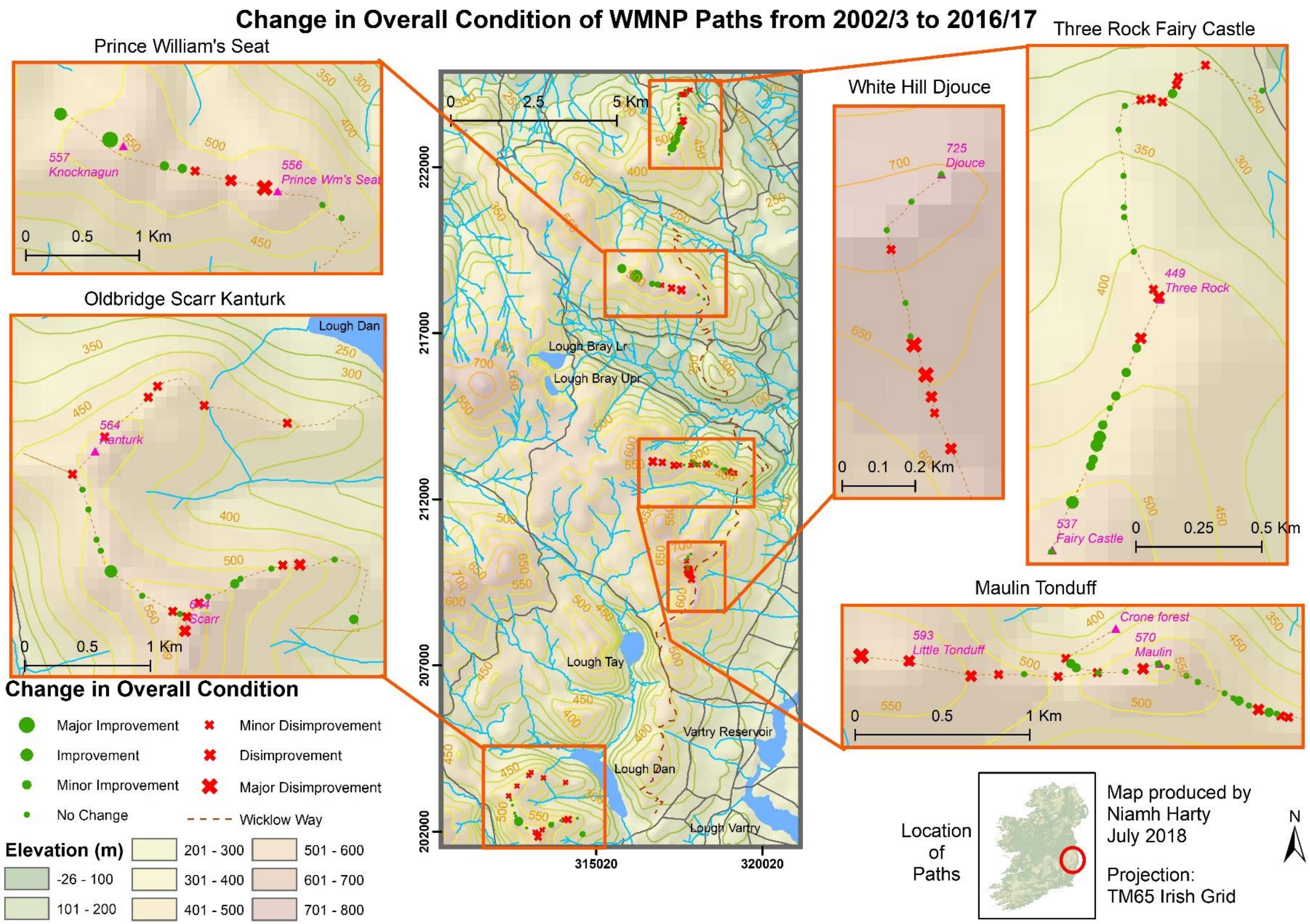

Figure 4-7 Change in Overall Condition from 2002/3 to 2016/17

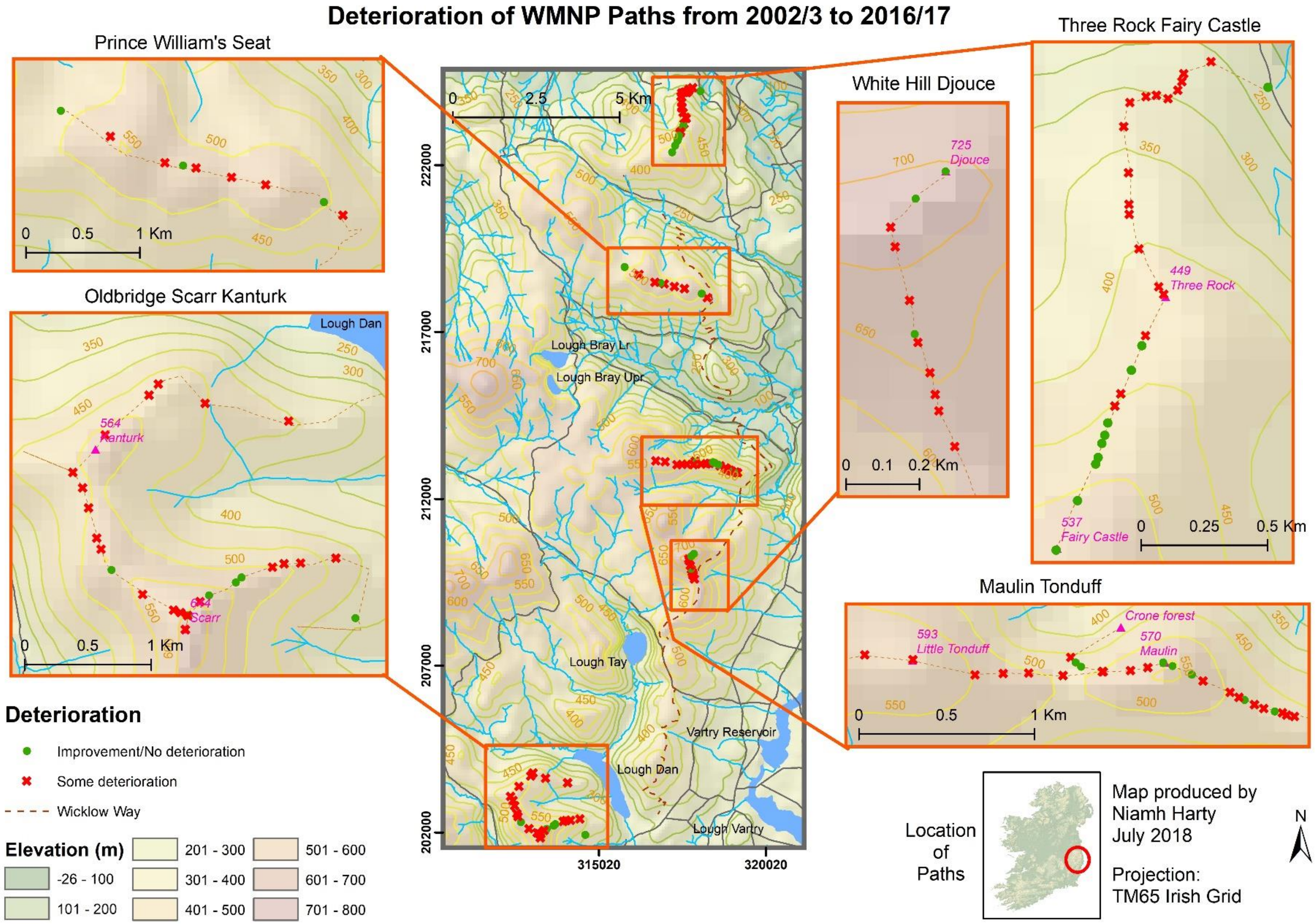

Figure 4-8 Deterioration in Condition from 2002/3 to 2016/17

Table 4-8 Descriptive Statistics for Path Condition in 2016/17 vs 2002/3

Path	Number of points surveyed in 2016/17	Number of photos taken 2016/17	% points with very good, good, or fair overall condition in 2016/17	% points with poor or very poor overall condition in 2016/17	% points with improved or no change in overall condition since 2002/3	% points with disimproved overall condition since 2002/3	% with no deterioration since 2002/3	% with some deterioration since 2002/3
Three Rock	16	23	100%	0%	50%	50%	6%	94%
Three Rock Fairy Castle	12	23	100%	0%	92%	8%	75%	25%
Maulin East	13	18	92%	8%	77%	23%	38%	62%
Prince William's Seat	9	9	67%	33%	67%	33%	33%	67%
Oldbridge Scarr	11	16	82%	18%	55%	45%	36%	64%
White Hill Djouce	10	20	60%	40%	40%	60%	20%	80%
Maulin Tonduff	13	20	62%	38%	46%	54%	23%	77%
Scarr Kanturk	16	32	94%	6%	56%	44%	13%	88%
SUMMARY	**100**	**161**	**84%**	**16%**	**60%**	**40%**	**29%**	**71%**

Table 4-9 Path Quality based on average overall condition score in 2016/17 vs 2002/3

Path	Number of survey points in 2016/17	Length surveyed (km)	Points surveyed /km	Path Quality				
				2016/17		2002/3		Change
				Average Score	Std. Dev.	Average Score	Std. Dev.	Average Score
Three Rock	16	1.40	11.43	1.00	0.50	0.50	0.50	0.50
Three Rock Fairy Castle	12	1.10	10.91	0.50	0.76	1.33	0.62	-0.83
Maulin East	13	0.85	15.38	1.15	0.77	1.00	0.00	0.15
Prince William's Seat	9	3.30	2.73	1.78	1.23	1.89	1.10	-0.11
Oldbridge Scarr	11	2.70	4.07	1.27	1.14	0.82	0.57	0.45
White Hill Djouce	10	0.85	11.83	1.80	0.98	0.60	0.49	1.20
Maulin Tonduff	13	3.44	3.78	2.00	1.24	1.23	0.97	0.77
Scarr Kanturk	16	5.50	2.91	1.25	0.66	0.94	0.83	0.31

Table 4-10 Average width and depth on each path in 2016/17 vs 2002/3

Path	2016/17				2002/3				Change			
	Width (m)		Depth (m)		Width (m)		Depth (m)		Width (m)		Depth (m)	
	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
Three Rock	2.00	1.34	0.07	0.09	1.55	0.98	0.03	0.08	0.45	1.51	0.04	0.09
Three Rock Fairy Castle	2.25	1.48	0.00	0.00	5.00	2.31	0.01	0.03	-2.75	3.03	-0.01	0.03
Maulin East	4.04	2.27	0.02	0.08	4.08	2.64	0.00	0.00	-0.04	1.97	0.02	0.08
Prince William's Seat	3.19	2.75	0.19	0.33	2.06	0.37	0.17	0.24	1.13	2.79	0.02	0.48
Oldbridge Scarr	3.56	1.41	0.12	0.28	2.73	2.41	0.01	0.02	0.84	2.36	0.11	0.28
White Hill Djouce	5.81	1.77	0.35	0.60	4.05	2.46	0.00	0.00	1.76	1.46	0.35	0.60
Maulin Tonduff	4.72	3.17	0.47	0.59	2.73	2.02	0.06	0.15	1.98	2.08	0.41	0.64
Scarr Kanturk	4.13	2.04	0.09	0.12	2.78	2.43	0.00	0.00	1.35	1.60	0.09	0.12

As part of the participatory aspect of this project, the survey results and maps were shown to a number of stakeholders and their feedback was requested. Details of these meetings are in Appendix M.

The District Conservation Officer and a number of her colleagues in WMNP made the following observations:

- All of the different types of maps produced with the data collected using HOP! are very valuable to park management.
- The simple green-yellow-orange-red scoring system to indicate the condition is approximate but effective.
- Comparison of the current condition with that recorded in 2002/3 provides very important information.
- The inclusion of muddiness and water flow in the scoring system could lead to distortion depending on the weather at the time of the survey. Width, depth and braiding on their own give a good indication of the state of a path.

Mountain Meitheal members stated that the comparisons with earlier conditions were useful. They were, however, far more interested in seeing the details of the actual width, depth and braiding of the paths, rather than the condition scores. They do not have any interest in the other details such path type and surface.

A National Trails Office GIS expert said that the map showing all paths with their current condition would be useful and would enable prioritisation of maintenance work.

In order to assist in the investigation of some of the errors which arise in the comparison of the 2016/17 data with the 2002/3 data, the distance between the target point set for the surveyor based on the 2002/3 survey coordinates and the point at which the condition was actually recorded in 2016/17 was calculated for each point on each path. The results are summarised in Table 4-11. This table shows how far away, on average, the volunteer surveyor was from the target point set in the app. The surveyor on the Maulin Tonduff path was closest to the target point most of the time, and was within 4m on average with a standard deviation of 2.2m. The farthest away he was from the target was 9.6m. Most of the others were on average over 10m away from the target and on occasions over 30m away. A number of the volunteer surveyors reported that they thought some of the target points on the app were incorrect and were off the path they were surveying.

Table 4-11 Distance between target point and point at which condition was recorded in 2016/17

Path	Average distance from target (m)	Maximum distance from target (m)	Minimum distance from target (m)	Std. Dev. (m)
Three Rock	11.6	24.6	3.5	5.9
Three Rock Fairy Castle	13.0	40.6	2.0	10.9
Maulin East	12.9	21.4	2.2	5.5
Prince William's Seat	10.7	23.1	1.8	7.4
Oldbridge Scarr	6.8	21.1	1.4	6.2
White Hill Djouce	11.2	41.2	2.0	11.6
Maulin Tonduff	4.2	9.6	1.5	2.2
Scarr Kanturk	18.3	45.8	2.3	15.0

Chapter 5 Discussion

This chapter presents a discussion of the results for each research objective.

5.1 Discussion – RO 1: *To develop an app to collect data on hiking path conditions in WMNP, based on a PGIS and citizen science approach*

5.1.1 RO 1 – The app

The HOP! app allows volunteer data collectors to easily record path condition through a simple user interface, which is optimised for use on mobile devices. In addition to recording the condition at specified locations, the app records the full path of the surveyor. This full path data has a number of uses, including providing the potential to calculate the slope of the ground walked along, and to provide maps of paths in the park.

The usability of the app is assessed below, in terms of Preecec's usability goals cited by Ekstedt and Endoff (2012), and in terms of the attributes listed by Harrison et al. (2013):

Effectiveness: With HOP! the user can record the required survey data on their own iOS or Android mobile device at specified locations. Some technical issues need to be resolved.

Efficiency: HOP! is quite efficient, but it can be repetitive because sometimes it requires the same data to be input several times.

Satisfaction: The user can see the useful data he/she is recording and all volunteers were happy to have taken part in the project. The email of data and the manual transfer of photographs are parts of the process with which users would prefer not to have to be concerned.

Learnability: Users found HOP! very easy to learn how to use, though they said afterwards that training would help to improve the quality of the data recorded.

Memorability: Users should be able to remember how to use the app from one survey to another. The app has information buttons for most of the options in the app, but many of these are not complete.

Safety: The app is safe to use, but there is a risk that the mobile device could be dropped as the surveyor is walking over rough terrain.

Errors: There are some technical bugs in the app which resulted in the loss of data on one survey. The data recorded by the volunteers may include GPS errors and errors due to lack of training. The errors are discussed in more detail in Sections 5.2.3 and 5.4.

Cognitive load: The app is so easy to use that it does not noticeably affect the user's ability to multi-task.

The use of PhoneGap to build the app proved to be a good decision. The use of only HTML, JS, and CSS was a great benefit, although it was essential to also learn and use JQ and JQM to efficiently produce a usable app. In particular, the functionality provided by JQM (e.g. sliders and radio buttons) was excellent. In addition to the relative ease of coding, another advertised benefit of PhoneGap is that the same code can be used to produce an app which works on several different mobile platforms, and this was found to be true. A third advantage of PhoneGap is that the cost of development was very small – the only cost was the Apple Developer annual registration fee of €99.

Using open source software for development has the benefit that it is used by a huge community of developers who are very generous with their knowledge and expertise. Most issues which arose during app development were solved by referring to the online forums.

The one major problem I encountered with PhoneGap related to the use of external plugins to extend the functionality. Plugins are an essential part of working with PhoneGap. There are many basic plugins which caused no problems, but some of the specialised ones did. These were the plugins to enable the app to send an email with attachments, to record the Exif data with a photograph taken with the camera, to allow the phone to continue recording the location when in background mode, and to send notifications when in background mode. The problems which arose with these plugins were that they were not always updated when PhoneGap or the phone operating systems were updated, which occurs regularly. After most upgrades, the app code had to be tested and sometimes updated, and occasionally sections of code had to be substantially re-written. Also, some of these specialised plugins work only on certain devices, and so the cross-platform benefits of the PhoneGap app are lost if one uses a plugin which works on an iPhone and not on an Android device.

Another issue which I had with developing the app was my unfamiliarity with the concept of asynchronous coding, which is a key feature of JQ and JQM. It was very difficult to get used to, because of my history with synchronous programming. In asynchronous coding, the computer program does not wait until one line of code has completed all of its processing before moving on to the next line, and this requires a very different approach to programming.

The use of mobile technology to collect data on path condition was successful, to varying degrees, on all of the eight path surveys. The only time that data was totally lost was on the survey of the last path, but fortunately the surveyor had done a preliminary survey a few days earlier and the data from it had been saved. The problem of Google Maps not working due to lack of access to the internet is also serious and could jeopardise general use of the app. The issue of the email of the data from the app not working was not as serious, because the data was recovered later by other means.

The inclusion of the notifications required a lot of extra coding and specialised PhoneGap plugins. It was interesting to note that the notifications were not used by all surveyors, and that some preferred to self-locate.

5.1.2 RO 1 – PGIS and citizen science

An essential element of this project is the recruitment of volunteers to collect the path condition data. The experience of this employment of citizen science was very positive. There was no shortage of volunteers, and the willingness of one of them to do several more surveys was very encouraging. This reflects his positive experience on the first survey he did. It is possible that his competence with technology is an important factor in his success using the app alone.

The feedback from the volunteer surveyors after each survey was constructive, because it comprised positive comments (ease of use and good bird sound), suggestions for improvements (target points not too close together), and recommendations for future use (do survey on a dedicated walk, do not survey on a short winter's day, bring battery pack and a walking pole). The comment on the difficulty of using the app in bright sunshine is worth pointing out to future users. The quality of the comments demonstrates the commitment of the volunteers and implies their belief in the usefulness of their surveys. There were no negative comments.

The feedback from the DCO and colleagues when they reviewed the app for the last time was also very positive. The fact that they could see the potential for using the app for their own monitoring activities in the park, as well as for path condition monitoring, means that they see a huge benefit in being able to use a simple app on a mobile device to obtain geolocated data records of many park phenomena.

5.2 Discussion – RO 2: *To compare the path condition data collected using PGIS and citizen science with that collected by a professional surveyor in 2002/3*

5.2.1 RO 2 – Path condition data

The data collected using HOP! is all in tabular format and is therefore much easier to import into a GIS than the 2002/3 surveys reports.

Neither the 2016/17 surveyors nor the 2002/3 surveyor reported every indicator at every point. For many points, in both sets of surveys, the photographs of the point are the only record of condition, and these were used to estimate indicators such as path width, depth and braiding. So long as the photograph contains a hiking pole of known length, reasonable estimates of the indicators can be made.

5.2.2 RO 2 – PGIS and citizen science

It is encouraging to note that the DCO sees the data collected using HOP! as very useful to the WMNP management, even though the amount of data collected and the level of expertise in the surveys is limited. This indicates that the PGIS approach to survey design was successful and resulted in a useful way for volunteer surveyors to survey hiking paths.

All of the volunteer surveyors took at least one photograph at each target point and it was clear that they found this easier to do than to write notes and fill in the other condition data.

These geolocated photographs are key elements of the data collected, but two issues arose in relation to their value and relevance. They are:

i. The location of the point from which the photograph should be taken needs to be clarified. Should the photograph be taken *at* the point at which the measurements are taken, or should the photograph be *of* the point for which the measurements are recorded? In the 2002/3 surveys, both approaches were used.
   Sometimes, the photograph associated with a point was taken about five or ten metres from the point at which measurements were recorded, as seen in the photograph taken on the White Hill-Djouce path (on the right in Figure 4-2). It is seen in the 2003 caption that the path width of 3m is the width at a point in the centre of the photograph, and not at the point at which the photograph was taken.
   At other times, the photograph was taken from the point at which measurements were recorded, as shown in the two photographs from the 2002/3 PWS report in Table 4-3. The photographs were taken from the same point, one looking up the path and the other looking back down the path.
ii. The geolocated photographs taken with HOP! are valuable records of the current condition at known locations, but they are only useful in the comparison with the condition in 2002/3 if they are taken from the same point as those photographs taken in the earlier surveys, and in the same direction.

The data collected by the citizen scientists carrying out the surveys in 2016/17 was valuable, but the fact that they did not collect all the requested data at each point requires investigation. There are two probable reasons for this:

a. The first is that the volunteers received only a brief user manual and the 2002/3 survey report, and had no training on what they were looking for and how they could best record the path condition. They did not understand the importance of recording as much information as possible. It was decided that full training would not be feasible on this project, nor would it be necessary because its purpose was as a pilot study. The fact that, after they had conducted a survey, the volunteers saw the need for training is worth noting.
b. The second probable reason for the lack of full recording at each point was the length of time required to record all the data, which the volunteers pointed out to be an issue. The calculations showed that users spent about three and a half minutes recording most of the required data without notes or captions to photographs. Therefore, one might infer that if complete data was recorded at a point – including captions and notes – it should take about five minutes per point.

5.2.3 RO 2 – Error analysis

The errors in the data which occur in the measurements of path width and depth, and the GPS coordinates of the points, for both the 2016/17 and 2002/3 surveys are discussed here.

Errors in path width and depth measurements

In 2002/3, the professional surveyor used a measuring tape to measure path width and depth, and therefore it may be assumed that the measurements could have been recorded to within approximately 10mm. However, in his surveys, he usually recorded the width to the nearest 0.5m or 1m, and often expressed the width as a range (e.g. 3-4m). The implication is that widths do not need to be recorded to a greater degree of precision than 0.5m. The depth measurements in his surveys were recorded to the nearest 0.1m.

In some cases, the measurement recorded in the survey appeared to contradict the accompanying photograph. For example, a photograph taken at point R8 on the White Hill-Djouce survey (shown in Figure 5-1) appeared to show a path width different to that recorded. The text in the survey report says: "…. looking up shows the path ahead, damaged vegetation on the left, stone in the middle, bare peat on the right; tape = 1m; total path width = 11m"

In the photograph, the path width looks as if it is about 5.5m at the most, and not 11m. It is possible that the width was calculated for a tape length of 0.5m and not 1m. This apparent doubling of path width was observed at several points in this particular survey. On this project, the path width was taken to be 5.5m at this point.

Figure 5-1 White Hill-Djouce Path Width in 2002/3

The surveyors using HOP! used a hiking pole of approximately 1m in length to estimate the path width. It is reasonable to assume that, using this method, they can estimate the path width to within 0.25m, which is a quarter of the length of the hiking pole. The surveyors judged the path depth by eye, and this is probably correct to within 0.15m, which is half of the length of a 0.30m ruler with which most are familiar since childhood. The DCO was satisfied with the magnitude of the errors in the HOP! measurements. The path width and depth typically vary significantly along its length, and measurements within 0.25m (width) and 0.15m (depth) are acceptable and useful. However, the width and depth measurements recorded with the app are expressed to the nearest 0.1m. This results in misleading values, particularly of width, because it gives the impression of far greater precision than is likely to be possible or useful.

Errors in GPS coordinates

The GPS coordinates recorded using HOP! are device-dependent and not user-dependent, so the only errors will be introduced by the device and the GPS system. The test to compare the paths recorded simultaneously on two different mobile devices gave an RMSE of between 1.6m and 1.7m. This indicates that most points measured on the two devices were within 1.7m of each other, and there is a very good correlation between the locations recorded on the two devices. A conservative estimate of RMSE of 1.7m means that the data quality is acceptable, but the test was a simple standalone one, on a single path about 550m long, and the reliability of these results cannot be generalised for the whole project.

In GIS, location errors between measured points and true positions are often estimated using the Root Mean Square error. RMSE was used here to compare measurements on two difference devices, and the true location was not known. The calculation of the RMSE did not use the difference vectors between data points recorded at the same location, because the devices did not record at exactly the same time along the path. The grid system used to divide the paths obtained from the data points recorded adds an approximation to the RMSE calculation. It is approximately parallel to the overall direction of the path. This method was only possible because the path was a straight one. The RMSE values calculated for the different grid widths are close to each other, indicating that the calculation was not very sensitive to the grid width and sample size.

The attempt to use GPS coordinates to measure the path width at one point on the path gave values of 11m and 23m on different phones. From this, it is clear that GPS coordinates recorded by a mobile device cannot currently be used to estimate the path width.

The study of the "accuracy level" value returned by the mobile devices with each GPS location recorded showed that this value has very limited usefulness (if any) in the estimation of the errors in the GPS coordinates returned. High "accuracy level" values recorded by the mobile device rarely corresponded to point locations which appeared to be far out of line with other points on the path, apart from one case. When the app recorded the coordinates of the point as being 9km away from the actual location, the condition of the path was being recorded at the same time. It is possible that some coding issue in the app caused the geolocation to be incorrectly recorded. The results suggest that the actual value of the "accuracy level" is not useful, but it is possible that values higher than the minimum may indicate when a value is not reliable.

The phone with which the user had problems of the app crashing repeatedly recorded a very high "accuracy level" value of 1.2km at one point, even though the coordinates of the point appear to be in line with the path on which the user was surveying. The app crash and the poor "accuracy level" may be related.

The 2002/3 reports were fit for purpose, but were not designed to be used as input data for an app or a GIS. Furthermore, the DCO stated that the GPS coordinates recorded in the 2002/3 surveys were not as accurate as the GPS coordinates available on mobile devices today, and this adds an additional error to the 2002/3 point locations. This error cannot be estimated.

5.3 Discussion– RO 3: *To convert the path condition surveys of 2002/3 into a format that can be used for comparison with the current condition*

The conversion of the routes of twenty four of the paths surveyed in 2002/3, together with the condition of eight of them, from textual reports into ArcGIS shapefile format, resulted in a very useful set of maps for WMNP.

A considerable amount of work was required to prepare the data for each new path survey. The 2002/3 condition had to be converted to Excel format and suitable targets had to be identified. As experience was gained in this task, and the data structure was finalised, the required preparation time reduced. App preparation took about one day per path for the last two path surveys.

The method of selecting target points evolved during the project. Initially, all points surveyed in 2002/3 were set as targets in the app. However, the number of targets per path was reduced to ten after the first few surveys, because it was found that the time required to record data at each target was considerable, and ten was thought to be a reasonable number to ask the volunteers to survey. A number of factors were taken into consideration when selecting the ten target points for a path. The points chosen as targets were points:

- which were not too close together, as suggested by the volunteers on the early surveys
- at which the condition appeared to be different from others, and representative of the points close by
- which had full precision coordinates in the 2002/3 surveys

The 2002/3 data which was to be used as baseline data for the 2016/17 surveys was not 100% reliable, because so much estimation and interpretation had to be performed, but it was decided that it would be adequate for this pilot study.

5.4 Discussion– RO 4: *To determine the condition of the WMNP hiking paths today, and to compare it with the condition in 2002/3*

The 2016/17 survey results have been used to present various aspects of the current path condition and the change in condition since 2002/3 in the format of maps and descriptive statistical summaries. A number of ways of presenting the path condition in GIS have been used. The formats of the summary and detailed maps were decided on after many iterations, and the production of these maps for each path is now a routine operation.

The overall condition score gives a high level assessment of path condition at each point and it is heartening to see that 84% of points were in "fair" condition or better in 2016/17. More worrying is the statistic that the condition of 40% of the points have disimproved since 2002/3. The deterioration scores indicate that actually 71% of the points have deteriorated in some way. Each view of the data gives useful information. It is evident that there has been general deterioration in the last fifteen years, but that in most cases it is not yet led to many points having "poor" or "very poor" overall condition.

A review of the quality of each path as a whole provides a different view of the data. One would expect to see a general trend of deterioration after a period of fifteen years on the paths, and this is what was observed on six of the eight paths. Therefore, one should seek an explanation for the marked improvement in the overall condition of the path from Three Rock to Fairy Castle from an overall score of 1.33 in 2002/3 to a score of 0.50 in 2016/17. This change is undoubtedly due to the major work which was done on sections of the path in the intervening period, with surface improvements and re-direction of hikers back to the main path. Further details are in Appendix L.3. The small improvement on the Prince William's Seat path from 1.89 to 1.78 is small and not significant.

The average widths and depths for each path also provide useful detailed information. The fact that the paths with average width over 4m have widened by at least 1.35m in the last fifteen years is cause for concern.

A number of different scoring systems were explored before settling on the ones outlined in Section 3.4. Any scoring system will be a bit arbitrary and small changes in the values of the impact variables may or may not have a significant effect. In spite of this shortcoming, the DCO thought that the maps using the scoring systems were very useful to the park, and that the fact that the score is only an approximation was acceptable. The distortion caused by including the muddiness and water flow, which are weather dependent, in the score was noted. However, because the weather had been very dry before and during most of the surveys in 2002/3 and 2016/17, their inclusion actually only affected the score on the Three Rock and Oldbridge-Scarr paths.

The comments from the MM volunteers, suggesting that changes in actual path widths, depths and braiding would be more useful on maps than the condition scores, led to the production of additional maps for each path. These provide a different valuable view of the same information.

It was established in Section 5.2.3 that the errors in the key 2016/17 data (path width, depth, and GPS location) are acceptable. However, when comparing the current condition with that in 2002/3, additional significant errors are introduced. There are two sources for these errors:

i. The inaccuracy and lack of precision of the GPS locations of some of the target points, obtained from the 2002/3 survey reports, resulted in some data being recorded in 2016/17 at different locations to where it was recorded in 2002/3. This was only discovered when the data from the two time periods (2002/3 and 2016/17) were viewed together in ArcGIS. The extent of the problem has not been established.
ii. The volunteer surveyors were often quite far away from the target point set for them in the app, as shown in Table 4-11. The surveyor on the Maulin Tonduff path has the best record, being within 4.2m on average, and at most only 9.6 m away. The fact that a number of volunteers stated that they thought the target points were incorrect and were not actually on the path could be the explanation for the significant distance between the target and the point at which the condition was recorded.

The result of both of these issues is that the maps which show the change in condition may not be correct at all, because the condition recorded in 2016/17 may be the condition at quite a different location to that where it was recorded in 2002/3.

Even if the locations at which the condition was recorded in 2016/17 and 2002/3 were the same, much of the baseline 2002/3 data was not explicitly written in the survey reports, and had to be estimated from them, and this is another source of error.

Finally, it should be noted that the results for the Scarr-Kanturk path are a combination of the results recorded on two surveys, but the errors introduced by this should be minimal.

Chapter 6 Conclusions

The aim of this research is to design an app to collect data on the condition of hiking paths in WMNP using a PGIS approach combined with citizen science, and to compare the current condition with that recorded in 2002/3 surveys. The conclusions for the four research objectives are presented in this chapter.

6.1 Conclusions – RO 1: *To develop an app to collect data on hiking path conditions in WMNP, based on a PGIS and citizen science approach*

6.1.1 RO 1 – PGIS and citizen science

The use of a PGIS and citizen science approach to develop the app was very successful on this project. The expertise of the District Conservation Officer of Wicklow Mountains National Park, other path managers, and the experience of the hillwalkers were incorporated into the app by using the suggestions, advice, and comments elicited through the participatory research techniques of informal semi-structured interviews and focus groups, together with feedback and regular reviews. Hillwalkers acted as citizen scientists to collect data using the app, with varying levels of success. It is important to note that the function of the app as a tool to be used by citizen scientists to conduct a formal re-survey of the paths was specified by the DCO, in preference to a possible VGI approach of allowing all hillwalkers to report path condition issues whenever they found them. Establishing this important aspect of the app at an early stage was key to the success of the project, and may be attributed to the participatory research approach adopted.

This project has shown the potential of PGIS and citizen science as an approach to the monitoring of path conditions by non-professionals. A full campaign of recording path conditions in WMNP using HOP! is a feasible proposition. Experience indicates that it would be possible to get volunteer surveyors without difficulty. An in-depth study of successful citizen science projects should be carried out before launching a formal campaign. The lessons learnt on other projects should help to make the WMNP project successful. Publicity is essential, and the use of social network sites such as Facebook should be part of it. This has already started - the recording of the White Hill-Djouce survey was recorded on Facebook, as shown in Figure 6-1. Hillwalkers from other clubs should be encouraged to participate, and the idea of a hillwalker "adopting" a path (or paths) should be explored. This research project has looked only at the paths in WMNP, but the idea could be used throughout the country, if the program in WMNP is successful.

The varying levels of success of the volunteers using the app should be explored further. In particular, the relationship between the technical aptitude of the volunteers, their success with the app, and the results they collect should be investigated, especially because of the very different results of the two volunteers who did their surveys alone.

Figure 6-1 Publicising the project on Facebook

6.1.2 RO 1 – The app

The objective to develop an app which citizen scientists could use to collect path condition data was achieved. The app was deemed to have satisfied most of the usability goals identified by Preece and Harrison. The use of the open source PhoneGap software resulted in an app that could be used on the majority of mobile devices in Ireland (iOS and Android). The use of JQuery and JQuery Mobile, together with design suggestions from a professional designer, resulted in a good-looking user-friendly app which has all the functionality to which app users are accustomed.

The app still has a few technical problems which should be resolved. In particular, the issue which caused the app to crash on the last survey will have to be investigated. Volunteers will be less inclined to help on this project if they think the app is unreliable and that they risk losing all the data they carefully collect.

In addition, the following improvements should be made to the app:

- Remove the reliance on Google Maps and the requirement to be online while using the app.
- Send recorded data and full-size photographs to the cloud when online, instead of using email, so that the user does not have to be concerned with the transfer of the survey data.
- Consider the removal of notifications of closeness to target points to simplify the coding.
- Modify the app to use only the most standard PhoneGap plugins, to reduce the work required after each upgrade of PhoneGap or phone software.

6.2 Conclusions - RO 2: *To compare the path condition data collected using PGIS and citizen science with that collected by a professional surveyor in 2002/3*

6.2.1 RO 2 – Path condition data

In terms of identifying the path condition data which can be collected by amateur surveyors using an app and comparing it to the data collected in 2002/3, this objective was achieved fully.

As recommended by Marion and Leung (2011), the volunteer surveyors (citizen scientists) collect only objective data and make no subjective observations. Geolocated photographs are taken at each survey point. These include a hiking pole to assist in judging scale, and may be used later, either to verify some of the data recorded or to enable the addition of unrecorded data after the survey. The use of pre-determined points at which the condition is recorded removes the requirement for a professional surveyor's expertise. The path condition data collected has a structured and consistent format which is easily viewed in a GIS, unlike the professional surveyor's reports which were designed only to be read.

The data collected using HOP! is a subset of the full data collected in the professional surveys of 2002/3. The data collected does not replicate the professional surveys, but provides very useful information when no professional surveys can be carried out. As recommended by York (2015), this data, if collected frequently by volunteers, could greatly assist in the monitoring, and ultimately the long term sustainable management, of the hiking paths in WMNP.

6.2.2 RO 2 – PGIS and citizen science

The HOP! survey was designed using a PGIS approach, and path data was collected using a citizen science approach, and thus this objective was achieved. The DCO identified the condition data which would be most useful to the park and could be measured objectively by citizen scientists. The volunteer surveyors collected varying amounts of data, with varying levels of success. Feedback throughout the project helped to identify some of the issues which should be addressed.

It is clear that basic training of volunteers is essential for the continuation of this project. This could be very brief, possibly a three hour session, with the following learning outcomes which the experience on this project showed to be important.

The volunteers should be able to:

- Use HOP! to record path condition indicators at each target point.
- Appreciate and accept that all the data required should be recorded at each target point.
- Locate the points at which to record the condition and the position from which to take photographs, bearing in mind that these may be different. The photographs may

either show the points whose measurements have been recorded or may be taken at the survey point.

- Take photographs of what was photographed in 2002/3, as far as possible.
- Decide in what direction(s) photographs should be taken at each point.
- Decide what additional important and relevant information should be recorded in notes and captions of photographs.
- Appreciate and accept that the recording of the survey data will probably add at least an hour to their walking time. This is based on the recommendation that the number of points at which the volunteers are asked to record data should be limited to a maximum of ten points, with approximately five minutes required per survey point.

Scotland’s “Adopt a Path” program (COAT, 2017) runs regular training days, and these should be investigated further in order to design training on HOP!

A detailed manual should be produced to accompany the training. A manual like the excellent one produced by NPS (2008) should be relatively easy to produce. The manual could be incorporated into the app, as well as being available in a separate document.

The following developments in the app could improve the quality of the data recorded by making things easier for the user:

- The app could record the direction of view for each photograph. This could be used to indicate easily if the photograph was taken looking ahead or behind, without the user having to note it explicitly.
- The choice lists given to the user on the app could be tailored, based on current location and previous survey data, so that the most likely choices appear at the top of the list.
- The requirement for the user to input the same data several times should be reduced.
- The explanations which are provided to the user on clicking the information buttons throughout the app should be completed.

6.2.3 RO 2 – Error analysis

It was important to investigate the errors in both the 2002/3 and 2016/17 data as part of this research objective, in particular the errors in path width and depth measurements, and in GPS locations.

Errors in path width and depth measurements

The errors made in these measurements in both 2016/17 and 2002/3 were small, in most cases. It has been judged that the volunteer surveyors can estimate path width correctly to the nearest 0.25m with their hiking pole, but that it may be sufficient (based on the widths recorded by the professional surveyor) to record the path width to the nearest 0.5m for values up to 5m, and to the nearest 1m for widths above 5m.

The volunteers can estimate path depth to the nearest 0.15m. In order to be able to measure path depth to the nearest 0.1m, as the professional surveyor did, it may be useful to mark intervals of 100mm on the volunteer's hiking pole.

The volunteer surveyors should be trained in how to estimate the measurements so that they are as correct as possible. The app should be changed to restrict the user to record the width and depth with the appropriate precision.

Errors in GPS coordinates

It appears, from the limited testing carried out, that the GPS location data is much more reliable in the 2016/17 surveys than in those conducted in 2002/3. An RMS error of 1.7m is acceptable for this kind of survey, but further in-depth testing should be carried out on different paths and on different devices to get a more reliable estimate of RMSE. Also, an explanation should be sought for why seven different points were recorded on the Android phone when trying to measure the width of the Djouce East path (described in Section 4.2.3), but only three different points were recorded on the iPhone.

The project has highlighted some issues with the GPS coordinates recorded on mobile devices being far from the actual location of the volunteer. This should be investigated further.

The study of the "accuracy level" values returned by the mobile devices was inconclusive. Their relevance and usefulness should be further assessed. It may be of benefit for the app to reject any points for which the "accuracy level" value returned is above the minimum for the mobile device.

6.3 Conclusions - RO 3: *To convert the path condition surveys of 2002/3 into a format that can be used for comparison with the current condition*

This objective was achieved to a certain degree. Eight of the 2002/3 surveys were converted, but the quality of the converted data is limited. The 2002/3 path survey reports are excellent reports written by a professional surveyor. Unfortunately, they were not written in a way that suits direct conversion to a structured database format, and the conversion was a very difficult and imprecise task. The locations of many points were found to be specified with a low degree of precision, the accuracy of the GPS coordinates was questionable in some instances, and the condition of the paths was not reported in the consistent, repetitive manner required for input into a GIS database. The descriptive, "analogue", nature of the reports did not make conversion of path condition to digital format fully reliable.

Work needs to be done to investigate if it is possible to get more accurate baseline 2002/3 data. Advice could be sought from the original surveyor and other experts could be consulted. New volunteer surveyors could possibly be asked, as part of their new survey, to try to identify as accurately as possible all the points recorded in the 2002/3 surveys.

As part of future work on this project, all of the 2002/3 survey reports (including the fourteen paths which were not included in this study because the reports were not provided to me in MS Word format) should be obtained and the data should be extracted from them into HOP! and GIS. This would result in the complete set of 2002/3 surveys in ArcGIS format.

6.4 Conclusions - RO 4: *To determine the condition of the WMNP hiking paths today, and to compare it with the condition in 2002/3*

The condition of eight paths in WMNP in 2016/17 has been determined with a reasonable degree of success, but the comparison with the condition in 2002/3 was less successful. The HOP! surveys show that the overall condition of the paths in 2016/17 was mainly “fair” or better, but that most paths have deteriorated since 2002/3. The reliability of the 2016/17 results is acceptable, but further improvements are required as explained in Section 6.2.3.

The study of the change in the condition since 2002/3 has revealed problems which result in that data being unreliable. This is primarily due to two factors: the estimations required to convert the 2002/3 data into GIS format; and the probability that many of the comparisons are not comparing the condition at the same point in 2016/17 and 2002/3. These issues should be looked into, as discussed in Section 6.3.

In spite of the inherent errors, the GIS maps produced in this project were said to be very useful to the WMNP, primarily because they quite accurately show the condition in 2016/17. The overall condition scoring system should be changed so that the muddiness and water flow are not included. Discussions should be held with WMNP management on the format of standard maps from the system if HOP! is to be used in the future. Map production could possibly be automated for subsequent path surveys.

This project has shown how GIS can be used to present path condition data in a very different way to the textual reports which were produced in 2002/3. Ólafsdóttir and Runnström (2013) and Svajda et al. (2016) used this presentation method but it has not been used for path condition in Ireland, apart from the survey of Errigal. One potential problem with this aspect of the project is the scarcity of people in WMNP with skills in ArcGIS. Even though a large amount of park data is now stored in the GIS, only one person knows how to use it. The possibilities which path condition data in a GIS offer to path managers may not be immediately apparent to them, and a simple user interface should be developed to help break down this barrier.

Another useful addition would be the production of reports from the survey data, in the format of the 2002/3 surveys. This should be a straightforward task and, even though it appears to be a step backwards to those who appreciate the power of GIS, it would make the 2016/17 and 2002/3 data accessible to all.

6.5 Final Conclusions

6.5.1 Path condition monitoring

This project has shown that valuable data on path condition can be collected with HOP! and it is recommended that its use should become part of a regular monitoring programme. Newsome et al. (2013) defined monitoring as the "systematic gathering and analysis of data over time". It has been shown that HOP! can be used for *systematic* gathering of data, and the *analysis* of that data is achieved by converting that data into ArcGIS format where it can be compared with baseline data.

Newsome et al. (2013) recommended five Principles of Monitoring, and these are listed in Table 6-1. In order to assess the feasibility of employing HOP! in the monitoring of the condition of upland paths, the experiences with the surveys conducted using HOP! are reviewed in relation to these five principles.

Table 6-1 Five Principles of Monitoring (Newsome et al., 2013)

	Principle
i	Clear objectives
ii	Well-planned and managed information storage and retrieval system
iii	Sampling strategy providing cost-effective and robust data
iv	Quality assurance
v	Skilled manager who can build on existing data

Each of these principles is discussed in detail below.

i. Objectives: The objectives of the HOP! surveys are clear. They are to enable volunteers to conduct partial surveys which are very low-cost and will result in useful data for WMNP. The data recorded can be compared with data reported in 2002/3.
ii. Storage and Retrieval System: The storage and retrieval system used in this project was basic, but efficient. The use of an SQLite database in the app, with easy import from, and output to, Excel files, facilitates subsequent easy input into ArcGIS.
iii. Sampling Strategy: The sampling strategy was designed to be both cost-effective and robust, by directing the surveyor to record the condition at those points already sampled in 2002/3. The surveyor also has the option to record the condition at additional points if desired. The data recorded at each point is a subset of the data recorded in an Amber Survey, thus potentially providing a partial dataset for subsequent surveys and comparisons.
iv. Quality Assurance: In this research project, which may be regarded as a pilot study in advance of the production of a fully functioning survey tool, the Quality Assurance (QA) was not a high priority. It was not envisaged that the data collected would actually be used by the WMNP. The project highlighted the problems of using the

2002/3 reports as baseline data, and the necessity of providing training for the volunteer surveyors.

v. Skilled Manager: The summary and detailed maps presented show what could be produced relatively easily using the data recorded with HOP! ArcGIS skills would be required for this and also for any further exploration of the data. The HOP! app could be updated to record additional data if required, with the skill of a programmer.

Following this analysis, it is concluded that the HOP! app could be part of a procedure to monitor the condition of hiking paths in WMNP and other paths around the country, subject to some modifications which have been identified.

6.5.2 PGIS and citizen science

In an effort to "try and make geographical research more relevant to the lives of ordinary people", this research was influenced in many stages of the project by the strategies for participation listed in the "gold standard" of 'deep' participatory research produced by Kesby et al. (2005). The specific strategies adopted were:

- Early association was sought with a statutory body (WMNP) at the same time as the research topic was formulated. Ideas were received from them about "burning questions that need addressing".
- Early pilot focus group discussions were held with potential participants to find out what they see as relevant.
- Work was carried out with the partner organisation (WMNP) and participants to establish the appropriate research tools and methodological processes.
- Participants were encouraged to become actively involved in data collection, as citizen scientists.
- Early results were analysed and fine-tuned with participants.

Because of the nature of the project, the level of participation in the form of locals' knowledge and views was relatively low, compared to a full PGIS in which these are explicitly represented. However, participation in the form of citizen scientists collecting data about their environment was significant.

The project may be reviewed in terms of the factors for success of a PGIS implementation identified by Quan et al. (2001) which were presented in Section 2.3:

- All of the stakeholders acknowledge the usefulness of the project.
- Good communication with the stakeholders was achieved. This was helped by the facts that the expert, the DCO, is a scientist with GIS knowledge, and I am a hillwalker with the same wish to protect the environment as the citizen scientists who worked on the project.
- The citizen scientists had good GPS on their mobile devices.
- Regular feedback was an essential part of the project, both to and from the hillwalkers and the DCO
- The project was implemented on a phased basis, using an incremental approach.

- The data collected is quite accurate, but the issues with the 2002/3 data remain.

Finally, this PGIS project may be evaluated in terms of the three guidelines proposed by Barndt (2002), cited by Dunn (2007) presented in Section 2.3.1:

- The project has been shown to produce results which provide appropriate and timely information upon which WMNP can usefully act.
- The project can be managed so that it is sustainable and properly integrated into the activities of WMNP, with the additional work already identified.
- The willingness of hillwalkers to participate in the project shows that there is a consensus to support a local working system which will integrate with path management plans.

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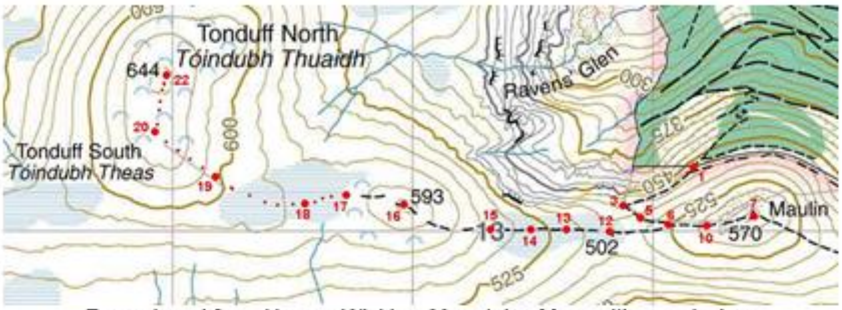
Appendix A Sample 2002/3 Survey

Screenshots of the first two pages and the last page of the 2002/3 survey report for the path from Maulin to Tonduff are shown in Figure A-1, Figure A-2, and Figure A-3. The survey was reported in MS Word format, with most of the data presented in tables and photographs. The format of all other 2002/3 surveys is similar to this one.

Wicklow Mountains Path Survey

Maulin Tonduff	
Start to Finish:	O 18186 13289 to O 1595 1367
Altitude (lowest – highest):	500m - 644m
Weather:	Wet morning, windy and overcast
Access:	Crone forest car park
Surveyed by:	John Monaghan, 30 / 7 / 02.



Reproduced from Harvey Wicklow Mountains Map, with permission.
© Harvey Maps 2002

No	Pos Irish Grid O	Comments / Photographs
1	18186 13289	Top of Crone forest, at stile
2		follow 3m wide grass / stony track contouring to the right (WSW) around Maulin towards the saddle between Maulin and Tonduff

Figure A-1 Excerpts from first page of 2002/3 survey report of Maulin-Tonduff

3	17903 13120	At stone wall a minor path goes straight on towards col between M and T; I followed the main path turning left (SW) up onto Maulin  pic57 looking back down to stone wall shows island in centre of path; tape = 0.5m
4	50m on up	a 50cms gully in the peat; path width average 1m; path surface of loose stones and peat
5	17962 13066	path terracing; the "new" path on the left on peat is 30cms above the "old" one on stone  pic58 shows this; tape = 0.5m

Figure A-2 Second page of 2002/3 survey report of Maulin-Tonduff

16	170 131	Little Tonduff (Pt. 593); summit area weathered and eroded
17	16727 13130	the path W indefinite and difficult to locate; walkers making their own way down the gentle slope (I observed a party of five doing this later, as I had done)
18	16560 13100	ran out of path; the wet bog surface now contains sphagnum moss, peat haggs and wet flushes
19	16196 13231	bottom of slope up to Tonduff South – no path; natural blanket bog erosion  pic64 looking back (E) shows the flat, wet area towards Little Tonduff and Maulin
20	15904 13423	a single file path for about 60m leads to Tonduff South summit; the result of walkers finally converging on the cairn
21		no definite path from the South to the North summit
22	1595 1367	Tonduff North summit; an expanse of naturally eroded blanket bog with isolated peat haggs
		END

Figure A-3 Final page of 2002/3 survey report of Maulin-Tonduff

Appendix B Soil type on paths surveyed in 2002/3

A soil map of the Wicklow/Dublin area was obtained from the Environmental Protection Agency's Geo Portal (EPA, 2017). The map shows that almost all the land within WMNP is either "Blanket Peats" or "Podzols (Peaty), Lithosols, Peats, Some outcropping rock".

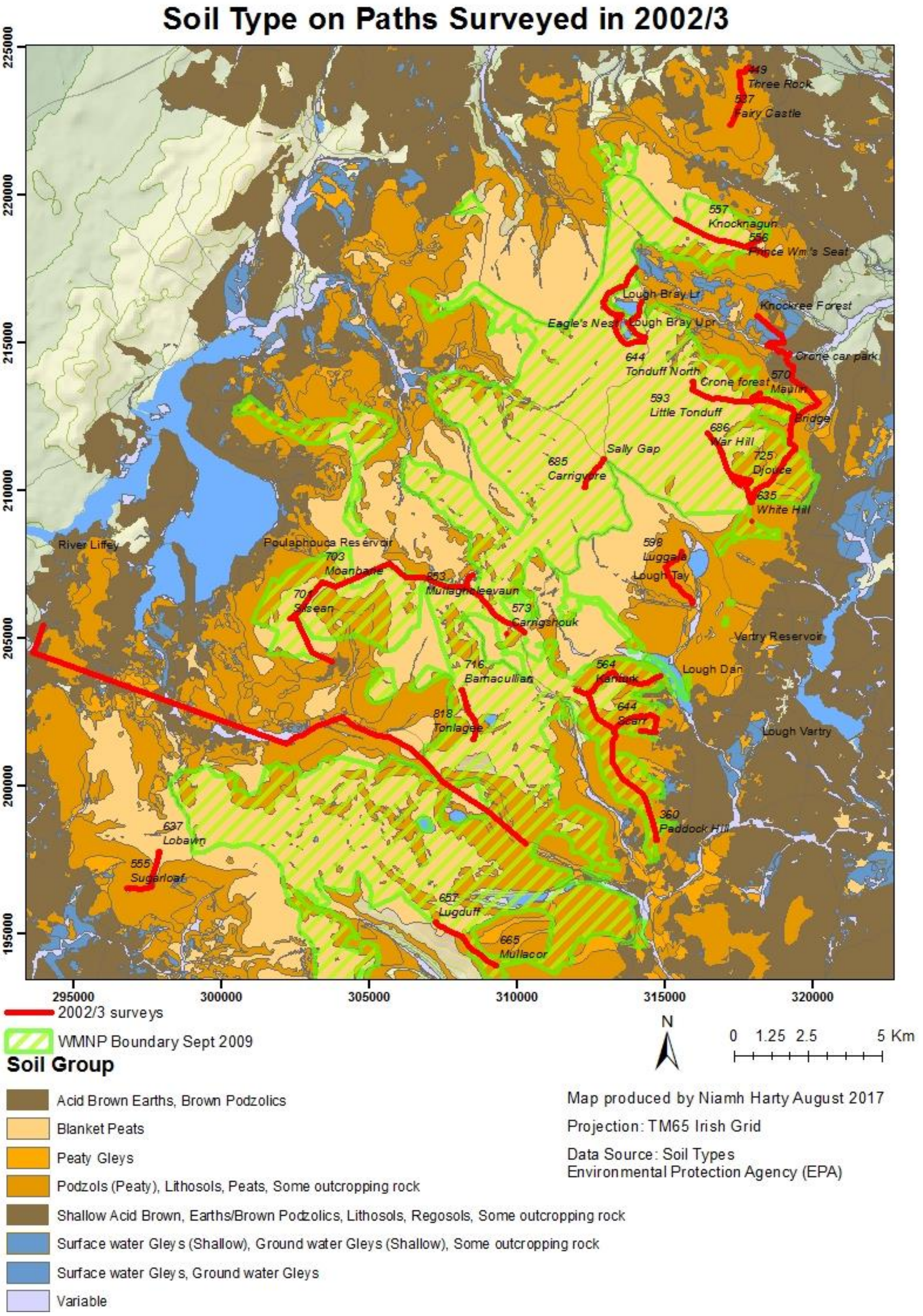


Figure B-1 Soil Types in region of Wicklow Paths (EPA, 2017)

Appendix C User-interfaces of apps

Screenshots of a number of apps are presented in this appendix. They were used as a starting point for the design of the interface of the app developed in this research project.

Screenshots of the app used in the Big Pathwatch project are shown in Figure C-1. They show the location of the user in their pre-selected map square, the ability to record a positive or negative experience, and the choice of problems available.

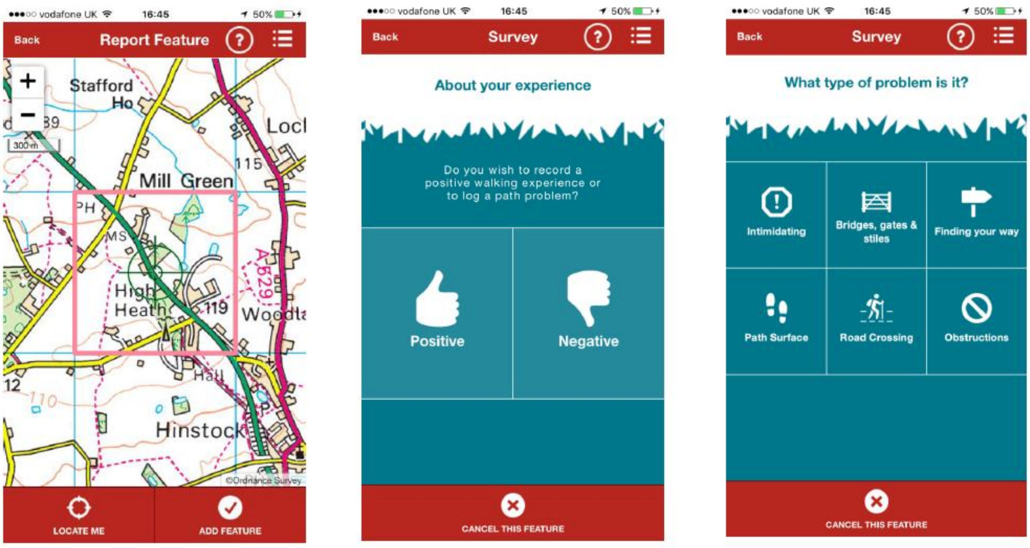


Figure C-1 Big Pathwatch app screenshots (Ramblers, 2016)

Screenshots from the app developed in Hylander's project (2015) on cultural ecosystem services are shown in Figure C-2.

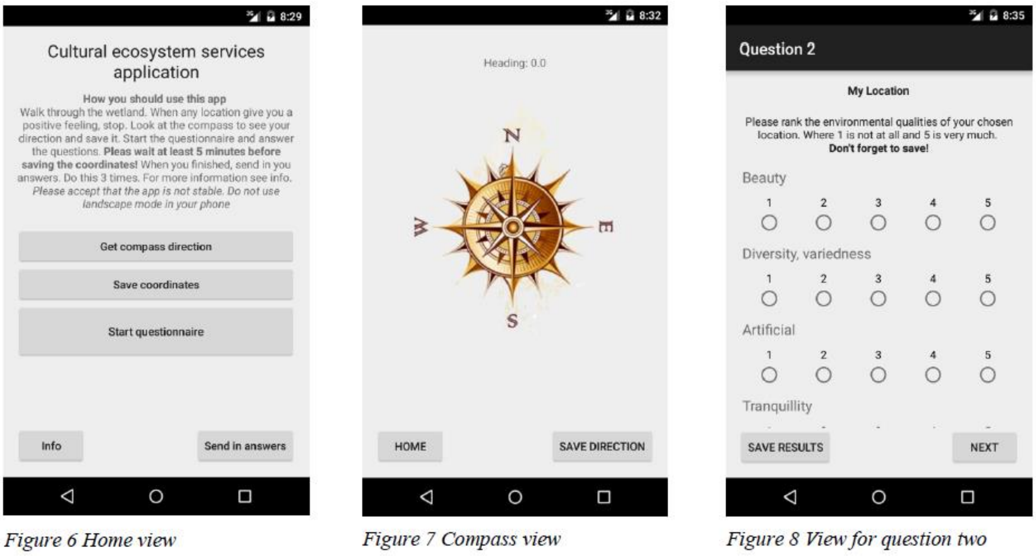


Figure C-2 Screenshots from cultural ecosystem services app (Hylander, 2015)

Screenshots of the Tienoo app for recording opinion on forest areas (Kangas et al., 2015) are shown in Figure C-3.

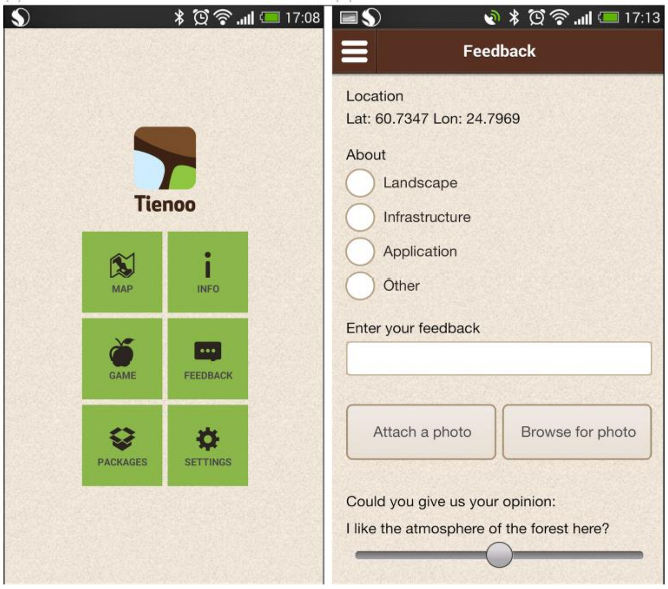


Figure C-3 Screenshots of Tienoo app for recording opinion on forest areas (Kangas et al., 2015)

A screenshot from the MoM-NOCS system to record nature observations (Skevakis et al., 2014) is shown in Figure C-4.

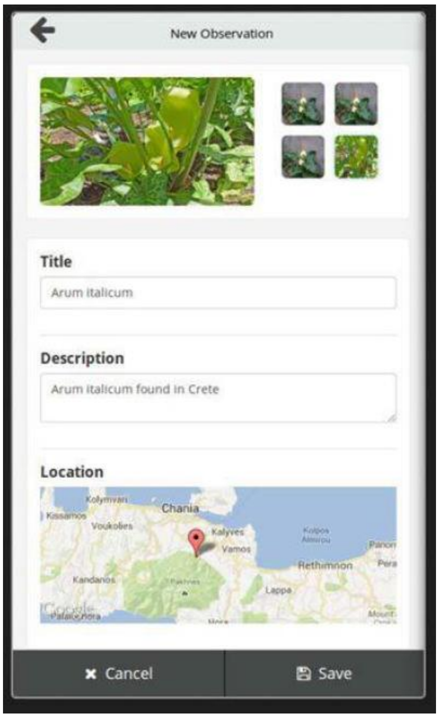


Figure C-4 Screenshot of app in MoM-NOCS system to record nature observations (Skevakis et al., 2014)

Appendix D Record of initial consultation with hillwalkers

This appendix contains details of the points raised at an initial meeting with hillwalkers.

The following issues were discussed with six experienced hillwalkers from one hillwalking club at the first meeting in June 2016, at which the idea and aim of the research were outlined, a map showing the paths which had been surveyed in 2002/3 was distributed, and the paper mock-up of the app was presented:

- There is a club rule that no one can use their mobile phone while out on a walk. It was agreed that doing the survey would not be part of a regular walk, so this would not be a problem.
- Concern was expressed that doing the survey would slow you down, but it was agreed that if you only did it once or twice a year, it was OK
- A training session would be good and necessary
- Most said they would be willing to give up a day to recording the path condition – it is similar to volunteering to work with Mountain Meitheal.
- Concerns were expressed about privacy and anonymity
- Not everyone has a smartphone! This was an embarrassing discovery – actually very few in the group had a smartphone, so it was made clear to me that I must not assume they do
- The paths we will be looking at are "pre-repair" – unlike the Cairngorms
- They really liked the idea of "adopt a path". They thought it would not be necessary to have several condition records for the same path – one should be enough. Agreed that each person should pick a path to survey. No duplication – one club/person, one path
- They asked if there would be a problem with battery life
- They asked what kind of weather the survey should be carried out in – good day but after rain if possible
- One member of the group said that she had observed deterioration in the condition of one path in the last 5 to 7 years
- They asked if the app could be used on other routes – i.e. do the first condition recording and then go back to it again and again
- They asked if it could be used to report spot erosion
- They liked the fact that the app seemed very simple to use and was very useful

Appendix E Mobile operating systems in Ireland

Figure E-1 shows the percentage of market share of the many different mobile operating systems in Ireland from May 2016 to May 2017 (StatCounter, 2017). Android and iOS have over 98% of the market in Ireland - 55.8% and 42.8% respectively.

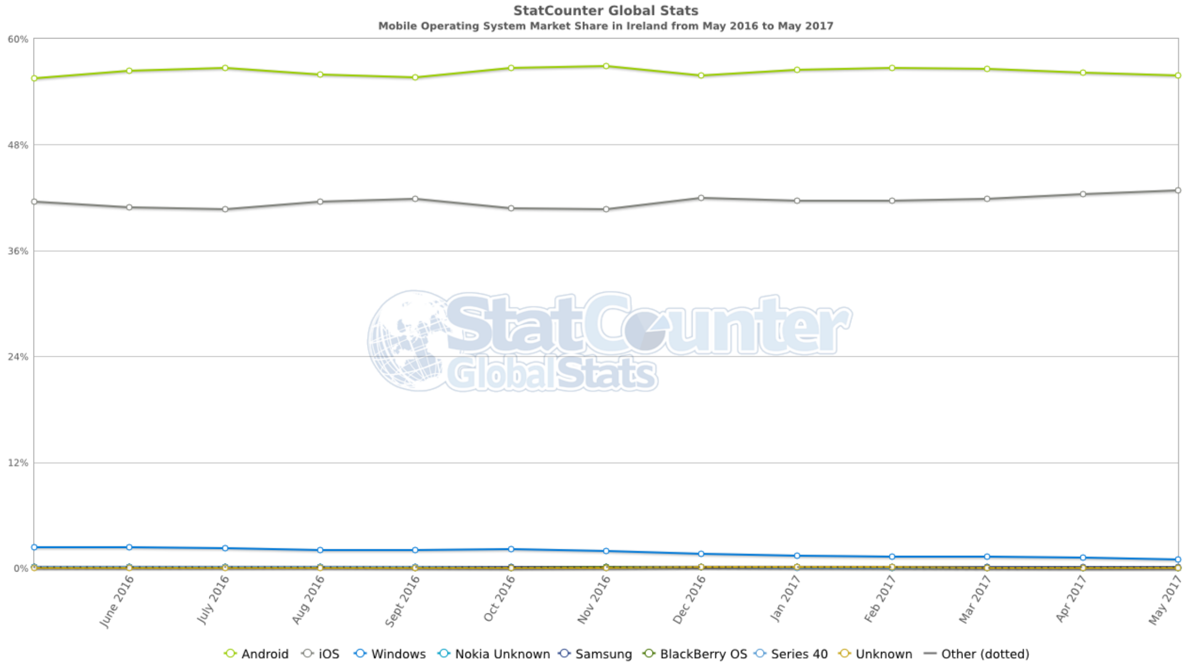


Figure E-1 Percentage market share of mobile operating systems in Ireland from May 2016 to May 2017 (StatCounter, 2017)

Appendix F Initial sample apps and PhoneGap Build

Having got an (almost featureless) sample “Hello World” app (provided by PhoneGap (2015a)) to work, I then built four small simple apps which work on my iPhone, iPad, and an Android phone – they are in the bottom row of the icons in the screenshot of my phone in Figure F-1. Three of the apps were based directly on examples published on the web – Employee Directory (Coenraets, 2012) (shown in Figure F-2 and Figure F-3), the tip calculator FasTip (Traeg, 2014) (shown in Figure F-4), and Employee List (Coenraets, 2014) (shown in Figure F-5). The fourth (My Amazing Map App (MaMa)) (shown in Figure F-6) is my adaptation of a number of samples of demo code on the JQueryMobile website (JQuery, 2015).

The apps include much of the functionality which I expected to need in my app including:

- Display of a map (Google Maps) and the user’s current location (in MaMa)
- Using the phone’s camera to take a photo (in Employee Directory)
- Sending an email (in Employee List)
- Buttons to perform functions (e.g. calculation of tip in FasTip)
- Navigation between pages (in all except MaMa)
- Input of values via input boxes (in all except MaMa), sliders and radio buttons (in MaMa)

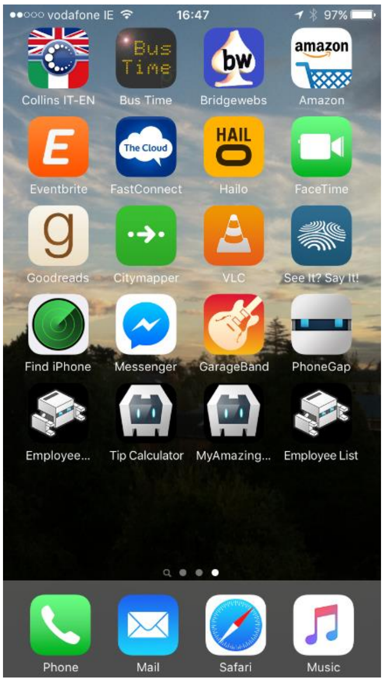


Figure F-1 Four PhoneGap apps on bottom row on my iPhone

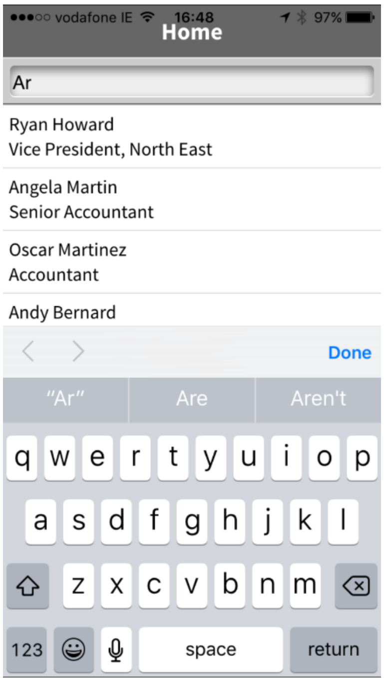


Figure F-2 Employee Directory: typing in part of name

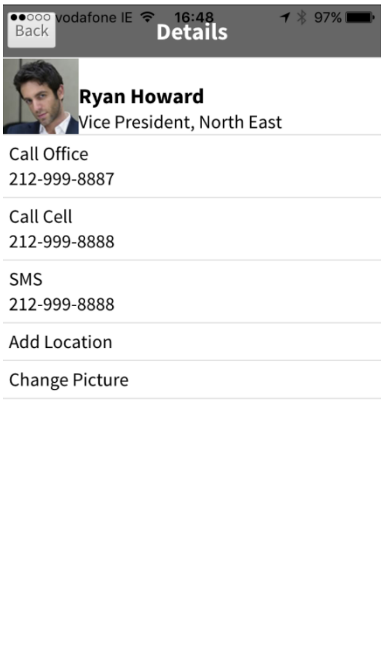


Figure F-3 Employee Directory: details of selected employee

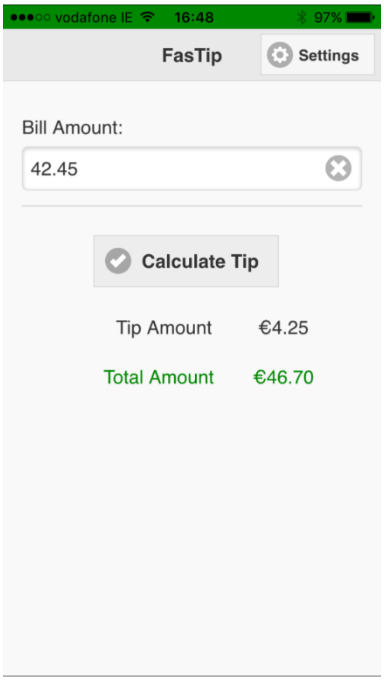


Figure F-4 FasTip: calculate tip and total amount from bill amount

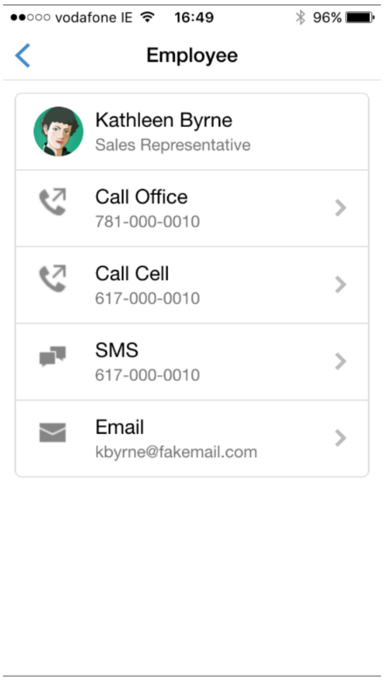


Figure F-5 Employee List: can call or email selected employee

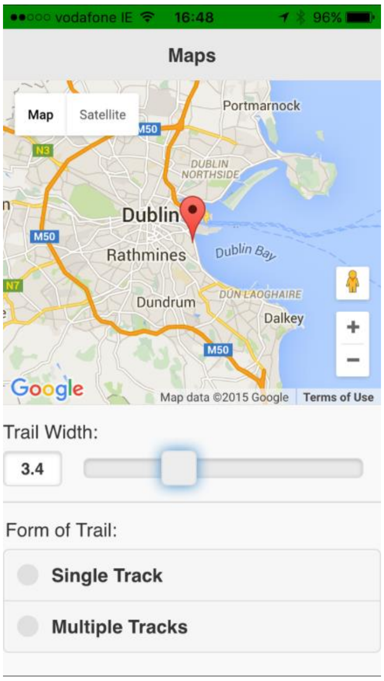


Figure F-6 My amazing Map app - MaMa

PhoneGap Build was selected as the tool to distribute the app, because it appeared to be simpler than the alternative (which was to build and package locally). Figure F-7 shows how a zip file containing the JS, HTML and CSS code is uploaded to PhoneGap Build, and it is processed to produce separate deployment bundles for each of the selected platforms.

In order for PhoneGap Build to produce an iOS bundle, the developer must carry out a sequence of complicated (and nerve-wracking) steps. First, one must register as an Apple Developer, then register with Apple each device which will be used, and finally obtain a Provisioning Profile, details of which are input into PhoneGap Build. The procedure for Android is a bit less convoluted – one has to generate a private key, which is then submitted to PhoneGap Build.

Once the steps above have been completed, it is a very simple process to update and create a new version of an app.

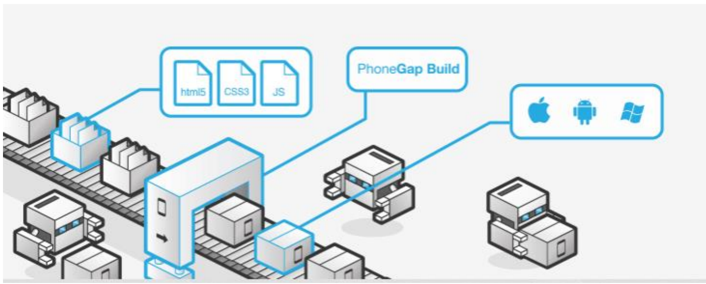


Figure F-7 Building an app for different platforms using PhoneGap Build (build.phonegap.com)

Appendix G Initial mock-up of app

Mock-ups of the screen pages in the app were produced using Visio (Microsoft, 2017). They are shown in Figure G-1 to Figure G-6. Figure G-1 shows the opening screen to be shown when the user starts the app. When the “Record Walk” button is pressed, the screen shown in Figure G-2 appears. The user may press the “Record Path Condition” button to record the condition at a point, and this brings up a new page, the top part of which is shown in Figure G-3 and the lower part of which is shown in Figure G-4.   Some of the items to be entered are selected from choice lists, such the path type list shown in Figure G-5 and the path surface choice list shown in Figure G-6.

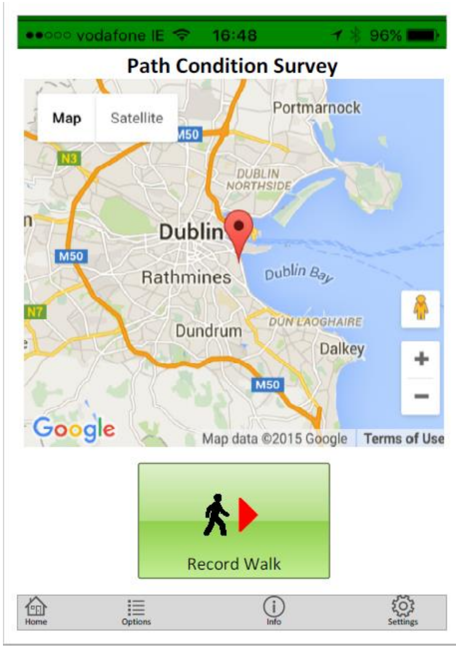


Figure G-1 App Mock-up: Opening Screen

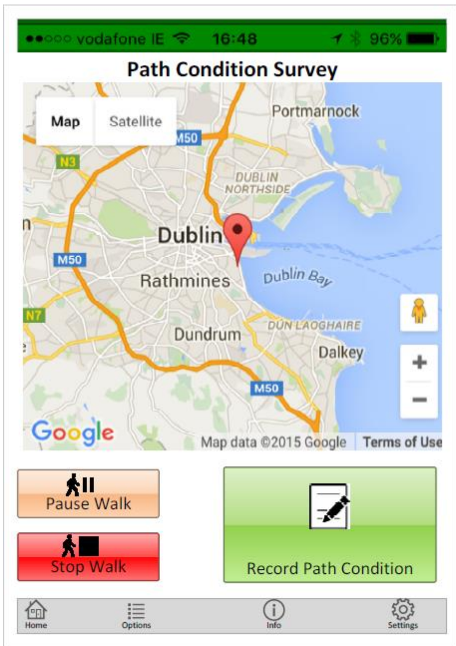


Figure G-2 App Mock-up: Record Walk Screen

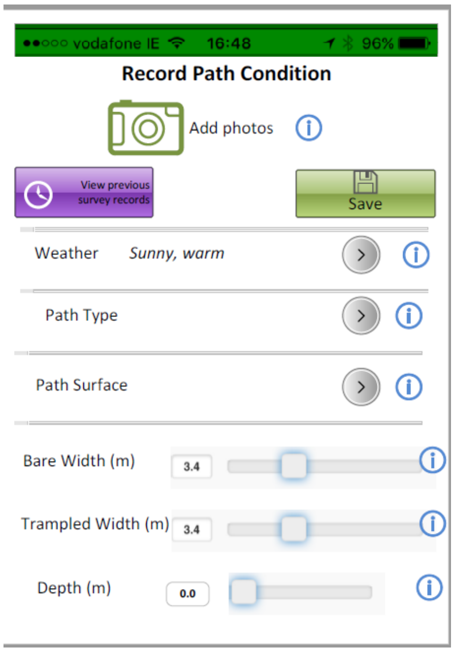


Figure G-3 App Mock-up: Record Path Condition Screen (part 1 of 2)

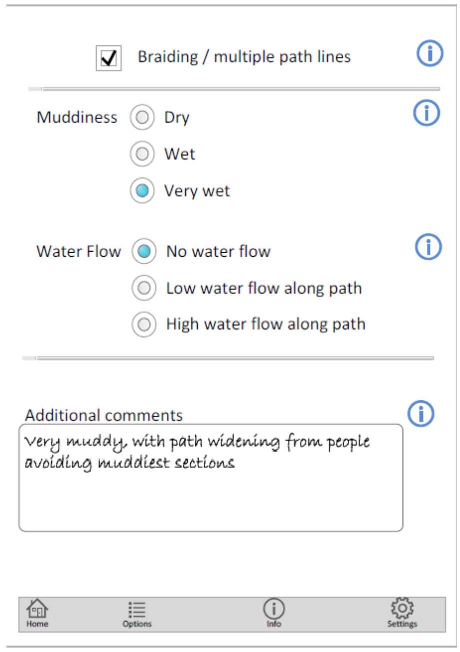


Figure G-4 App Mock-up Record Path Condition Screen (part 2 of 2)

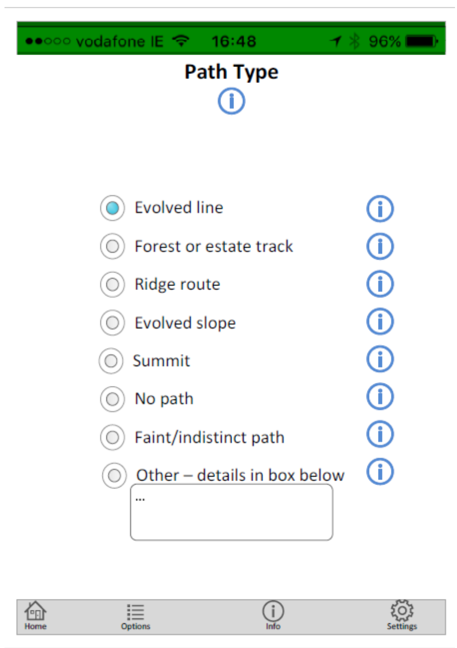


Figure G-5 App Mock-up: Choice List for Path Type

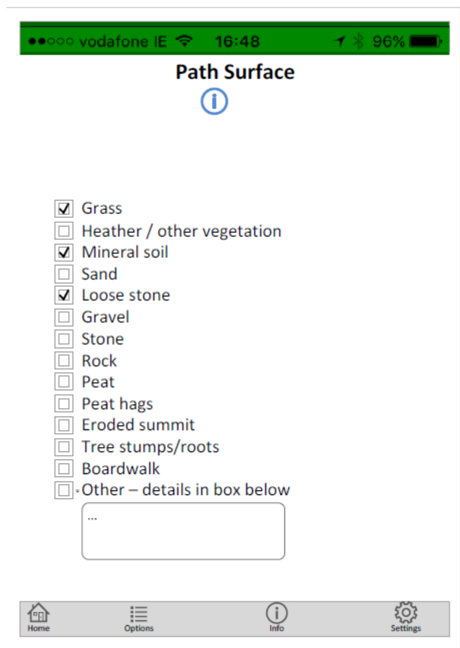


Figure G-6 App Mock-up: Choice List for Path Surface

Appendix H Details of HOP! app, samples of code, and user manual

Based on the suggestions from the DCO and the hillwalkers, and design styling recommended by a professional graphic designer, the app was produced. Its functionality is described in the following section, with screenshots from a mobile device. The brief manual is outlined in the second section in this appendix.

H.1 HOP! app

The app is called HOP! which stands for How’s Our Path! Figure H-1 shows the opening screen, which includes the name of the path to be surveyed. The app is setup for each user for a specific path, and an SQLite database is pre-populated with the 2002/3 survey data for that path. The details of how the 2002/3 data was obtained are described in Appendix I. When the user presses the “Record Condition” button, the next screen looks like that shown in Figure H-2. The route is shown as a red line, and the target points as blue dots. The target points were selected from all the points at which data was recorded in the 2002/3 surveys. They are a subset of all points in the original survey and were chosen as representative of the path as a whole. The next target is shown with a blue flag. When the user gets close to the target, the app tweets with a bird call and the user is asked if he/she wishes to record the condition at the point, get closer to the target point, or go on to the next target point, as shown in Figure H-3.

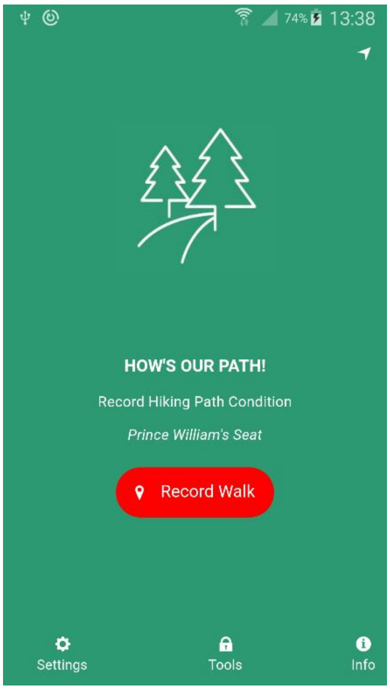


Figure H-1 Opening screen

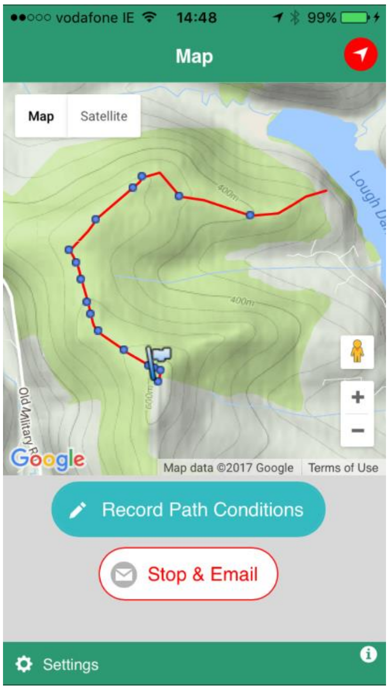


Figure H-2 Screen showing path and target points

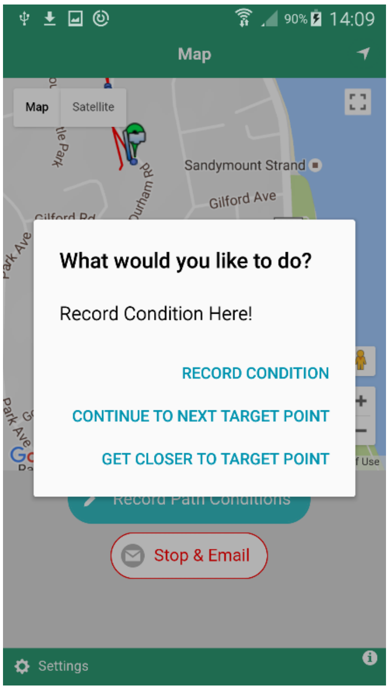


Figure H-3 Notification when close to target

If the user chooses to record the condition, the screen on which the condition data may be entered is displayed. The first part of the screen is shown in Figure H-4. On this part of the page, the user can take and view photographs, add captions for photographs, type in the weather, and record the width of the path in meters in terms of the bare width and the trampled width. The “ⓘ” symbol may be pressed to get more information on the field to be recorded. When the user scrolls down, the screen looks like that in Figure H-5. Here, the user can record the depth of the path in meters, the braiding by recording that the path is a single path or multiple paths, and the path type, path surface, muddiness and water flow. At the bottom of the screen, as shown in Figure H-6, the user may key in notes in which any extra comments not addressed in the standard data collected may be recorded, and then press either “Save & Continue” or “Cancel & Continue”. If the user opts to “Save & Continue”, the data is saved in the SQLite database, and the target flag is moved to the next target point.

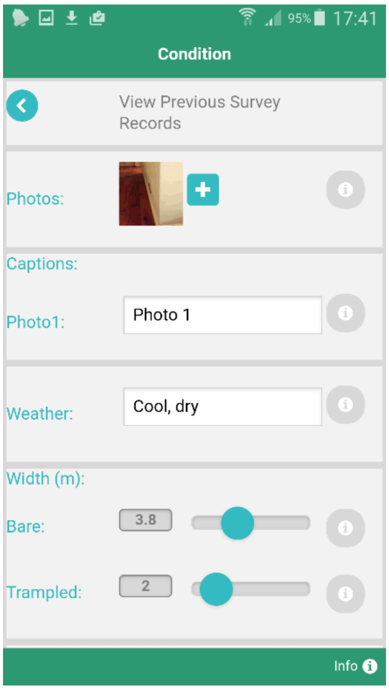


Figure H-4 Part 1 of Record Condition Screen

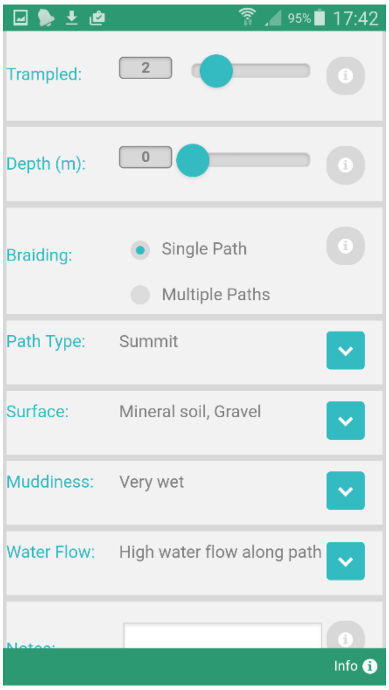


Figure H-5 Part 2 of Record Condition Screen

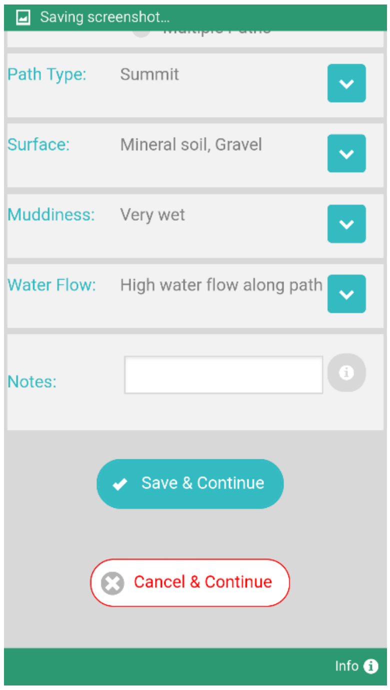


Figure H-6 Part 3 of Record Condition Screen

The path type, path surface, muddiness and water flow are recorded by choosing item(s) from choice lists. The choice list screens for path surface and muddiness are shown in Figure H-7 and Figure H-8.

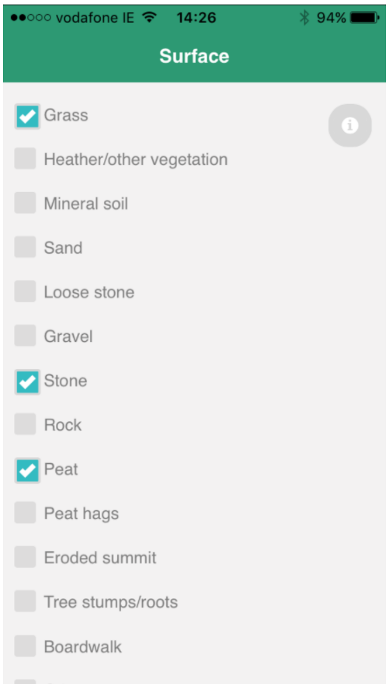


Figure H-7 Path Surface Choice List

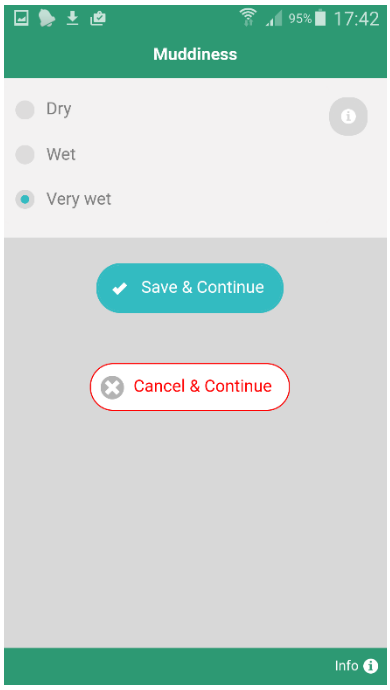


Figure H-8 Muddiness Choice List

The first item on the screen shown in Figure H-4 is an arrow on the top left, labelled “View Previous Survey Records”. This allows the user to view the 2002/3 survey data. The upper and lower parts of the screen are shown in Figure H-9 and Figure H-10. The user may touch one of the photos to see a larger, zoomed, version of it, as shown in Figure H-11.

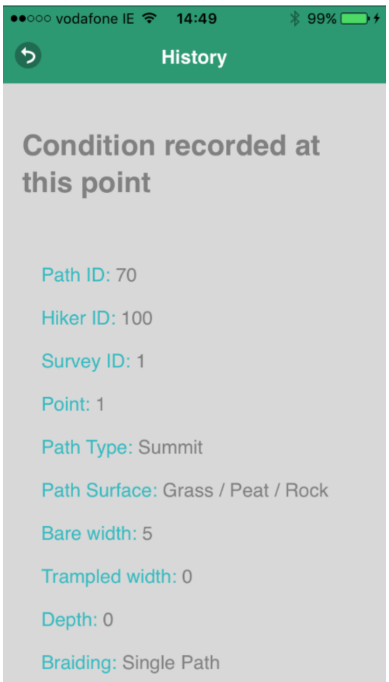


Figure H-9 View Survey History Part 1

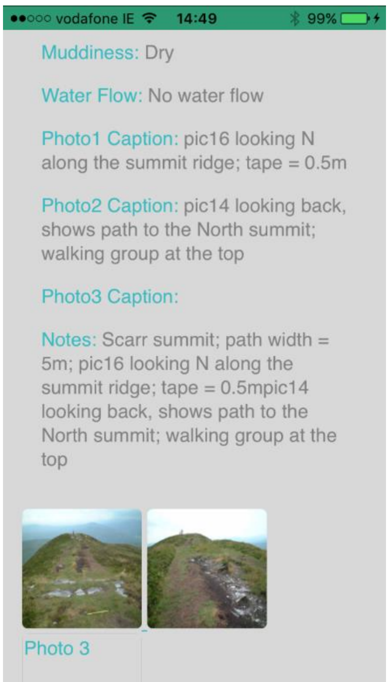


Figure H-10 View Survey History Part 2

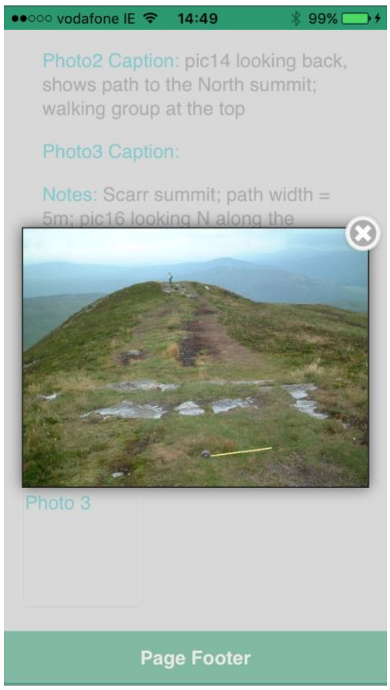


Figure H-11 View Survey History Zoom on Photo

In addition to saving the path condition data recorded by the user at each target point, the app records and saves the path followed by the user (as latitude, longitude, accuracy, date, time, and elevation). This data has a number of uses, including providing the possibility of being able to calculate the slope of the ground walked along, and to provide maps of paths in the park.

H.2 Samples of code

The code for the HOP! app is contained in seven files which are outlined in Table H-1.

Table H-1 Files of code for HOP! app

File	Number of lines of code	Description
config.xml	203	Gives PhoneGap details of the app name, version, etc. Specifies what PhoneGap version to use and what plugins to include.
index.html	1112	Specifies the layout of the screens on the app, including the fields where data can be input and the buttons which carry actions, such as "save and email".
map.css	528	Specifies the format of the screens in terms of colours, font sizes, field sizes etc.
appSQLiteDB.js	1389	This file contains the first code run, sets up the SQLite database access, defines actions on button clicks (take photos, save, etc.), creates small photos for emailing, and controls access to the password protected app tools page.
MapFns.js	702	This file includes JS code for finding the current position accurately, displaying the map with current position and target points, recording the walk watching for closeness to next target.
FileIOFns.js	708	This JS code includes the setup of global variables, the saving of photos in the app storage area, the tools to list files and optionally delete, and the copying of the SQLite database as required.
MySQLFns.js	434	This file includes JS code to open the SQLite database, add and retrieve data, and save points on the current path.
TOTAL	5076	

The extract from config.xml shown in Figure H-12 contains details of some of the plugins to be included in the compiled app. Lines 1 to 7 give details of plugins to be included in the iOS version of the app and the (almost) equivalent ones to be included in the Android version are set out in lines 9 to 14. Lines 16 to 26 show the history of the use of a plugin for SQLite database functionality. Changes in PhoneGap in November 2016 resulted in the need to find a new plugin because the old one was not updated for use with the new system.

The extract from index.html in Figure H-13 shows the HTML code for the home page resulting in the screen shown in Figure H-1.

The extract from map.css in Figure H-14 shows the basic styling for the three columns of data in the Record Condition screen shown in Figure H-4.

The extract from mapfns.js in Figure H-15 shows the JS code to draw the map on the screen, as shown in Figure H-2. Global variables are used in the app, and all have a name starting with “g”.

```xml
<platform name="ios">
   <plugin name="cordova-plugin-media" source="npm" />
   <plugin name="cordova-plugin-email-composer" version="0.8.3" source="npm" />
   <plugin name="cordova-plugin-camera-with-exif" source="npm"/>
   <!-- Use full screen for ios only - on Android it covers app -->
   <preference name="fullscreen" value="true"></preference>
 </platform>

<platform name="android">
   <plugin name="cordova-plugin-media" version="2.4.0" source="npm" />
   <plugin spec="https://github.com/katzer/cordova-plugin-email-composer.git#0.8.2"
   source="git" />
   <plugin name="cordova-plugin-camera" spec="2.3.0" source="npm"/>
   <preference name="AndroidExtraFilesystems"
   value="files,files-external,documents,sdcard,cache,cache-external,assets,root" />
 </platform>

 <!-- https://github.com/litehelpers/Cordova-sqlite-storage/tree/5da711a and
 https://build.phonegap.com/plugins/2751 -->
 <!-- Cannot use after November 15th 2016 - not in npm system -->
 <!-- <plugin name="io.litehelpers.cordova.sqlitestorage" spec="0.7.5" source="pgb"
 /> -->

 <!-- don't work:  -->
 <!-- <plugin
 spec="https://github.com/litehelpers/Cordova-sqlite-storage/tree/5da711a"
 source="git" /> -->
 <!-- <plugin
 spec="https://github.com/litehelpers/Cordova-sqlite-legacy-build-support"
 source="git" /> -->

 <!-- Had to change to use this after November 15th 2016 - but it does not support
 pre-populated databases -->
 <!-- so had to add manual copy of db -->
 <plugin spec="https://github.com/litehelpers/Cordova-sqlite-evcore-extbuild-free"
 source="git" />


 <plugin name="cordova-plugin-background-mode" source="npm" />
```

Figure H-12 Extract from config.xml

```html
<div data-role="page" id="home-page" data-url="home-page" data-theme="h"
style="background-color:#2d9973;">
    <div data-role="header" data-theme="h">
        <a href="" id="rec-indic" class="ui-btn ui-btn-right ui-corner-all
        ui-icon-navigation ui-nodisc-icon ui-btn-icon-notext" >Locn</a>
    </div>

    <div role="main" class="ui-content" data-theme="h"
    style="background-color:#2d9973;" >


                    <img class="hop-photo" id="hop-photo" src="img/myhopicon.JPG"
                    alt="Hop" >

                    <p style="text-align:center; font-weight: bold; font-size: 1em;
                    font-variant: small-caps;">HOW'S OUR PATH!</p>

                    <p style="text-align:center; font-size: .85em;">Record Hiking Path
                    Condition</p>
                    <p id ="PathName" style="text-align:center; font-style: italic;
                    font-size: .85em;">Path Name</p>



                    <div class="ui-grid-solo">
                        <div class="ui-block-a" style="background-color: #2d9973;">
                            <p><a class="ui-btn ui-btn-inline ui-corner-all
                            ui-icon-location ui-nodisc-icon ui-btn-icon-left"
                                    id="rec-walk-btn" href="#rec-walk-page" >
                                Record Walk</a></p>
                        </div>
                    </div>

    </div>
    <div data-role="footer" data-id="home-page-footer" data-position="fixed"
    data-theme="h">
        <div data-role="navbar">
            <ul>
                <li><a href="#settings-page"
                        class="ui-btn ui-icon-gear ui-nodisc-icon
                        ui-btn-icon-top">Settings</a></li>
                <li><a href="#tools-page" id="tools-page-btn"
                        class="ui-btn ui-icon-lock ui-nodisc-icon
                        ui-btn-icon-top">Tools</a></li>
                <li><a href="#info-on-home-page" id="info-home-page-btn"
                        class="ui-btn ui-icon-info ui-nodisc-icon
                        ui-btn-icon-top">Info</a></li>

            </ul>
        </div>
    </div>
</div>
```

Figure H-13 Extract from index.html

```
.ui-block-a {
    width: 30% !important;
    background-color: #f3f2f2;
    border: none;
    color: #33bbc1;
    font-weight: normal;
    text-align: left;
    padding: 0 0 0 0;
}
.ui-block-b {
    width: 55% !important;
    background-color:  #f3f2f2 !important;
    border: none;
    color: #808080;
    font-weight: normal;
    text-align: left;
    padding: 10px 0 0 0;
}
.ui-block-c {
    width: 15% !important;
    background-color:  #f3f2f2;
    border: none;
    color: #33bbc1;
    font-weight: normal;
    text-align: left;
    padding: 0;
}
```

Figure H-14 Extract from map.css

```
function drawMap(latlng, callback) {
        // Display map centred on current location - latlng
        var myOptions = {
            zoom: 10,
            center: latlng,
            mapTypeId: google.maps.MapTypeId.TERRAIN // May be ROADMAP
        };
        gMap = new google.maps.Map(document.getElementById("map-canvas"), myOptions);

        // Show route of previous walk (2002/2003) with target points at which condition should be recorded
        // Route of walk
        var Route1Path = new google.maps.Polyline({
            path: gRouteLatLon,
            geodesic: true,
            strokeColor: '#FF0000',
            strokeOpacity: 1.0,
            strokeWeight: 2,
            map: gMap
          });
        for (var i = 0; i < gRouteTargetPoints.length; i++) {
            var marker = new google.maps.Marker({
                icon: {
                    url:
                    "https://maps.gstatic.com/intl/en_us/mapfiles/markers2/measle_blue.png",
                    size: new google.maps.Size(7, 7),
                    anchor: new google.maps.Point(4, 4)
                },
                position: gRouteTargetPoints[i],
                map: gMap
                });
        }
        // Add an overlay to the map of first target
        gTrgtMarker = new google.maps.Marker({
            icon: {url: "https://maps.google.com/mapfiles/ms/icons/flag.png"},
            position: gRouteTargetPoints[0],
            map: gMap,
            title: "Next Target"
        });
        // Set up first point on hiker path polyline
        gHikerPathLatLon.push({ lat: gCurrPosition.coords.latitude, lng: gCurrPosition.coords.longitude});
        gHikerPath = new google.maps.Polyline({
                        path: gHikerPathLatLon,
                        geodesic: true,
                        strokeColor: 'green',
                        strokeOpacity: 1.0,
                        strokeWeight: 2,
                        map: gMap
                      });
        // Use setpath to display updated path - as explained in
        // http://stackoverflow.com/questions/19665063/google-maps-live-drawing-and-updating-a-polyline
        gHikerPath.setPath(gHikerPathLatLon);
       // Add an overlay to the map of current lat/lng
        gHikerMarker = new google.maps.Marker({
            position: latlng,
            map: gMap,
            icon: {url: "https://maps.google.com/mapfiles/ms/icons/green-dot.png"},
            title: "You are here!"
        });
        // Wait until map has fully loaded before continuing
        // http://stackoverflow.com/questions/832692/how-can-i-check-whether-google-maps-is-fully-loaded
        google.maps.event.addListenerOnce(gMap, 'idle', function(){
            setTimeout(callback(), 5000);
        });
        $('.rec-walk-page-btn').css('display', "inline");
    }
```

Figure H-15 Extract from mapfns.js

H.3 User manual

A simple manual was written for users. It covered the following points:

- Installing the app – different instructions were provided for iOS and Android devices
- Testing the app at home before going out with it on the hills
- Recommendations:
    - Bring a spare battery pack
    - Don’t go out when it is very cold or raining
    - Remember doing the survey is time-consuming
- How to record the condition of a path using the app
- Troubleshooting

Appendix I Data conversion of 2002/3 survey reports

The 2002/3 survey results are in tables in MS Word documents. Sections of the Maulin to Tonduff survey are shown in Appendix A. A macro obtained online (Tamburino, 2011) was adapted to extract, into a single Excel worksheet, the contents of all tables of survey data in all the files. The data for each path survey was then put on a separate worksheet. The sheet for the Maulin to Tonduff path is shown in Figure I-1.

Maulin Tonduff		
Filename	C:\Users\hartyn\My Documents\10LUMA-GIS\THESIS GISM01\Upland Paths\Path Surveys\Path Survey 02-03\Survey	
Start to Finish	O 18186 13289 to	O 1595 1367
Altitude (lowest – highest):	500m - 644m	
Weather:	Wet morning, windy and overcast	
Access:	Crone forest car park	
Surveyed by:	John Monaghan, 30 / 7 / 02.	
No	PosIrishGridO	Comments / Photographs
1	18186 13289	Top of Crone forest, at stile
2	0	follow 3m wide grass / stony track contouring to the right (WSW) around Maulin towards the saddle between Maulin and Tonduff
3	17903 13120	At stone wall a minor path goes straight on towards col between M and T; I followed the main path turning left (SW) up onto Maulin pic57 looking back down to stone wall shows island in centre of path; tape = 0.5m
4	50m on up	a 50cms gully in the peat; path width average 1m; path surface of loose stones and peat
5	17962 13066	path terracing; the "new" path on the left on peat is 30cms above the "old" one on stone pic58 shows this; tape = 0.5m
6	18084 13038	path joins the main Maulin to Tonduff path
	0	END
0	0	0
7	18438 13088	START : Maulin summit
8	0	pic51 looking W shows the wide path off the summit towards Tonduff
9	0	pic52 further out; shows the path deteriorating; Tonduff in the distance
10	18243 13041	wet, wide and eroded; damage here goes out to 10m pic59 looking down from the high rock step, shows this dark area in the middle of the pic; the path continuing down to the saddle between Maulin and Tonduff
11	0	On the downhill section a lot of loose stones; braided in 3 or 4 places; width <= 2m pic60 shows an example of this
12	17857 13011	at lowest point [col] surface changes to peat; wet area here with wide damage pic61 shows this and slope up towards Little Tonduff (Pt. 593m)
13	17666 13027	path going up the slope is a mess; widening out to 15m; braided and broken pic62 looking back down the slope shows path width of 6m in foreground; paths to Maulin in background, including today's first path (No's 1-6) above
14	17519 13029	wet area
15	17354 13022	Wide eroded peat area pic63 looking WNW shows this
16	17000 13100	Little Tonduff (Pt. 593); summit area weathered and eroded
17	16727 13130	the path W indefinite and difficult to locate; walkers making their own way down the gentle slope (I observed a party of five doing this later, as I had done)
18	16560 13100	ran out of path; the wet bog surface now contains sphagnum moss, peat haggs and wet flushes
19	16196 13231	bottom of slope up to Tonduff South – no path; natural blanket bog erosion pic64 looking back (E) shows the flat, wet area towards Little Tonduff and Maulin
20	15904 13423	a single file path for about 60m leads to Tonduff South summit; the result of walkers finally converging on the cairn
21	0	no definite path from the South to the North summit
22	15950 13670	Tonduff North summit; an expanse of naturally eroded blanket bog with isolated peat haggs
	0	END

Figure I-1 2002/3 survey report for the Maulin to Tonduff path imported into an Excel spreadsheet

“Strange” characters were hidden in much of the data when it was imported into Excel. These were only found by switching to the “Dotum” font which displayed them. They were then removed.

Each path was assigned a letter, as shown in Table I-1. The numbers of all points at which data was recorded in the surveys were given the path letter as a prefix. For example, the Maulin-Tonduff path was assigned the letter D, so all points along it are D1, D2, D3, etc.

Table I-1 Letters assigned to paths in 2002/3 surveys

Path	Letter
Lough Bray	A
Luggala	B
Maulin East	C
Maulin Tonduff	D
Moanbane Mullaghcleevaun	E
Mullaghcleevaun Mull E Top	F
Oldbridge Scarr	G
Paddock Scarr	H
PWs Seat	I
Sally Carrigvore	J
Scarr Kanturk	K
Silsean Moanbane	L
Sugarloaf Lobawn	M
Three Rock	N
Three Rock Fairy Castle	O
Tonelagee Barnacullian	P
War Hill Djouce	Q
White Hill Djouce	R
WWay Crone White Hill	S
WWay Knockree Crone	T
Mullacor Lugduff	U
Mull E Top Duff Hill	V
Mull E Top Carrigshouk	W
St Kevins Path	X

The surveys followed a format of data collection which was far less rigidly structured than in an Amber Survey, and this made it difficult to accurately represent the data in a GIS. There were many issues with the data which had to be addressed before it could be input into ArcGIS to create shapefiles with attribute tables. Two types of information were recorded – the locations of points and the conditions at those points.

I.1 Irish National Grid and locations of survey points

The Irish National Grid (TM65) is the coordinate system in which all Ordnance Survey maps of Ireland are displayed (OSi, 2018). The locations of all points in the country are specified, in this coordinate system, in meters to the East and North of the origin, which is located off the south west coast. The system is based on a modified Transverse Mercator Projection, using a modified Airy Reference Ellipsoid.

Figure I-2 shows the way in which Ireland has been divided into twenty 100km*100km squares. The origin of the TM65 coordinate system is at the bottom left hand corner of the grid square V.

A commonly-used way of describing a location in Ireland is to specify the square in which it lies, together with its Easting and Northing in relation to the origin of the square, which is at the bottom left-hand corner.

The locations of survey points in the 2002/3 surveys were recorded in this way. These coordinates had to be converted into full National Grid coordinates. For example, the start of the Maulin to Tonduff path recorded in the survey shown in Figure I-1 is “O 18186 13289”. In National Grid coordinates the x,y coordinates of this point are 318186,213289 (=300000+18186, 200000+13289).

The Wicklow Mountains National Park is located in grid squares N, O, S, and T, and formulae were written in Excel to calculate the point locations in National Grid coordinates, based on the square in which the point lay.

If the Easting and Northing of a point are expressed as two five-digit numbers, they define the location to the nearest meter. If only three- or four-digit numbers are used, the location is defined to the nearest 100m or 10m, respectively.

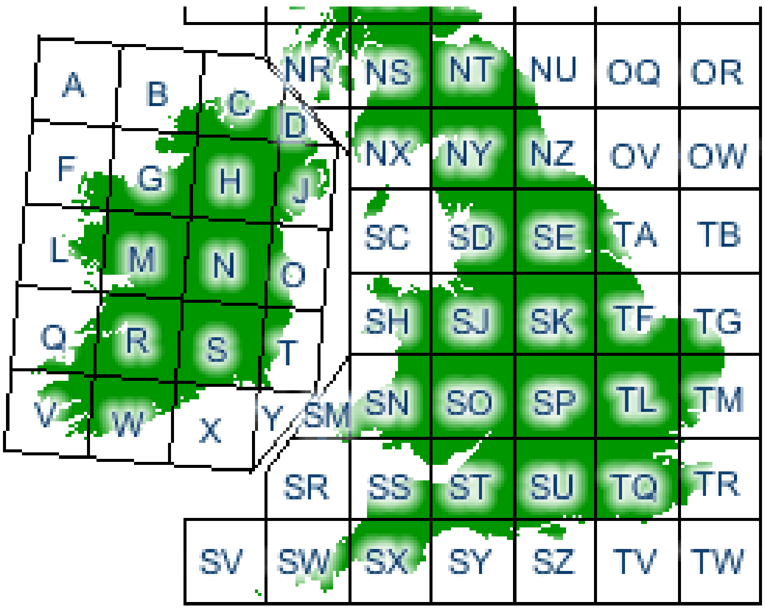


Figure I-2 100km*100km squares in Irish National Grid

Issues which were found included:

- The most accurate locations of survey points were recorded as two five-digit coordinates. The square in which a point lies was specified either at the start of the document (if all points are in the same square) or throughout the document if the path crossed into another square. These locations had to be converted into complete x,y National Grid coordinates, as described above.

- Many locations were recorded with less accuracy, with only three-digit Eastings and Northings. These were "filled out" with zeroes, but the resulting location was possibly 100m from the actual location.
- Some locations were recorded as "same" or "x m along" (where x was a number). These values had to be manually changed to x,y coordinates, and it is very possible that the accuracy was compromised in several cases.

I.2 Condition of the path at survey points

Not all indicators were recorded at all points. For example, the width of the path was not noted at each point. Photographs were taken at many of the points, and the path width could be estimated from the photograph, but if there was no photograph, it was not possible to know what the path width was.

The condition of each path was saved in an Excel spreadsheet, with columns containing the following data:

- The notes recorded at each point
- The file names and paths of the photos at a point were saved with a HTML image tag
- Condition measures corresponding to those to be recorded with HOP! These included path width (bare and trampled), depth, braiding, muddiness, and water flow. Where they were not recorded, they were estimated.

Because extracting the detailed condition data was very time-consuming, it was only completed for those paths that volunteers chose to survey.

A section of the final Excel file for the Maulin to Tonduff path is shown in Figure I-3. For clarity, rows and columns have been transposed. The first column contains the field names, and the rest of the columns contain the data for each point in the survey. Points used as target points in HOP! have a number in the final field.

This Excel spreadsheet was imported into ArcGIS and a shapefile was created.

PathID_2002	60	60	60	60	60	60	60
Path Name_2002	Maulin Tonduff	Maulin Ton	Maulin Ton	Maulin Ton	Maulin Ton	Maulin Ton	Maulin Ton
HikerID_2002	100	100	100	100	100	100	100
SurveyID_2002	1	1	1	1	1	1	1
PointID_2002	1	2	3	4	5	6	7
HistPointID_2002	D1	D2	D3	D4	D5	D6	D7
x_2002	318186	318044	317903	317932	317962	318084	318438
y_2002	213289	213204	213120	213093	213066	213038	213088
Lat_2002	53.15726	53.15653	53.15581	53.15556	53.15531	53.15503	53.15540
Lng_2002	-6.23393	-6.23608	-6.23822	-6.23780	-6.23736	-6.23555	-6.23024
Weather_2002	Wet morning, win	Wet mornir	Wet mornir	Wet mornir	Wet mornir	Wet mornir	Wet mornir
Date_2002	30/07/2002	30/07/2002	30/07/2002	30/07/2002	30/07/2002	30/07/2002	30/07/2002
Photo1_2002			<img alt="File" src="C:\		<img alt="File" src="C:\		<img alt="Fi
Capt1_2002			pic57 looking back dowr		path terracing; the "nev		pic51 lookir
Photo2_2002							
Capt2_2002							
Photo3_2002							
Capt3_2002							
NotesPt1_2002	Top of Crone fores	Follow 3m v	At stone wa	a 50cms gul	path terraci	path joins t	Maulin sum
NotesPt2_2002			pic57 lookir				
PathType_2002	Forest track	Evolved line	Evolved line	Evolved line	Evolved line	Evolved line	Summit
PathSurface_2002		Grass / Ston	Grass / Ston	Stone / Pea	Stone / Peat		Grass / Grav
BareWidth_2002		3	1.5	1	1	2	2.5
TrmpldWidth_2002		0	0	0	0	0	0
Depth_2002		0	0	0.5	0.3	0	0
Braiding_2002		Single Path	Single Path	Single Path	Multiple Pa	Single Path	Single Path
Muddiness_2002		Dry	Dry	Dry	Dry	Dry	Dry
WaterFlow_2002		No water fl	No water fl	No water fl	No water fl	No water fl	No water fl
PathWSc_2002	0	2	1	1	1	1	1
PathDSc_2002	0	0	0	3	2	0	0
PathBrSc_2002	0	0	0	0	1.5	0	0
MudSc_2002	0	0	0	0	0	0	0
WatrSc_2002	0	0	0	0	0	0	0
RawTot_2002	0	2	1	4	4.5	1	1
TotSc_2002	0	1	0	2	2	0	0
Target in HOP			1	2	3		4

Figure I-3 Section of final Excel spreadsheet for Maulin to Tonduff path survey 2002/3

Appendix J Feedback from path surveys

Each survey provided insight into the use of the app to survey upland paths. A number of issues were noted when HOP! was used on the hills, and most of these were addressed before the next survey. They are summarised in the following subsections, with the survey during which they arose. The final subsection presents general feedback on the app.

J.1 Three Rock and Three Rock-Fairy Castle

The surveys of the two paths, Three Rock and Three Rock-Fairy Castle, were carried out on 16/10/2016, by me, and were the first test of HOP! on the hills.

The thirty six points at which the condition was recorded in 2003 were the targets for the TR and TRF surveys in 2016. It was very quickly found that the process of recording a lot of data at each point was very time-consuming, and it was decided to simply take photographs and to add the related data later, using the photographs to provide the information.

The app crashed twice, probably because too many photographs had been taken. Because of this and the slowness of recording the condition at each point, it was decided to limit the path length and number of points on future surveys.

The app was set to "tweet" a bird sound when the user was within 500m of a target point. This was found to be much too large a distance, particularly on a well-defined path, and it was reduced to 20m on subsequent surveys, with an option for the user to manually change the distance if required.

J.2 Maulin East

I did a partial survey of the Maulin East path on 13/11/2016. I used an iPhone, and also, at a few points, an Android phone for the first time as a test. I tried to do the survey as part of a regular walk with my club, and found that it was not possible to combine the two activities. Eventually, after taking photographs at thirteen points, I stopped using HOP! and re-joined the group.

An additional issue which I had on this survey was that I did the survey in the reverse direction to that saved in HOP! This meant that I had to manually adjust the target point each time because, instead of using the automatically incremented target calculated by HOP!, I had to decrement it.

I found that the points to be surveyed were very close together, many only 50m apart. This meant that if one was not at exactly the correct location for one target, it could be very easy to be half way between two target points. It was decided that in future the targets should be well-spaced out, and that a limited number of points from the 2002/3 survey should be flagged as targets. This meant that points on each subsequent survey had to be selected as suitable targets from all the points surveyed in 2002/3. It was decided, where possible, to select points at which significant condition was recorded in 2002/3.

J.3 Prince William's Seat

The survey of the Prince William's Seat path was conducted on 4/12/2016 by a volunteer hillwalker accompanied by me. It was the first use of HOP! by a person other than me. Having learnt from the experience on previous surveys, the number of target points was reduced to thirteen points which were well spaced out along the route.

On a dark, cold and short winter's day, the survey was difficult and slow, and at the end of the survey the car was finally reached in the dark. The second path was not surveyed at all because of the failing light. Another problem with surveying in mid-winter was that the conditions were very different to those in the summers of 2002/3 when the earlier surveys took place, so direct comparisons may have inbuilt errors.

The intention was for the surveyor to use her own Android phone, which worked correctly when tested briefly in her home. However, the app would not work at all on this path. It did not work either on my Android phone, but did on my iPhone, so this is what the surveyor used for the survey. After much testing and a number of trips to the path in early May 2017, the problem was eventually fixed – it was a combination of a coding issue and poor access to mobile data and Google Maps.

J.4 Oldbridge-Scarr

This survey was carried out on 18/6/2017 and was the first one conducted by a hillwalker without me in attendance. He is an experienced hillwalker who is very comfortable with technology.

The "Stop & Email" option did not work, and he had to email me the database and photographs separately later, but no data was lost. He also recorded the condition at some point a few times, unknown to himself. This was a misunderstanding of how the app works – he thought if he recorded the condition at the same point a second time he would be able to edit the data he had put in earlier. It did not cause any problems, but the extra records had to be deleted.

He managed to record the condition at exactly the correct spot for all targets. He did not use the "tweets" on the app to locate the target, and instead used the map on the app to get to the next target. It is interesting to see how different people use the same app differently. The screenshot in Figure J-1 shows the accuracy of the target locations - a blue flag identifies the prescribed target points and a large green circle the points at which the condition was recorded.

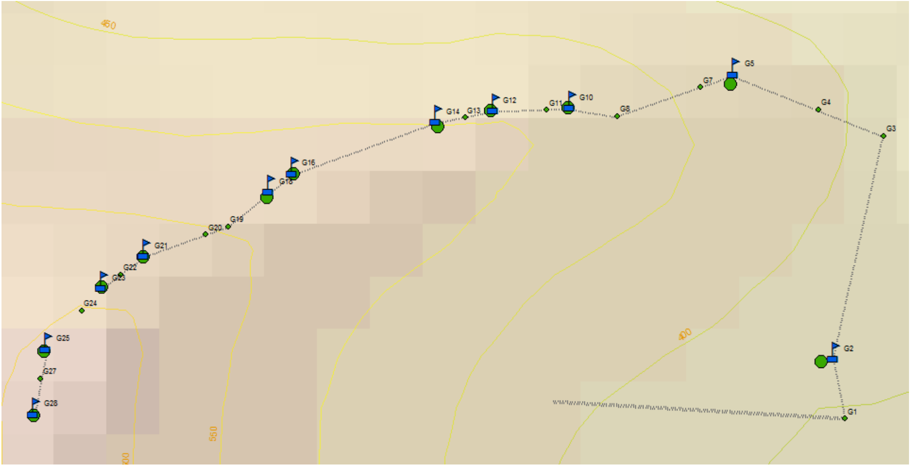


Figure J-1 Accuracy of survey on Oldbridge-Scarr

J.5 White Hill-Djouce

This path was surveyed on 24/6/2017 by a hillwalker accompanied by me and another hillwalker. The volunteer surveyor describes herself as not technically-minded and is a reluctant smartphone owner. She is, however, an experienced hillwalker. She learnt very quickly how to use the app and to record the condition at each point. There were no issues, though she had a number of comments and suggestions for improvements.

J.6 Maulin-Tonduff

This path was surveyed on 22/7/2017 by the volunteer who had already surveyed Oldbridge-Scarr, and was confident that his experience on that would make this survey even better.

He recorded the condition at fourteen points before his phone battery died. He was able to send me the database and the photographs later. He forgot to bring his walking pole, so it is not in the photographs to help estimate distance. Apart from that, there were no issues.

J.7 Scarr-Kanturk

The survey of Scarr-Kanturk was the final one to be carried out. A hillwalker from another club volunteered to do this one. He went out twice, once on 17/7/2017 to do a preliminary test of the app, and then on 24/7/17 to do the full survey. The preliminary test appeared to be successful, but unfortunately, something went wrong on the full survey, and the notes from very few points were all that were recorded. All the photographs were on the surveyor’s phone, however, so these were used to re-create as much of the data as possible. The cause of the problem has yet to be discovered – it will require me to accompany the surveyor on walk to see exactly what the issue was.

J.8 General comments

When asked for their feedback on the experience using HOP!, the volunteer surveyors suggested a number of modifications for the app, most of which would make the app easier to use, and would not change its basic functionality. Other issues they raised are outlined here.

All found the app very easy to use, and said that data was quite easy to enter. They really liked the bird sound made by HOP! which prompts when one is close to a target – in the hills one can really hear the osprey sound.

A number of volunteers commented that one could not do a survey in the rain, and this could be a problem in Ireland. The email at the end of the survey did not work on several surveys, but the users were able to send the data later.

A problem not often experienced in Ireland was found by two volunteers. As one of them reported:

> "It was a bit of a problem to see the screen in the bright sunlight and with sun cream smudges on it :-)"

Appendix K 2002/3 path condition in ArcGIS

The path from Maulin to Tonduff is used as an example to show what was done with the 2002/3 data for the eight paths surveyed in 2016/17 with HOP!

The condition, based on the scoring system in Table 3-3, of the path from Maulin to Tonduff in 2002/3 is shown in Figure K-1. The green dots show where the path was in quite good condition, and the yellow and orange dots show where it was fair and poor respectively (maps of other paths also have red dots for a “Very Poor” score). These points at which the condition was not good are in the saddle between Maulin and Little Tonduff. The soil at these points is peat and it is very wet all year round and walkers have been making multiple paths to get across the area.

As well as providing path managers with summary maps of the path condition, the 2002/3 survey data at each point can be viewed using the HTML popup function in ArcGIS. Figure K-2 shows a screenshot with some of the data for a point on the Maulin Tonduff path with a dark green “Very good” condition score, including a photograph. Even though the notes of the surveyor say the path is deteriorating, the scoring system gives this point a score of 0 (“Very good”) because the path had no braiding, no incisions, and was dry and no water was flowing. The way in which the scoring system appears to contradict the survey report highlights the limitations of the scoring system.

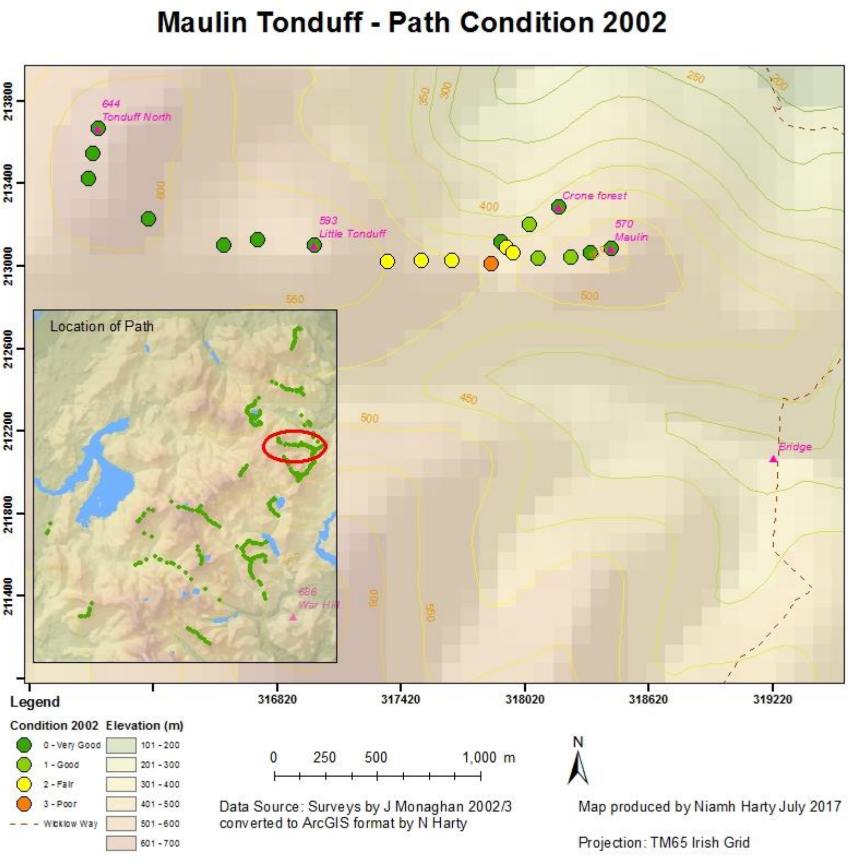


Figure K-1 Maulin Tonduff Condition 2002

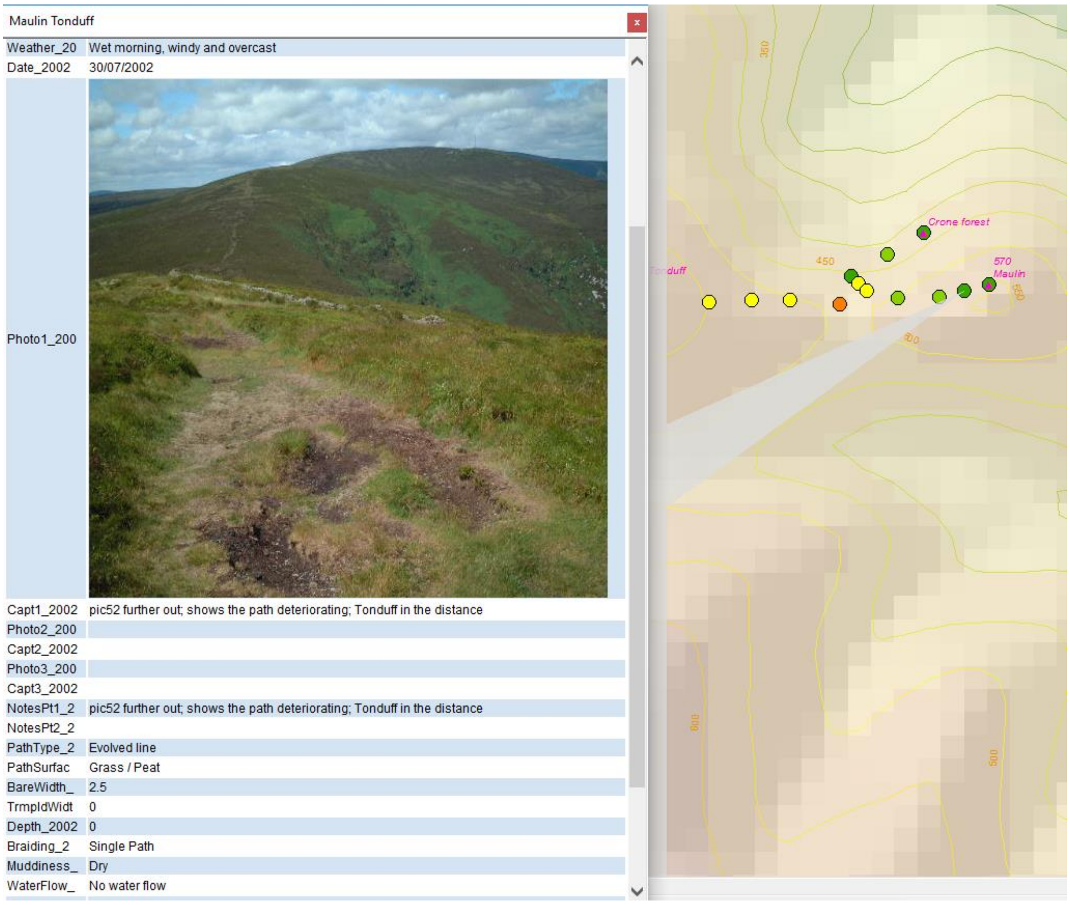


Figure K-2 2002 Survey Data at a point with "Very Good" condition along the Maulin Tonduff path as viewed in ArcGIS

Appendix L Data recorded in 2016/17

The results of all surveys carried out with the HOP! app are presented in this appendix. The first section gives summary information about all the surveys, the second section gives an example of the actual data recorded, and the condition details of each path surveyed are reported in the remaining sections.

L.1 Summary of surveys carried out in 2016/17

Eight paths were surveyed with the HOP! app. The locations of the eight paths are shown on the map in Figure L-1.

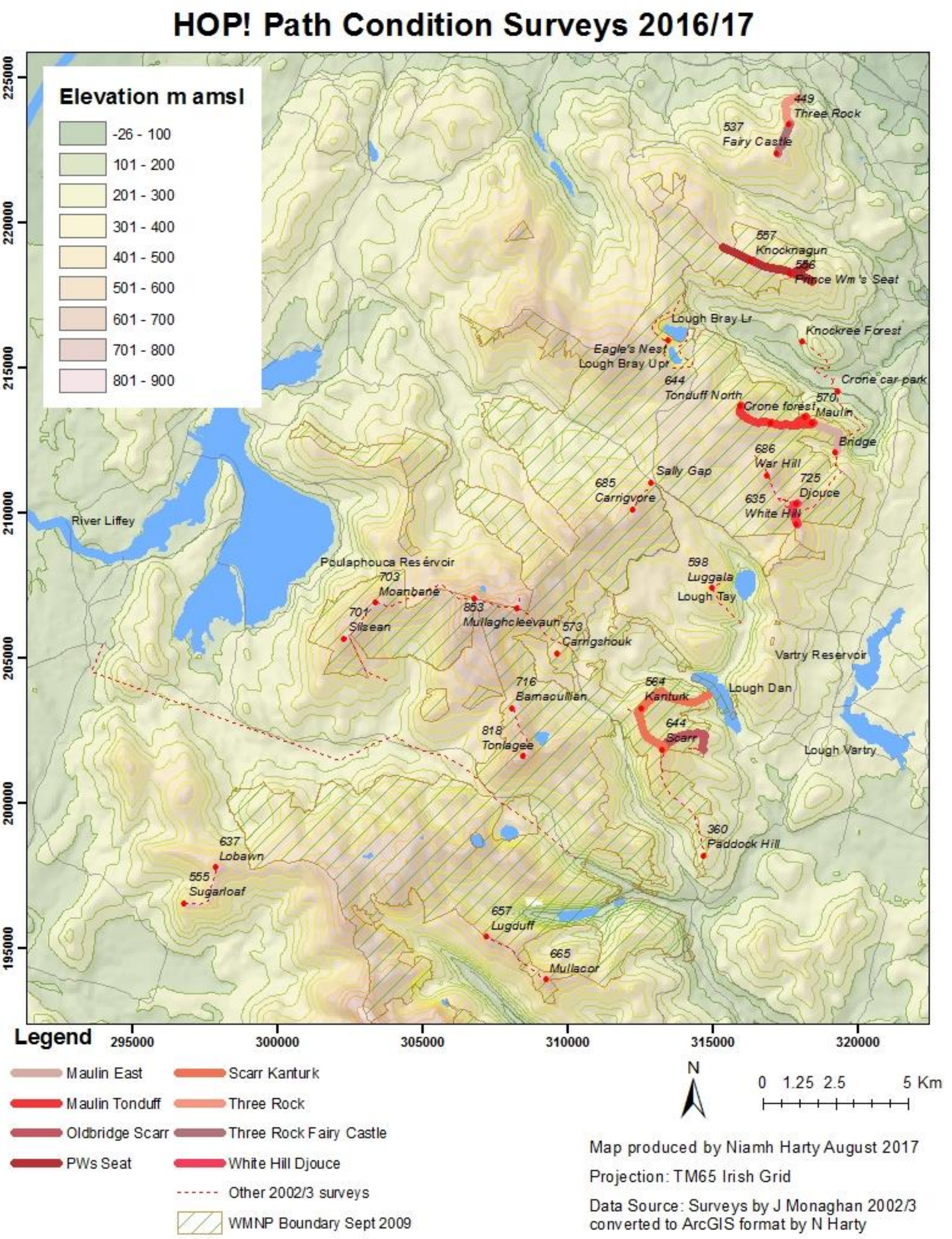


Figure L-1 Map of paths surveyed with HOP! in 2016/17

Details of each survey are listed in Table L-1, including the ID of the hillwalker who conducted the survey, the date on which it was carried out, and the type of device used.

Table L-1 Details of paths surveyed with HOP! app

Path ID	Path Name	Hiker ID	Date of Survey	Phone used
5	Three Rock	1	16/10/2016	iPhone
10	Three Rock Fairy Castle	1	16/10/2016	iPhone
20	Maulin East	1	13/11/2016	iPhone (and Android)
30	PWs Seat	10	04/12/2016	iPhone
40	Oldbridge Scarr	20	18/06/2017	Android
50	White Hill Djouce	30	24/06/2017	Android (and iPhone)
60	Maulin Tonduff	20	22/07/2017	Android
70	Scarr Kanturk	40	17/07/2017 and 24/7/17	iPhone

L.2 Example of actual data recorded on a survey

An example of the recorded data is shown for the first three points on the Prince William's Seat path in Table L-2, with the accompanying photographs in Figure L-2.

Table L-2 Data recorded at the first three points on the Prince William's Seat path

PathID	30	30	30
Path_Name	Prince William's Seat	Prince William's Seat	Prince William's Seat
HikerID	10	10	10
SurveyID	2	2	2
PointID	1	2	3
HistPointID	I2	I4	I8
Lat	53.19978063	53.20086144	53.20233808
Lng	-6.231018137	-6.23350203	-6.241045492
Weather	Cold, cloudy, dry	Cold, cloudy, dry	Cold, cloudy, dry
Date	04/12/2016	04/12/2016	04/12/2016
Time	12:50:36	12:59:59	13:39:16
Photo1	Photo1_1_2	Photo1_2_2	Photo1_3_2
Photo1Capt	Ref pic 24	Looking onwards towards Prince William seat	Ref 30
Photo2		Photo2_2_2	
Photo2Capt		Looking back	
NotesPt1	Appears to be a previously used/infrequently used trail		
NotesPt2			
PathType	Evolved slope	Evolved line	Evolved line
PathSurface	Heather/other vegetation, Stone, Peat	Heather/other vegetation, Rock, Peat	Grass, Heather/other vegetation, Peat
BareWidth	2.5	1	1.5
TrmpldWidth	0	1	1.5
Depth	0	0	0.2
Braiding	Single Path	Single Path	Multiple Paths
Muddiness	Wet	Wet	Wet
WaterFlow	No water flow	No water flow	No water flow

Figure L-2 Photos taken at first three points on Prince William's Seat survey

L.3 Three Rock and Three Rock-Fairy Castle – path condition

The start of the Three Rock path is just over 10km from the centre of Dublin, and these two paths are very popular with walkers of all abilities. The paths are in County Dublin, not Wicklow, but were included in the Wicklow 2002/3 surveys. The 1.4km path to Three Rock goes west from a public road at an elevation of 310m and then turns south-southeast alongside a forest to close to the summit of Three Rock (elevation 449m). There are several communications masts at Three Rock, and a public road also goes to the summit. A 1.1km path continues in south-southwest direction from Three Rock up to Fairy Castle (elevation 537m), where there is a wonderful view of the Wicklow mountains to the south. This path is part of the way-marked Dublin Mountains Way which is a roughly east-west path along the Dublin Mountains range.

In 2003, the condition was recorded at thirty six points on the two paths (twenty on Three Rock and sixteen on Three-Fairy Castle). The soil along the paths is "Podzols (Peaty), Lithosols, Peats, Some outcropping rock". The summary maps of the condition in 2016 and 2003 are shown in Figure L-3 and Figure L-4.

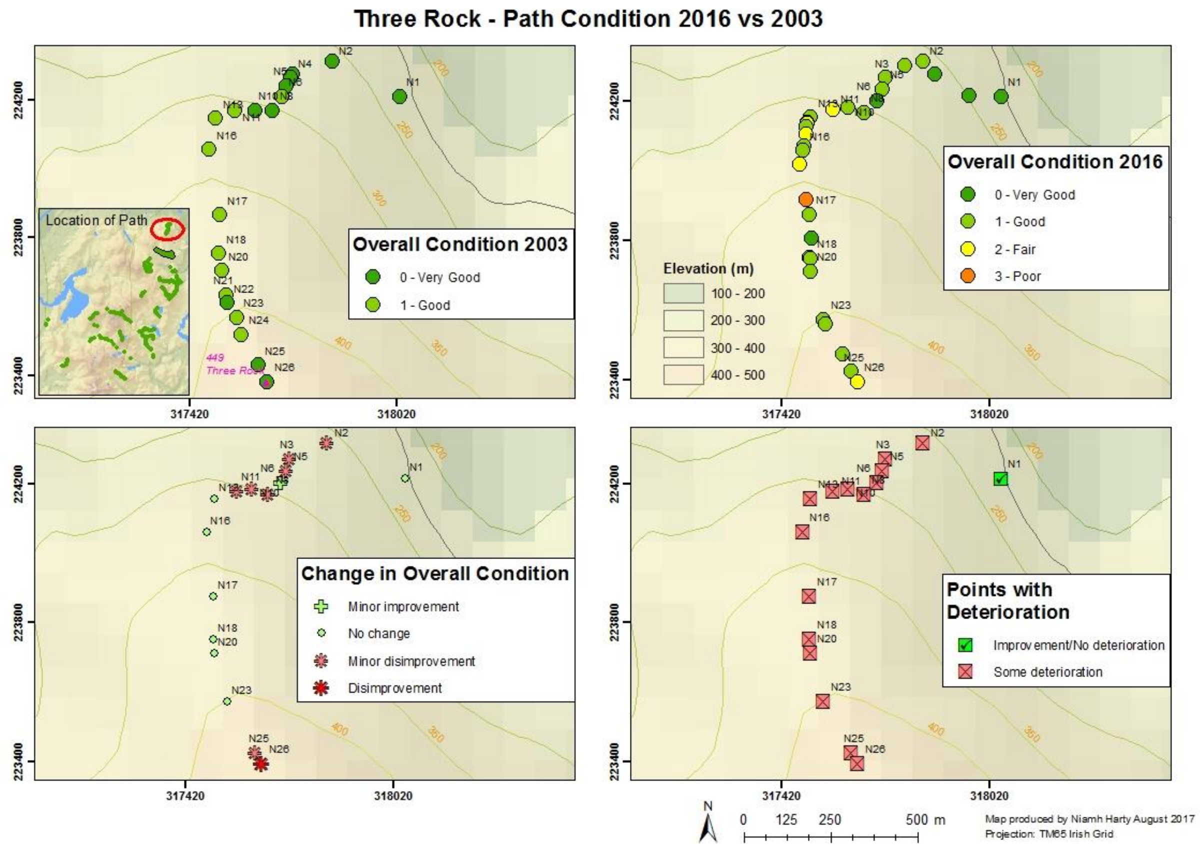


Figure L-3 Three Rock Summary Condition Maps

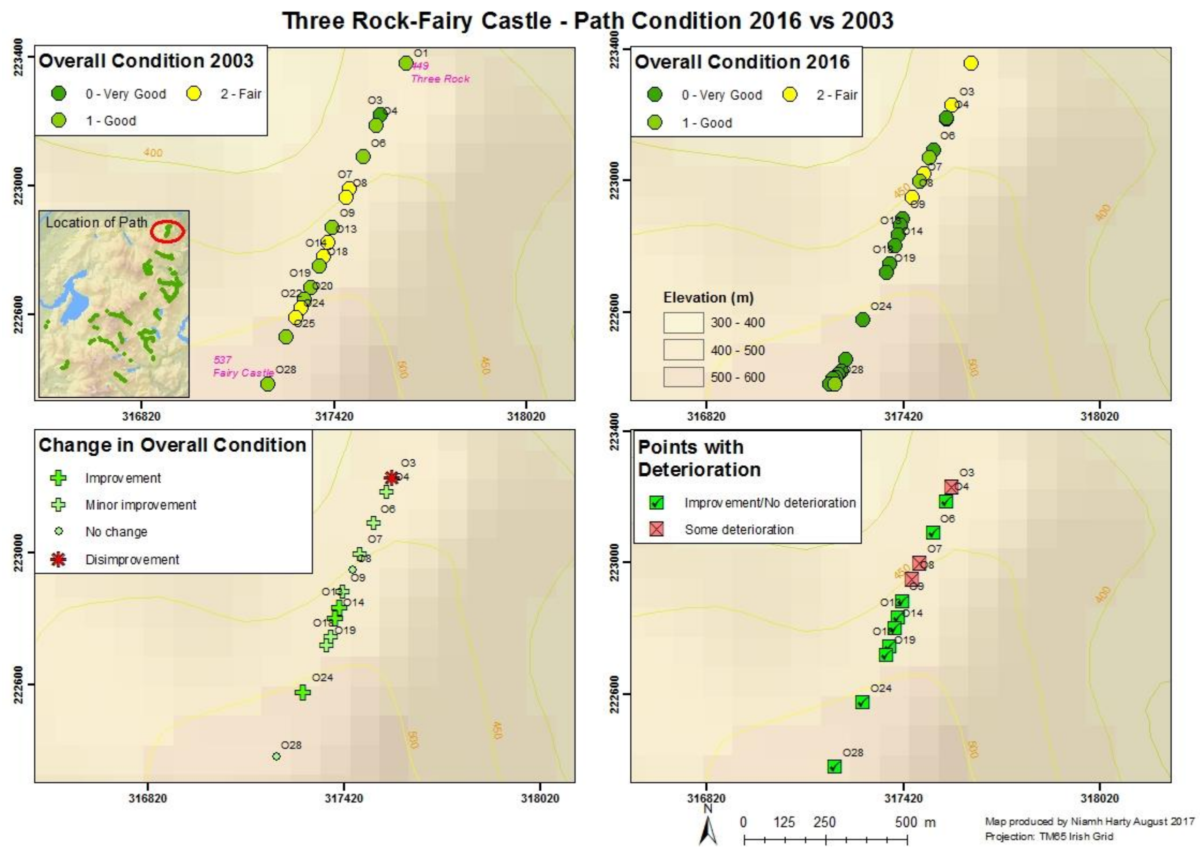


Figure L-4 Three Rock-Fairy Castle Summary Condition Maps

In 2003, the overall condition of the points on the Three Rock (TR) path was either "Good" or "Very Good", while on the Three Rock-Fairy Castle (TRF) path most points had condition "Good", and only one point had condition "Very Good" and six had condition "Fair".

In 2016, the condition was recorded (mostly only with photographs) at many more points along the two paths than in 2003 – thirty on the TR path and twenty four on the TRF path. The overall condition at some of the points on the TR points was found to be "Fair" or "Poor", and that along the TRF path was found to be "Very Good" at far more points than in 2003.

The maps showing the change in condition use only the points at which the condition was recorded in both 2003 and 2016. These show that the overall condition on the TR path disimproved along the first points on the path and also close to the summit, while some deterioration was observed at all but one point. The condition of the TRF path however shows significant improvement at the majority of points. This reflects pathwork which was carried out on the path since 2003. A long section of this path has been covered in stone and gravel and drains have been put in, with the result that walkers have been "moved" from the parallel paths on the side of the main path back to a single main path, and the vegetation has grown back to a large extent. As an example of this, the photograph taken in 2016 at point O19 along this section can be seen in Figure L-5. It shows a single well surfaced path with abundant vegetation either side. The surveyor in 2003 took a photograph at about the same point (shown in Figure L-6) and described the condition as follows:

> "… looking back shows the path, total width 7m; from right to left in the picture: a bare peat section half a metre wide / stone and soil section / heather island in the middle / stony section / heather island / and finally a braided single file section (the last not in picture); tape 1m"

Figure L-5 Three Rock-Fairy Castle Point O19 in 2016

Figure L-6 Three Rock-Fairy Castle Point O19 in 2003

One of the old parallel paths is shown on the right in the photograph in Figure L-7 taken in 2016, and it was not being used in 2016 – it is actually quite difficult to see it now from the main path.

Figure L-7 Three Rock-Fairy Castle Old Parallel Path not in use in 2016

The weather during the 2003 survey was recorded as “Hot, dry”, while the survey in 2016 was conducted on a day when the weather was “Sunny, 14 degrees. Rain for last few days”. This resulted in several points having a higher score for muddiness and water flow in 2016 compared to the 2003 survey. This resulted in a distortion of the overall condition score, mostly on the TR path. The detailed maps in Figure L-8 and Figure L-9 show the condition elements width, depth, and braiding, and are independent of muddiness and water flow.

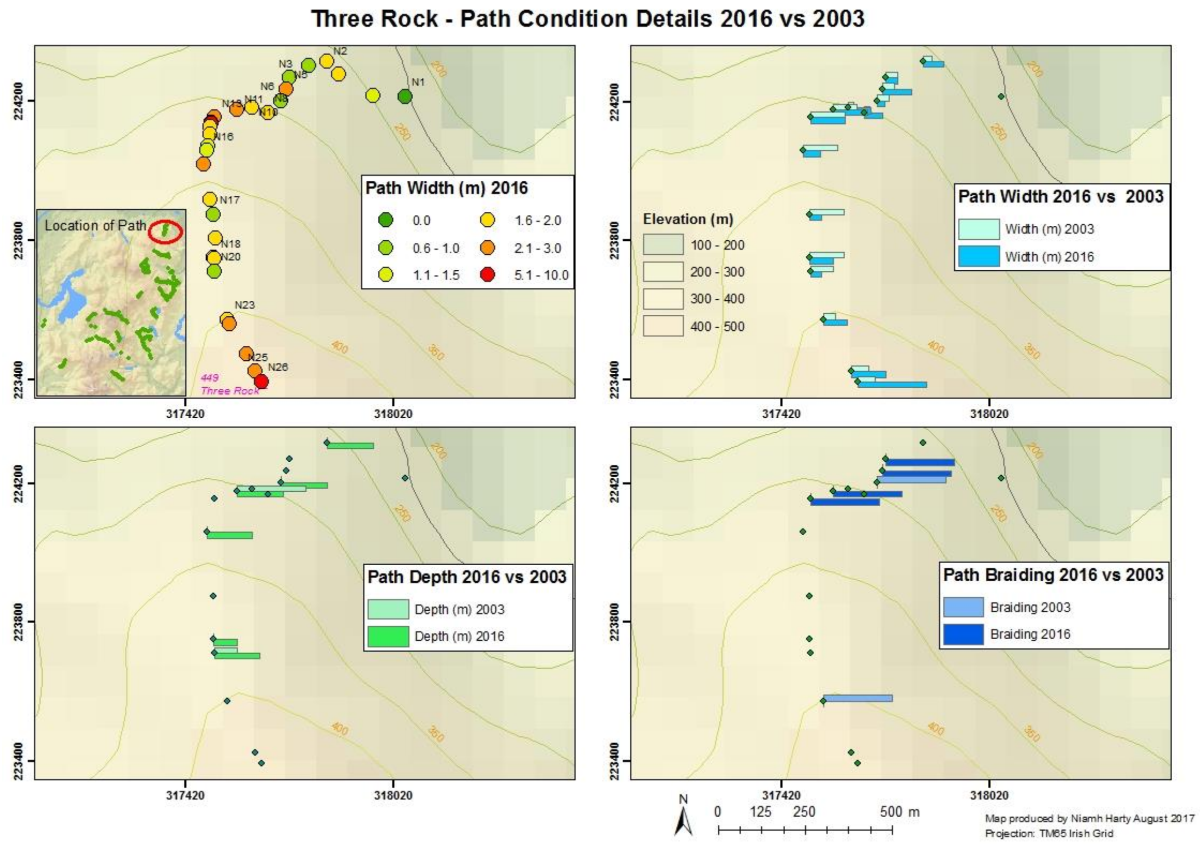


Figure L-8 Three Rock Condition Details

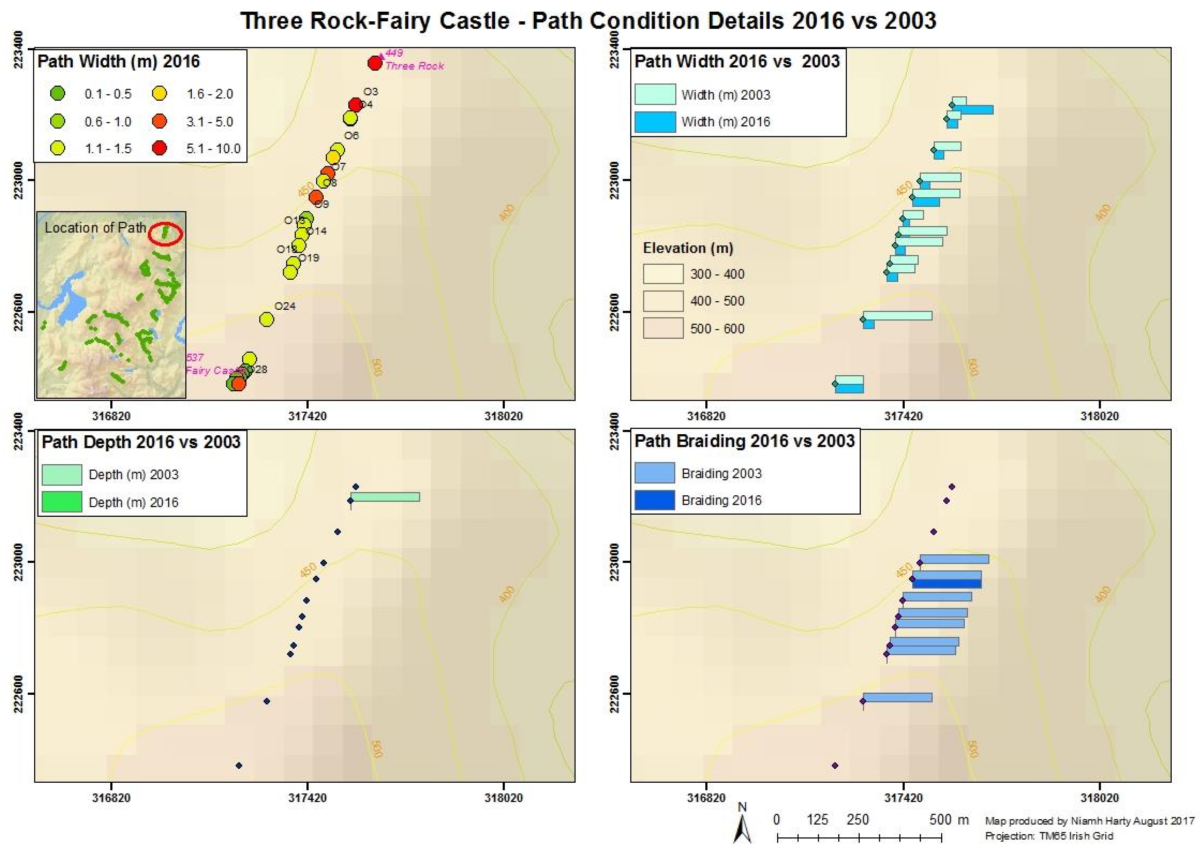


Figure L-9 Three Rock-Fairy Castle Condition Details

The width of the TR path in 2016 is seen to be under 3m at all points except the summit (where there is a road). The width was found to have both increased and decreased at different points, with no huge change. At several points, the depth of the path was seen to have increased and some extra paths were found at some points (braiding). From this, one can reasonably infer that the serious disimprovement in overall condition at many points was probably mostly due to the muddiness and water flow, and this section of path has not deteriorated significantly.

The width of TRF path in 2016 was mostly under 3m, with values greater than 3m recorded at five points. When the width in 2016 is compared to 2003, it is seen that there are nine points at which the width has decreased, as is to be expected from the maintenance work on the path. The path was recorded to have depth at one point in 2003 and at none in 2016. The braiding observed at eight points in 2003 was only visible at one point in 2016.

L.4 Maulin East – path condition

The full Maulin East (ME) path is 1.64km. It starts at a bridge over the Dargle River at an elevation of 330m, goes north along a section of the Wicklow Way, and continues northwards after the Wicklow Way veers off to the east. After climbing to an elevation of 440m, the path turns in a northeast direction towards the summit of Maulin (elevation 570m). The soil along most of the path is “Podzols (Peaty), Lithosols, Peats, Some outcropping rock”, apart from a 500m section of “Blanket peat” along the northwest path up to the summit. The summary maps of the condition in 2016 and 2002 are shown in Figure L-10.

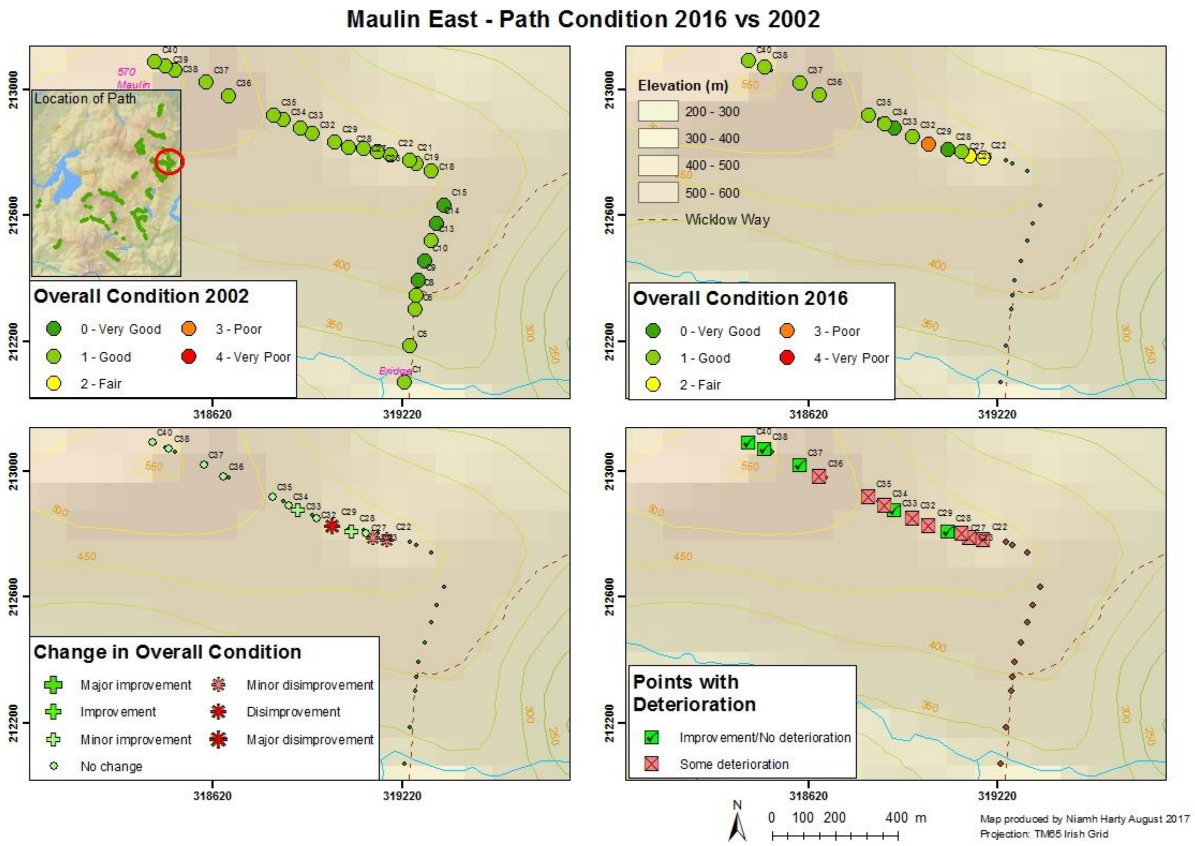


Figure L-10 Maulin East Summary Condition Maps

In the 2002 survey, the condition was recorded at twenty six points. The condition score at all points was either “Good” or “Very Good”. Points C23 to C35 are in the “Blanket Peat zone.

In 2016, the condition at thirteen points along the first 845m of the path from Maulin summit was recorded with photographs, and the data (width, depth, braiding, etc.) was filled in later by using the photographs. Two of the three points with a score of “Fair” or “Poor” are in the “Blanket Peat” section. These are the only points with a disimprovement, though five other points also showed elements of deterioration. Details are shown in the maps in Figure L-11.

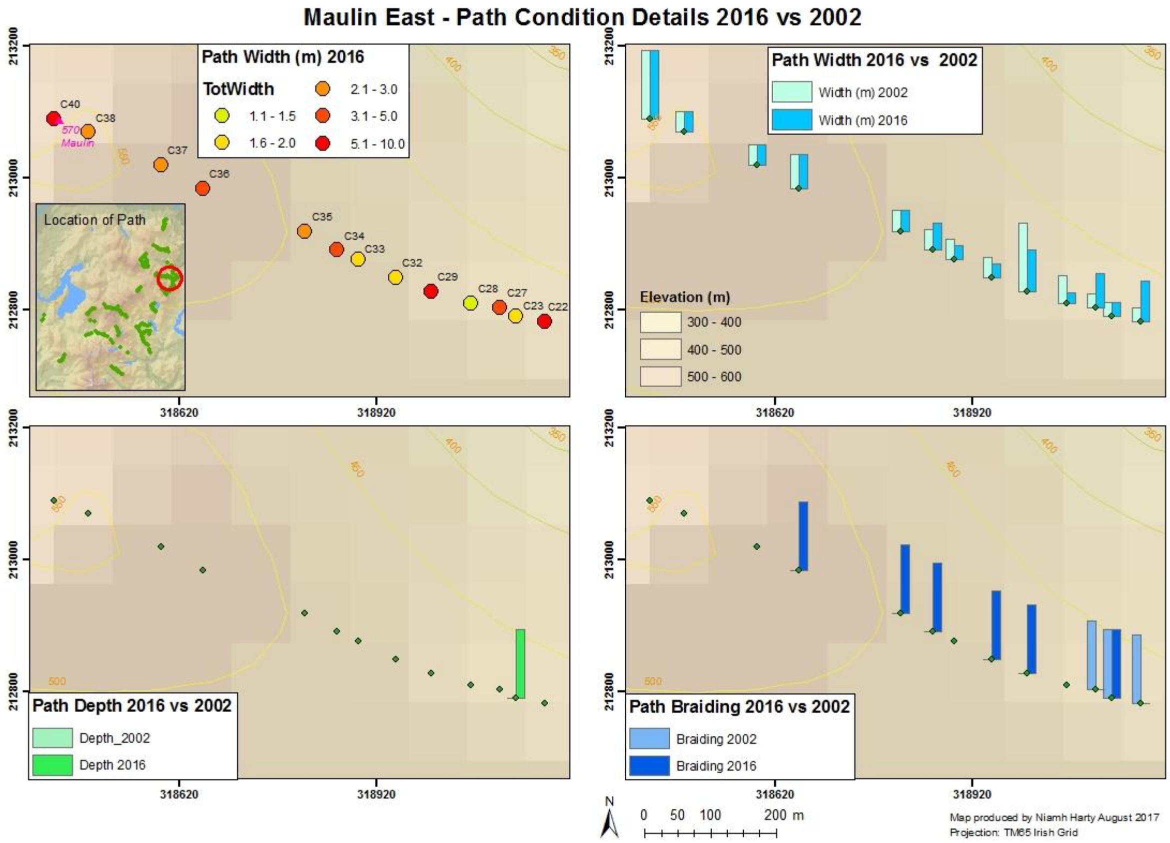


Figure L-11 Maulin East Condition Details

It can be seen that most of the points had a path width greater than 1.6m, with four points with width 5m or above. In most cases the width was recorded to have stayed the same or increased since 2002, though there are four points at which the recorded width in 2002 was greater than that in 2016. Only one point showed a path depth in 2016, but five points showed braiding had appeared where it had not been present before. Two points at which braiding was observed in 2002 did not appear to have braiding in 2016, but they did have increased path width, so possibly the braids have merged into a single path.

L.5 Prince William’s Seat – path condition

This 3.3km path goes west-northwest from the Wicklow Way to the summit of Prince William’s Seat (PWS) (elevation 556m, also known as Glencullen Mountain), down to a saddle (elevation 510m), up to the summit of Knocknagun (elevation 557m) and then down to a saddle (elevation 500m) on the far side. There is a 2km walk along the Wicklow Way from the car-park on the road to the start of the path, which means that a total walk of 10.6km is required to carry out the survey. The soil is “Blanket Peat” on this path, and gets very wet on the flat sections. In the 2002 survey, a second “new” path was also surveyed, but this was not surveyed in 2016. This second path was 500m in length going from Prince William’s Seat in a north-east direction to the Wicklow Way. The summary maps of the condition in 2016 and 2002 are shown in Figure L-12.

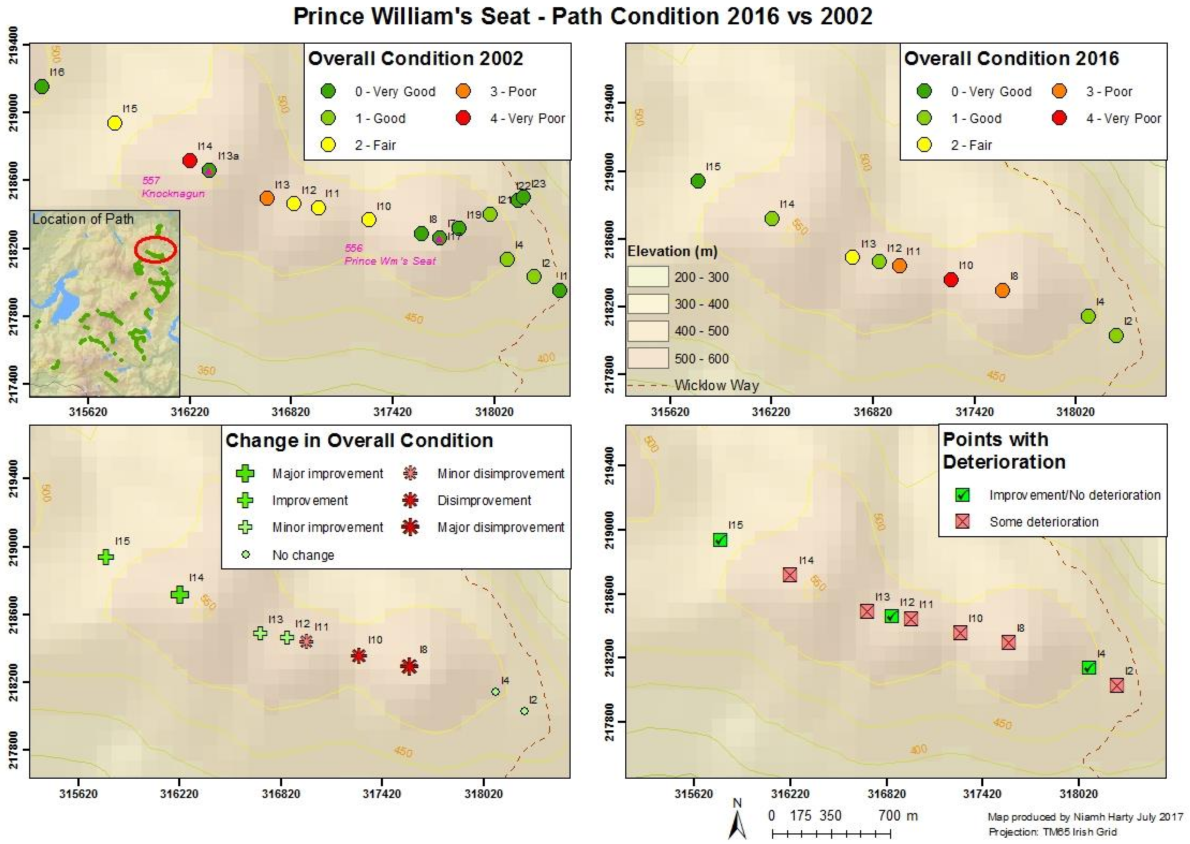


Figure L-12 Prince William's Seat Summary Condition Maps

In 2002, thirteen points were surveyed along the main path (points I1 to I16) and five points were surveyed on the second path (from I17 to I23). The condition of the path in the saddle between Prince William’s Seat and Knocknagun was “Fair” or “Poor”, and west of Knocknagun it was “Fair” or “Very Poor”.

In 2016, nine points on the main path was surveyed, up to point I15. The condition score for the points in the saddle between Prince William’s Seat and Knocknagun varied from “Good” at I12 to “Very Poor” at I10. The map of change in overall condition shows that this saddle area is where there was disimprovement, though some points showed improvement. However, all but three points (I4, I12 and I15) shows some element of deterioration. The details are shown on the maps in Figure L-13.

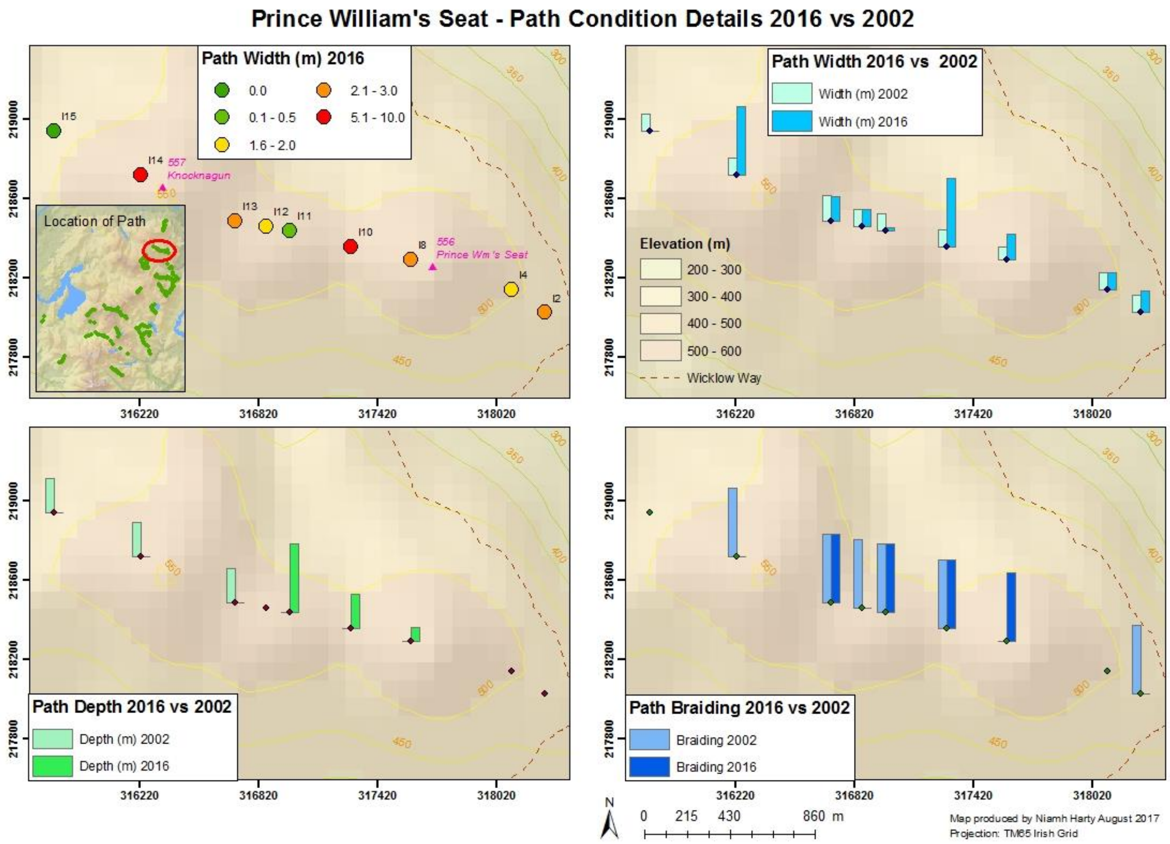


Figure L-13 Prince William's Seat Condition Details

The width of the path in 2016 was found to vary a lot over the length of the path – from 0.3m at I11 to 8m an I10 and I14. It was recorded as 0m at I15 because there was no path visible. The surveyor noted that possibly she had not found the correct point, because the width in the 2002 report appears to be 2m. It is possible that the same problem arose at I11 where the 2002 width is also about 2m. The map of change in path depth shows three points where there is path depth observed in 2016 and three different points at which path depth was observed in 2002. Similarly, while three points showed braiding in 2002 and 2016, three showed braiding in 2002 and not in 2016, and one point had braiding in 2016 and not in 2002.

L.6 Oldbridge-Scarr – path condition

The Oldbridge-Scarr (OS) path starts at an elevation of 350m and rises to Scarr summit which is at 644m. The soil along the path is "Podzols (Peaty), Lithosols, Peats, Some outcropping rock", and the 2.7km path roughly follows a semi-circle in an anti-clockwise direction. The ascent is gradual all along the path. The summary maps of the condition in 2017 and 2002 are shown in Figure L-14.

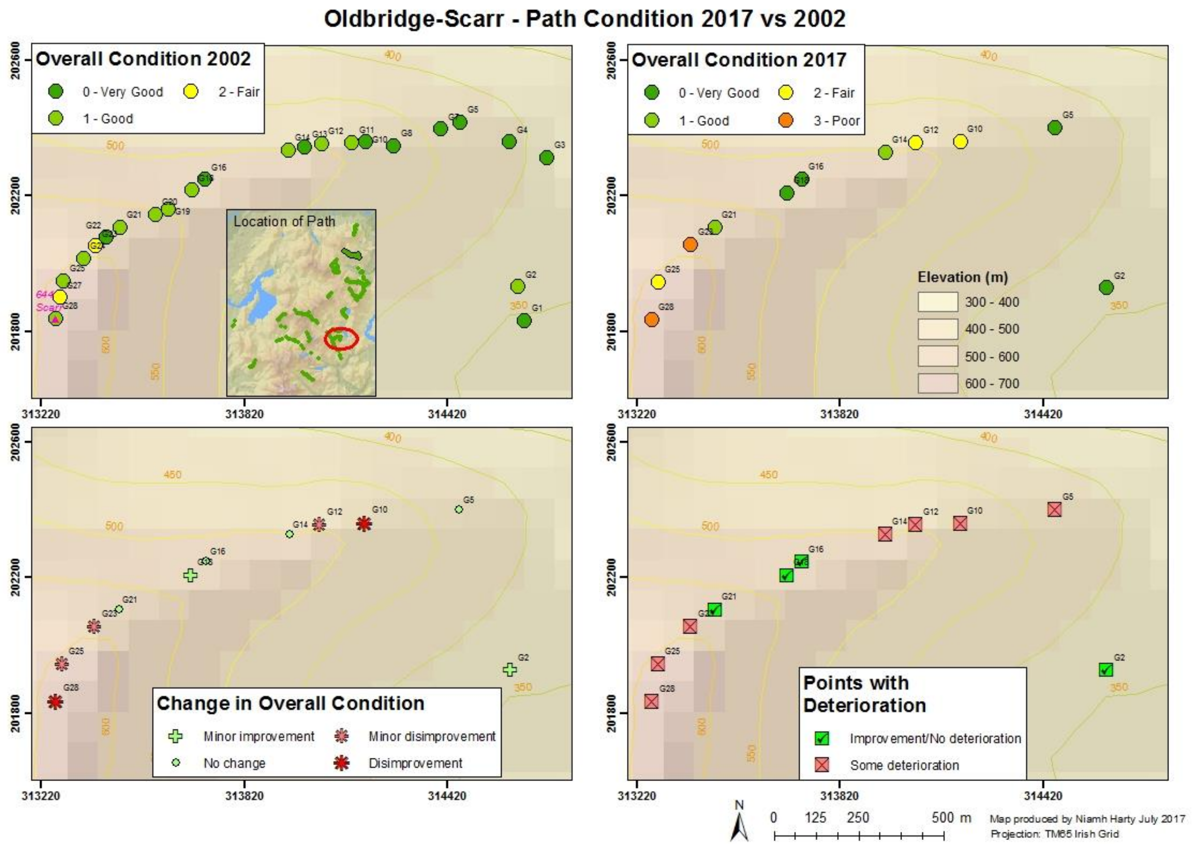


Figure L-14 Oldbridge-Scarr Summary Condition Maps

The condition was recorded at twenty three points along the path in 2002. The overall condition was "Good" or "Very Good" at all but two points which have a score of "Fair".

In 2017, the condition was recorded at eleven of these points which had been set as targets. Six points had a score of "Good" or "Very Good", three had a score of "Fair", and two had a score of "Poor". The change in overall condition was found to have improved a little at two points (G2 and G18), and had disimproved at five points, though none showed major disimprovement. Seven points had at least one element of deterioration and four had none or had some improvement.

The detailed maps showing what exactly had deteriorated/improved at each point, in terms of path width, depth and braiding, are shown in Figure L-15.

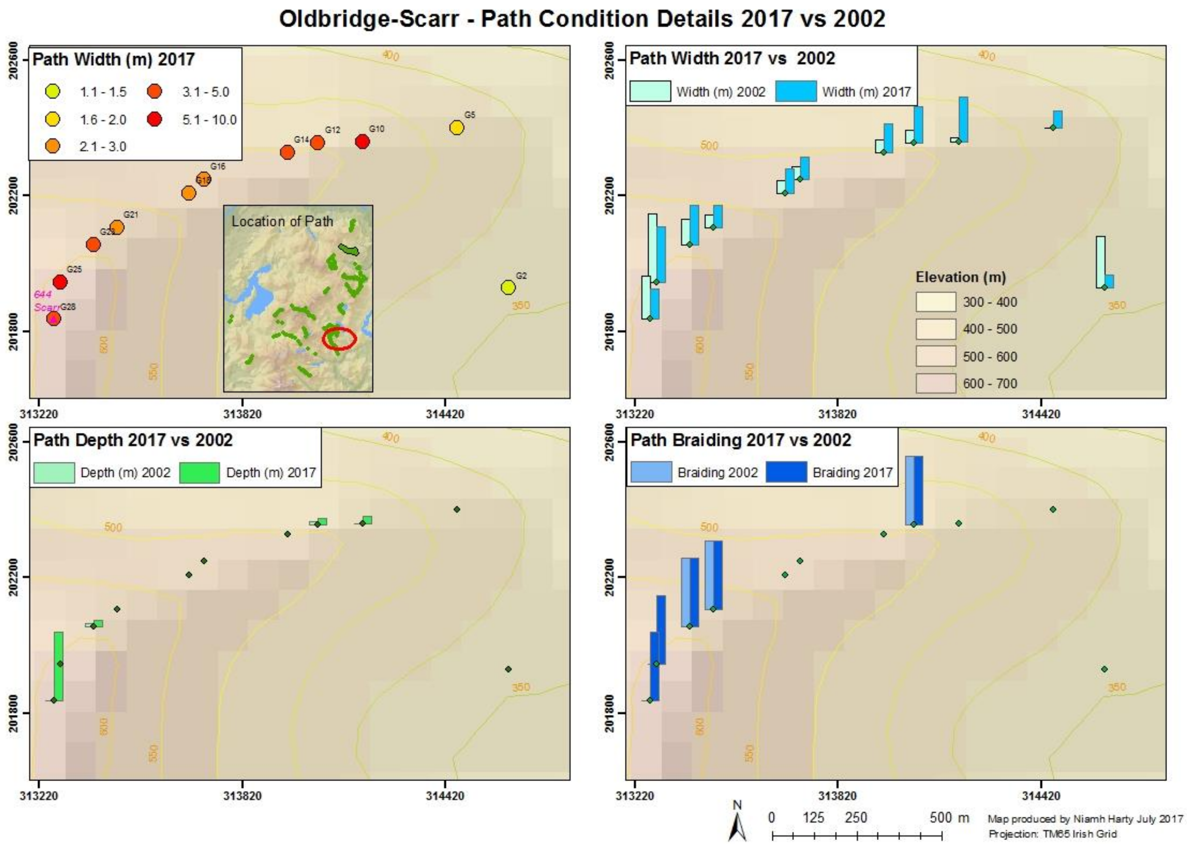


Figure L-15 Oldbridge-Scarr Condition Details

The path width is seen to have increased at several points along the path, in some cases by a considerable amount. For example, at point G10, the width in 2002 was 0.5m and in 2017 was recorded as 5.2m. At the first point and the last two points on the path (at the summit of Scarr) the width has decreased. At the two points at the summit, the path is recorded as braided in 2017, while it was not braided in 2002. Four points have increased depth compared to 2002.

L.7 White Hill-Djouce – path condition

The White Hill-Djouce (WhDj) path goes from the Wicklow Way close to White Hill, up to the summit of Djouce. The soil in the area is "Podzols (Peaty), Lithosols, Peats, Some outcropping rock", and this part of the Wicklow Way was in danger of becoming so eroded that a boardwalk was constructed in the 1990's to protect the ground. The boardwalk does not go up Djouce. The 845m long path rises from an elevation 610m to 730m, and first goes 630m in a northwest direction and then 215m in a northeast direction. The summary maps of the condition in 2017 and 2003 are shown in Figure L-16.

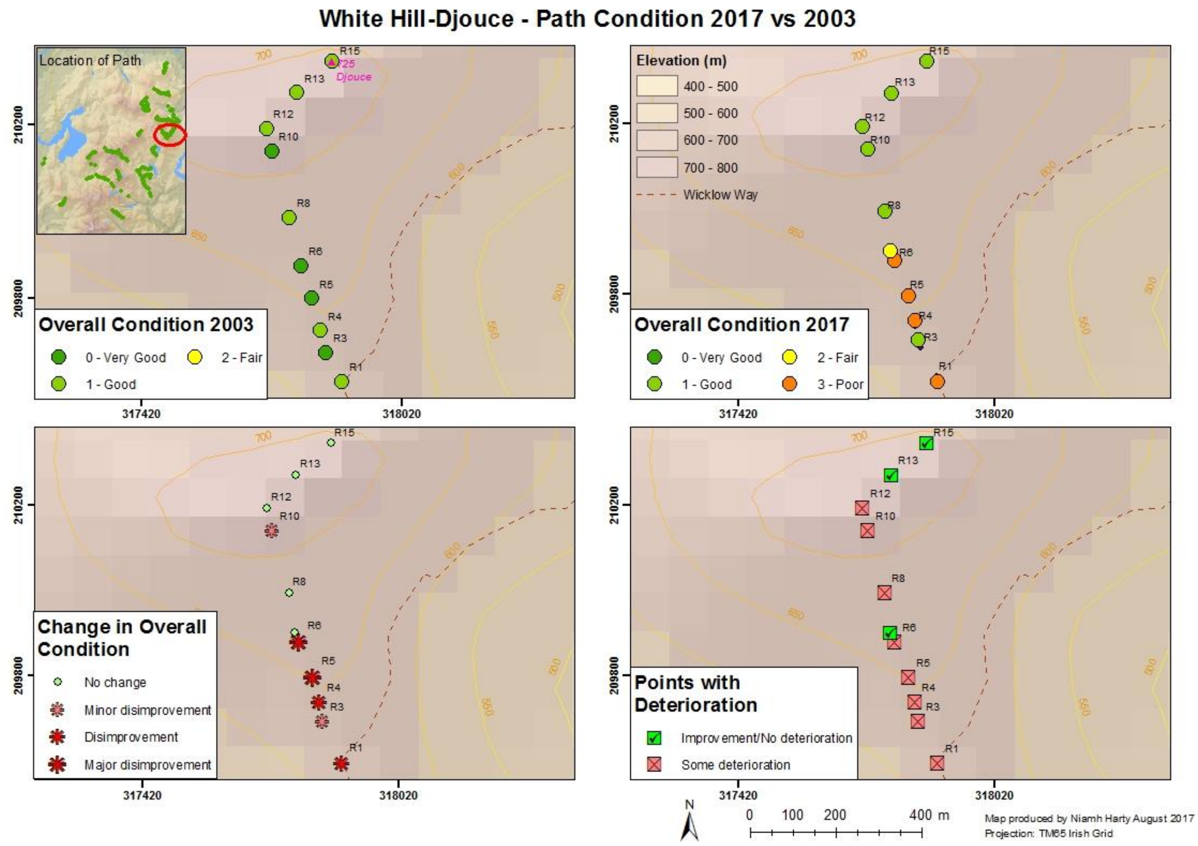


Figure L-16 White Hill-Djouce Summary Condition Maps

In 2002, the condition was recorded at ten points, and all points had a "Good" or "Very Good" condition score. In 2017, the condition was recorded at the same ten points, together with an extra point, which can be seen in the Overall Condition 2017 summary map as the yellow point between R6 and R8. The condition score of many points on the first half of the path are "Poor", with no point having a score of "Very Good". The change in overall condition can be seen to not have changed at points R8, R12, R13 and R15; there has been some minor disimprovement at R3 and R10; disimprovement was observed at R1 and R4; and there was major disimprovement at points R5 and R6. Points R8 and R12 do however have some deterioration as shown in the final map.

The detailed maps showing path width, depth and braiding are in Figure L-17.

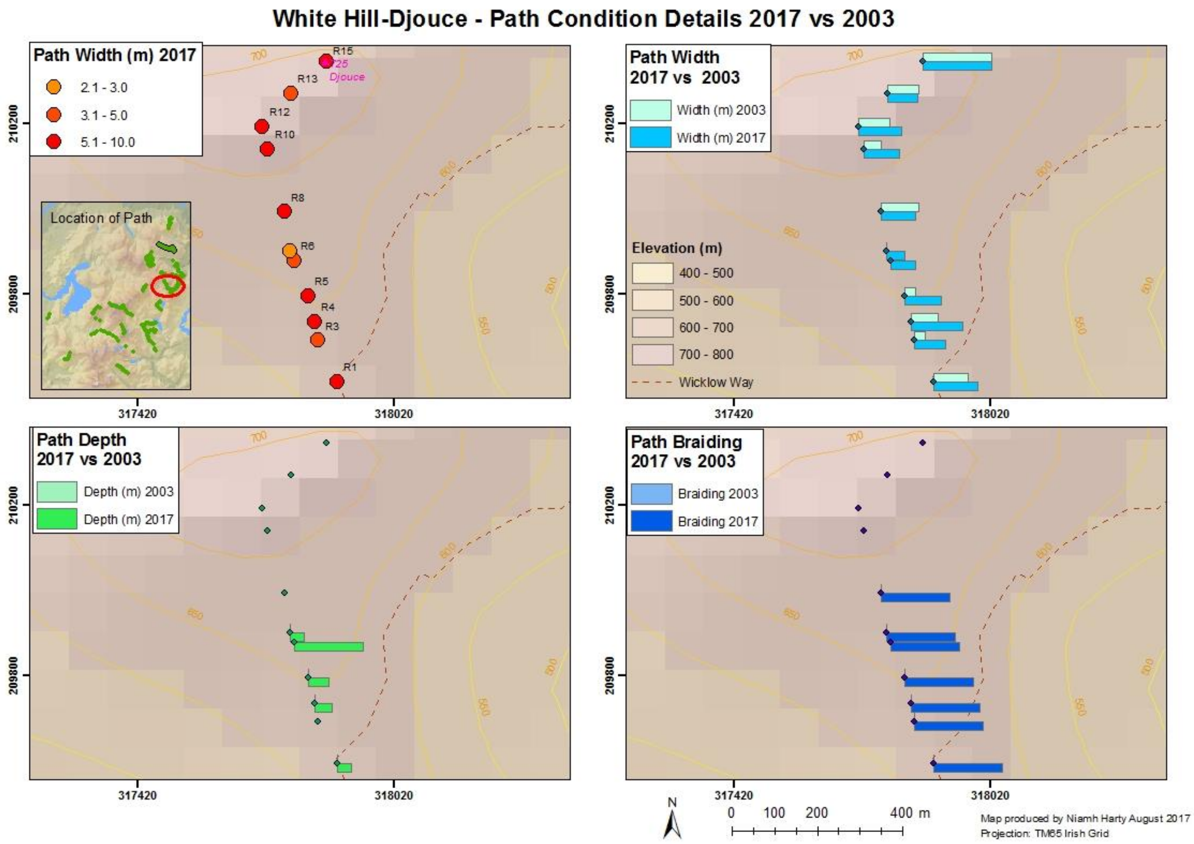


Figure L-17 White Hill-Djouce Condition Details

These maps show the points with increases since 2003. It is noticeable that from point R10 to the summit, there is no braiding and no depth, and not very much increase in path width. This appears to be because the ground is not as steep in this section (it is flattening out towards the summit) and also gravel has been placed along the path in that section which seems to be helping the path condition to not deteriorate further. This is shown in the photograph in Figure L-18. At most points along the path, the path width is over 3m, and most of these are greater than 5m. This results in the path being visible from quite far off.

The extra point at which data was recorded with HOP! by the volunteer surveyor is shown in the photograph in Figure L-19. She observed a large gully alongside the path which had not been recorded in 2003, and decided it was worth recording.

Figure L-18 White Hill-Djouce - Gravel on path close to summit

Figure L-19 White Hill-Djouce - Extra point with deep gully recorded with HOP!

L.8 Maulin-Tonduff – path condition

The Maulin-Tonduff (MT) path starts at the edge of Crone Forest, at elevation 450m, and climbs in a southwest direction to the saddle between Maulin and Tonduff (500m elevation approximately). This section of path is 535m long. The path then goes (without any recording) to the summit of Maulin (elevation 576m) and then goes west-northwest towards the summit of Tonduff (646m elevation), passing through the saddle point again. The length of this section is 2.9km. The soil type from the start of the path to the saddle to the summit of Maulin is “Podzols (Peaty), Lithosols, Peats, Some outcropping rock”, while the soil between the saddle and Tonduff is “Blanket Peat” (the softest surface of all). The summary maps of the condition in 2017 and 2002 are shown in Figure L-20.

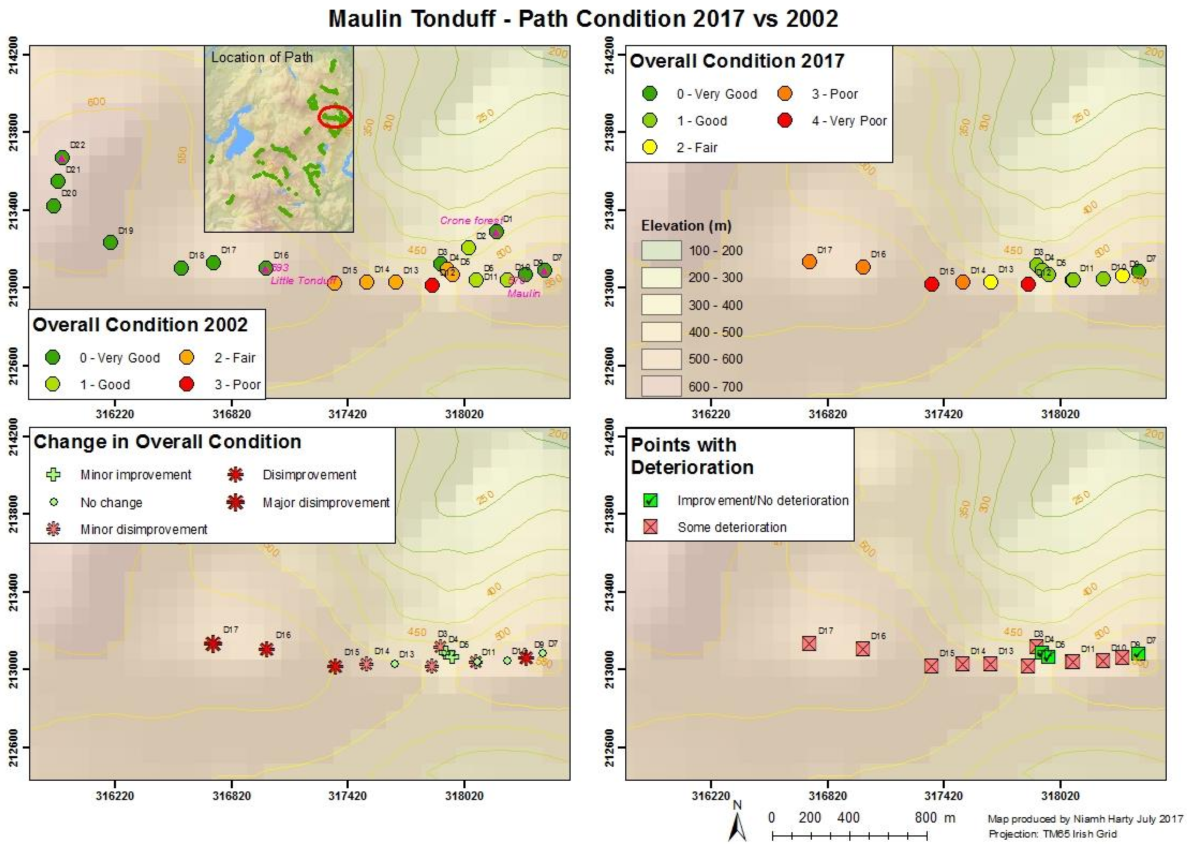


Figure L-20 Maulin-Tonduff Summary Condition Maps

The path condition was recorded at twenty one points in 2002, and the condition score was mostly "Good" or "Very Good" except for six points in the area of the saddle where the condition was either "Fair" or "Poor".

In 2017, the condition was recorded at fourteen points. Again the points in the area of the saddle got poor scores, but so too did points D16 and D17 in the area of blanket peat. There was a mixture of points improving and disimproving, with all but three points showing some level of deterioration. Details are shown in the maps in Figure L-21.

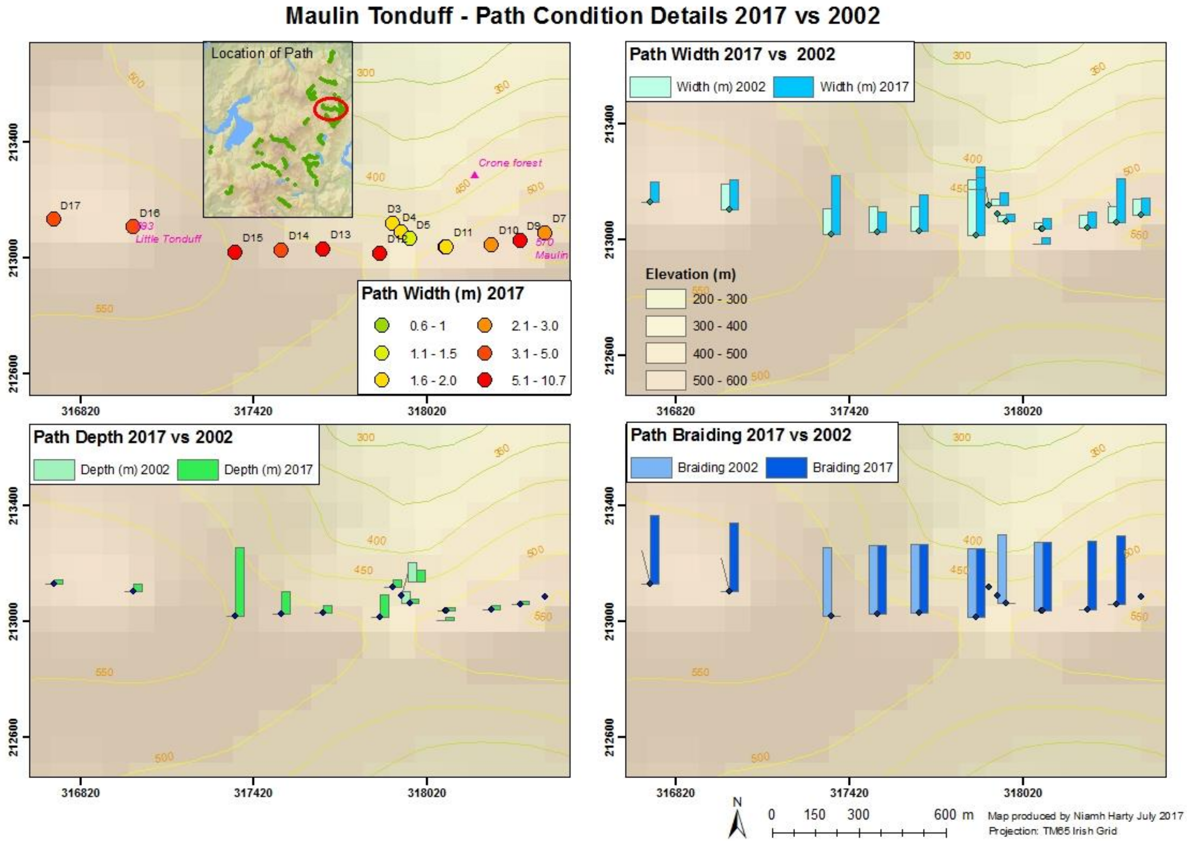


Figure L-21 Maulin-Tonduff Condition Details

The width of the path is over 3m at all points on the blanket peat (D12 to D17), 10.7m at D12 and 9.2m at D15. There was an increase in path width at all points surveyed in 2017. The path depth decreased on the section from the start of the path to the saddle, but increased at all points from the saddle towards Tonduff. Braiding changed at a few points – at four points braiding was observed in 2017 and not in 2002, while at two other points the braiding observed in 2002 was not observed in 2017.

L.9 Scarr-Kanturk – path condition

The 5.5km Scarr-Kanturk (SK) path goes down from the summit of Scarr (elevation 544m, already surveyed in the Oldbridge-Scarr survey) northwest and up to Kanturk (elevation 564m), and then down and up again to another peak of elevation 532m called Bracket Rocks and then swings northeast and then east-southeast back down to Lough Dan. The soil type on most of the path is “Podzols (Peaty), Lithosols, Peats, Some outcropping rock”, except for a section of “Blanket Peat” towards the end. The summary maps of the condition in 2017 and 2002 are shown in Figure L-22.

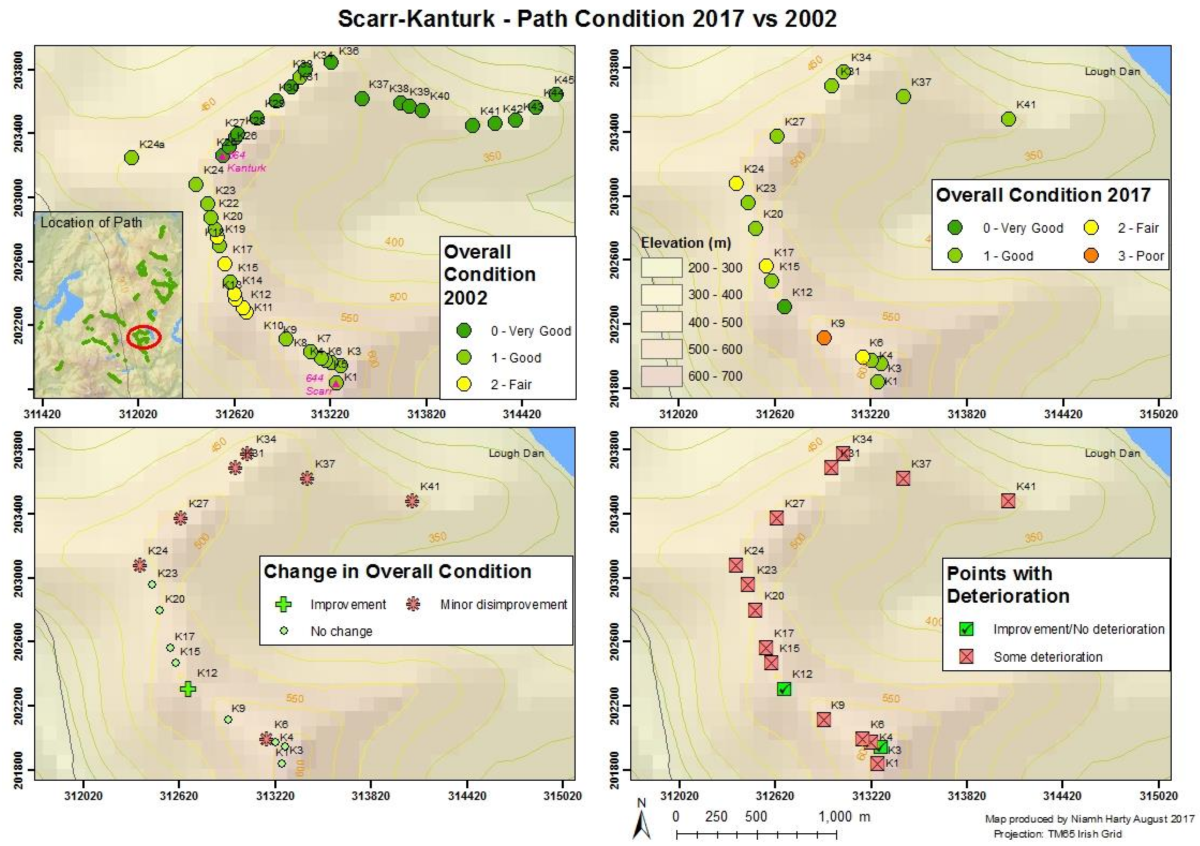


Figure L-22 Scarr-Kanturk Summary Condition Maps

In 2002, the path condition was recorded at forty two points. The overall condition was found to be “Good” or “Very Good” apart from a number of points in the saddle between Scarr and Kanturk (elevation 564m) where it was “Fair”.

Sixteen of the 2002 points were specified as the target points at which the condition should be recorded in 2017. At these points, the condition varied from “Good” to “Poor” in 2017. Interestingly, the points with the worst condition in 2002 were found to be the ones where there had been either no change or improvement in 2017.However, only two points were found to have had no deterioration since 2002.

Details of changes in path width, depth and braiding are shown in the maps in Figure L-23.

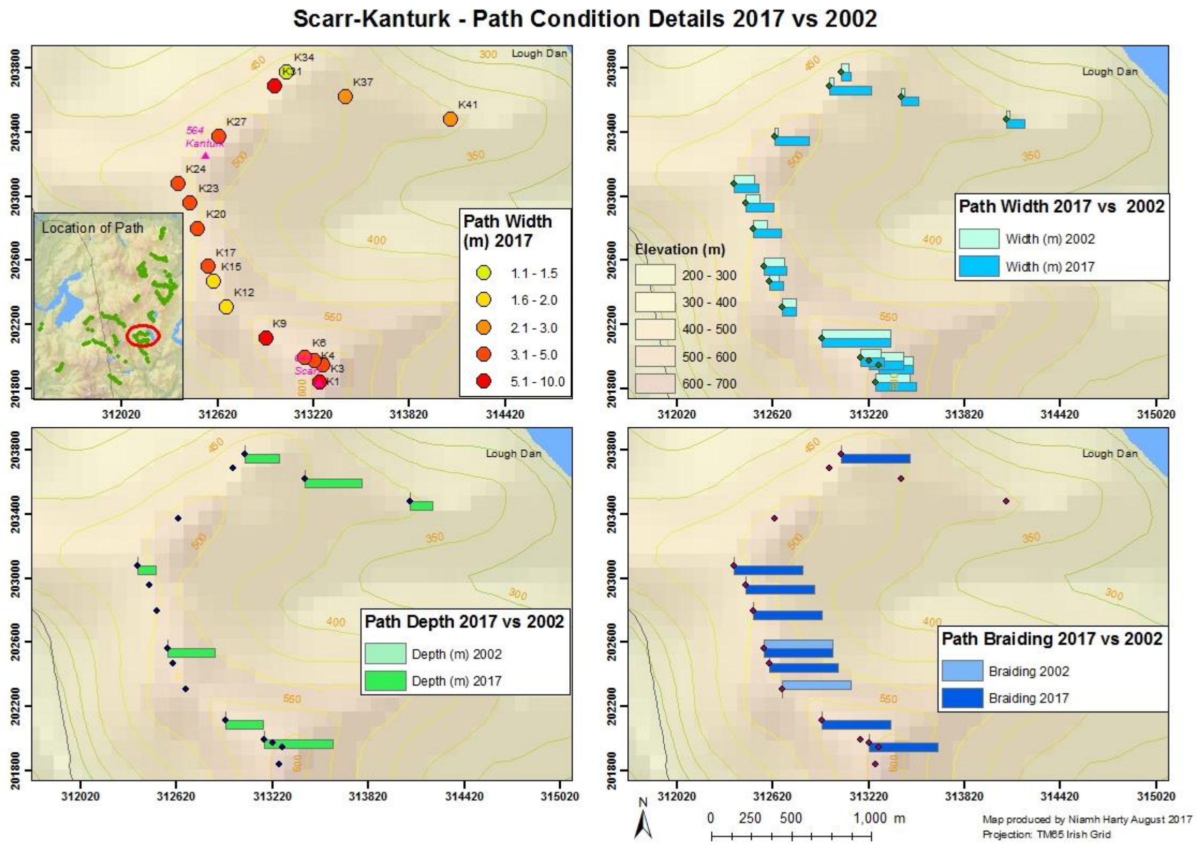


Figure L-23 Scarr-Kanturk Condition Details

The path was found to be quite wide in 2017, with most points having a path width of 3m or more. Several points were found to have a width greater than that recorded in 2002. Seven points had a path depth recorded in 2017, while no points had path depth in 2002. Braiding was found at seven points in 2017. One of these also had braiding in 2002, while another point had braiding in 2002 but not in 2017.

Appendix M Feedback from experts in path management

All of the feedback received from the DCO and Mountain Meitheal is presented in this appendix.

M.1 District Conservation Officer, WMNP

The District Conservation Officer in WMNP was very enthusiastic about HOP! and the results that were produced. Two meetings were held at which the results were reviewed.

At a meeting with her and three of her colleagues in December 2016, after the first four surveys had been carried out, the Overall Condition 2002 and 2016 maps for the Prince William's Seat path, as shown in the two maps on the upper part of Figure L-12, were reviewed. The lower maps showing change and deterioration had not been produced at that time.

The consensus was that the maps provided very useful information on hiking path condition, and they could see HOP! working both as a tool which hillwalkers could use as in this project, and also which park staff could use for their own projects. For example they could use it before and after events in the park which would have several hundred people walking on the hills along a path, to see the effect it had.

They liked the simple green-yellow-orange-red scoring system for the condition, and thought it was useful even if it was approximate. They suggested that the problems finding the correct points on the path could have been due to the inaccuracy of the GPS coordinates in 2002/3, and not problems with app or the tester in 2016. They thought it was useful to have used the 2002 survey as a baseline for comparisons.

At the final meeting with the DCO at the end of July 2017, the full set of summary maps for Prince William's Seat (Figure L-12), the Condition Details map for Oldbridge-Scarr (Figure L-15), and the scoring system (Table 3-3) were reviewed. The DCO said that both sets of maps would be very useful in the park. She agreed that the inclusion of muddiness and water flow in the scoring system could lead to distortion depending on the weather at the time of the survey, and pointed out that width, depth and braiding on their own give a good indication of the state of a path: an increase in depth can indicate volume of walkers on the path; an increase in braiding can indicate muddiness in the area; and an increase in width can indicate both.

M.2 Mountain Meitheal

A meeting with some Mountain Meitheal volunteers was conducted during one of their work days in July 2017. They were coming to the end of a project on a path which joins up the Avonmore Way (NTO, 2016a) with the Wicklow Way. A boardwalk and steps constructed on the path are shown in Figure M-1 and Figure M-2.

Figure M-1 Boardwalk built by MM 2017 on path between Wicklow Way and Avonmore Way

Figure M-2 Steps built by MM 2017 on path between Wicklow Way and Avonmore Way

Volunteers were shown pictures of the app, and the summary maps for Prince William's Seat (as shown in Figure L-12). A number of the MM volunteers whom I met had been involved in the Wicklow Path Surveys 2002/3. While they thought the app and the results were useful, they said they would be far more interested in seeing, instead of condition scores, the details of the actual width, depth and braiding of the paths, together with comparisons. They also said that they would not have any interest in the other details such path type and surface.

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