Population futures and Dartmoor National Park

Implications of development around the outskirts of Dartmoor for recreational use and management of access

September 2018

Report to Dartmoor National Park Authority

Brett Day
Amii Harwood
Charles Tyler
Sara Zonneveld

THIS REPORT IS A REDACTED VERSION OF A FULL REPORT PREPARED BY SWEEP FOR THE DARTMOOR NATIONAL PARK AUTHORITY. FIGURES AND TEXT CONTAINING INFORMATION ON HIGHLY SENSTIVE SPECIES HAVE BEEN REMOVED.

PLEASE DO NOT DISTRIBUTE THIS FILE WITHOUT PERMISSION FROM SWEEP OR DNPA – CONTAINS SOME SENSITIVE INFORMATION

sweep

Applying research to benefit our environment and economy

Acknowledgements:

The research in this report was funded by Dartmoor National Parks Authority and by the Natural Environment Research Council (NERC) through the SWEEP project.

We would like to thank all local species experts for sharing their knowledge on the local ecology and distribution of key species. The names of individuals who contributed by filling in key species questionnaires can be found in the full version of this report.

Executive Summary

- Dartmoor National Park is enjoyed by large numbers of visitors. Significant new housing developments and population growth in the districts around Dartmoor will inevitably result in increases in the number of visitors to the National Park.

- The statutory purposes for National Parks (Environment Act 1995) are to i) "*conserve and enhance the natural beauty, wildlife and cultural heritage*" and ii) "*promote opportunities for the understanding and enjoyment of the special qualities of national parks by the public*".

- In connection with these statutory purposes, the aim of this report is to identify both how the expanding population of Dartmoor's hinterland will benefit from the National Park as a recreational resource and also how the pressure of the additional visits coming from those new residents will impact on the National Park's environment.

- The report is compiled by academics from the SWEEP project (www.sweep.ac.uk) at the University of Exeter, and draws on secondary data, modelling capacity and on expert inputs in order to present a comprehensive assessment of the recreational future of Dartmoor..

- The first major contribution of this report is to construct spatialized predictions of population change in the Dartmoor hinterland from 2014 to 2039. Those predictions draw on Office of National Statistics population projections augmented by details of proposed property developments described in the Local Plans of the eight Local Authority Districts (LADs) that surround the National Park.

- To understand how new residents of the region might use Dartmoor, the spatialised population projections have been coupled with the Outdoor Recreation Valuation (ORVal) tool. ORVal is a sophisticated recreation demand model developed by the LEEP institute at the University of Exeter. As part of this project a bespoke calibration of the ORVal tool was developed and used to predict current and future patterns of visits to the array of recreation sites across Dartmoor National Park.

- The model indicates that Dartmoor is currently the backdrop for over 7 million day trips per year from residents of the eight neighbouring LADs. Moreover, increased populations in those LADs will result in more than 870,000 additional annual visits to Dartmoor per year, a rise of some 12%.

- The report also describes the development of a second bespoke modelling tool that extends the ORVal estimates of visitation into estimates of intensity of footfall through the National Park. That model used evidence from various sources to approximate how far visitors might travel through the paths network during their visits. The resulting estimates of the spatial dispersion of visitors and the intensity of footfall across the National Park allows us to address a number of questions regarding the impact of recreation on Dartmoor.

- The report addresses both the benefits and the costs of increased recreation activity on Dartmoor. With regards to benefits, a key measure is that of economic welfare. Welfare refers to the sense of well-being or utility experienced by an individual. Economic welfare is a figure capturing the monetary equivalent of this welfare enjoyed by visitors from their visits. Economic welfare can be directly estimated using the calibrated ORVAl tool. Indeed the model indicates that Dartmoor is currently the source of £25.6 million of welfare benefits to the residents of the 8 neighbouring LADs each year and that as a result of population increases that number will likely rise to £28.1 million by 2039; an increase in annual welfare of £2.5 million..

- Those welfare benefits are not evenly distributed across the neighbouring LADs. Rather the largest economic welfare values are realised in those LADs with significant populations in and around Dartmoor including Teignbridge, West Devon and Plymouth.

- The report also attempts to quantify the health benefits of the physical activity enabled by recreational access to the National Park. The footfall model provides prediction as to how far visitors to Dartmoor might be expected to walk in the National Park. Translating walking distances into energy expenditure provides an estimate of the level of fat burned by visitors, a quantity amounting to 100,000 kg of fat each year for the residents of the eight LADs neighbouring Dartmoor.

- Increased recreational activity on Dartmoor also generates the possibility of increased environmental and management costs. Transferring findings from a detailed study of the English Lake District, the report uses the footfall intensity estimates along with measures of path slope and altitude to predict rates of footpath erosion. Our analyses suggest that increasing recreational pressure on Dartmoor may result in 10,854 m^2 of bare ground being exposed along the path network and increased gullying along 42km of path.

- With regards to wildlife the research team carried out an extensive review of literature on the disturbance impacts of recreation. That review indicates that recreation impacts are complex and that it is difficult to make generalisations regarding how wildlife responds to recreation pressures. The report provides some detailed pen pictures of a selection of studies that are most relevant to the environment and wildlife of Dartmoor.

- To better understand the potential for recreational disturbance of wildlife on Dartmoor a selection of species of local, national and international importance, were identified from two local publications, 'The State of Dartmoor's Key Wildlife' and the 'Devon Special Species List'. For each species a recreation impact questionnaire was conducted with a local expert. The questionnaire gathered information on the distribution of each species across the Dartmoor landscape and sought insights as to whether and how exposure to increased recreation activity might impaction on the species population.

- Our analysis identifies twelve species that stand as examples of species that might be vulnerable to disturbance from increased intensity of recreational activity. Examples of species of particular concern include Cuckoo, Nightjar, Ring Ouzel and Wood Warbler. Activity types which have negative effects differ between species, but walking, dog-walking and large events are key concerns across many of the investigated key species.

- Overlaying the distributions of those species with our estimates of increasing visitor pressure across the National Park allows us to highlight some species that might be a focus of concern and the locations in which they are made vulnerable by rising recreation pressures. Those locations include the areas around i) Burrator, ii) the Dart Valley and Venford Reservoir, iii) Haytor, iv) Warren House, Soussons and Fernworthy.

- At these sites, an increased conflict between recreation and wildlife can be expected, and mitigation measures could therefore be prioritised there. Mitigation measures derived from both expert opinion and past research are outlined in the report. Measures suggested to be beneficial to a broad range of species include (temporary) access restrictions, management of large events, enforcement of the dogs on lead policy and public education.

- Recommendations for future data collection and research are discussed. These include further study to establish footfall thresholds for wildlife disturbance, an assessment of footfall intensity in relation to erosion patterns, and a quantification of recreational activities across the National Park.

Table of Contents

Tables

Figures

1 INTRODUCTION

Dartmoor National Park is enjoyed by large numbers of visitors. Significant new housing developments and population growth in the districts around Dartmoor will inevitably result in increases in the number of visitors to the National Park. In order to ensure both high quality recreational experiences and successful environmental protection, there is a need to better understand how new housing developments will impact Dartmoor. In response to that challenge, the Dartmoor National Park Authority (DNPA) outlined the following key questions for which answers were needed:

- Where do visitors currently come from?
- How will housing levels change in the areas around the National Park?
- How may visitor numbers, visitor distribution and types of access change?
- What are the impacts from National Park access and how important are those impacts?
- What needs to be done in terms of mitigation or changes to access management to provide for the changes forecast?

This report, compiled by staff of the SWEEP partnership (www.sweep.ac.uk) at the University of Exeter, sets out to provide answers to those questions.

In achieving that goal the research team have drawn on numerous information sources bringing together secondary data, modelling capacity and drawing on expert inputs in order to present a comprehensive assessment of the impacts on Dartmoor of future population increases.

The report begins with an assessment of what those future population changes might look like. Drawing on population predictions provided by the Office of National Statistics, Section 1 uses information provided in the Local Plans of numerous Local Authority Districts (LADs) to provide a detailed spatial prediction of the distribution of population increases around Dartmoor.

Section 2 of the report begins the examination of future recreational use of the National Park. Using a bespoke calibration of the Outdoor Recreation Valuation (ORVal) Model for Dartmoor, we predict current and future patterns of visitation across the National Park. In particular, our spatial population growth forecasts allow us to identify the distribution and intensity of day visits that arise from the growing populations of the LADs in Dartmoor's hinterland. This forecast focuses on day visits only, overnight visitors are not included in the ORVal Model. Section 2 goes on to develop a model of route choice which builds on data from the Monitor of Engagement with Natural England survey to approximate how visitors use the National Park and, more specifically, how visitors disperse through the recreation paths network during their visits. Our model allows us to make predictions regarding the intensity of footfall along paths in the National Park on any particular day or hour during the year.

Section 3 of the report considers the benefits of the recreation experiences provided to visitors by Dartmoor National Park. The report focuses on two measures. The first is that of economic welfare, a monetary measure of the enjoyment that visitors realise from their visits. Economic welfare is the standard measure of benefit used in social cost-benefit analyses as prescribed by government guidance in the Treasury Greenbook. Those estimates are derived from the ORVal model and show that the National Park is responsible for millions of pounds worth of recreational benefit each year. More specifically, the predictions indicate that by 2039, Dartmoor will be offering services to the expanded population of neighbouring LADs that deliver some £2.5 million of additional recreation benefits every year.

The second measure of benefit addressed in Section 3 is that of physical activity. The footfall model developed in Section 2, allows us to predict how far visitors to Dartmoor might be expected to walk during their time in the National Park. Translating walking distances into energy expenditure allows us to estimate the level of fat burned by visitors. Those estimates suggest that residents of the 8 local LADs burn around 100,000 kg of fat each year as a result of their physical activities on Dartmoor.

Section 4 moves on to consider the costs of recreational activity on Dartmoor. Again we address two potential costs, the physical erosion of paths resulting from recreation activities and the disturbance that activity might call to Dartmoor's wildlife.

With regards to erosion, we transfer findings from a study done in the English Lake District that allows us to predict rates of erosion on paths to path slope and altitude and, most importantly, to the intensity of daily footfall. Our analyses suggest that increasing recreational pressure on Dartmoor may result in 10,854 m^2 of bare ground being exposed along the path network and increased gullying along 42km of path.

With regards to wildlife the research team carried out an extensive review of literature on the disturbance impacts of recreation. That review indicates that recreation impacts are complex and that it is difficult to make generalisations about how the environment and wildlife respond to recreation pressures. The report focuses in on a selection of studies that are most relevant to Dartmoor, particularly those that address wildlife impacts in upland, heathland, moorland and oak woodland. To support the literature review, a selection of key Dartmoor species of local, national and international importance, and representing a broad range of habitats and species groups, were selected and a recreation impact questionnaire conducted with local species experts. The purpose of that questionnaire was to gather insights into the distribution of each species across the Dartmoor landscape so as to understand where that population might likely be exposed to mounting recreational pressures as well as to seek expert opinion on the possible impacts of that exposure on species populations.

Our analysis identifies twelve species that stand as examples of species that might be vulnerable to disturbance from increased intensity of recreational activity. Superimposing the distributions of those species with our estimates of increased visitor pressure across the National Park allows us to highlight some species that might be a focus of concern. In addition our analysis allows us to identify locations of concern where vulnerable wildlife distributions are associated with places where particularly strong increases in footfall are expected between now and 2039.

This report presents evidence supporting the contention that population growth in the region around Dartmoor will result in significant increases in recreational use of the National Park. For those new residents of the region, Dartmoor offers a significant resource that will likely be the source of substantial economic welfare and also the backdrop that encourages significant physical activity. Of course, that activity will also have impacts on the National Park and drawing on best available evidence the report identifies the possible extent of increased erosion along Dartmoor's paths network and the species and locations most vulnerable to disturbance as a result of increasing recreational pressure.

2 POPULATION FUTURES

In order to assess the future impacts of recreation on Dartmoor National Park, we first need to draw together information on the magnitude and spatial distribution of population around the National Park and generate predictions of how that population might change going into the future. This first section describes the data sources and analyses that have been used in developing those population distribution predictions

2.1 THE DARTMOOR HINTERLAND

Due to their connectivity to Dartmoor National Park, our analysis focuses primarily on eight local government areas (i.e. Unitary Authorities and Districts) that define Dartmoor's hinterland (Figure 1). For simplicity we refer to these subsequently just as Local Authority Districts or LADs. Notice from Figure 1 that three of the LADs in Dartmoor's neighbourhood (West Devon, Teignbridge and South Hams) have some significant physical overlap with the National Park. Of the remaining neighbouring LADs, three (Exeter, Plymouth and Torbay) represent relatively urbanised areas while the Mid-Devon and East Devon are relatively rural and generally more remote from Dartmoor.

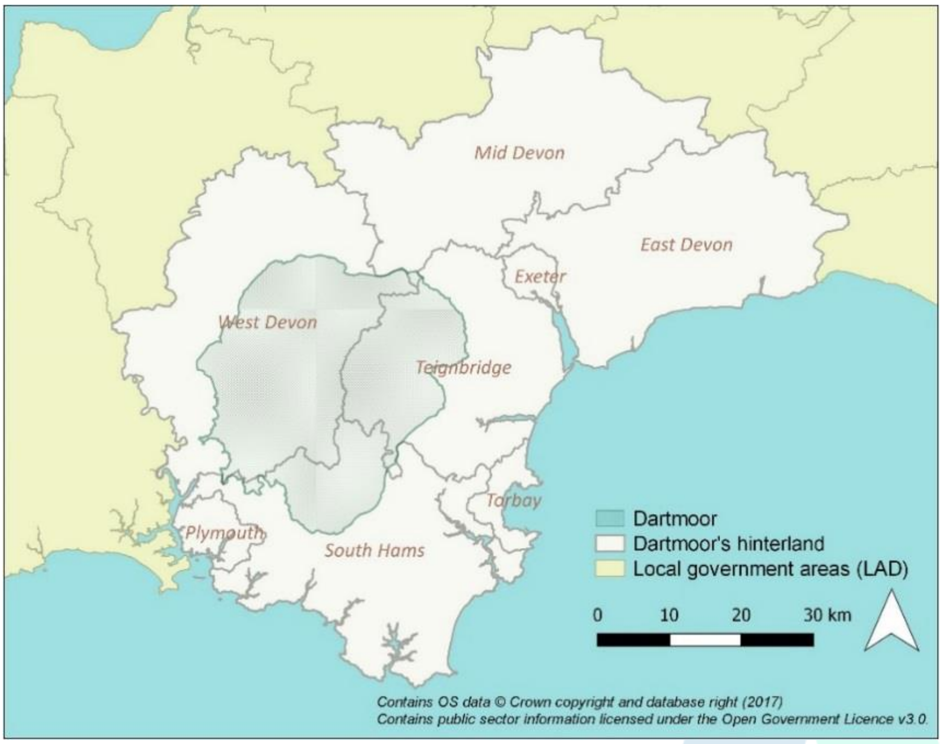


Figure 1. Dartmoor's hinterland as defined by eight LADs (as labelled).

Table 1 provides some details of the populations of the 8 LADs taken from the 2011 census. In this table we have focused on the adult population since our later analyses of recreation also focus on adult populations. Observe that the LADs' populations are different both in magnitude and the socioeconomic composition. Plymouth for example has by far the largest population (222,096 adults) but, along with Torbay, a relatively high proportion of residents in the lowest socioeconomic category (26.3%). South Hams, in contrast, has an adult population of only 72,757 of home only 17.2% are in the DE socioeconomic category.

Table 1: Adult population (> age 16) in 2011 and its distribution across socioeconomic segments for LADs in Dartmoor's hinterland (Source: 2011 census). Socioeconomic segments are displayed according to the National Readership Survey social grade classification system.

Region	Adult Populations				
	AB	C1	C2	DE	Total
East Devon	24.1%	30.0%	26.2%	19.8%	118,684
Exeter	21.9%	36.2%	20.4%	21.6%	108,914
Teignbridge	23.6%	29.9%	25.8%	20.6%	109,827
West Devon	24.6%	27.1%	28.1%	20.2%	49,467
Mid Devon	21.1%	26.5%	30.3%	22.2%	66,194
Torbay	15.8%	29.9%	25.9%	28.4%	112,798
Plymouth	15.9%	33.6%	24.2%	26.3%	222,096
South Hams	27.8%	29.4%	25.5%	17.2%	72,757
Total:	20.7%	31.2%	25.2%	22.9%	860,736

Each LAD is responsible for maintaining an up-to-date Local Plan which identifies how land in their area is to be used particularly with regards to what will be built and where. Under the Localism Act, in developing their Plans neighbouring LADs have a duty to cooperate, identifying and solving boundary issues, for a more integrated planning approach.

Following a scoping exercise of the provision for development in local plans, three such groupings around major settlements are important for Dartmoor (referred to herein as Plymouth and surrounds, Exeter and surrounds and Torquay and surrounds).

2.2 POPULATION PROJECTIONS

A key source of data for our subsequent analyses is provided by the Office of National Statistics (ONS) population projections. Those projections provide an indication of the future size and age structure of the population based on mid-year population estimates and a set of assumptions of future fertility, mortality and migration. The ONS releases those estimates at a variety of regional scales, with the finest spatial resolution being at the LAD level (ONS, 2014; DCLG, 2016). Accordingly we take ONS population projections at the LAD spatial scale selecting information at 5 year time slices starting from 2014 through to 2039 as the basis of our subsequent analyses.

Table 2 provides some headline details of those population projections for the LADs in Dartmoor's hinterland. Over the 25 years from 2014 to 2039, the population in the region is projected to increase by 13% from around 1 million people in mid-2014 to 1.1 million in mid-2039. Notice that in contrast to Table 1 the data refers to the entire population and not just the adult population. According to the ONS projections, the strategic grouping of Exeter and surrounds will see the greatest population increase of 77 000 people, Plymouth and surrounds will increase by 42 000 and Torquay and surrounds will increase by 15 000. Relative to its baseline population size, the local government area of East Devon will experience the greatest increase in population (17.9%).

Table 2. Population change in Dartmoor's hinterland, from mid-2014 to mid-2039 (Source: ONS 2014, SNPP Z1; rounded)

Strategic grouping	Unitary Authority or District (LAD)	Persons 2014	Persons 2039	Change	%Change
Plymouth and surrounds	Plymouth	262,000	287,000	25,400	9.7
	South Hams	84,000	92,000	7,600	9.1
	West Devon	54,000	63,000	8,600	15.9
Exeter and surrounds	Exeter	124,000	145,000	21,100	17.0
	Teignbridge	127,000	149,000	21,200	16.7
	East Devon	136,000	161,000	24,400	17.9
	Mid Devon	79,000	89,000	10,100	12.7
Torquay and surrounds	Torbay	133,000	148,000	15,500	11.7
Total		1,000,000	1,134,000		

The ONS projections are provided with a detailed estimate of the age and gender structure of the predicted population. Those age-gender compositions are illustrated in Figure 2. While the working age population will remain broadly similar, the predictions suggest increases to the number elderly will create an ageing population structure in the hinterland.

Our subsequent analysis of recreational activity on Dartmoor requires information not only on the size of population and its age and gender structure but also information on other socioeconomic details such as distribution across ethnic groups, distribution across socioeconomic segments and car ownership. In the absence of detailed predictions of those variables from the ONS we make the assumption they remain the same as those observed in the 2011 census data.

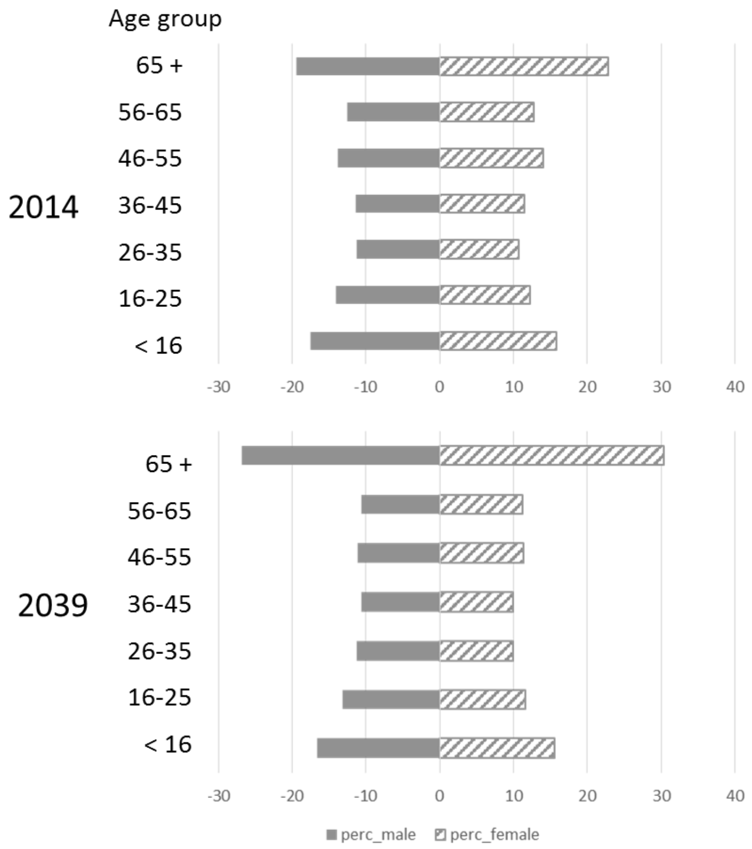


Figure 2. Changed population structure for Dartmoor's hinterland over a 25-year period (Source: ONS 2014, SNPP Z1)

2.3 LOCAL PLANS

The ONS predictions remain relatively coarse, detailing as they do, population information at the level of the LAD. In this project, our objective is to spatialize projections so as to provide population estimates at the level of the Lower Super Output Area (LSOA). LSOAs are reasonably small scale census areas with populations ranging from around 1,000 up to around 3,000. The key source of information we exploit in achieving that finer resolution distribution of population across LSOAs in a LAD is provided by the Local Plans.

We review the relevant plans here, highlighting information which provides insights as to where and when development is expected and therefore where population increases are likely to be concentrated.

2.3.1 Local plans for new homes – Plymouth and surrounds

Plymouth, South Hams and West Devon LADs have produced a Joint Local Plan (2014-2034) which is currently under review (JLP, 2017). This is an overarching strategic plan for the area of Plymouth and South West Devon that is outside of the Dartmoor National Park. The spatial strategy operates at three different levels: the Plan Area (Plymouth Housing Management Area – all three local authorities), the Plymouth Policy Area (Plymouth and urban fringe) and Thriving Towns and Villages Policy Area (rural South Hams and West Devon). Around 71% of growth is directed to the Plymouth Policy Area and 29% in the Thriving Towns and Villages Policy Area.

Housing provision is made for 26,700 new homes in the Plan Area (during the plan period 2014-2034). Within the Plymouth Policy Area there will be provision for 19,000 new homes (4550 affordable) and within the Thriving Towns and Villages Policy Area there will be 7,700 new homes (2050 affordable). The figure of 26,700 new houses includes an allowance of around 600 on Dartmoor, as well as allowance for second homes and vacant properties.

Analysis of Objectively Assessed Needs (OAN) for new housing used ONS population projections but these were criticised for their reliance on short-term trends, an inability to incorporate policy-led growth aspirations for Plymouth and capping to control the national projections (SHMNA, 2017; DCC, 2017). Local revised population growth is projected to 42,800 people (20,500 households) between 2014 and 2034 across the Plan Area (while official projections estimate 35,000 people, ONS 2014).

Although development will be through a phased release, this level of temporal resolution is not available through policy maps. For planning purposes, SHMNA (2017) assumes 881 households per year in Plymouth (189 of these labelled 'affordable').

2.3.2 Local plans for new homes – Exeter and surrounds

Information on developments within and surrounding Exeter are available from four local authority and district plans[1].

1. Exeter Core Strategy (2012-2026) outlines a development need for at least 12,000 dwellings. Of these, around 5,000 were being built or had been granted planning permission. A further 977 were identified within the urban area and 1048 from regeneration areas. Sustainable urban extensions (Strategic Allocation areas) were planned for Monkerton/Hill Barton (2,500), Newcourt (2,300) and Alphington (500).

2. East Devon Local Plan (2013-2031) describes housing development for 18 250 new homes, of these 10 550 new homes are near the border with Exeter.

3. Teignbridge Local Plan (2013-2033) outline housing provision of 12 429 dwellings over the plan period, with about 50% in the heart of Teignbridge and 15% in South West Exeter.

4. Mid Devon Core Strategy (2006-2026) outlines provision for new homes in Tiverton (6000 new homes), Cullompton (4000) and Crediton (2000).

The Exeter Core Strategy provides a graph estimating the trajectory of the developments over time. Mid Devon District Council provide development rates (average annual dwellings)[2] for two time periods for the area: 2006-2016 (390 dwellings per year) and 2017-2026 (290 per year). Development rates are alternatively provided by settlement (e.g. 145 per year in Tiverton, of which 43 are affordable). East Devon Local Plan provides a schedule for housing sites and numbers on an annual basis.

2.3.3 Local plans for new homes – Torquay and surrounds

The Strategic Housing Land Availability Assessment identifies a capacity of 11 200 new homes in the district over a twenty year period. The Torbay Local Plan (2012-

[1] Details of the forthcoming Greater Exeter Strategic Plan will not be available during the life of this project.

[2] These come from the Regional Spatial Strategy which was revoked following the General Election.

2030), however, states that constraints (e.g. infrastructure) set a more realistic target of 9 200 homes.

Over a third of houses in Torbay contain only one person. The Torbay Local Plan draws reference to DCLG household projections (7 550 new households; DCLG, 2016) in the Plan Period and population projections of 9 900 people. With a higher death rate than birth rate, the majority of population growth in Torbay is linked to inward migration. ONS projections have historically been adjusted downwards.

2.4 SPATIALISING POPULATION PROJECTIONS

As just reviewed, spatially explicit information on housing developments in Dartmoor's hinterland is available for the next 10-20 years from local government reports and plans. Many individual developments or Strategic Allocations can be mapped to LSOA(s) with confidence. Where not given, new population estimates can be inferred from the addition of new dwellings in a particular location making assumptions about average household size.

Temporally explicit information is somewhat inconsistent across the LADs. For example, assumptions need to be made about (average annual) development rates in Plymouth and surrounds. Likewise the Exeter Core Strategy and Mid Devon Core Strategy only plan development until 2026.

Our methodology for bringing together the ONS population projections and information from the Local Plans is undertaken in two stages:

- At Stage 1, we take the population predictions made by the ONS for a LAD and distribute this across all internal LSOAs. To mimic a natural growth rate, we spread that population increase out across LSOAs in proportion to each LSOA's share of the 2011 LAD population. Since LSOAs are generated to be reasonably consistent in terms of population size, this results in a reasonably even distribution of population increases across LADs.

- At Stage 2, while the baseline population in a LAD is evenly distributed across all internal LSOAs, population changes are redistributed proportionate to new homes (site allocations) in local plans. This runs until the end of the plan period. Beyond this, LAD-level projections are evenly distributed across all LSOAs.

Full details on population projections are available in Appendix 1 (national population projections) and Appendix 2 (population changes in Dartmoor's hinterland). Full details on methodology are provided in the full version of this report.

Our predictions of population change are made in 5 year time slices from 2014 to 2039. Figure 3 summarises the overall change in that period, mapping out the predicted population changes between 2014 and 2039 in the eight LADs of the Dartmoor hinterland. Notice that the increases in population show marked differences across space. The Cranbrook new town to the east of Exeter stands out as a location in which population is expected to grow rapidly. Similar, hotspots of predicted population growth can be seen around Okehampton to the north of Dartmoor, around Plymouth to the south west and Newton Abbot to the south east.

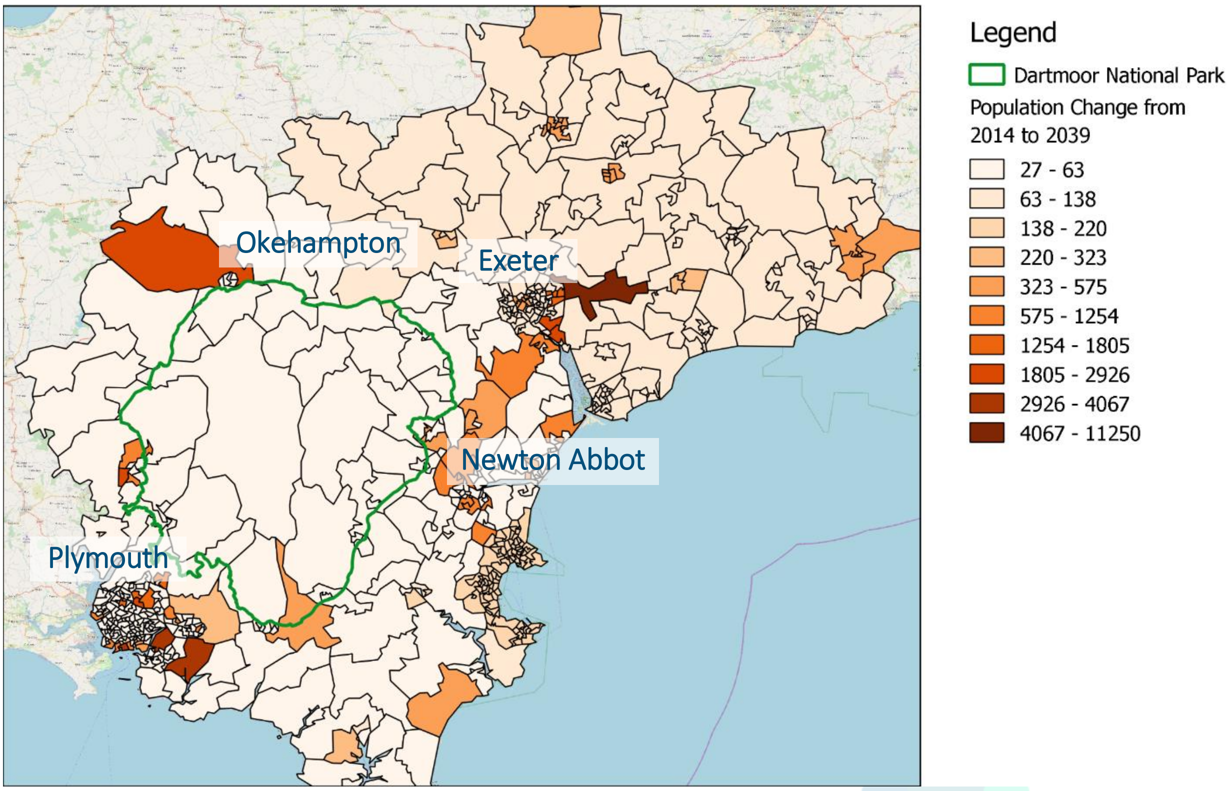


Figure 3: Projected population increases from 2014 to 2039 by LSOA

3 RECREATION FUTURES

Understanding the likely impacts of the future population changes described in Section 2 requires making forecasts about the future. In this project our approach to forecasting is to use models. In particular, we use models based on empirical data describing currently observed behaviour and use that to predict how future populations might be expected to behave. In this section, we describe how we develop those predictions, beginning with estimates of future trips to Dartmoor and progressing to a framework that allows us to estimate how footfall and intensity of use of the landscape might develop over the period to 2039. In particular, we look at how population growth in the 8 Local Authority Areas (LAAs) around Dartmoor is expected to contribute to that intensity of use.

3.1 THE ORVAL MODEL

The core modelling tool used in our analysis is the Outdoor Recreation Valuation (ORVal) model, developed by the LEEP Institute in the University of Exeter. The research in this project uses the soon to be released version 2.0 of the ORVal model (see Day and Smith, 2018).

The ORVal model is a statistical recreation demand model that can be used to predict the number of visits that are made by adult residents of England to different outdoor greenspaces. The model adjusts its predictions according to a number of factors, most particularly the socioeconomic characteristics of people, the day of the week, the month of the year, the attributes of a greenspace and the availability and qualities of alternative greenspaces. In this section, we briefly outline the key elements of this modelling tool but more detail can be found in Day and Smith (2018).

3.1.1 Overview of the ORVal Model

The ORVal model is estimated from data collected in the Monitor of Engagement with the Natural Environment (MENE) survey from 2009 to 2016. The MENE survey provides information on the recreational behaviour of a very large, representative sample of adults (over 16 years of age) resident in England. Over the course of a week, each respondent records when they visited greenspaces and for one randomly-selected visit the exact location of that visit and the mode of transport used in travelling to and from that recreation site.

Estimation of the ORVal model requires locating the particular greenspace visited by each respondent in the sample. Indeed, since the model assumes that visitors are making a choice between different greenspaces, a fundamental building block of the ORVal model is a map of greenspace locations across England and Wales which we describe in the next section.

The fundamental assumption of the statistical model is that the choices observed in the MENE data are welfare-maximising. By 'welfare' we are referring to the sense of well-being or utility that an individual feels from their experiences. So when an individual is observed to have taken a trip to enjoy a greenspace, we assume that the welfare of taking a trip at that time exceeds the welfare of doing something entirely different (say watching the TV or going shopping). Likewise when an individual is observed to have chosen a visit to one particular recreational site, we assume that the welfare derived from that visit exceeds the welfare that would be enjoyed from visiting an alternative site.

Without going into detail, the ORVal model is an example of a discrete choice model which attempts to capture the key decisions in recreational activity; whether to take a trip, which recreation site to visit and whether to travel to that site on foot or by car. The statistical framework within which this model is estimated directly addresses the question of substitution; that is to say, it tells us how visitors choose one particular outdoor recreation trip over other possibilities and even which other choices they might have made if their preferred option were not available to them.

In the model, a large number of variables are used to capture important arguments in the welfare function that determines choice. For example, the welfare that a person gets from taking a trip is modelled as depending on a person's socioeconomic characteristics, the location in which they live, the weather, the day of the week and the month of the year. In a similar vein, the welfare derived from visiting a particular greenspace is modelled as a trade-off between the benefits of enjoying time at that site and the costs incurred in getting there. In the model, those on-site benefits depend on the size, land covers, environmental qualities, water margins, designations and points of interest that characterise a particular greenspace. Likewise, the costs of getting to the site depend on whether they choose to walk or drive to that greenspace and the time and money costs of making that journey.

Ultimately, the statistical analysis presents us with an estimate of the function that determines the welfare an individual gets from making different recreational choices and determines the choices they might make given the options open to them. Of course, since this is a statistical analysis the model is probabilistic; in other words, it is only capable of making probabilistic predictions; how likely is it that a person with particular characteristics living in a particular location will choose to take a visit to greenspace on some particular day? How likely it is they will choose to visit some particular greenspace? How likely is it that they will choose to walk rather than drive to that greenspace?

In this project we use the probabilities predicted by the ORVal model to predict visits to Dartmoor. The model allows us to disaggregate those predictions in a number of ways. In particular, we can disaggregate them by home location in order to examine the contribution to visits made by residents of the eight LAAs in the Dartmoor hinterland. We can make predictions as to how many of those trips are made by car as opposed to on foot. Moreover, we can disaggregate trips by the locations on Dartmoor at which visitors begin their recreational activity in order to understand how recreational activity is spread across the National Park.

3.1.2 The ORVal Greenspace Map

The ORVal greenspace map is a detailed spatial dataset compiled through the combination and manipulation of a large number of primary data sources that describes the location and characteristics of accessible greenspace across England and Wales. Details of the construction of the ORVal greenspace map is provided in Day (2016). In brief, the recreation features identified on the ORVal greenspace map come in three basic forms;

- parks which consist of areas of accessible greenspace within well-defined boundaries over which visitors usually have freedom to wander at will,
- paths which consist of accessible, walkable routes that pass through the landscape, often traversing a variety of different greenspaces and tending to restrict visitors to defined routes of passage.
- beaches.

The paths stretches identified in the ORVal greenspace map are those that plotted on the Open Street Map project. Paths tagged as not being publically accessible or not passing through greenspace were removed. Using a simple recursive function path stretches were connected into networks. Finally, access points to each path network were identified by finding dangling ends of paths in a network within 50m of roads.

In some cases a paths network was served by a number of access points in close proximity. Since those access points present visitors with a very similar recreational opportunity we replaced groups of two or more access points that were not further than 250m from each other with a single approximating access point at the centroid of the group. For that reason, some access points in the ORVal paths data layer do not lie exactly on the intersection of a path and road.

In what follows we consider parks and path access points (and beaches) as being the foci of outdoor recreational trips and refer to these jointly as recreational sites. Each recreation site is described by various aspects of its physical characteristics;

- Landcover: For parks the quantity of each different landcover is recorded as the hectares of that landcover in the park boundary. For paths landcovers are defined by the quantity of different landcovers found in a 25m buffer either side of that path. In addition, we assume that there is a declining likelihood that a visitor will encounter some particular stretch of a paths network the farther that stretch is from the path access point. We calculate the land cover characteristics associated with accessing a paths network from some particular access point as a weighted sum over the length of a path with the weights declining linearly from a value of 1 for locations at the access point to 0 at a distance of 10km from that access point. Landcovers recorded in the ORVal greenspace map include broadleaf woodland, coniferous woodland, felled or young woodland, wood pasture, agriculture, natural grass, moors and heath, mountain, coastal, saltmarsh, marsh and fen, managed grass, sports pitches, gardens, allotments and cemeteries.
- Water margins: The presence of water at recreation sites is captured through the length of water margins. Four different forms of water are recognised; rivers, lakes, estuaries and sea. The data also records of the WFD ecological status of rivers and the bathing water quality at beaches.
- Designations: The ORVal greenspace map records the extent of recreation site in a National Park, AONB, Heritage Coast, National Trail, Historic Park, Millennium or Doorstep Green, or with some form of nature conservation designation.
- Facilities and Points of Interest: The dataset also records the presence of various facilities and points of interest including the existence of a car park, a children's playground, an archaeological feature, historic building, scenic feature (e.g. water fall) or a viewpoint. Figure 4 provides an excerpt from the ORVal greenspace map showing recreation sites within the boundaries of Dartmoor National Park. The map identifies 118 recreation sites classified as

parks and a further 549 path network access points within the National Park boundaries.

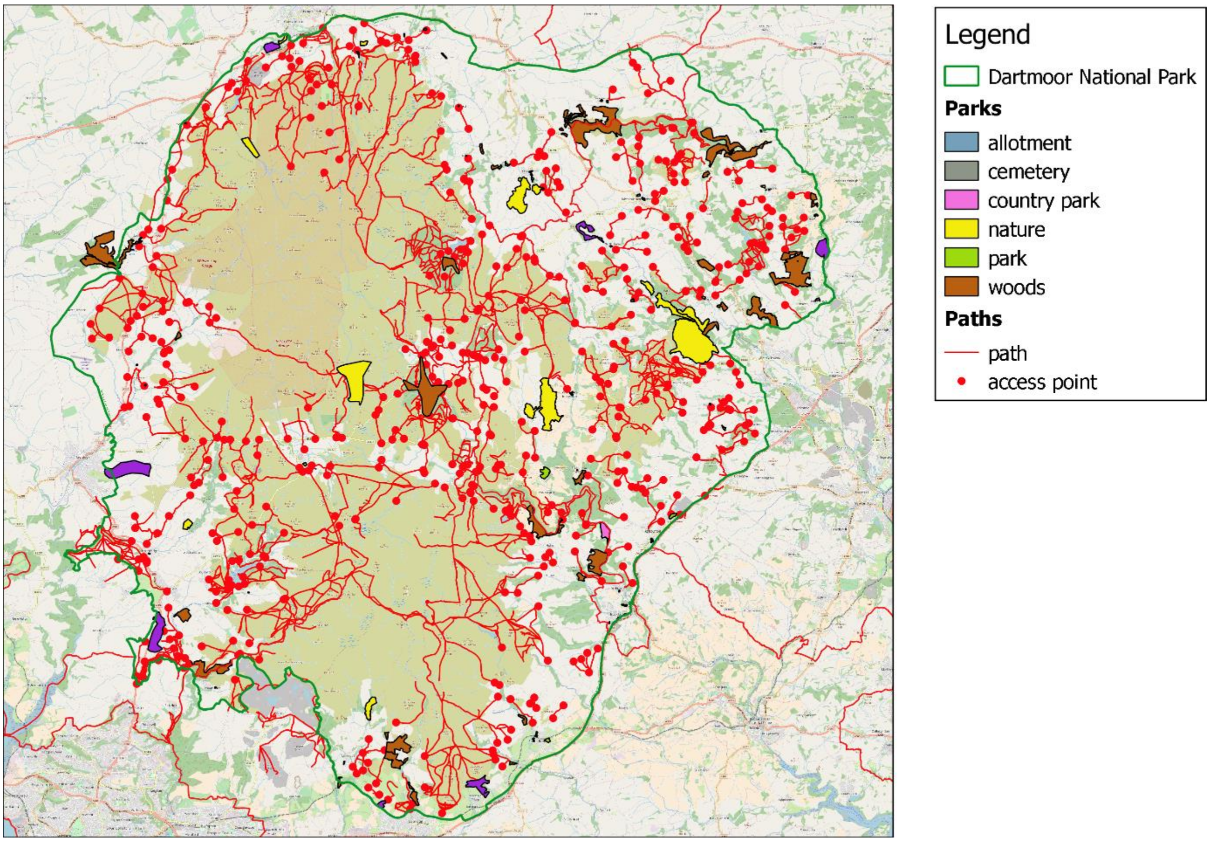


Figure 4: The network of recreation areas in Dartmoor National Park

3.1.3 Predictions using the ORVal model

The ORVal recreation demand model can be used to estimate the number of visits to different greenspaces. In particular, the model allows us to predict how likely it is that an individual will take a trip to a particular greenspace on a particular day. That likelihood differs according to the socioeconomic characteristics of the person, the attributes and proximity of the greenspace and the attributes and proximity of alternative recreational greenspaces.

To generate estimates of the annual number of visits to a particular greenspace we draw on the data outlined in section 2 regarding the size and characteristics of populations in each LSOA across England. Visitation predictions for each particular access point on Dartmoor are reached through the following set of calculations:

- Since participation differs across day of the year and across socioeconomic segments, for each LSOA we first find the number of adults in each socioeconomic segment (i.e. segments A&B, C1, C2 and D&E).
- For a particular day of the year we find average weather conditions in that LSOA and then use the ORVal model to calculate the probability of an adult in a particular socioeconomic segment taking a trip to the focus access point on that particular day at that particular time of year. We then multiply up by the number of adults in that segment in that LSOA.
- Repeating those calculations for individuals in each other socioeconomic group provides an estimate of the expected number of visits from that LSOA to that access point on that day.
- We reach an annual visitation figure from an LSOA by summing expected visitation numbers calculated for each different day of the year.
- Finally, we repeat those calculations for each of the 32,844 LSOAs in England and sum the results to arrive at a final prediction of the annual number of visits to a particular access point.

In addition to predictions of annual visitation, the ORVal model can also provide other interesting predictions regarding trips to a site;

- Visits by mode of transport: predictions of how many of the visits to a site are made by car or on foot.
- New visits: predictions of the number of 'new' visits generated by the site. Here the model is examining the substitution possibilities open to people visiting a particular site. Clearly, some of those visits will be by people who would go to an alternative greenspace if that particular site were not available. On the other hand, some of the trips will be made by people who would otherwise simply not have made a trip to an outdoor greenspace. The new visits reported by the tool are estimates of how many of the visits to a particular site are greenspace trips that would not have occurred without that site.

The ORVal model can also be used to estimate welfare values for greenspaces. By 'welfare value' we mean a figure describing the monetary equivalent of the welfare enjoyed by individuals as a result of having access to a greenspace. In economics this welfare value is often alternatively called an 'economic value' or a 'willingness to pay'. Welfare values are useful for decision-makers in applying cost-benefit analysis to appraise projects or policies that impact on greenspace.

Our calculation of welfare values is enabled by the fact that the recreation demand model provides an estimate of the recreation welfare function. That function identifies how much welfare an individual enjoys as a result of beneficial attributes of a greenspace (e.g. the extent of woodland, the presence of a children's playground). Likewise, it identifies how much welfare is lost from each extra pound of cost incurred in travelling to a greenspace. The latter amount is crucial in calculating welfare values. It tells us the amount of welfare a person considers is equivalent to having one extra pound. In other words, it provides an exchange rate that we can use to convert estimates of changes in welfare into equivalent amounts of money.

Welfare values for an existing recreation site are estimated by calculating how much each individual's welfare would fall if they were no longer able to access that site and then converting that welfare quantity into an equivalent monetary amount. Those welfare values can then be aggregated over the adult population of England for an entire year using the same sequence of steps as used to aggregate estimates of visitation. We return to consider welfare values in section 4.1.

Applying the ORVal model to the 2014 population estimates provides us with our initial estimates of recreation activity on Dartmoor and its distribution across the National Park. The headline figure from that analysis suggests that Dartmoor currently receives around 7,758,500 visits from adult residents of England over the course of a year.

One short-coming of ORVal is that it is unable to account for each of the multifarious features of recreation sites that determine how attractive they are to visitors. Put simply, ORVal uses observed behaviour to provide an estimate of how many visitors we might expect at a recreation site given its broad characteristics; its extent, its landcovers, whether it provides access to some special feature (e.g. an archaeological site or a scenic feature) whether it has a car park etc. While it accounts for those broad characteristics ORVal is unable to deal with the idiosyncratic features of each and every site; for example, it does not distinguish between the recreational experience of visiting Stonehenge or Hay Tor compared to some other less iconic archaeological remain or rock outcrop.

To address this issue, the baseline ORVal predictions were adjusted through a process of calibration to ensure they better captured the varying attractiveness of sites across Dartmoor. As a first step, we gathered the various recreation sites shown in Figure 4 into 45 groups that provided access to similar geographic areas of the

National Park. The areas identified by those groupings are shown as the green cells outlined in green on Figure 5. The left hand panel of that Figure shows the baseline ORVal estimates of visits to each area based on the 2014 population estimates.

A panel of experts from Dartmoor National Park Authority were convened to review those estimates alongside information provided by various visitor and car counters across the National Park. Drawing on that expert knowledge and observed data the model was recalibrated, introducing new parameters to the model whose values reflected the idiosyncratic features of those sites that made them more or less attractive to visitors than was suggested by the baseline model.

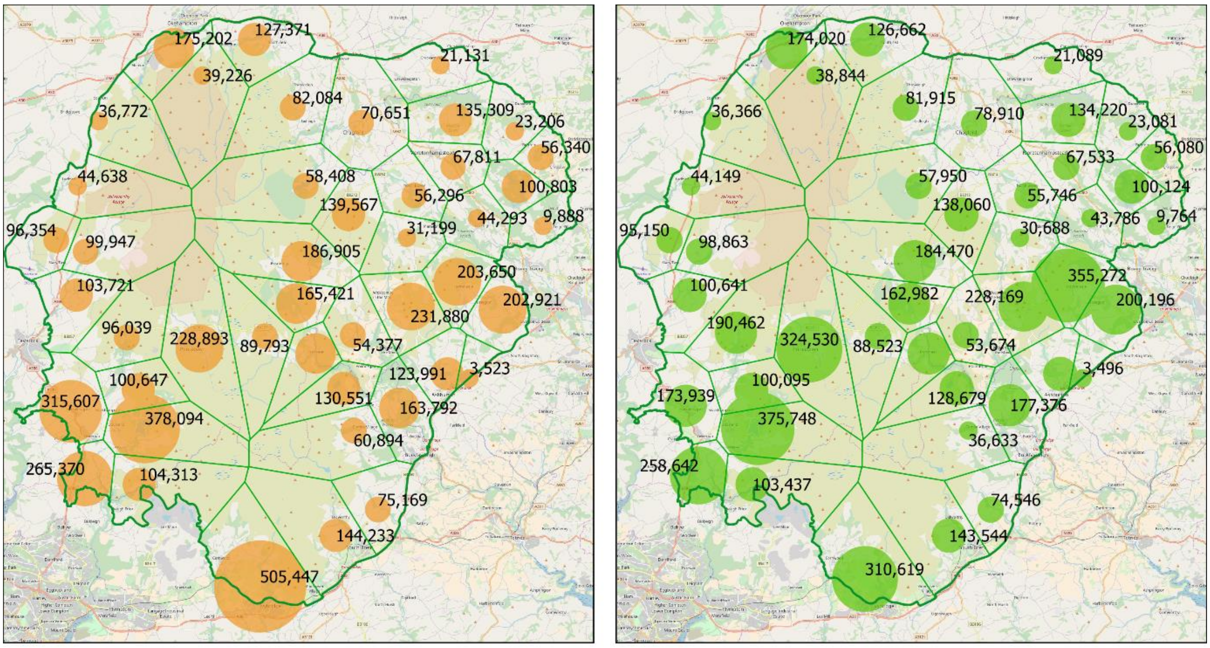


Figure 5: ORVal uncalibrated and calibrated predictions of visits to groups of access points across Dartmoor using 2014 population

To attribute values to those calibration parameters, an iterative algorithm was written that searched for a set of parameter values that best matched the expert input while maintaining the level of overall visitation to Dartmoor suggested by the baseline model (the assumption here is that the ORVal model does a good job at estimating overall visits but improvements can be made in the predictions of the distribution of those visits across the National Park). In order to make that algorithm manageable the focus of attention was reduced to visitors form the south west of England, a restriction that sped up iterations of the algorithm 10 fold. Accordingly, while the calibrated model made predictions of overall visits that are identical to that of the uncalibrated model for the population of the south west, it ended up suggesting an additional 6,500 visits from England as a whole (an error of less than one tenth of one percent). The predicted patterns of visitation from the calibrated model are shown in the right hand panel of Figure 5. Notice that the calibration parameters have concentrated more visits to the 'honey pots' such as those at Princetown and Haytor.

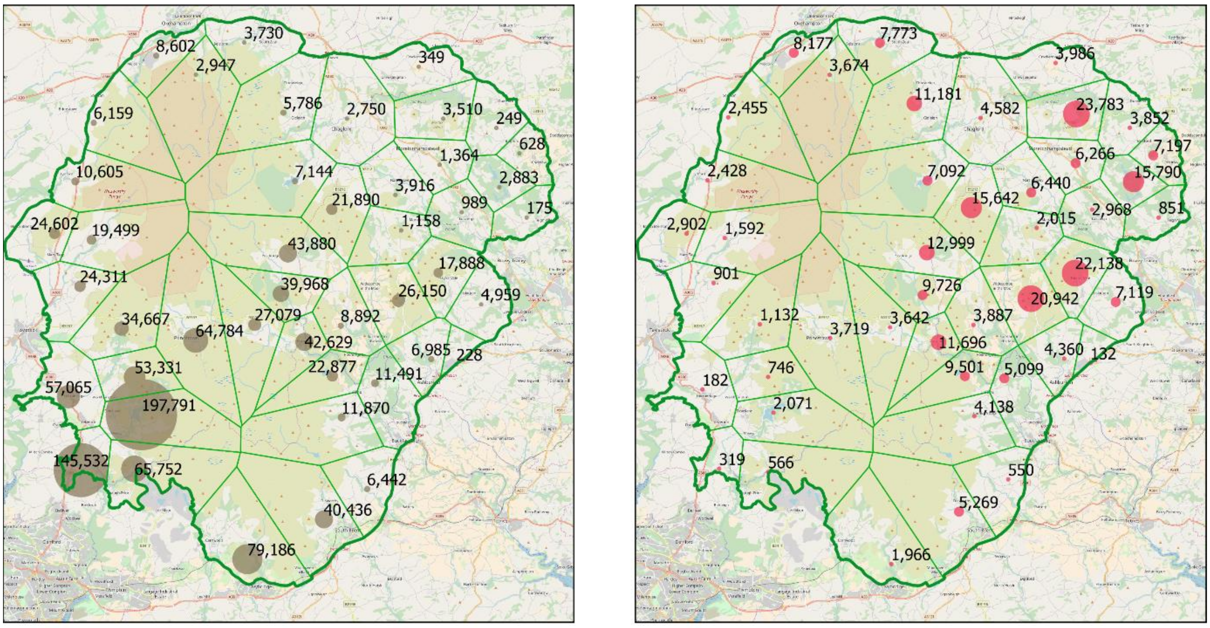
Applying the calibrated model to the 2014 population estimates allows us to provide estimates of visits to Dartmoor. Table 3 presents those estimates calculated for England as a whole and then the contributions to that total visitation from each of the 8 LADs in the neighbourhood of the National Park.

Table 3: Visit and welfare predictions for Dartmoor recreation day visits from England and neighbouring Local Authority Districts for 2014 population estimates

Region	Visits	% On foot	% New Visits
England	7,765,104	0.25	0.30
East Devon	210,908	0.00	0.37
Exeter	429,031	0.00	0.35
Teignbridge	1,899,369	0.39	0.27
West Devon	1,500,946	0.53	0.25
Mid Devon	230,784	0.02	0.34
Torbay	473,268	0.00	0.35
Plymouth	1,374,116	0.01	0.34
South Hams	992,481	0.42	0.27

From Table 3 we see that of the total 7.8 million estimated visits to the National Park, 25% are predicted to be made by travelling to the recreation site on foot. Of course, visits made on foot are only likely to be made by those living in or very near to the National Park. That fact is reflected in the information for the separate LADs, where we see significant numbers of trips on foot emanating only from those areas that overlap the National Park; Teignbridge, West Devon and South Hams (see Figure 1). The ORVal model also estimates that 30% of the visits to Dartmoor are 'new' visits; that is, without being able to access Dartmoor, those visits to outdoor greenspace would not have happened.

Table 3 also makes clear that the majority of the predicted visits, some 92%, come from the 8 neighbouring LADs. Recall the focus of the analysis is recreation day visits so the concentration of visits from relatively proximate locations is not surprising. Of course, the locations in the National Park that are closest to any visitor will depend on where they live. Indeed the ORVal model allows us to derive predictions as to where residents of each individual LAD are likely to recreate on Dartmoor. Figure 6 illustrates this difference in preferred destination for the two urban LADs of Plymouth and Exeter. Observe how visitors from Plymouth focus trips on areas in the south west of the National Park that are nearest to that city, while visitors from Exeter tend to visit locations in the east of the National Park that are relatively closer to Exeter.



Plymouth **Exeter**

Figure 6: Distribution of estimated visits in 2014 from Plymouth and Exeter LADs

3.2 PREDICTING FUTURE LEVELS OF RECREATION ON DARTMOOR

Most importantly for our purposes, the calibrated ORVal model allows us to make predictions regarding visits from the expanding populations of the 8 neighbouring LADs. A summary of those predictions of future visitation is provided in Table 4. Figure 7 provides yet more detail illustrating the annual quantities of visitors to Dartmoor from each LSOA in the local region both in 2019 and in 2039.

Table 4: Growth in predicted visits to Dartmoor National Park 2014-39

LAD	2014	2019	2024	2029	2034	2039	Change 2014-39
East Devon	210,908	224,005	240,233	256,727	271,443	278,587	32.1%
Exeter	429,031	446,877	459,191	477,393	492,139	506,672	18.1%
Teignbridge	1,899,369	1,937,994	1,983,966	2,033,513	2,078,499	2,136,734	12.5%
West Devon	1,500,946	1,560,296	1,577,714	1,599,585	1,617,671	1,650,840	10.0%
Mid Devon	230,784	234,852	239,714	244,713	251,192	257,132	11.4%
Torbay	473,268	481,883	494,208	508,203	521,194	533,101	12.6%
Plymouth	1,374,116	1,413,406	1,438,915	1,476,701	1,506,000	1,532,663	11.5%
South Hams	992,481	1,015,249	1,029,116	1,050,436	1,067,131	1,087,488	9.6%
Total:	7,110,903	7,314,562	7,463,057	7,647,271	7,805,269	7,983,217	12.3%

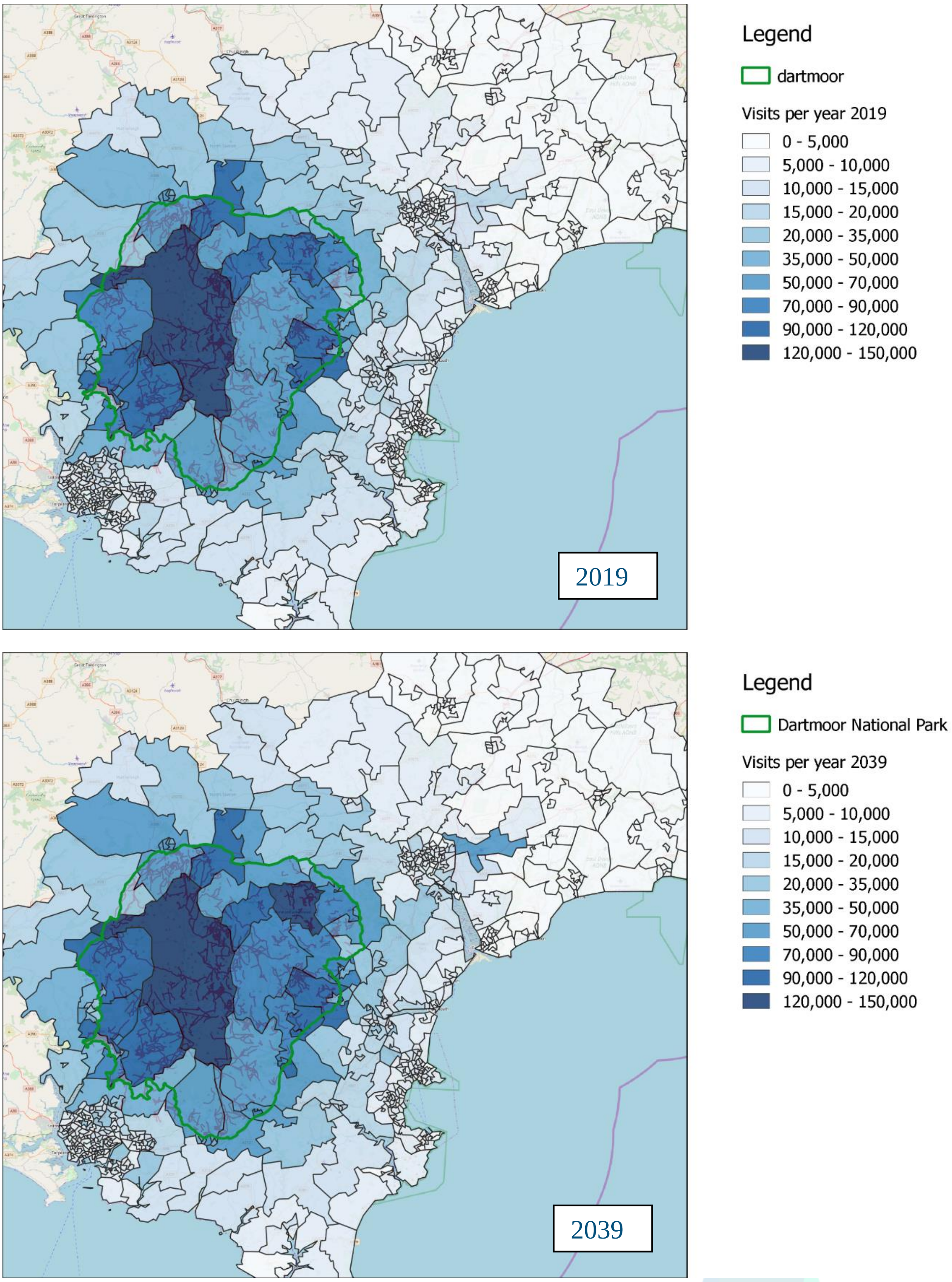


Figure 7: Numbers of annual visits to Dartmoor originating from each LSOA in 2019 (top panel) and 2039 (bottom panel). LSOAs from Dartmoor's eight neighbouring LADs are displayed.

Notice that as we go through time the LADs responsible for the largest quantity of visits are still those with a significant population residing within or on the border of the National Park. Obviously, those populations are far more likely to use the recreational opportunities on their doorstep than those who have to travel a significant distance to get to Dartmoor. Notice also from Table 4 that the largest percentage increase in visitation comes from the relatively remote East Devon LAD. An indication of why this is so can be seen from the dark blue shaded LSOA that appears in East Devon just to the right of Exeter in the 2039 predictions displayed in Figure 7. That LSOA contains the new town of Cranbrook whose population is expected to rise to over 10,000 residents by 2039. The growth of visitors from Cranbrook is even more evident in Figure 8 which depicts only the predicted increase in visitation from each LSOA in 2039 compared to 2019. In addition to Cranbrook, Figure 8 highlights a number of other locations where population increases (see Figure 3) are expected to result in large visitation increases including those around Okehampton to the north of Dartmoor, Plymouth to the south west, Newton Abbot to the south east and Exeter to the east.

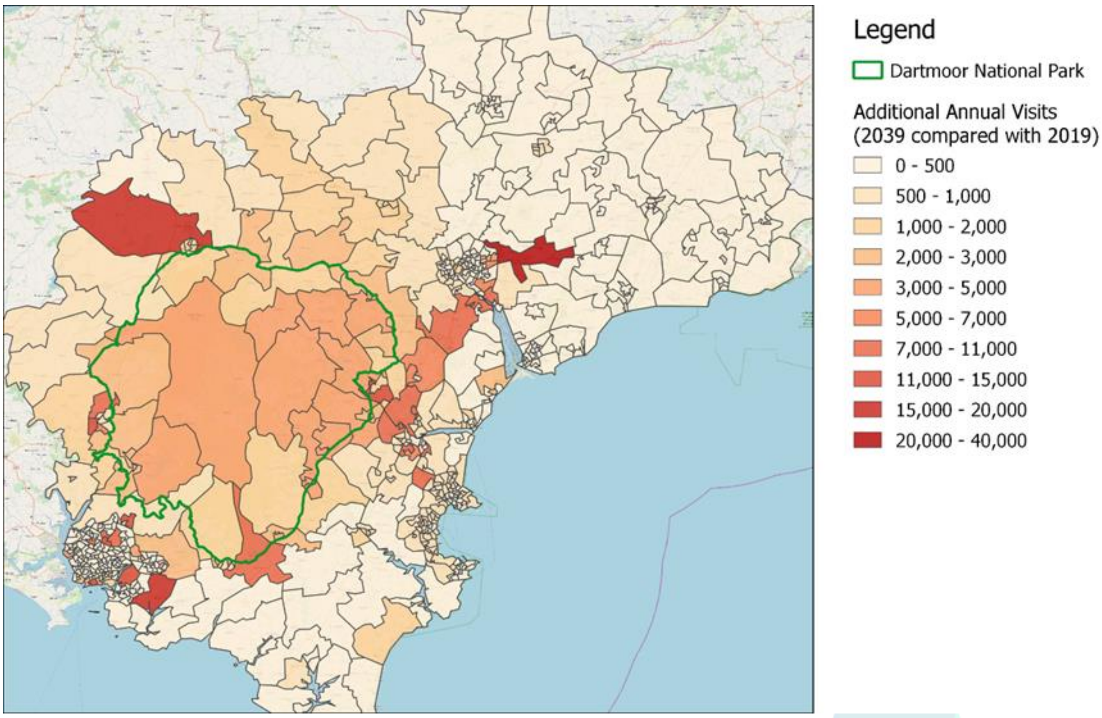


Figure 8: Increase in visitors from 2019 to 2039 from LSOAs in neighbouring LADs.

3.3 PREDICTING RECREATIONAL ACTIVITY ACROSS DARTMOOR

A central objective of this project is to develop an understanding of the possible impacts of increased visits to Dartmoor. To do that we not only need to know the levels of future visitation to access points on Dartmoor but also something about those visitors activities and how that translates into intensity of use across the Dartmoor landscape.

3.3.1 Characterising Visitor Activities

While the ORVal model provides us with an insight into the distribution of visits across Dartmoor, it does not tell us anything about their subsequent activities. Unfortunately, reliable statistical information on visitor activities on Dartmoor is scarce. Table 5 summarises data from the MENE survey of recreation day visits taken by English residents to the upland national parks of England. The MENE survey asks respondents about their activities and in Table 5 these are organised into two basic types; those that focus on roaming across the landscape and those that are focused on undertaking some particular leisure activity usually in a particular location (e.g. fishing, eating out, visiting an attraction etc.).[3] A further 'other' category captures those outdoor pursuits that are not specified in the MENE survey where 'climbing' is given as an example of such an activity. For our purposes, we assume that this 'other' category can be taken as being more similar to leisure activity recreation than roaming recreation.

Observe from Table 5 that the pattern of recreation activity is reasonably similar across the upland National Parks with the exception of Northumberland National Park where far fewer visitors partake in walking but relatively more engage in off-road biking and wildlife watching. The distribution of activities in Dartmoor is reasonably typical of the remaining upland National Parks. We find that 78% of visitors come to Dartmoor to walk or run, with some 43% of those 78% being accompanied by a dog. Other roaming activities such as off-road biking and horse-riding occur, but are relatively infrequent. Activity-focused recreation, therefore, accounts for 19% of visits, with the category 'food & games', (which includes eating out, picnicking, playing with children and playing informal games) representing the largest share of those activities.

[3] Note that as with the ORVal model we exclude visits where the respondent indicated their activity was road-biking or enjoying the countryside from their car.

Table 5: Activities during visits to upland National Parks in England (from MENE 2009-2016)

Activity	Dartmoor	Exmoor	Lake District	North York Moors	Northum-berland	Peak District	South Downs	Yorkshire Dales	All Upland Parks
Roaming Recreation									
Walking & running	78.0%	73.2%	79.4%	81.2%	21.4%	72.6%	83.0%	78.7%	76.5%
no dog	*44.4%*	*44.7%*	*62.0%*	*48.5%*	*16.7%*	*54.4%*	*47.4%*	*65.3%*	*51.9%*
with dog	*33.6%*	*28.5%*	*19.2%*	*32.6%*	*47.6%*	*15.8%*	*35.5%*	*13.7%*	*25.4%*
Horse riding	1.4%	0.8%	0.2%	1.2%	7.1%	1.4%	0.1%		0.9%
Off-road biking	1.1%	3.3%	3.3%	4.1%	17.9%	3.5%			2.7%
Boating & kayaking	0.7%	1.6%	2.2%	0.2%	2.4%	0.5%			0.7%
Leisure Activity Recreation									
Food & play	5.1%	4.1%	3.5%	2.9%	26.2%	9.5%	0.9%		4.7%
Visit an attraction	4.0%	5.7%	3.3%	2.5%	1.2%	7.1%	6.0%	8.2%	5.1%
Fishing	2.2%	0.8%	0.8%	1.4%	4.8%				0.7%
Shooting	1.8%	5.7%	2.9%	2.9%	2.4%	3.4%	4.1%	2.7%	3.3%
Watch wildlife	0.4%	1.6%	0.2%	1.0%	15.5%	1.8%	0.6%		1.3%
Other	5.4%	3.3%	4.1%	2.7%	1.2%	2.5%	5.2%	10.4%	4.2%
Observations in MENE	277	123	510	487	84	733	782	183	3,179

To progress, we make the assumption that the patterns of activity in the future will remain similar to those suggested by the MENE data. In other words, we assume that 81% of visits to those access points will be for the purposes of roaming recreation and 19% of visits will be for leisure activity recreation. Likewise, we make the assumption that that same mix of activities is observed at each different site (access point) in the National Park. In reality, of course, the relative levels of the two forms of recreation activity will differ across activity points. We know for example, that leisure activity recreation will be concentrated in locations endowed with the relevant leisure facilities and attractions (e.g. cafes, picnic sites, archaeological points of interest, etc.). Within the constraints of this project, however, we have not been able to achieve that level of detail in our consideration of distribution of activities across the National Park.

3.3.2 Distribution of Walking Distances

In order to translate predictions of visits to National Park access points into measures of intensity of use of the Dartmoor landscape the next step is to develop predictions of where and how far visitors travel through that landscape. Our division of recreation activities into roaming and leisure activity recreation is designed to enable that translation. In particular, we consider the objective of roaming recreation to be one in which a visitor transports themselves to a National Park access point and then derives benefit primarily from moving, perhaps large distances, through the landscape. For simplicity, we assume that visitors making such trips take round trips, returning to their original access point. In contrast, we assume that visitors engaging in leisure activity recreation transport themselves to an access point that is in easy reach of the location in which they wish to undertake their leisure activity then walk to and from that location.

As shown in Figure 4, we imagine the Dartmoor recreational landscape as being a network of paths and National Parks accessed from particular locations that we describe as access points. To understand intensity of use we need to be able to predict how far different visitors will pass through that network while pursuing their recreation activities. Our ultimate goal is to predict intensity of use of each location along the recreation network. The two forms of recreation imply very different depth of penetration of the recreation network by visitors setting out from some particular access point.

With respect to roaming recreation, we require some measure of the distribution of distances walked by visitors to National Parks participating in in such activity.

Unfortunately, no direct evidence of that distribution was available from data available for Dartmoor. An extensive search of the literature, however, revealed a recent survey of visitors to the Lake District National Park carried out by Nick Davies in 2016 as part of his PhD research. Amongst many other questions, that survey asked a sample of 518 visitors to record the distance of their walk in the National Park. The survey was carried out at a large number of different access points, with data being collected in every month of the year and on weekdays and weekends.

The data reported categorise length of trips into ones under 2 miles, between 2 and 5 miles, between 5 and 10 miles and greater than 10 miles. That data is depicted as the green dots on Figure 9. Each dot represents the proportion of visitors making a (round) trip walk of a particular distance or more. So for the Lake District data we see 100% of visitors walking at least 0 miles, 90% walking at least 2 miles, 55% walking at least 5 miles and 13% at least 10 miles.

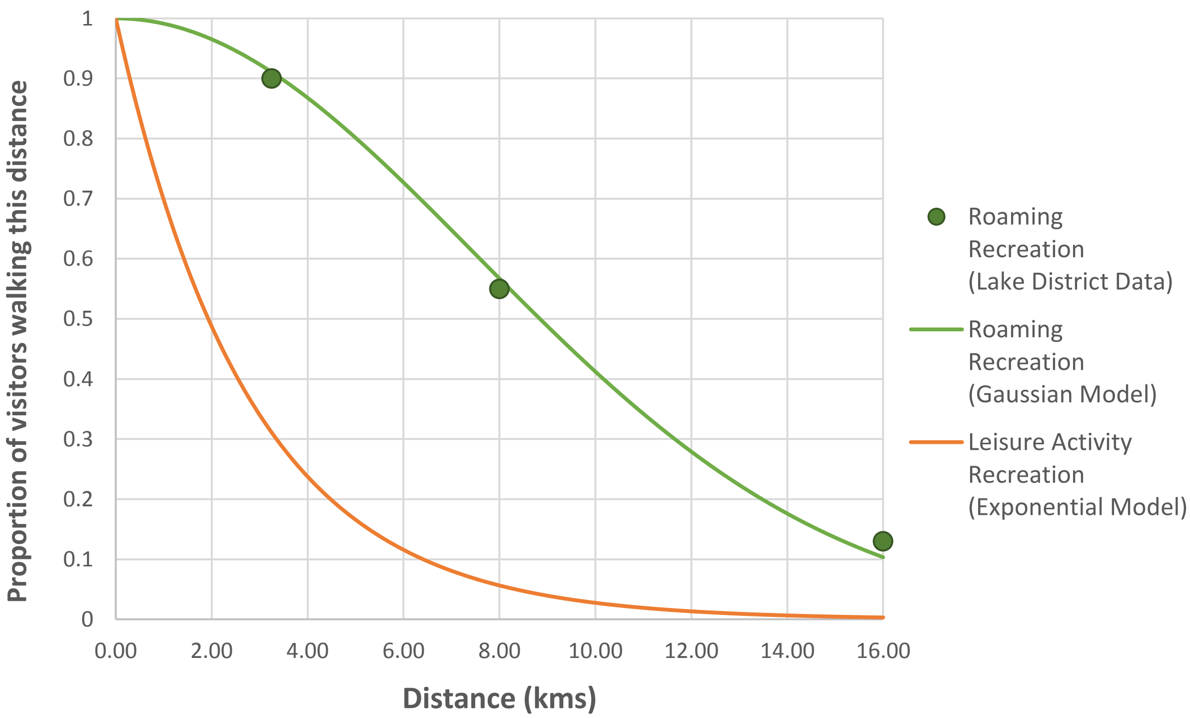


Figure 9: Distribution of (round trip) travel distances for different forms of recreational activity

As shown in Figure 9, we find that a reasonably accurate fit to the data is provided by using a Gaussian (Normal) distribution (with most visitors walking average distances, and smaller proportions of visitors taking very long and very short walks). This provides us with a model which predicts the proportion of roaming recreationists that will take trips of different distances. To illustrate, imagine we have an access point that we expect to be visited by 100 roaming recreationists. Of those 100, we would expect 90 to make trips that took them at least 2 miles from that access point, 55 who will travel at least 5 miles and 13 who will travel at least 10 miles. Our fitted line effectively traces out the distance decay function for penetration of recreational walkers through a paths network from a particular access point.

Notice that to use this distance decay function for Dartmoor we have to assume that walkers visiting Dartmoor behave similarly to walkers visiting the Lake District. We have no way of verifying that assumption though we do note that the Lake District data includes holiday makers as well as local day visitors that are the focus of our project.

We contend that the distance decay function for leisure-activity recreation will be different to that of roaming recreation. Again, there is no actual data to support that contention or to indicate the appropriate form of distance decay for this alternative form of recreation. Accordingly, we proceed by considering the walking done in pursuit of leisure-activity recreation as being like 'travel'; that is to say, we imagine people transport themselves to an access point in proximity of the location in which they wish to undertake their leisure activity and that their walk to that location through the paths network can be treated like an extra element of travel.

Again rather limited evidence exists to understand how far individuals are prepared to travel on foot in order to enjoy leisure activities in the UK. Instead, we took information from a US study by Yang and Diez-Roux (2012). Drawing on data from the US National Household Travel Survey from 2008-09 the Yang and Diez-Roux study developed travel distance distributions for trips for different purposes. The authors found that the distances of walking in order to access recreation were substantially longer than for other purposes and fitting their data to an exponential distribution report a distance decay function for such trips that is replicated in Figure 9.[4]

[4] The exponential function fitted by Yang and Diez-Roux (2012) has a coefficient of 1.15. That distance decay function refers to one-way distances. To be compatible with the distance decay function for the distribution of round-trip distances for roaming recreation, the curve in Figure 9 is adjusted to include the distance of the return journey.

As might be expected, the distances walked for leisure-activity recreation tend to be shorter than for recreation where walking itself is the focus of the activity. Indeed, according to the assumptions underpinning Figure 9, the median distance walked for the purposes of leisure-activity recreation is a little less than 2km, while that for roaming recreation is nearer 9km.

3.3.3 Forecasting Route Choice

So far we have determined that approximately 81% of the visitors arriving at a recreation access point on Dartmoor might be pursuing roaming recreation and 19% leisure-activity recreation. Moreover, the assumptions laid out in the last section lead us to the distribution of walking distances we might expect to see from recreationists of each type. Accordingly, if the ORVal model were, for example, to predict 100 visitors arriving at a particular access point over some particular time period, then we could estimate that 81 of those will be roaming recreationists and 19 leisure-activity recreationists. Of the 81 roaming recreationists we can estimate that at least 78 will make round-trips walks of 2 km or more, 46 of 8km or more and 8 of 16km or more. Of the 19 leisure-activity recreationist the equivalent figures are 9 visitors walking 2km or more, 1 taking an 8km walk and none taking a 16km walk. Indeed, given our assumptions we can plot out through the paths network of Dartmoor how many people we might expect to walk as far as that location from an access point.

Applying those assumed distance decays to our predictions of visitors accessing the National Park from certain locations allows us to build up estimates of the intensity of use of different locations across the Dartmoor landscape. Since our eventual focus will concern possible levels of disturbance caused by recreation on Dartmoor, we choose to illustrate footfall intensity by examining activity on the busiest days of the year. To that end we extract the ORVal visit predictions for a weekend day in the height of summer. We assume that visitation across the day is not uniform and that dividing the daily visits by 5 will give us a rough idea of the number of arrivals at each access point during a peak hour of that day.

The left hand panel of Figure 10 shows how visits from each access point can be traced through a path network where the red dots along the path are set at 50m intervals and the size of those dots indicates the number of individuals per hour expected to pass that point during the period of peak activity.

Notice from that left hand panel of Figure 10 that a complexity arises where two paths join. In order to develop an algorithm that mimics recreation behaviour we need some way of making choices regarding how many visitors decide to take each path when arriving at a junction in the network. In this work, we make the assumption that at a junction walkers are most likely to pursue a path that takes them on in the same direction as they approached the junction and ascribe such paths the weight 1. Likewise we assume that walkers are least likely to take a path which takes them back exactly the way that they have just come and ascribe such a path the weight 0. For paths leaving a junction at other angles we choose weights in between those two extremes using the weighting function shown in Figure 11. Here a path leaving the junction at a 45° angle from the direction of arrival is allotted a weight of 0.9, while one leaving at right angles to the arrival direction receives a weight of 0.5.

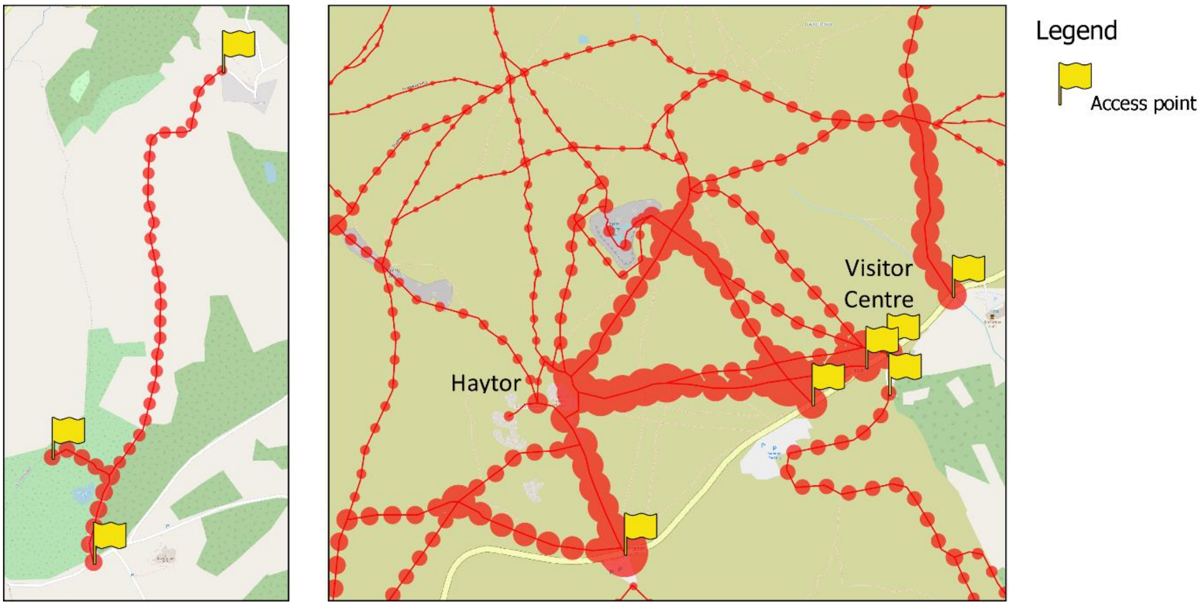


Figure 10: Examples of predictions of footfall intensity along two path networks on Dartmoor

In order to predict the choices of visitors arising at a junction, we first use the function in Figure 11 to assign a weight to each path leaving that junction, then sum those to arrive at a total weight. Visitors are ascribed to each path in exact proportion to the ratio of a path's weight to that sum of weights. The right hand panel of Figure 10 illustrates how the distance decay and route choice algorithms combine to distribute visitors through the complex network of interconnected paths around Haytor.

3.3.4 Predictions of Changing Intensity of Footfall across Dartmoor

When brought together the steps taken in predicting footfall across Dartmoor entail;

i. Predict the spatial distribution of population using ONS estimates refined to LSOAs in the 8 neighbouring LADs through interrogation of local plans.
ii. Use the ORVal model, calibrated to information on visitation to Dartmoor recreation sites, to predict the number of adults from the population arriving at access points to the National Park on a particular day
iii. Estimate arrivals on a particular hour of that day then apply the distance decay and route choice algorithms to predict how those visitors disperse across Dartmoor and hence the intensity of footfall across the National Park.

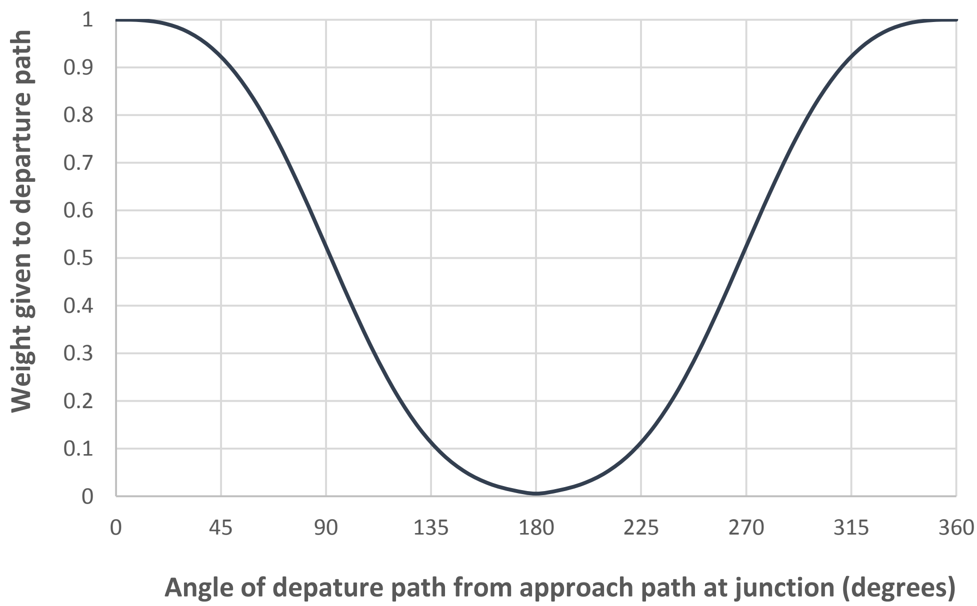


Figure 11: Weighting used to attribute likelihoods to choice of departure path from junction

Figure 12 provides an illustration of footfall intensity estimates made for the 2019 population predictions at a time of peak activity on a summer weekend.

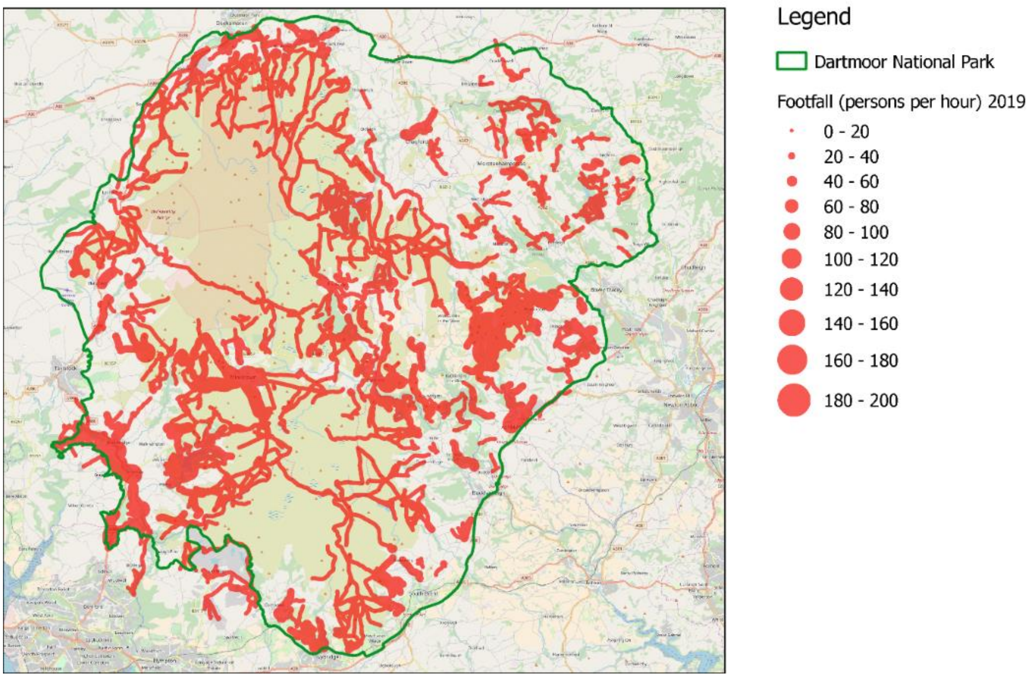


Figure 12. Predictions of peak hourly (summer weekend) footfall across Dartmoor in 2019.

While it is difficult to summarise the detail of these spatialized predictions, it is clear from Figure 12 that a number of high intensity footfall areas exist across the National Park. On the Figure we pick out those around Haytor, Princetown and Burrator, though other areas of intensive use are also evident.

Applying the same methods to the populations expected in future years allows us to make predictions as to how footfall intensity might increase across the National Park over time. Those predictions of growth in footfall are illustrated in Figure 13. Be aware that the scale of the size of symbols illustrated footfall has changed from that in Figure 12 which shows absolute levels in 2019.

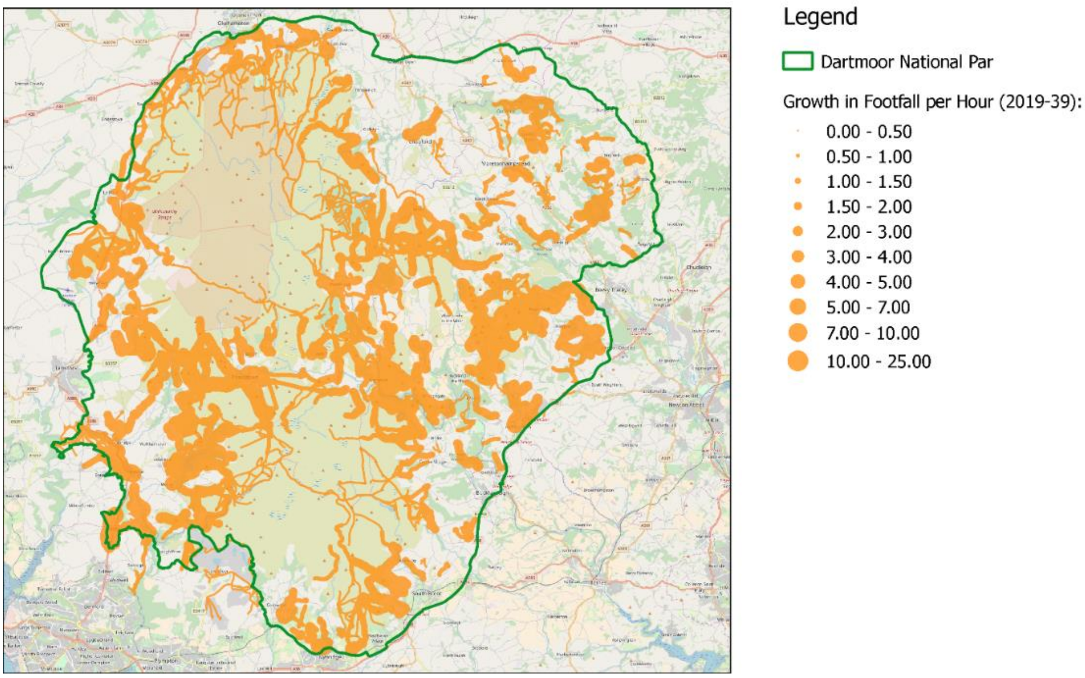


Figure 13. Growth in footfall (increase in persons per hour at peak times) across Dartmoor from 2019 to 2039.

From Figure 13 it is clear that fairly substantial increases in footfall intensity are expected in several locations across the National Park with peak increases of around 25 persons per hour at peak times. Not surprisingly, the locations attracting the largest increases in footfall are those that are also currently most attractive to visitors. The prediction algorithms also allow us to disaggregate the growth in footfall intensity by the local authority area from which visits arose. Figure 14 to Figure 21 present those visualisations for the 8 different LADs in the Dartmoor region. These maps illustrate also that the growth in footfall intensity shows spatial differences between the LADs. Growth in footfall tends to be greatest in areas within the National Park that fall within or near the corresponding LAD, with for example Teignbridge contributing most significantly to footfall growth in the east of Dartmoor, and Plymouth to the southwest of Dartmoor. As might be expected, LADs more distant from Dartmoor, such as East Devon and Mid Devon, contribute relatively little to the growth in footfall, and change is more evenly spread across the National Park.

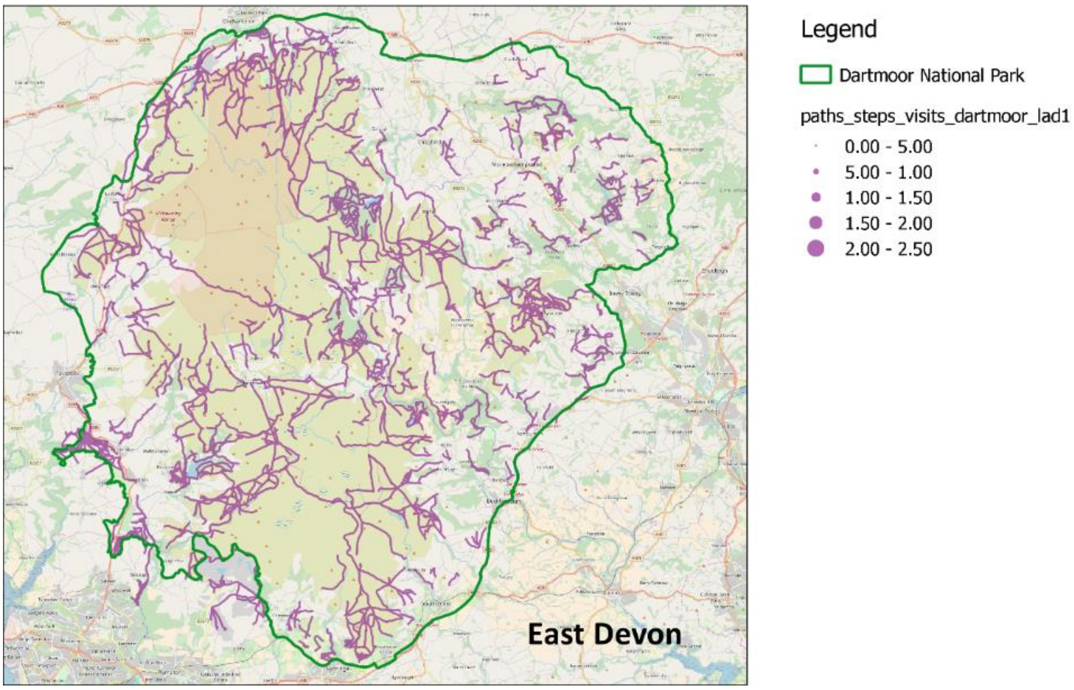


Figure 14. Predicted contribution to growth in peak hourly footfall from East Devon (2019-2039)

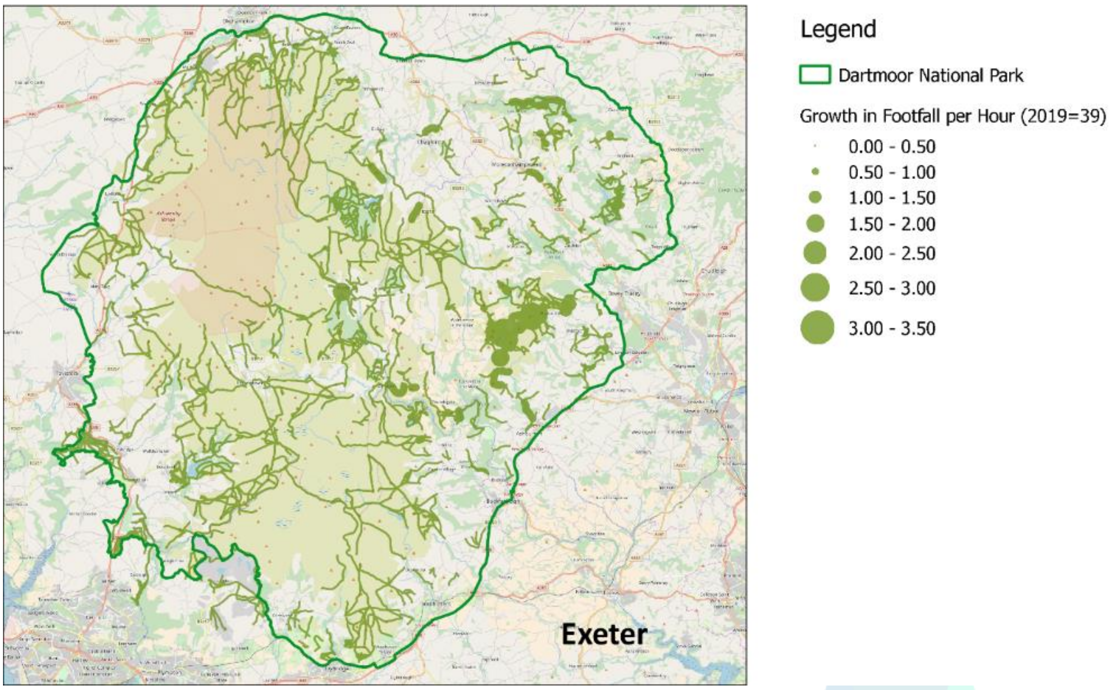


Figure 15. Predicted contribution to growth in peak hourly footfall from Exeter (2019-2039)

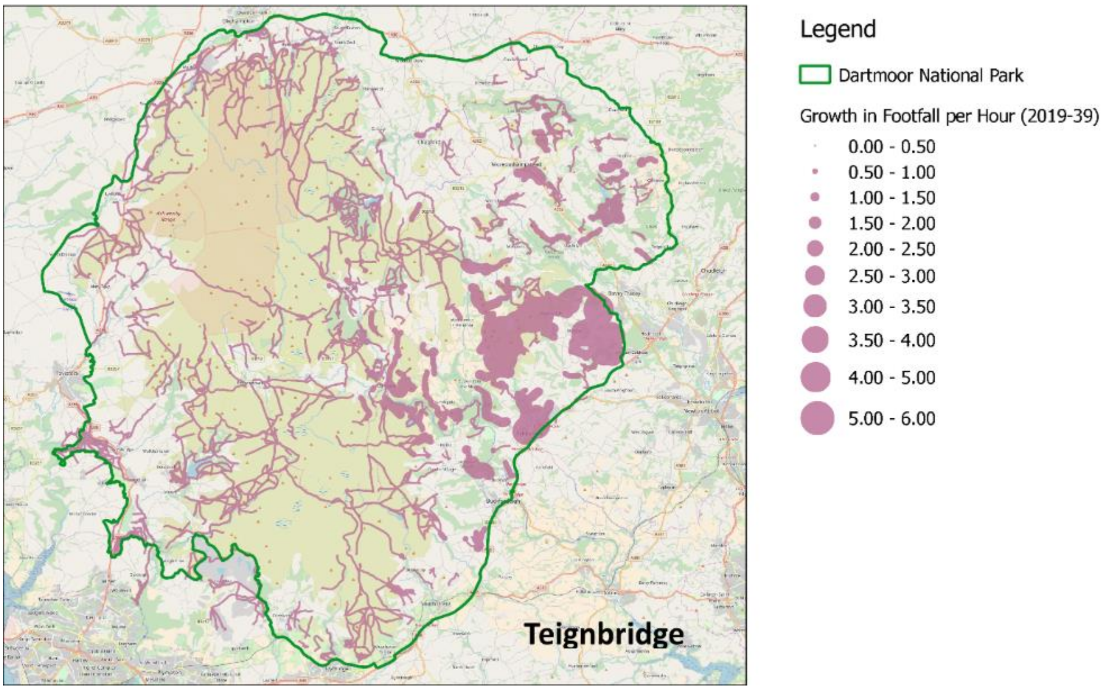


Figure 16. Predicted contribution to growth in peak hourly footfall from Teignbridge (2019-39)

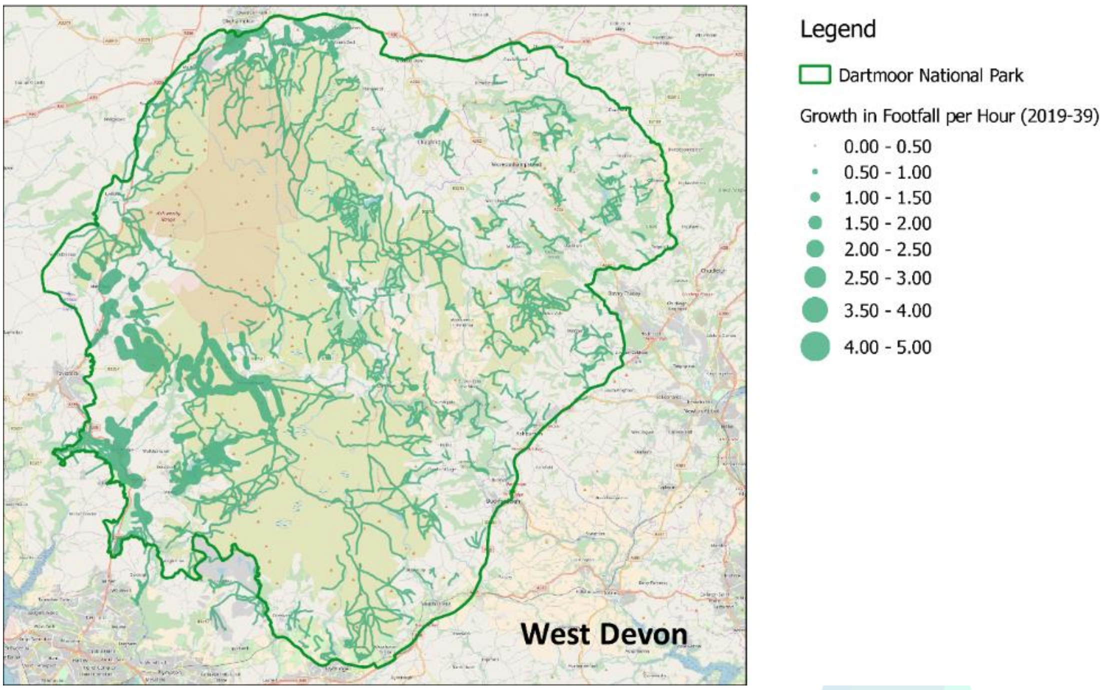


Figure 17. Predicted contribution to growth in peak hourly footfall from West Devon (2019-2039)

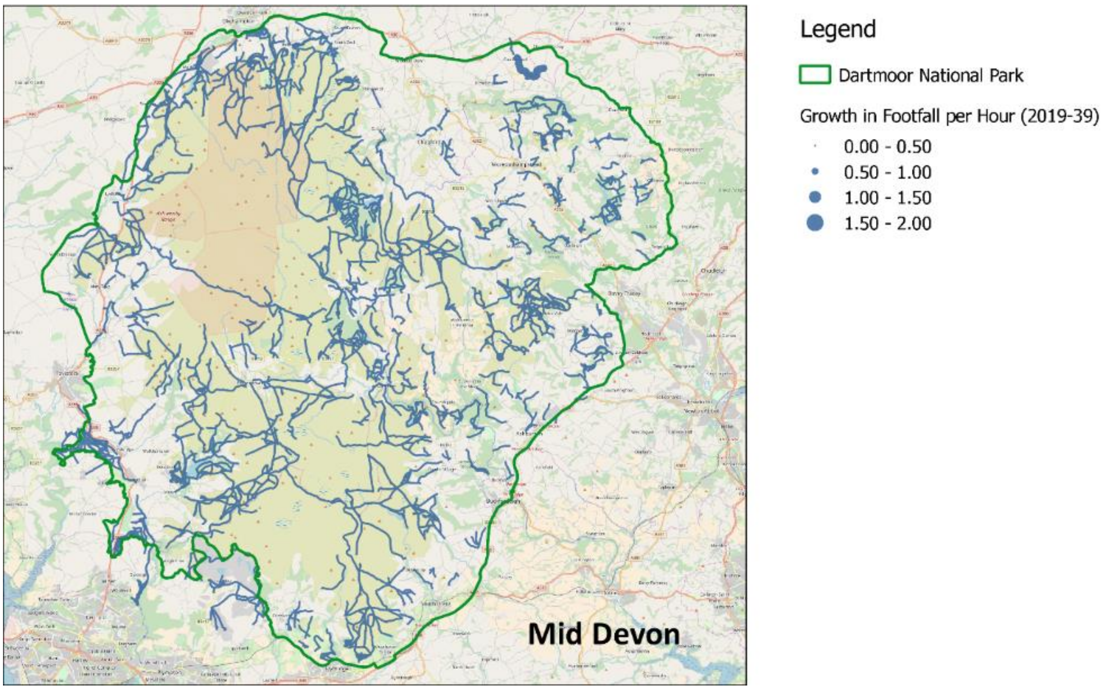


Figure 18. Predicted contribution to growth in peak hourly footfall from Mid Devon (2019-2039)

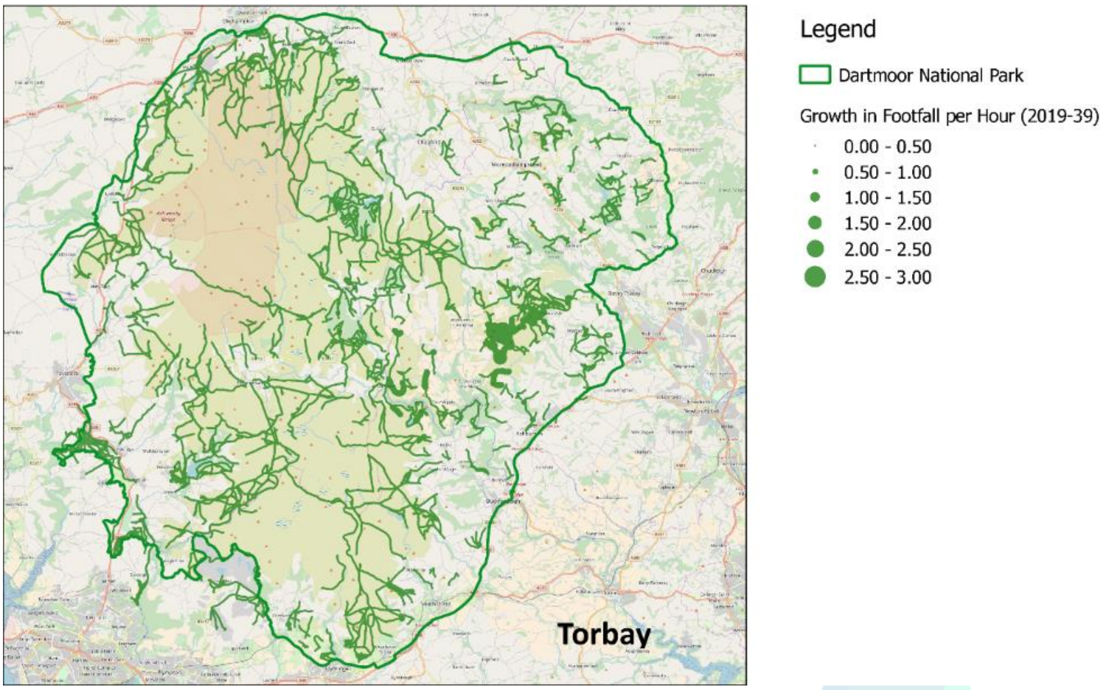


Figure 19. Predicted contribution to growth in peak hourly footfall from Torbay (2019-2039)

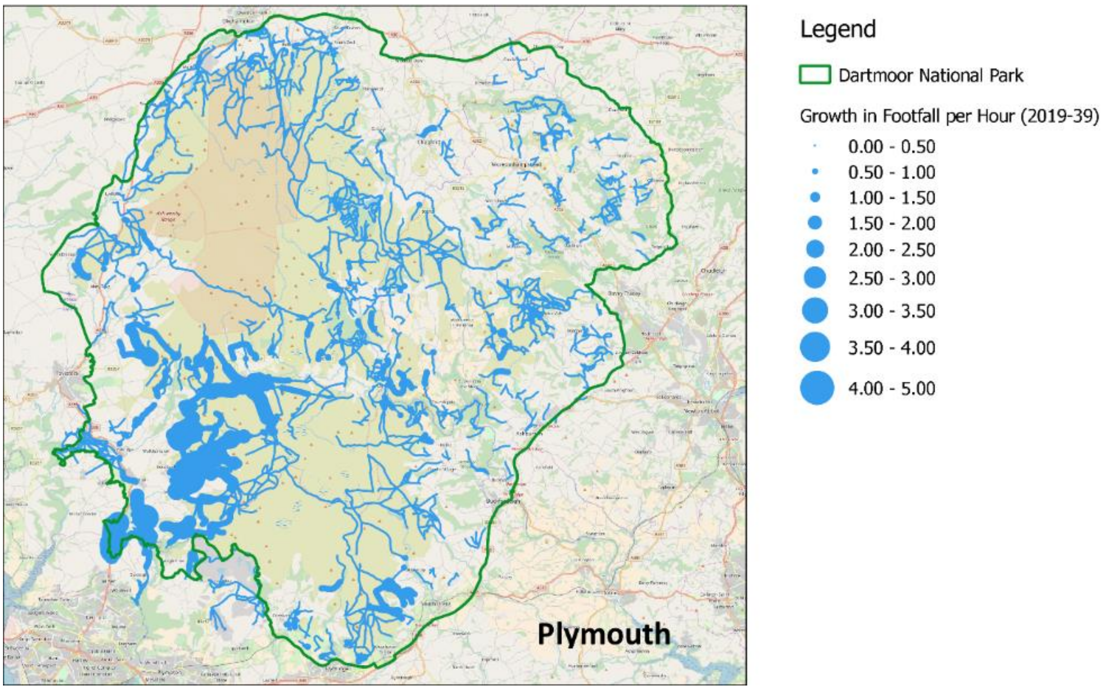


Figure 20. Predicted contribution to growth in peak hourly footfall from Plymouth (2019-2039)

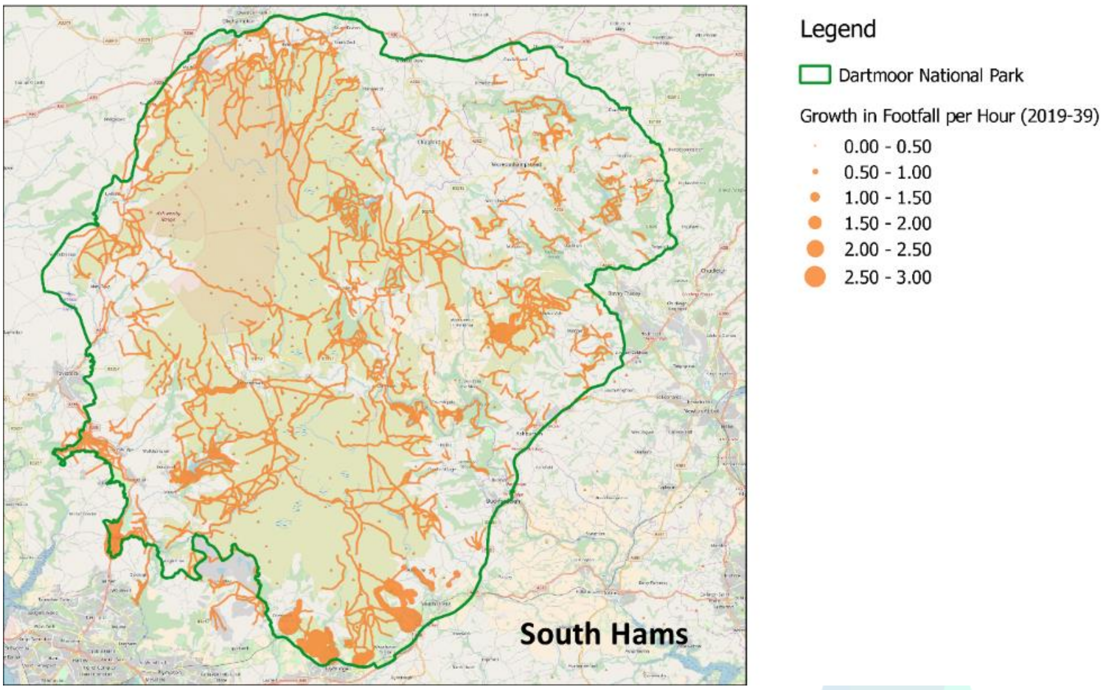


Figure 21. Predicted contribution to growth in peak hourly footfall from South Hams (2019-2039)

4 BENEFITS OF DARTMOOR

Recreation on Dartmoor is of key importance directly contributing to the second statutory purpose for National Parks (Environment Act 1995); *"promoting opportunities for the understanding and enjoyment of the special qualities of those areas"*. In this section we conduct a detailed analysis of the benefits of both current and future recreation levels, focusing on the welfare benefits and activity benefits of Dartmoor visits. This analysis is focused on day visits from visitors from Local Authority Districts (LADs).

4.1 WELFARE BENEFITS

As a focus of recreation activity, Dartmoor is a source of enjoyment for the many visitors who travel to the National Park each year. In social cost-benefit analysis (as prescribed, for example, in the Treasury Greenbook) the way in which that enjoyment can be quantified is by translating it into a measure of Willingness to Pay (WTP). In this particular context, WTP measures the maximum amount of money that an individual would be prepared to give up in order to ensure that they could visit a recreation site on Dartmoor.

For clarity, WTP is not to be confused with the travel cost of getting to a recreation site. Rather one can think of the monetary amount that a visitor would think equivalent to the experience of enjoying time at the recreation site. To have that experience they must travel to and from the site; that is to say, incur a travel cost. Roughly speaking, WTP for the recreation site will be the difference between the value of the onsite experience and the cost of being able to enjoy that experience. If we assume that the value of the onsite experience is similar across individuals then it follows that WTP is likely to be higher for those who live in or near Dartmoor since they have low costs of enjoying that experience and progressively lower for those living at greater distances.

While the term can be a little confusing, in economics this WTP measure of benefits is often simply referred to as a measure of welfare and we follows that convention here.

As explained in Section 3.1.3 the basic building block of the ORVal model is the estimation of a function which quantifies the level of enjoyment (or in economic terms, utility) that an individual realises from visiting some particular recreation site. That function includes a large number of variables including the qualities of the recreation site and, of course, the travel costs of getting to that site. While the details of the calculation are somewhat complicated (see Day and Smith, 2018) the ORVal model can be used to calculate the WTP of each adult in England for each recreation site on Dartmoor and aggregate these up either to give a total welfare value or a welfare value by LAD or LSOA.

Table 6 provides estimates of welfare benefits derived from recreational use of Dartmoor for the residents of each of the eight LADs in the National Park's neighbourhood. The welfare values are quoted in 2016 prices and provide the annual total for all residents and the welfare value per head of population in that LAD. In addition Table 6 shows how these welfare values are predicted to change from 2019 to 2039.

Table 6: Welfare predictions for Dartmoor recreation day visits from neighbouring Local Authority Districts for 2019 population estimates

Region	2019 Welfare (£2016)		2039 Welfare (£2016)		Change in annual Welfare 2019-39 (£2016)
	Total	Per Head	Total	Per Head	
East Devon	970,758	8.18	1,200,070	8.77	229,313
Exeter	1,807,818	16.60	2,051,361	16.61	243,543
Teignbridge	6,417,551	58.43	7,116,188	56.97	698,637
West Devon	4,728,658	95.59	5,025,164	93.10	296,506
Mid Devon	928,539	14.03	1,017,552	13.84	89,013
Torbay	2,050,026	18.17	2,267,994	18.17	217,968
Plymouth	5,351,929	24.10	5,803,982	23.99	452,053
South Hams	3,376,965	46.41	3,631,514	45.96	254,548
Total:	25,634,263		28,115,865		2,481,582

From Table 6, the headline figures are that Dartmoor currently provides an estimated £25.6 million of welfare benefits to the residents of the 8 neighbouring LADs each year and that as a result of population increases that number will rise annually. By 2039, welfare benefit is predicted to have risen from £25.6 million to £28.1 million; an increase of annual welfare benefit of £2.5 million. Notice also that our expectations are fulfilled insomuch as the largest welfare values are again realised in those LADs with significant populations in and around Dartmoor including Teignbridge, Plymouth, West Devon and the South Hams.

Table 7 provides one final analysis of the welfare generated by recreation on Dartmoor. In particular it disaggregates the annual welfare flows enjoyed by the residents in each LAD by socioeconomic segment, using the 2019 predictions to illustrate.

Table 7: Welfare predictions by socioeconomic segment for 2019 population estimates

Region	Socioeconomic Segment			
	AB	C1	C2	DE
East Devon	295,569	311,363	216,902	146,924
Exeter	481,080	669,902	338,884	317,952
Teignbridge	1,964,552	1,934,168	1,496,535	1,022,295
West Devon	1,487,237	1,357,937	1,144,525	738,960
Mid Devon	258,977	265,227	249,845	154,490
Torbay	401,696	663,311	496,278	488,741
Plymouth	1,086,216	1,907,566	1,208,458	1,149,688
South Hams	1,148,914	1,014,824	751,796	461,432
Total:	7,124,240	8,124,298	5,903,223	4,480,482
	(27.8%)	(31.7%)	(23.0%)	(17.5%)

One interesting thing to note from Table 7 is that the AB socioeconomic segment make up 20.7% of the regional population (see Table 1) but enjoy a 27.8% share of the welfare benefits from Dartmoor. In contrast, the DE socioeconomic group make up 22.9% of the regional population but enjoy only 17.5% of the welfare benefits. The fact that the AB group take a relatively high proportion of the welfare benefits arises from two facts. First the statistical model underpinning the ORVal tool shows that the AB group are more likely to engage in outdoor recreation than other socioeconomic groups. Second, the AB group are more likely to have access to a car than the DE group and hence are more likely to possess the means of getting to the National Park.

4.2 ACTIVITY BENEFITS

Clearly Dartmoor is a location from which a large number of individuals gain recreational welfare. As we have seen, for many of those visitors a key element of that enjoyment is derived from the physical activity of roaming across Dartmoor's landscape. Accordingly, another benefit provided by the National Park arises from the potential health benefits of that activity.

The obesity epidemic is estimated to have cost the NHS £6.1 billion in 2014/2015, and a reduction in physical activity levels over recent decades is thought to be a substantial contributor to the problem.[5] The government has previously published a call to action to local governments and communities to tackle the issue.[6] Dartmoor National Park Authority's "Naturally Healthy" Project piloted a "green care" programme with local GPs and communities, which showed a positive effect on the mental well-being of participants (DNPA 2018). Our modelling framework allows us to expand on this and provide further insights into the magnitude of health benefits of recreational activity in the National Park, using estimates of energy or fat burned to proxy for those health effects.

In particular, our analysis of footfall allows us to make predictions regarding the levels of walking activity on Dartmoor. The calibrated ORVal model provides the base data for this, predicting the number of visitors arriving at each recreation access point each year. From that data, and continuing our assumption of 81% roaming and 19% leisure-activity recreation, we use the distance-walked distributions of Figure 9 to estimate the total distance walked by visitors to the park over the course of a year. Those estimates for all visitors and for those from each neighbouring LAD in 2019 are shown in the second column of Table 8.

The third column of Table 8 converts distance into steps by dividing by an average step length of 0.75m. The fourth column of Table 8 converts distance walked to energy expenditure used in walking by assuming the commonly applied rule of thumb that an average individual uses 0.260 KJ of energy per meter when walking

[5] Public Health England Guidance. Health matters: obesity and the food environment. *https://www.gov.uk/government/publications/health-matters-obesity-and-the-food-environment/health-matters-obesity-and-the-food-environment--2*

[6] Healthy Lives, Healthy People: A Call to Action on Obesity in England. *https://www.gov.uk/government/publications/healthy-lives-healthy-people-a-call-to-action-on-obesity-in-england*

(LeCheminant et al, 2009). Finally we convert estimates of energy expenditure to estimates of fat burned by applying the assumption that one kg of fat represents 37,000 kJ of energy.

Table 8. Aggregate physical activity levels from predicted recreational activity on Dartmoor in 2019

Region	Distance (km)	Steps (million)	Energy Expenditure (kJ)	Fat Burned (kg)
England	18,376,854	24,502	4,774,098,770	129,030
East Devon	304,121	405	79,007,079	2,135
Exeter	694,528	926	180,430,554	4,877
Teignbridge	3,267,405	4,357	848,834,744	22,941
West Devon	3,579,904	4,773	930,018,622	25,136
Mid Devon	301,920	403	78,435,513	2,120
Torbay	827,370	1,103	214,941,293	5,809
City of Plymouth	3,580,704	4,774	930,226,352	25,141
South Hams	1,686,138	2,248	438,039,519	11,839

The headline figures from Table 8 are that access Dartmoor enables recreational activity that results in the population of England burning an estimated 129,030 kg of fat each year. Just under 100,000 kg of that fat-burn is realised by residents of the local LADs. It is also worth noting that previous research has shown that, when compared to individuals at rest, physical activity increases fat oxidation in the hours after the activity was completed, therefore leading to health benefits in addition to the fat burn calculated here (Votruba et al. 2002).

Table 9 provides another take on the same data. By dividing the physical activity levels in Table 8 for visitors from each LAD by that LAD's population (both at 2019 estimates) we arrive at an approximation of the average level of physical activity undertaken on Dartmoor for each adult in each LAD. Of course, the number of visits and their levels of activity will differ across individuals in each LAD, so the figures in

Table 9 represent the activity we might expect to see from an 'average' resident of each LAD.

Table 9. Per capita physical activity levels from predicted recreational activity on Dartmoor in 2019

Region	Distance (km)	Steps	Energy Expenditure (kJ)	Fat Burned (g)
East Devon	2.56	3,417	666	18.0
Exeter	6.38	8,502	1,657	44.8
Teignbridge	29.75	39,667	7,729	208.9
West Devon	72.37	96,492	18,801	508.1
Mid Devon	4.56	6,082	1,185	32.0
Torbay	7.33	9,780	1,906	51.5
City of Plymouth	16.12	21,496	4,188	113.2
South Hams	23.17	30,900	6,021	162.7

A commonly stated health objective is that individuals should attempt to walk 10,000 steps a day. From Table 9 we see that for LADs in or bordering the National Park, Dartmoor forms the backdrop for several days' worth of such levels of activity. Residents of West Devon, for example, will on average achieve 10 days' worth of their target number of daily steps each year while recreating on Dartmoor.

One thing to note about the figures in Table 8 and Table 9 is that we cannot assume that without Dartmoor the physical activity would not instead be enjoyed at some other outdoor recreation site. One reasonably defensible assumption is that the physical activity benefits of trips to Dartmoor that are 'new' (i.e. where the individual would not have taken an outdoor recreation trip instead of the trip to Dartmoor) are wholly attributable to the existence of the recreation facilities of the National Park. From Table 3 we see that ORVal estimates the number of new visits to be around 30% of total visits, such that a good lower bound estimate of physical activity benefits would be 30% of the figures in Table 8 and Table 9.

Finally, Table 10 identifies the physical benefits that we expect to be realised by new residents of the Dartmoor hinterland arriving in the area in the period 2019 to 2039. Observe that these estimates differ from those in Table 9 insomuch as these new populations are expected to live in particular locations that may differ in terms of their proximity to Dartmoor compared with the general population of each LAD in 2019. Taking East Devon as an example, the expected increase in population in that

LAD will tend to focus on the new town of Cranbrook which is located relatively close to Dartmoor compared to the rest of the geographical area of that LAD. Accordingly, we see more visits and more physical activity from these new residents (e.g. 36.9 grams of fat burned per year on Dartmoor per person) than we do from the current population (e.g. 18 grams of fat burned per year on Dartmoor per person). In other words, the average Dartmoor activity levels by residents of the East Devon LAD is expected to increase because the development of Cranbrook is increasing the amount of East Devon housing which lies geographically close to Dartmoor. This increases the proportion of East Devon residents choosing to visit Dartmoor, and therefore increases the average level of Dartmoor activity per head for the East Devon LAD.

Table 10: Physical activity benefits per year per adult for predicted new populations in Dartmoor hinterland

	Population Increase 2019 to 2039	Distance (km)	Steps	Energy (kJ)	Fat (g)
East Devon	18,167	5.26	7,009	1,366	36.9
Exeter	14,594	7.67	10,232	1,994	53.9
Teignbridge	15,087	24.25	32,327	6,299	170.2
West Devon	4,509	50.87	67,832	13,217	357.2
Mid Devon	7,324	5.11	6,810	1,327	35.9
Torbay	12,012	8.83	11,776	2,294	62.0
City of Plymouth	19,809	17.13	22,834	4,449	120.2
South Hams	6,266	24.45	32,607	6,353	171.7

5 COSTS TO DARTMOOR

The previous sections of this report covered current and future levels of recreation, and outlined the welfare and activity benefits which are derived from recreation on Dartmoor. In this section, we cover a selection of the negative impacts which recreational activity can have on Dartmoor.

The first impact we consider is path erosion. This was selected as a focal area as previous sections of the report established that the majority of Dartmoor recreational activity is in the form of walking and running, and because our models show a substantial predicted increase in footfall levels on Dartmoor paths. Understanding sites sensitive to path erosion can help Dartmoor National Park Authority prioritise appropriate sites for monitoring, funding allocation and management.

The second impact we consider is impacts to wildlife through human visitation. The Environment Act 1995 states two purposes for National Parks[7];

- *" conserving and enhancing the natural beauty, wildlife and cultural heritage and*
- *promoting opportunities for the understanding and enjoyment of the special qualities of those areas".*

As conserving and enhancing the natural beauty and wildlife is a key statutory aim for National Parks, it is of key importance to understand the potential impacts of recreational activity on conservation. Dartmoor is home to a wide range of species, with numerous species of national and international conservation importance. In this section on impact to wildlife we assess the impacts of human visitation on key Dartmoor species.

It is important to note that a range of other potential impacts of recreation were not considered in this report due to limitations in time and expertise. Examples include the impacts of increased recreational activity on cultural heritage (e.g. archaeological sites), as well as other anthropological impacts such as anti-social behaviour and increased pressure on infrastructure and park services. Therefore, in addition to the information presented in this report, a wider range of positive and negative impacts would need to be taken into consideration in any comprehensive management and policy decision-making.

[7] Environment Act 1995. Part III National Parks. Section 61.

5.1 PATH EROSION

Increasing recreation on Dartmoor has the potential to contribute to increased levels of path erosion. Walking through Dartmoor can lead to increased erosion first through the mechanical action of walking boots damaging vegetation and churning up plants and soil. A second impact that walkers have on paths is through compaction of the top soil. Compaction reduces the soils ability to absorb water encouraging the development of puddles along paths and potentially altering the courses of water flow. The consequences of these impacts are greatly exacerbated by rainfall. Standing water causes walkers to deviate from the original path leading to path-widening. In addition, with heavy rainfall especially on paths with steep gradients water flow can result in 'gullying'.

Numerous studies have been undertaken to establish the relationship between recreational use of paths and erosion. One method through which that relationship has been studied is through randomised controlled trials in which similar plots are subjected to different levels of use as measured by the number of walking 'passes' over that plot. Examples of experimental studies include that by Roovers et al (2004) who studied common forest and heath communities in Central Belgium and found that site structure and vegetation were already affected by low intensities of trampling, while vegetation recovery during the first year after trampling was limited in most plant communities. Another study by Korkanç (2014) in Aladag Mountains Natural Park in Turkey found that after 500 passes, soil penetration resistance of topsoils significantly increased, and total porosity significantly decreased, when compared to control plots. Vegetation cover was reduced to 84% after 25 passes and to 67% after 500 passes. The study by Whinam and Chilcott (2003) in the Western Arthur Range of Tasmania found that tracks formed on experimental plots at between 100 and 500 passes per annum and that, while there was some small recovery in vegetation cover after 30 and 100 passes per annum applied for three years, there was no evidence of recovery at the 500 pass treatments. The meta-analysis of such studies carried out by Pescott and Stewart (2014) concluded that the intrinsic properties of plant communities, such as the dominant plant type (e.g. water plant vs. small flowering plant vs shrub), were the most important factors determining the response of vegetation to trampling disturbance.

Another approach to the analysis of erosion has been to use technology to monitor path networks. Somewhat closer to Dartmoor, Rodway-Dyer and Ellis (2018) use LIDAR, aerial photography and on-site measurements to study rates of erosion along the South-West Coastal Path. Their study revealed that the average loss of soil along the studied sections of the path was 9 cm over five years. Erosion was generally greatest in heathland vegetation and near paths, with evidence of footpath widening and water channelling on the footpaths exacerbating erosion. Close to sites of interest, erosion levels as high as 59 cm were recorded. Whilst this study illustrates the rates of erosion seen in the southwest in habitat types similar to Dartmoor, it does not quantitatively assess the relationship between levels of erosion and intensity of footfall.

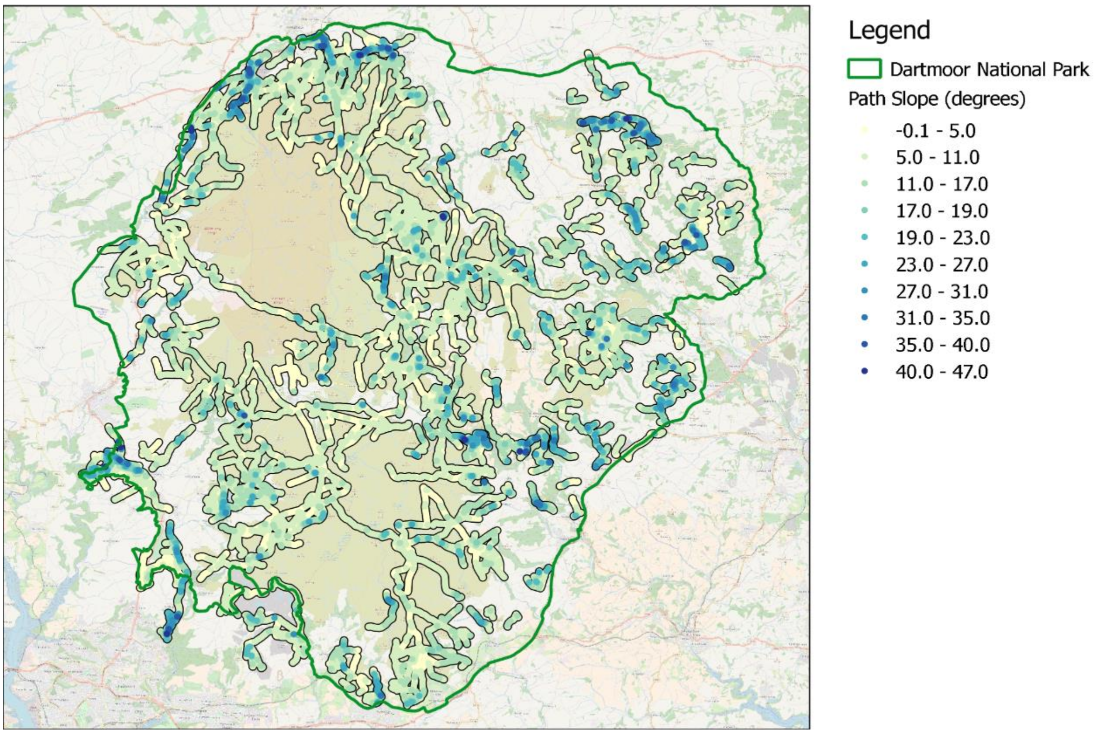


Figure 22. Locations of steep path sections at risk of erosion

The study we use to make predictions regarding rates of path erosion on Dartmoor is that by Coleman (1981) which provides a comprehensive assessment of factors impacting on footpath erosion in the Lake District. Coleman uses on the ground observations across the Lake District to relate path erosion to levels of recreational activity and characteristics of the path. The study showed that active erosion was evident on about one third of the path sites examined, and appeared on most paths with a slope of more than 17 degrees. Figure 22 provides an analysis that identifies the slope of paths across Dartmoor and hence the locations likely to be at risk of erosion from water flow.

For our purposes, the most relevant part of Coleman's study is that she provides a series of regression equations that relate number of visitor passes as well as path slope and altitude to levels of three different measures of erosion:

- Width of trampled grass along path
- Width of bare earth along path
- Depth of deepest gullying along path

The data in Coleman's study come from a sample of 485 sites along 25 different paths in the Lake District. While there are clearly significant differences between the Lake District and Dartmoor National Park (in for example geology and soils) which may affect the patterns of erosion, the regression equations provide some insight as to how increasing numbers of walkers on Dartmoor might add to levels of erosion. In particular, we take the footfall analysis from Section 3.3.4 and use the slope and height models from Figure 22 to gather the necessary variables at 50m intervals along the path network on Dartmoor. Applying the equations from Coleman (1981) allows us to make predictions regarding how the width of paths, the width of bare ground along paths and the depth of gullying might change across Dartmoor as a result of the changing levels of visitation into the future.

The results of that analysis are visualised in Figure 23 which shows how the three measures of erosion might increase from 2019 to 2039. Unsurprisingly, all three measures show the same spatial patterns with erosion risk focused on steep paths particularly in those areas experiencing the most predicted footfall.

As a rough guide to the magnitude of this potential future erosion, we took the point estimates of erosion extent and multiplied up by the 50m gap between those points on the path network. In terms of path width, therefore, we were able to calculate that by 2039 rising visitation might be responsible for an additional 74,135m^3 of vegetation being damaged by 2039 from recreation pressure widening footpaths. Likewise the model suggests that an additional 10,854 m^2 of bare ground might be exposed along the path network as a result of visitor pressure. Moreover, the predictions indicate that some 250m of path will experience increased gullying in excess of 5cm depth and 42km of path experiencing gullying of more than 1cm depth.

While a Dartmoor-specific primary study would likely be needed to properly understand the nature of erosion problems across the National Park, the analysis suggests that the magnitude of visitation increase will likely have widespread impacts on trampling of vegetation with substantial more localised erosion of paths particularly on steep sections of paths.

The top left panel of Figure 22 presents a Digital Terrain Model for Dartmoor from which measures of slope are derived and shown in the top right hand panel. Intersecting the paths network with the slope model identifies the level of slope of land over which paths pass as shown in the bottom panel of the Figure. Observe that steep sections of path can be found throughout the National Park but particularly on the Park fringes where Dartmoor rises up steeply from the surrounding countryside and also along the steep-sided river valleys that flow out of Dartmoor,

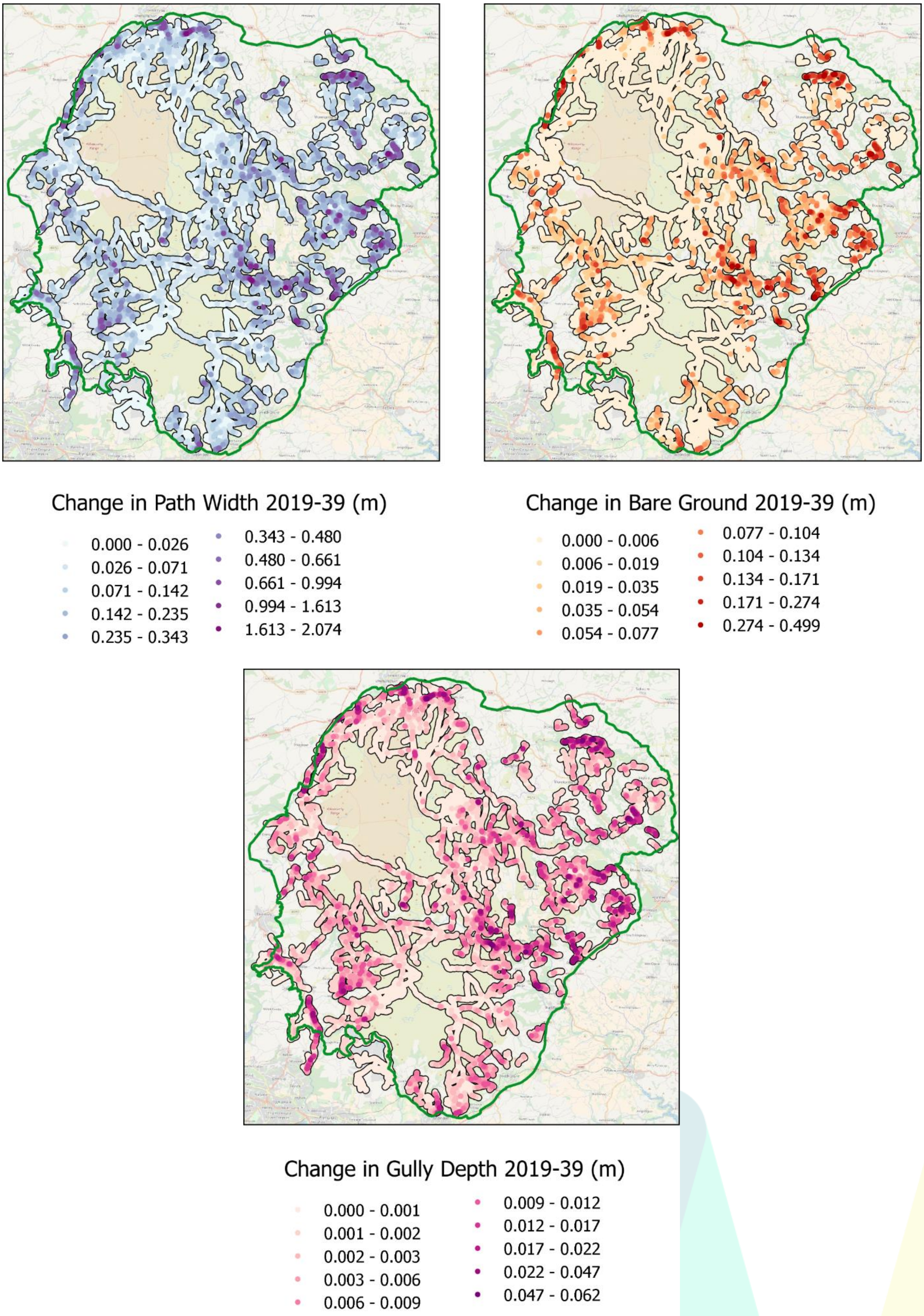


Figure 23. Predictions of locations of increasing erosion by 2039

5.2 WILDLIFE DISTURBANCE

One of the aims of this project was to understand how recreational pressures impact Dartmoor wildlife and conservation. To do so, improved understanding of the impacts of recreational activities on key Dartmoor species was needed. Here, we first provide an overview of scientific findings on the impacts of recreation on uplands and heathlands. To evaluate the potential impacts of recreation for Dartmoor specifically, this section then reports the results derived from recreation impact questionnaires with local species experts for a broad range of key Dartmoor species. Hotspot maps are shown (where known), and potential conflicts between recreational activities and key wildlife are discussed.

5.2.1 Literature overview – methodology

A literature search was conducted to provide an overview of current knowledge of recreational impacts on upland and moorland landscapes. To limit this literature search to studies most relevant to the report's objectives of assessing recreational impacts on Dartmoor, combinations of the search parameters described below were applied on the Web of Science literature database to obtain research on relevant topics and conducted in similar habitat types:

Recreational activity search terms:
"visitor", "recreation", "touris*", "footfall", "bicycl*", "cycl*", "mountainbik*", "fellwalk*", "rambl*", "walk*", "human disturbance" and "anthropogenic disturbance".
N.B. Stars (*) indicate words ending any in any letter, i.e. searching for "touris*" would find "tourist", "tourism" etc.

Impact search terms:
"impact*", "consequence*", "damage*", "degradation*" and "effect*".

Habitat search terms:
"upland", "moorland", "heathland", "oak woodland", "ancient oak woodland" and "ancient woodland"

5.2.2 Literature overview - findings

How recreation impacts on the ecology of species and landscapes is highly complex and therefore very challenging to unravel. Many studies highlight the fact that it is difficult to make generalisations about how the environment and wildlife respond to recreation pressures. Impact from recreation does not always increase proportionally as recreation increases; instead, a broad range of relationships exist between recreation levels and impacts (Monz et al. 2013). Other complicating factors need to also be considered. For instance, susceptibility to recreation impacts differs between species, intervals and timings of disturbance need to be considered alongside intensity, and interactions with other phenomena such as climate change can complicate patterns (Buckley 2013).

Furthermore, many different aspects of recreation impacts can be studied. For example, when studying the effects of anthropogenic disturbance on animals, one can measure and describe factors related to changes in individual behaviour, distribution, demography and/or population size (Gill 2007). Which factors are of interest will depend on the research or management questions. As Gill (2007) describes, impacts of recreation on species distribution will be of key importance when sites are managed to support specific wildlife, whereas if species conservation as a whole is of concern, effects on population size need to be understood.

In a set of two reviews, Marion (2016a and 2016b) assess the current literature on recreation ecology and describe mitigating management strategies. Although mostly based on US studies, these reviews provide a useful overview of current knowledge in the field. The first review provides evidence of impacts of recreation on vegetation, soils, water and wildlife (Marion 2016a), and the second review outlines five core management strategies to minimise recreation impacts; i. manage use levels, ii. modify location of use, iii. increase resource resistance, iv. modify visitor behaviour and v. close and rehabilitate the resource (Marion 2016b). Whilst not covering UK or upland landscapes, and not being written in the specific context of wildlife disturbance, these strategies could potentially be reviewed and adapted to be used to inform management decision-making strategies on Dartmoor.

In addition to the broad reviews described above, it is worth noting that a significant proportion of the research literature focuses on the impacts of recreation on birds, and several studies have reviewed that accumulated evidence. Steven et al. (2011) reviewed studies on the effects of nature-based recreation on individual, reproductive and population-level responses in birds. Out of 66 reviewed papers, they found that 88% reported negative effects of recreation on birds, with only one study (on corvids) recording positive effects (Steven et al. 2011). Similarly, a review by Showler et al. (2010) concluded that there is evidence that disturbance on foot can reduce breeding bird densities and reduce hatching and fledging success. They also mention that observational studies suggest that bird responses are stronger when dogs are present, highlighting possible additional negative effects of dog-walkers compared to regular walkers (Showler 2010).

All reviews described above form a general introduction to the wider recreation ecology literature. To illustrate studies of particular relevance to Dartmoor, we now outline findings from studies of recreation impacts which were carries out in upland, heathland, moorland and oak woodland (following the literature search methodology outlined in section 5.2.1.):

- Brambilla et al. (2004)
  Habitat type: upland/alpine cliffs
  Study overview: This study monitored ***Peregrine Falcon*** nest sites, and recorded the presence of Raven and rock climbing activity. They found that the presence of climbers lowers breeding success and productivity, which is lowered further when both Raven and rock climbers were present at a nesting cliff.
  Suggested mitigation measures: Ban or regulate climbing at and near Peregrine Falcon nesting sites.

- Botsch et al. (2017)
  Habitat type: oak woodland
  Study overview: This study experimentally tested the effects of human disturbance on bird territory settlement in oak woodlands. A total of 34 species were studied, including Wood Warbler, Lesser Spotted Woodpecker and Tree Pipit. Plots which were experimentally disturbed during the pre-breeding season (by 2-3 observers with loudspeakers with human conversation played at normal levels), showed a 15% reduction in both the numbers of territories and in species richness. This effect was not seen in long-distance migrants which arrived after the disturbance events.
  Suggested mitigation measures: This research highlights that mitigation measures should not only be restricted to the breeding season, as this study shows that relatively low levels of short-term disturbance can affect bird breeding in the pre-breeding season. Such concerns were also raised for Dartmoor (see expert opinion on Wood Warbler in the species factsheet in section 5.2.6). The authors suggest access limitations (including during the pre-breeding season), and educating the public about minimising impacts to mitigate effects.

- Finney et al. (2005)
  Habitat type: blanket bog
  Study overview: ***Golden plover*** distribution/density is affected by the presence of footpaths; the probability of recording Golden Plover decreased nearer to footpaths. It was found that after re-surfacing paths, decline in bird number was seen up to 50m from the path, whereas before resurfacing effects were seen at 200m from paths. It is important to note that from this we can derive that if (unsurfaced) paths are spaced less than 400m apart, birds such as Golden Plover could be excluded from otherwise suitable habitat. No effect on brood survival was found. See also Pearce-Higgins (2007).

Suggested mitigation measures: when footpaths are well-maintained, when clear access points are provided, and/or when visitors are encouraged not to stray from footpaths, the area and therefore extent of disturbance can be reduced. Furthermore, footpaths need to be well-spaced to ensure birds are not excluded from breeding habitats.

- Jayakody et al. (2011)
  Habitat type: upland woodland and heathland
  Study overview: Faecal diet analysis was used to compare diet of **Red Deer** at sites within 500m from a track (441 visitors/day in peak season) and 1000m+ from a track. The results suggest that human disturbance may affect the nutritional intake of Red Deer, as differences in diet composition between the disturbed and relatively undisturbed sites are shown.
  Suggested mitigation measures: Control of disturbance levels close to preferred feeding grounds in areas where high-quality food is in limited supply (although it needs to be noted that links between diet and Red Deer performance were not investigated in this study)

- Langston et al. (2007)
  Habitat type: heathland
  Study overview: It was found that failed ***Nightjar*** nests were closer to paths, access points, high-use areas and areas with higher footpath density. The total length of paths within 50m, 100m and 500m of nest sites was recorded, and in all three categories unsuccessful nests had a higher number of paths around the nest site. The increase in nest failure was largely due to increased predation rates (as eggs and nestlings are left exposed when adults are disturbed from the nest sites). It is worth noting that this study also provided some evidence of the fact that dogs disturb nest sites by recording flushing from a dog on a nest camera.
  Suggested mitigation measures: The author suggests a range of mitigation measures, including:
    - Use measures to minimise dogs straying of paths (in addition to "dogs on leads" policy). This could include managing habitat penetrability (e.g. gorse at path margins) to influence access.
    - Educating visitors
    - Access management: redirecting or closing paths, provision of access points and car parks away from breeding sites
    - Providing alternative recreation sites away from Nightjar/heathland sites

- Liley et al. (2003)
  Habitat type: heathland
  Study overview: Areas of heathland surrounded by more houses and/or urban areas supported a lower ***Nightjar*** density in this study on lowland heaths on Dorset. This reduction in density is likely to be caused by increased human visitation.
  Suggested mitigation measures: Modify/restrict visitor access, dogs on lead policy

- Mallord et al. (2007)
  Habitat type: heathland
  Study overview: Density and habitat colonisation of ***Woodlark*** is reduced by disturbance. The analysis showed that +- eight disturbance events per hour reduced the probability of habitat colonisation to less than 50%. Nest survival did not appear to be affected by distance from paths, but number of fledglings per pair *increased* at sites with high disturbance

(potentially due to reduction in competition from reduction in breeding density). Despite this increase in fledgling number, overall effects from disturbance on productivity were negative. Mallord (in the context of this study on Dorset heathland), mentions that "(…) *negative impacts are only likely to manifest themselves with large increases in overall disturbance. Although such increases are not a predicted consequence of the introduction of CRoW, they may arise from new housing developments from which heathlands in southern England are often under threat.*"

Suggested mitigation measures: The creation of suitable habitats in relatively undisturbed areas, to mitigate for the reduction in available breeding sites caused by increased disturbance in otherwise suitable habitats

- Murison et al. (2007)

  Habitat type: heathland

  Study overview: This study of ***Dartford Warbler*** found that in heather territories, the start date of first broods increases as disturbance increases (effects were not seen for territories with gorse). This results in reduced productivity, as birds are less likely to fledge and fewer successful broods can be raised. Although not measured explicitly, the authors suggest that dogs may be a main factor in causing this reduction in breeding productivity. Analyses showed that approximate 13-16 visitors per hour in a territory would prevent multiple broods.

  Suggested mitigation measures:

  - Ensure dogs are kept on leads
  - control visitor access through access restrictions/path diversions
  - encourage gorse vegetation in heather territories to provide cover and prevent access to heather from paths

- Pearce-Higgins et al. (2007)

  Habitat type: blanket bog

  Study overview: Survey at the same site as Finney et al. (2005) and second site with lower numbers of visitors. Found that ***Golden Plover*** did not avoid areas near paths at the quieter site. ***Dunlin*** was also studied, and although trends were similar to those in Golden Plover (increase in numbers near footpath after re-surfacing), but low sample sizes meant that statistical significance was not shown. The study concludes that situations where visitor pressures will impact uplands waders will be rare, and that birds are only likely to be (partially) excluded from habitats at sites where path quality is poor and visitor pressure is "greater than at least 30 visitors per weekend day".

  Suggested mitigation measures: see Finney et al (2005) above

- Rouifed et al. (2014)

  Habitat type: both upland and lowland sites

  Study overview: Levels of human visitation and distance from roads (along with a range of other factors) were compared for plots with and without ***Japanese Knotweed***. Statistical models were used to understand which factors predict the presence of Japanese Knotweed, and it was found that "*for the upland plots, a shift from low frequentation to inter-mediate or similarly from intermediate to high frequentation by humans increased more than four times the probability of encountering knotweeds*". In contrast to lowland areas, the study showed that in uplands only the anthropogenic factors predicted the presence of knotweed, leading the authors to conclude that the spread of knotweed in upland areas is mostly linked to anthropogenic activities.

Management suggestions: When surveying for the presence of Japanese Knotweed, prioritise areas where invasion risk is likely higher (i.e. near roads and sites with high visitor levels)

- Sibbald et al. (2011):
  Habitat type: upland heathland, grassland and woodland
  Study overview: This GPS tracking study compared behaviour of ***Red Deer*** on busy days (Sunday, mean of 204 walkers per day counted on main track) and quiet days (Wednesdays, mean of 49 walkers per day counted on main track) The study found that on busy days, the distance travelled by stags is higher, and individuals stay further from tracks. These effects were shown to last into the night despite the tracks being practically undisturbed at night. The study discussed that this disturbance could affect for example feeding behaviours and food intake, and physiological stress levels, but such factors were not investigated in this study.
  Suggested mitigation measures: none discussed

- Vangansbeke et al. (2017)
  Habitat type: pine plantation on former heathland
  Study overview: Recreational pressures on forest footpaths were recorded, as well as the distribution of seven species (***Crested Tit, Coal Tit, Nightjar, Common Lizard, Northern Dune Tiger Beetle, Grayling and Small Heath***). Statistical modelling was used to determine whether recreation showed a negative relationship with species distribution. Negative effects were shown for Coal Tit, Small Heath and Grayling, and vulnerability to recreation was shown to differ between different forest patches. Different hypothetical scenarios of equal amounts of visitor increase were explored, and it was shown that a land-sparing approach (where total visitor increase was not spread equally across all sites, but rather, visitor pressure was reduced in vulnerable sites, and increased more strongly at the least vulnerable sites) reduced the negative effects of increased visitor pressure. The authors note that while no negative effects on distribution were shown for the other species, past effects or other negative recreation impacts may be affecting those species.
  Suggested mitigation measures: A land-sparing approach, where (increases in) recreational activities are avoided in priority wildlife areas, could aid wildlife conservation.

- Yalden (1992)
  Habitat type: shores of upland reservoir
  Study overview: This relatively descriptive study showed that fewer Sandpiper territories were present at busy sections of shore, and that the Sandpiper presence on certain, but not all, reservoir shores showed a negative relationship with the number of anglers present. It was noted that birds flew of when a human approached within 27, and that birds with chicks are behaviourally disturbed (start alarm-calling) at distances of 75m.
  Suggested mitigation measures: The author suggest that access restrictions, as well as the provision of nearby retreat sites with low levels of recreation could help reduce conflict between recreation and breeding birds.

It is worth noting that although literature search terms (section 5.2.1) were not targeted to birds, most results covered the effects of recreation on birds. This suggest a possible research bias in the animal groups for which studies into recreation impacts on wildlife are carried out. This literature search was not comprehensive and restricted in the used search terms, and broader literature searches, particularly in habitat types not covered here, may therefore show further evidence of recreation impacts on a wider range of species.

A local study of interest and of direct relevance to Dartmoor is the 2006 Breeding Bird Survey of the Dartmoor Training Area, which includes a discussion on the effects of paths on bird distributions. It was found that path presence did not appear to affect Meadow Pipit, Skylark and Wheatear distributions, but that Stonechat and Grey Wagtail showed a negative relationship with path presence. A positive relationship was shown for Pied Wagtail.

From the literature reviewed above, it is clear that studies on recreational impacts are limited to very few bird species and habitat types, and that quantitative evidence on established levels of footfall and subsequent population consequences is lacking. In the next section we sought to complement this literature overview with local expert judgement in order to obtain qualitative Dartmoor-specific insights on (potential) recreation impacts for key species of interest. A range of potential mitigation measures for Dartmoor's species and habitats are outlined also.

5.2.3 Impacts on key Dartmoor species - methodology

To understand how recreational activities impact key species on Dartmoor, local experts on the species of interest were contacted to share their knowledge, captured through a questionnaire. The questionnaire contained questions on the local requirements, distribution and sensitivity to a range of recreational activities. The full questionnaire can be found in Appendix 3. A list of the experts who were consulted and kindly shared their expertise and research findings can be found in the full version of this report. A discussion of each key species or species group, based on the knowledge shared in the questionnaires, is found in the section below.

A selection of key Dartmoor species of local, national and international importance, and representing a broad range of habitats and species groups, was made from two local publications; the State of Dartmoor's Key Wildlife, and the Devon Special Species List. A number of additional species were added based on expert opinion (pers. comm. with Prof Charles R Tyler and Richard Knott (DNPA). It is important to note that these species represent only a case study of the potential effects of recreational activities, and that other Dartmoor species not covered here could be equally affected by recreational activities. Questionnaires and species impact case studies were completed for the following species:

Adder
Blue Ground Beetle
Bog Hoverfly
Cuckoo
Dartford Warbler
Dipper
Dunlin
Fairy Shrimp
Greater Horseshoe Bat
Hen Harrier
High Brown Fritillary (combined into one "butterflies" case study)
Marsh Fritillary (combined into one "butterflies" case study)
Narrow-bordered Bee Hawkmoth (combined into one "butterflies" case study)
Nightjar
Otter
Pearl-bordered Fritillary (combined into one "butterflies" case study)
Peregrine Falcon
Plants (generic overview across lower and higher plants)
Raven
Red Grouse
Ring Ouzel
Salmon
Skylark
Snipe
Southern Damselfly
Whinchat
Wood Warbler

The following species were also included in an initial list of selected species, but species impact case studies were not completed due to being unable to contact and/or receive questionnaire responses from suitable species experts:

Dormouse
Keeled Skimmer
Golden Plover (it is worth noting here Golden Plover is an intermittent winter visitor to Dartmoor, and that winter walkers and dogs are thought to cause substantial disturbance to this species. Some information on disturbance to this species can be found in the literature review above).

Following conversations with species experts, the following species that we identified for our initial listing of species were not followed up on because of their limited relevance for recreational impacts:

Cirl Bunting (small population mostly on private land)
Large Blue Butterfly (no longer seen on Dartmoor)
Willow Tit (mostly on closed and private land)
Woodlark (small population mostly on private land)

Two iconic species which breed on Dartmoor in very low numbers are Lapwing and Curlew. Due to their low numbers, species-specific case studies were not conducted as part of this work. However, there is awareness of the critical plight of these birds on Dartmoor, and their breeding is mapped as part of the Rare Bird nesting areas by DNPA. This mapping is briefly discussed below and maps can be seen in Figure 24.

5.2.4 Impacts on key Dartmoor species

Full case studies for can be found in Appendix 4 (note: sensitive information has been retracted – provided to DNPA in full report version). These case studies include an assessment of recreational impacts, along with details on the ecological requirements and conservation status of the species. Where information was available, maps of local hotspots and/or species distribution are presented. Threats other than those from recreational impacts are also discussed.

Recreational activity types and key species impacted by these activities are summarised in Table 11. This list includes only key species for which analyses were conducted via questionnaires, and is therefore not comprehensive.

Table 11. Activity types and impacted key species

Activity type	Affected key species

Walking/ hiking/ running	• Butterflies & moths
	    ▪ low levels of disturbance to individuals
	    ▪ trampling of key vegetation or food plants under high footfall
	• **Cuckoo** (disturbance to breeding behaviour and fledglings)
	• **Dartford Warbler** (reduced breeding performance)
	• **Dunlin** (potential disturbance but currently low spatial overlap with recreation)
	• **Nightjar** (disturbance leading to nest failure)
	• **Plants** (trampling damage)
	• **Raven** (potential future breeding disturbance)
	• **Ring Ouzel** (disturbance and nest failure)
	• **Whinchat** (breeding disturbance)
	• **Wood Warbler** (disturbance to territory settlement and breeding)

Large events	• **Adder** (disturbance to breeding areas) • **Butterflies & moths** (trampling of key vegetation or foodplants) • **Cuckoo** (prolonged disturbance and displacement of birds from sites) • **Dartford Warbler** (prolonged disturbance) • **Dunlin** (prolonged disturbance) • **Plants** (trampling damage) • **Red Grouse** (prolonged disturbance) • **Ring Ouzel** (prolonged disturbance) • **Skylark** (increased trampling risk due to nests in open vegetation) • **Southern Damselfly** (trampling of key habitat) • **Wood Warbler** (breeding disturbance and trampling risk)
Dog-walking	Effects similar to walking with additional negative effects,, e.g: • **Adder** (disturbance) • **Cuckoo** (disturbance to breeding behaviour and fledglings) • **Ground-nesting birds** (generally more easily disturbed by dogs than by humans only, increased flushing at nests can

Activity type	Affected key species
	lead to increased predation risk) • **Plants** (potential nutrification)
Mountain-biking	• **Nightjar** (disturbance from off-road cycling in conifer plantations) • **Plants** ("trampling" damage) • **Wood Warbler** (potential breeding disturbance)
Horse-riding	• **Plants** (trampling damage)
Increased car traffic	• **Adder** (occasional collision death) • **Butterflies & moths** (occasional collision death) • **Cuckoo** (occasional collision death) • **Greater Horseshoe Bat** (collision death, disturbance to commuting from lights at night) • **Otter** (occasional collision death) • **Plants** (possible indirect effects due to reduced air quality)
Wildlife watching/ naturalists	• **Butterflies & moths** (illegal collection) • **Hen Harrier** (disturbance of roost sites by birdwatchers) • **Ring Ouzel** (disturbance and nest site trampling can lead to displacement and reduced breeding success) • **Wood Warbler** (prolonged breeding disturbance due to information-sharing between photographers)
Fire/arson	• Butterflies & moths (habitat loss) • **Plants** (vegetation loss)
Camping/ barbecues/ picnics	Causes prolonged disturbance and/or displacement, such as: • Most **breeding birds** when activity takes place in/near territory
Kayaking/ swimming/ fishing	• **Dipper** (potential disturbance to territorial behaviour, foraging behaviour and fledglings) • **Plants** (loss of lower plant species from stones at access points, trampling) • **Salmon** (exploitation from illegal fishing, potential disturbance from dams created by visitors)
Caving	• **Greater Horseshoe Bat** (disturbance if roosting or hibernating in caves)
Climbing/ bouldering	• **Peregrine Falcon** (reduced breeding success) • **Raven** (breeding disturbance) • **Ring Ouzel** (potential for future disturbance at breeding sites)

Activity type	Affected key species
Illegal raves	General disturbance to wildlife, e.g. • Nightjar
Letterboxing/ geocaching	• **Plants** (loss of lower plants from stones) • **Ring Ouzel** (prolonged disturbance)
Joy-riding (motorised off-road vehicles)	• **Southern Damselfly** (damage to key habitat)

Based on the questionnaire results, we assigned the key species into three levels of sensitivity to recreation activities, using the following categories:

Green: recreation impact unlikely. Species are either:

- not likely to be affected by any of the listed recreational activities, or
- spatial overlap between recreation and species occurrence is minimal, therefore substantial conflict is unlikely

Orange: recreation impact possible or minor

- Minor or localised recreation impacts could be a concern
- Strong effects unlikely (unless there are major changes in recreation patterns)

Red: recreation impact high or likely

- Adverse impacts have been recorded
- Spatial conflict and recreational impacts deemed likely

The sensitivity category for each species is displayed in Table 12. Sensitivity colours are assigned in the context of the current status of the species on Dartmoor, and the level of recreational use currently seen and realistically expected in the future for Dartmoor. These groupings are therefore specific to Dartmoor, and would not necessarily be applicable to other locations, for example areas with higher recreational pressures or were there are different species distributions and hotspots. For example, although Skylark are sensitive to recreation impacts, strong population-level effects from recreation activities are unlikely due to their widespread presence on Dartmoor, and Skylark are therefore classed as “orange” in terms of sensitivity risk. Another example is the Peregrine Falcon, classed as “green” in our assessment because birds currently breeding on Dartmoor are mostly found on private sites, and are therefore unlikely to be impacted by recreational activities. It is worth emphasising however, that their past status may have included birds breeding on more publicly accessible sites, and that recreational activity may have already resulted in birds deserting those potential breeding sites. If Peregrine Falcon were to start breeding on tors were climbing takes place, sensitivity to recreation impacts would be high. Similar patterns apply to the other species in Table 12. It would therefore be desirable to review the information presented here periodically, especially when species distributions or recreational activities show significant changes.

Table 12. Current sensitivity of key Dartmoor species to recreational activities

Green: recreation impact unlikely	Orange: recreation impact possible or minor	Red: recreation impact high or likely
Blue Ground Beetle	Adder	Cuckoo
Bog Hoverfly	Hen Harrier	Dartford Warbler
Fairy Shrimp	High Brown Fritillary	Dipper
Otter	Marsh Fritillary	Dunlin
Peregrine Falcon	Narrow-Bordered Bee Hawkmoth	Greater Horseshoe Bat
Snipe	Pearl-Bordered Fritillary	Nightjar
	Plants	Raven
	Salmon	Red Grouse
	Skylark	Ring Ouzel
	Southern Damselfly	Whinchat
		Wood Warbler

It is important to emphasise that the species were assigned to the three groups by judging the species' sensitivity based on the above categories and questionnaire information; this is a relatively subjective method. This limitation should therefore be kept in mind. The information, nonetheless, provides a useful overview of the differences between species in their (potential) susceptibility to impacts from recreational activities on Dartmoor.

For the species for which mapping data were available, hotspot maps were produced for the red and orange sensitivity-classed species from Table 12 (maps were provided to DNPA – retracted here due to sensitive information on the location on vulnerable or rare species). Due to limitations in species data or species knowledge, these maps are not comprehensive; for some species it represents all known hotspots (e.g. Wood Warbler), for other species sites of high breeding potential (Salmon) or key foraging areas (Greater Horseshoe Bat). Such mapping efforts therefore do not therefore provide a comprehensive map of all species hotspots on Dartmoor, but rather it provides an informative overview of known hotspot sites for key species, and therefore illustrates sites of conservation importance across the moor.

Further key areas of conservation importance, namely Special Areas of Conservation (SAC), National Nature Reserves (NNR), Sites of Special Scientific Interest (SSSI) and

Rare Bird nesting areas are shown in Figure 24 below. The rare bird nesting area data layer was created by DNPA from rare bird data layers, including Ring Ouzel, Dunlin, Curlew and Lapwing. Dartmoor's Premier Archaeological Landscape Sites data was created as part of creating a Vision for Dartmoor's moorland in 2005. (Permission was granted to map the data layers for the purposes of this report.)

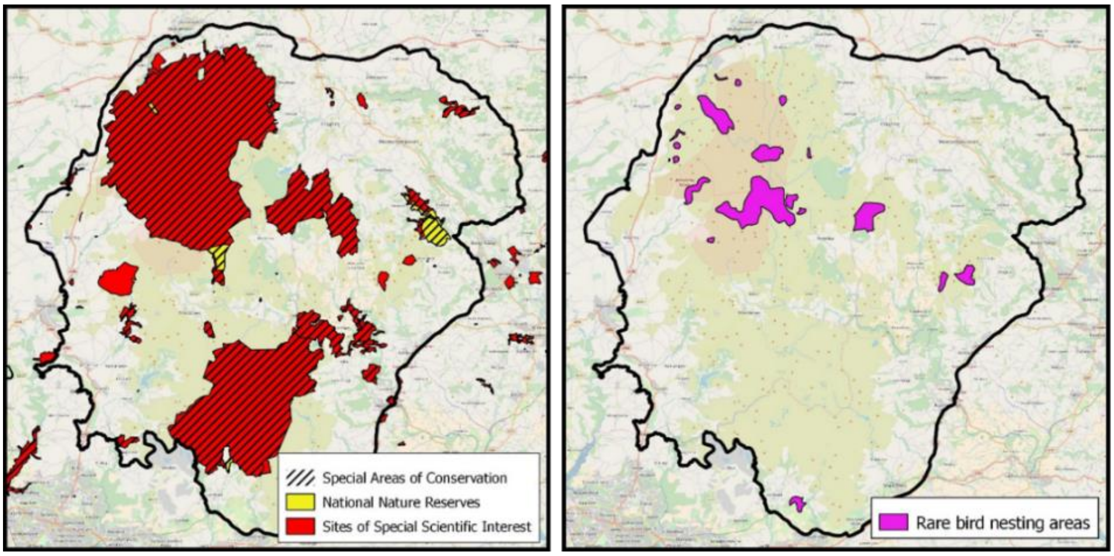


Figure 24. Maps illustrating known sites of conservation importance on Dartmoor.

5.2.5 Impacts on key Dartmoor species – vulnerable locations

Predictions of changes in footfall over the coming decades can be seen in section 3.3.4. This data on predicted changes in footfall can be combined with the information on key species hotspots (Section 5.2.4) to illustrate where species may be under threat from increased recreation. For the species deemed sensitive to recreation, impacts based on expert opinion (see Table 12), the predicted footfall data can be used to establish the likelihood of recreation impacts in future years. It is important to note that this can only be mapped for species where hotspot information was available. For the other case study species, insufficient hotspot information was available. Species such as Dartford Warbler and Whinchat, for which we have no specific hotspot data, but are nonetheless likely to be impacted by increased footfall, are therefore not covered in these mapping efforts. Due to the sensitive nature of several species – only maps for Cuckoo are shown here as an example. Full maps for other sensitive species were provided separately to DNPA.

Figure 25 shows the predicted growth in footfall (in numbers of visitors/hour) between 2019 and 2039, along with the hotspot locations for Cuckoo.

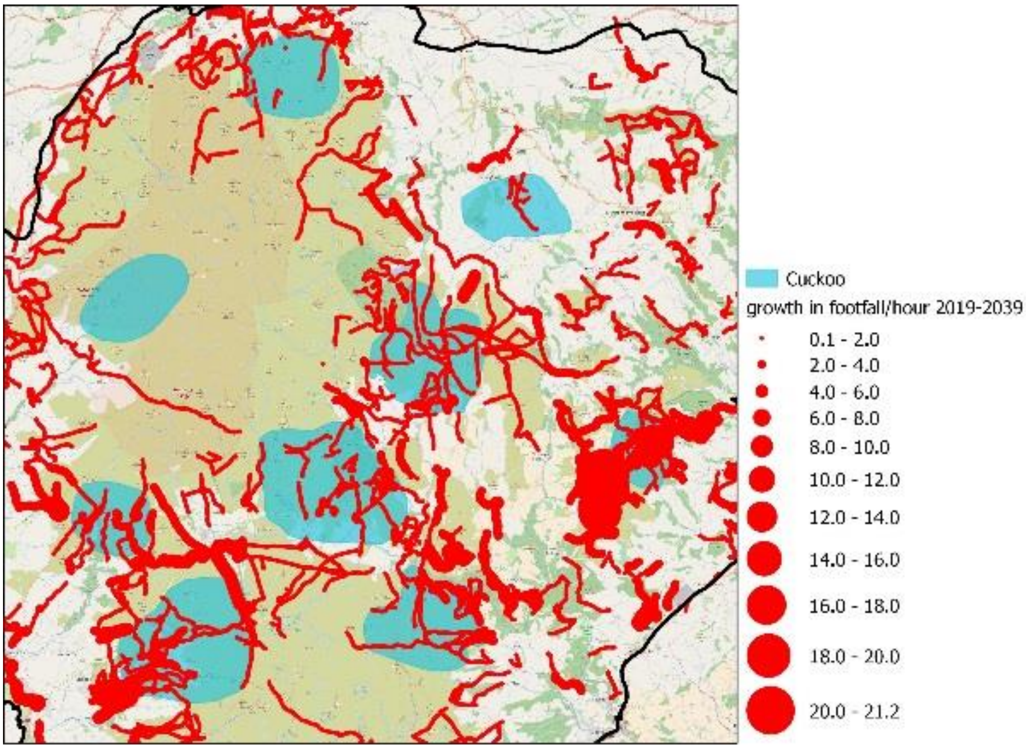


Figure 25. Predicted growth in footfall per hour between 2019 and 2039, superimposed on hotspots for Cuckoo. Figures on other species have been retracted from this report version due to the sensitive nature of the information.

From the mapping efforts for all sensitive species (retracted here due to sensitive location information), it can be seen that species differ in the amount of increased footfall they are expected to experience. The species can be divided into three categories:

- High concern, recreation impacts are likely to increase across most hotspots:
  - Nightjar, Cuckoo and Wood Warbler: footfall will increase at all, or nearly hotspot sites for these species.
- Sites of concern, recreation impacts increasing locally:
  - Dipper, Greater Horseshoe Bat, Red Grouse and Ring Ouzel: increased footfall is expected at part of the hotspot sites for these species.
- Increased impacts from recreation unlikely:
  - Dunlin: very little increased footfall is expected at Dunlin hotspots.

This information indicates that of the species deemed sensitive to recreation impacts, Cuckoo, Nightjar and Wood Warbler are of relatively high concern. Furthermore, increases in footfall are also expected on important sites for Ring Ouzel, Red Grouse, Greater Horseshoe Bat and Dipper (and also for the only current breeding site for Curlew). These species would benefit from further monitoring, and mitigation measures (see section 5.3) should be considered as being beneficial to ensure increased footfall does not negatively impact on their populations. Dunlin is unlikely to experience changes in recreation pressures, and therefore for this species, changes in management practices with regards to recreation impacts are unlikely to be a priority in the near future.

A combined map of key species hotspots and areas of growth in footfall is shown in Figure 26. This map includes all species deemed sensitive to recreation impacts based on expert opinion (see Table 12). It illustrates overall areas where key species and recreation are predicted to come into increased conflict.

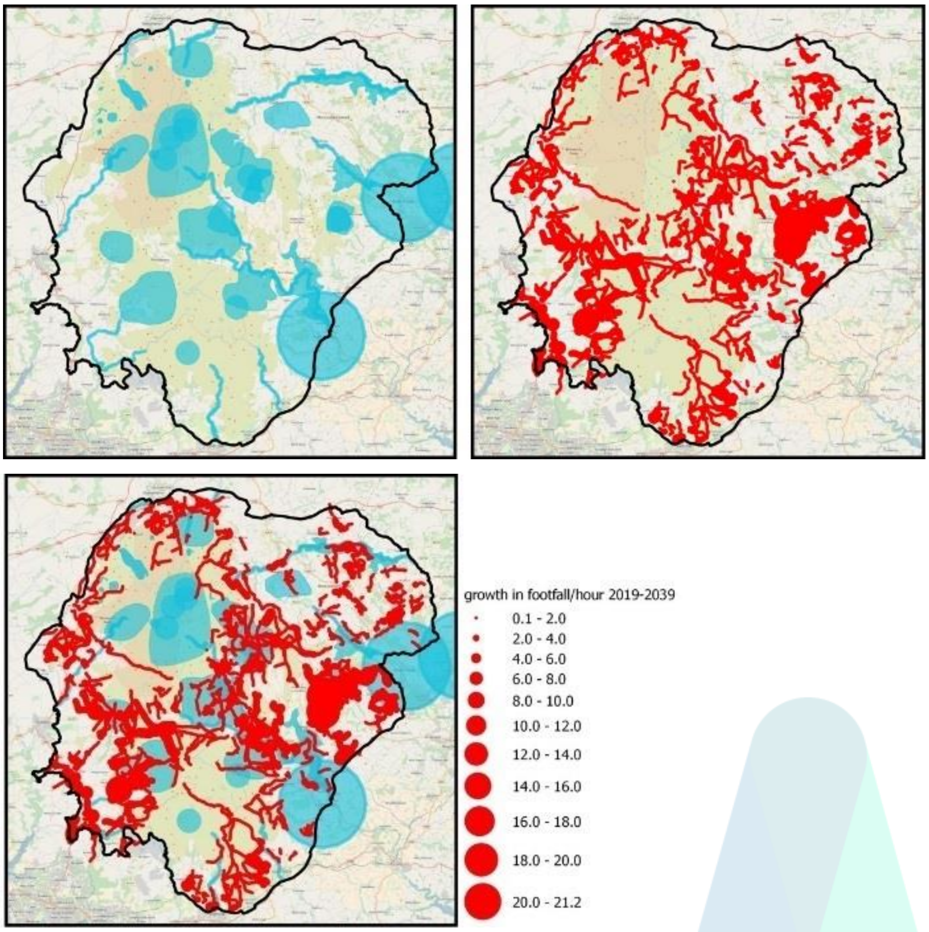


Figure 26. Key species hotspots (for which spatial information was available) (top left), predicted growth in footfall per hour 2019-39 (top right), and combined (bottom panel)

Based on Figure 26, we can highlight 4 vulnerable wildlife locations where particularly strong increases in footfall are expected between now and 2039 (Figure 27):

- Burrator area
- Dart Valley and Venford Reservoir
- Haytor area
- Warren House/Soussons/Fernworthy area

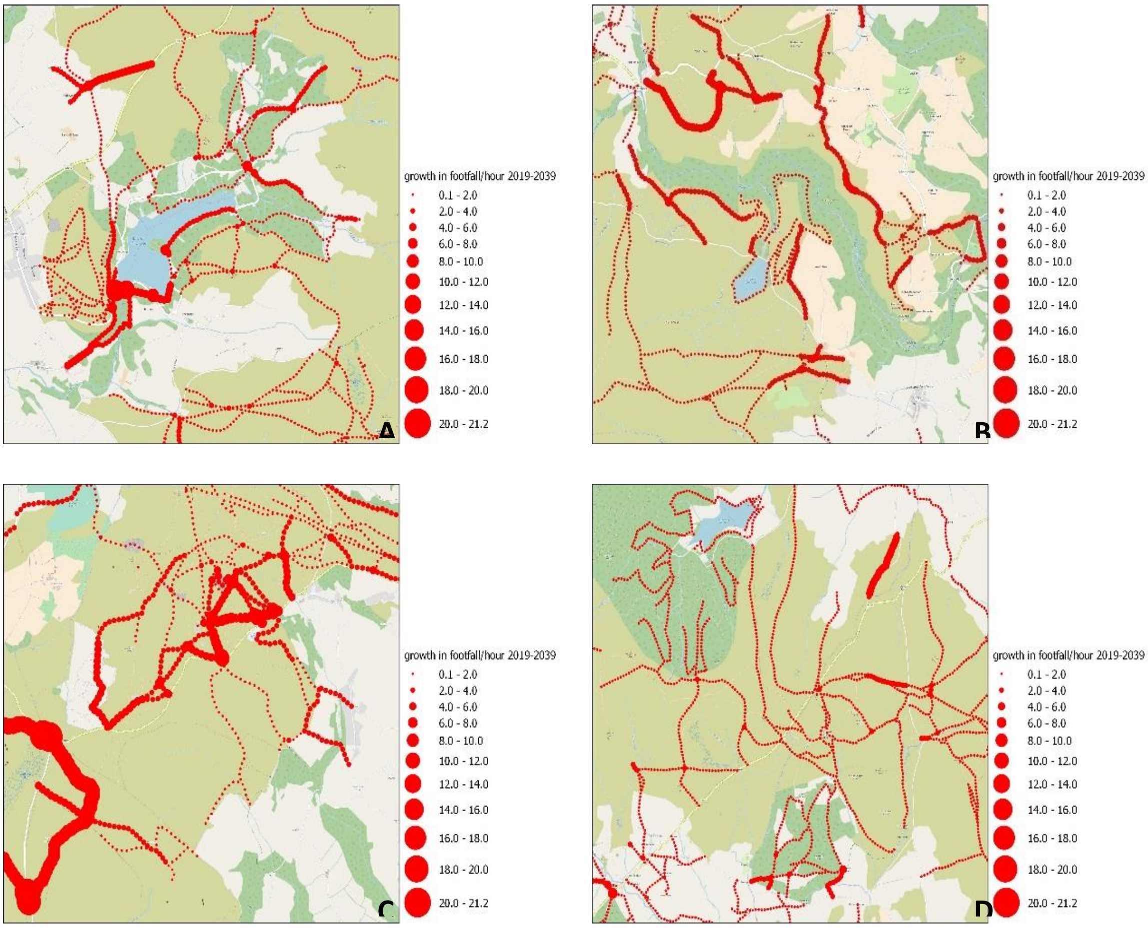


Figure 27. Vulnerable areas where key species hotspots and predicted increases in recreational pressure overlap. A: Burrator area, B: Dart Valley and Venford reservoir, C: Haytor area, D: Warren House/Soussons/Fernworthy area.

It was shown (section 3.1.4 and Figure 6) that visitors from a given LAD tend to focus trips to areas in the National Park that are closest to their location of residence. To understand from where the visitor growth in the four vulnerable areas (Figure 27) will originate, the growth in footfall is mapped separately for each LAD:

- **Burrator area** (Figure 28): The growth in footfall around this area is predicted to originate almost exclusively from the Plymouth, West Devon and the South Hams LADs. The highest increase in footfall is expected from the Plymouth area.
- **Dart Valley and Venford Reservoir** (Figure 29): The largest increase in footfall is predicted to come from the Teignbridge local authority area, with the Exeter, East Devon, Torbay, South Hams and Plymouth LADs also showing substantial growth in footfall across much of the Dart Valley and Venford Reservoir area.
- **Haytor area** (Figure 30): Increases in footfall around Haytor are predicted to originate from all local authority areas. The figure shows that visitors from the Teignbridge area are making the largest contribution to this growth
- **Warren House/Soussons/Fernworthy** (Figure 31): The total predicted hourly growth in footfall in this area appears to consist of visitor growth originating from all local authority areas, which is perhaps unsurprising given the central Dartmoor location of the Warren House/Soussons/Fernworthy area.

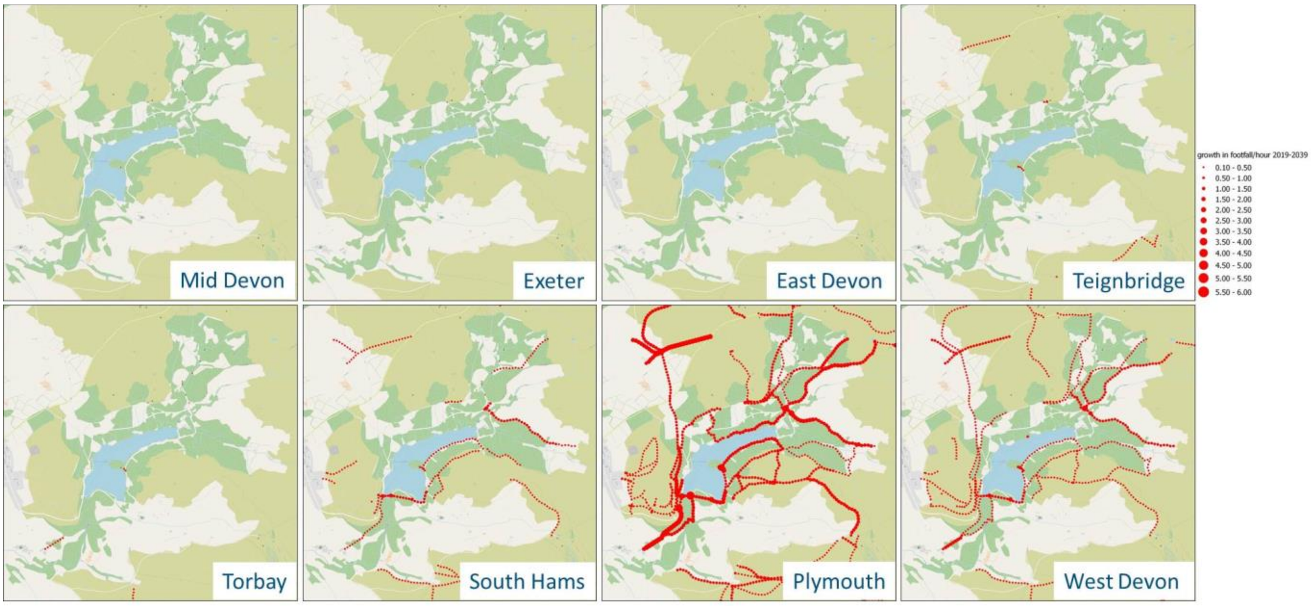


Figure 28. Growth in footfall per hour from 2019 to 2039 for the Burrator area, split by local authority area.

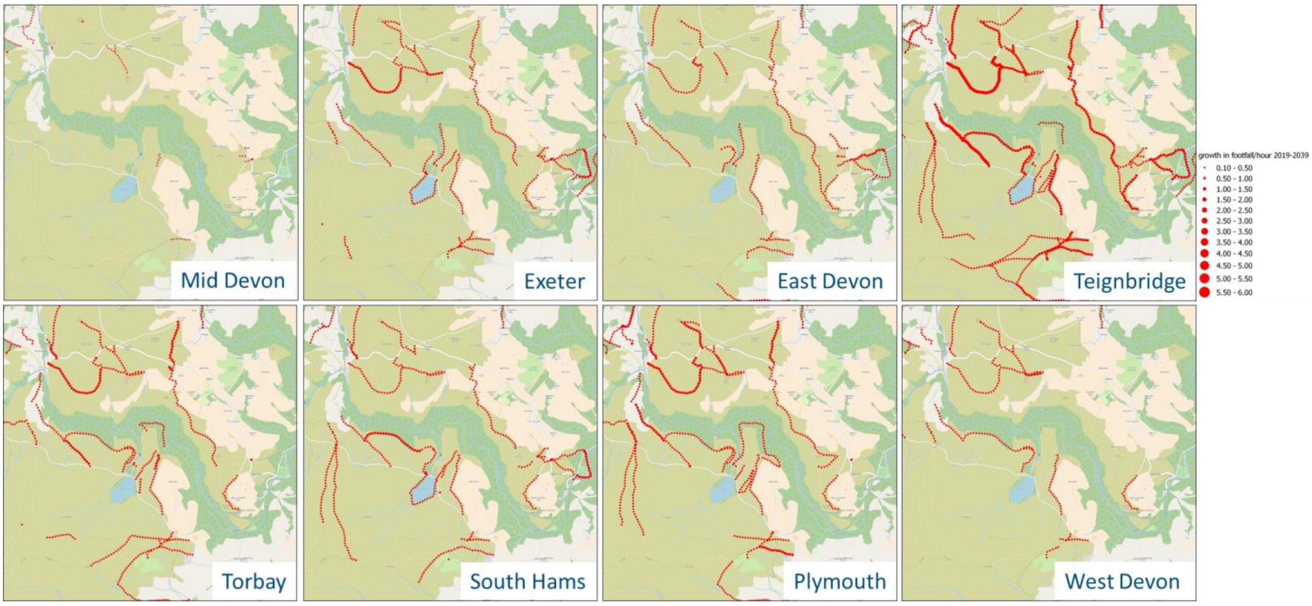


Figure 29. Growth in footfall per hour from 2019 to 2039 for the Dart Valley/Venford reservoir area, split by local authority area.

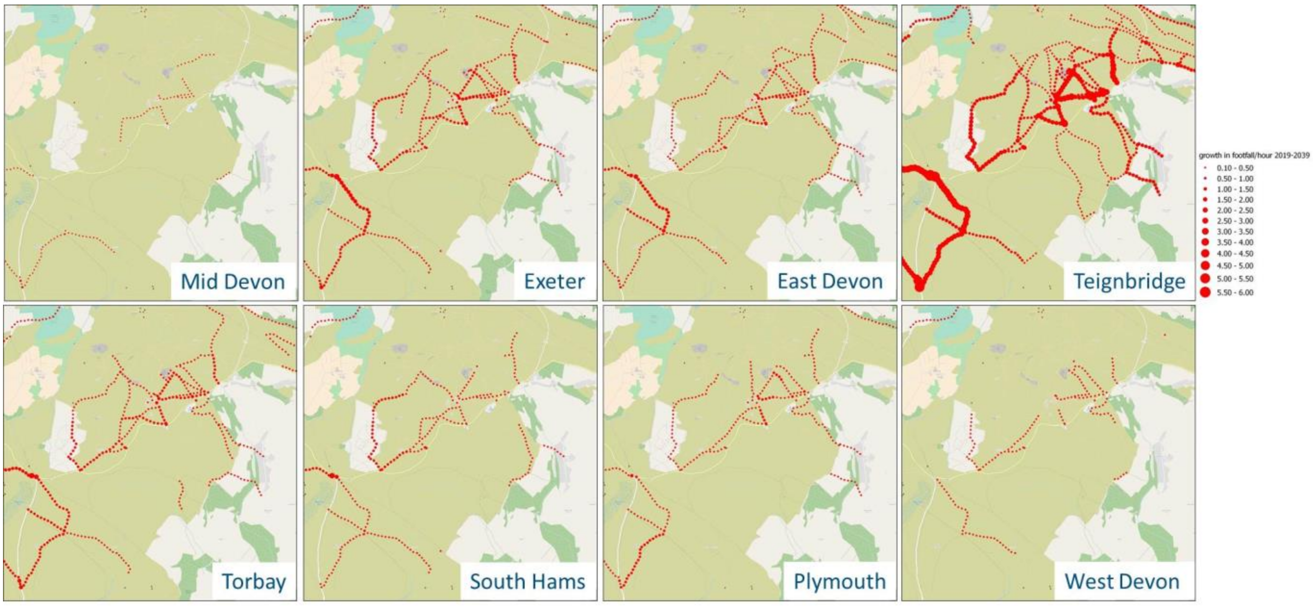


Figure 30. Growth in footfall per hour from 2019 to 2039 for the Haytor area, split by local authority area.

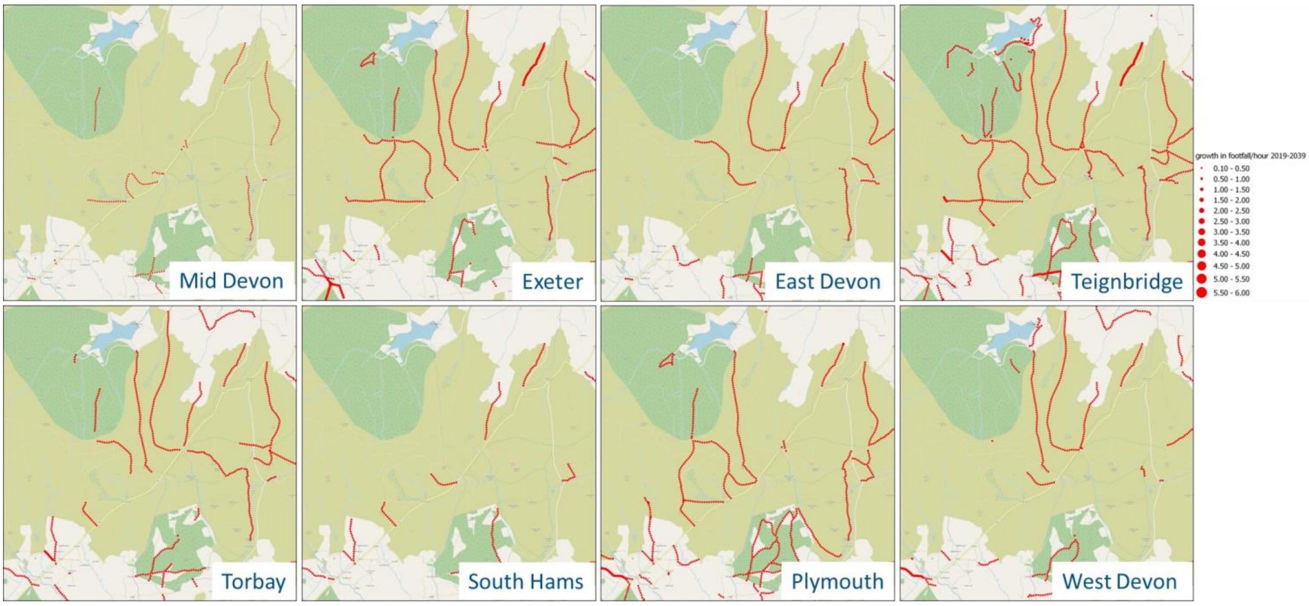


Figure 31. Growth in footfall per hour from 2019 to 2039 for area around Warren House, Fernworthy and Soussons, split by local authority area.

The vulnerable areas described above are examples only; wildlife and increased footfall may come into conflict at numerous other sites, also for species which were not investigated in this study. Furthermore, based on this information, precise effects of increased footfall on these species cannot be predicted. Threshold levels of footfall, above which negative effects occur, are largely unknown, and will differ between species, time of year, and other factors such as vegetation type or site geography. Detailed studies would be needed to derive species-specific recommendations on harmful footfall levels, but the information here can nonetheless be used to inform basic management decisions. For example, mitigation can be prioritised in the indicated vulnerable areas, as larger changes can be expected on those sites compared to other areas of Dartmoor.

Although threshold levels above which negative impacts of recreational activities occur are currently unknown, it is possible to make some abstractions for Dartmoor based on studies from other sits reported in the scientific literature. To illustrate this, we can use data from Murison et al. (2007)[8], who showed that reproductive output of Dartford Warbler in heather territories was reduced (by preventing multiple brooding) when 13 to 16 people passed through a territory each hour. Using this information, it is possible to map Dartmoor sites where the number of visitors is expected to change from less than 13 an hour (currently) to 13 or more per hour (in

---

[8] Murison et al. (2007) Habitat type determines the effects of disturbance on the breeding productivity of the Dartford Warbler *Sylvia undata*. Ibis. 149. p16-26

2039). These data are presented in Figure 32 (left panel). If Dartford Warbler are found breeding in heathland habitat on any of the sites marked in red (left panel), we could expect a decrease in breeding success at those sites due to disturbance from recreation. It is important to note that many sites have already passed the threshold over 13 visits per hour (see section 3.3.4), so Dartford Warbler breeding performance may already be currently affected by recreational pressures at current high footfall sites.

Dartford Warbler breeding sites are mapped in the Devon Bird Atlas (www.devonbirdatlas.org). Atlas data were not available for this report, but future exploration of this data would be recommended to allow for a more detailed exploration of potential conflict sites where mitigation measures would likely be beneficial for this species.

Figure 32 (middle and right-had panel) serves to illustrate sites with changes in footfall for hypothetical species with lower and higher disturbance threshold levels than Dartford Warbler.

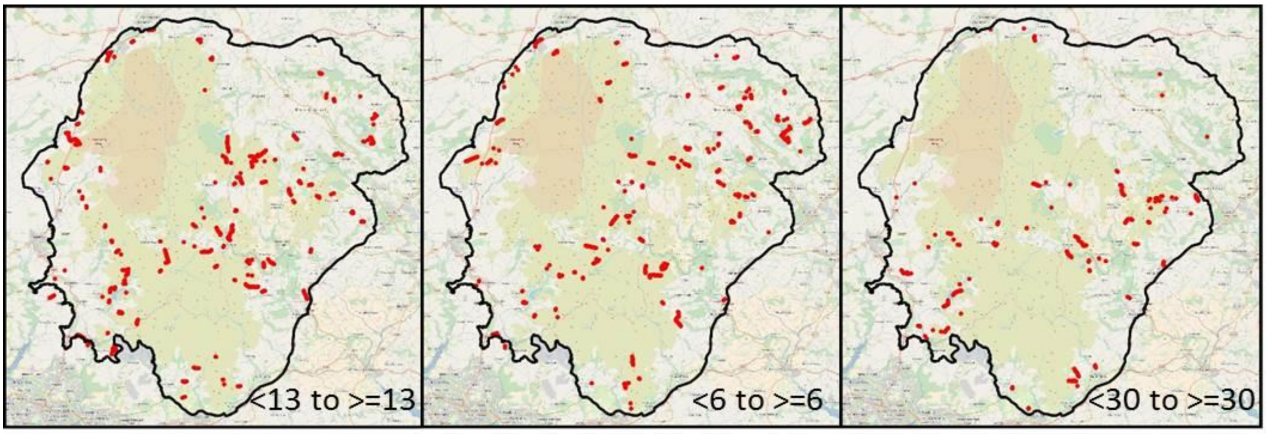


Figure 32. Sites where between 2019 and 2039, footfall per hour is expected to change from less than 13 to 13 or more (left panel), from less than 6 to 6 or more (middle panel) and from less than 30 to 30 or more (right panel).

The middle panel illustrates sites where levels of footfall increase to once every 10 minutes (6 per hour) between 2019 and 2039. The right hand panel illustrates sites where it increases to once every two minutes. This represents locations where thresholds will be crossed for species which are more resilient to disturbance, and for species which are more sensitive to disturbance. These values fall within a range of sensitivity levels which we can realistically expect to see in Dartmoor species, as illustrated by for example Mallord (2007), who showed that +- 8 disturbance events per hour decreased the probability of habitat colonisation in Woodlark. Local research into threshold levels would be valuable for better understanding the implications of increased footfall on sensitive species. Suitable model species for such a study could for example include Wood Warbler and Whinchat, where substantial local research effort and expertise is already available on Dartmoor.

The spatial distribution of further sites of conservation significance (protected areas, rare bird breeding areas and archaeological sites) were shown in Figure 24. To illustrate the expected increase in footfall in these areas, growth in footfall is mapped onto these areas in Figure 33. From this figure, it is apparent that increases in footfall are expected across a range of sites of high importance for wildlife and archaeology. Areas of concern show similarity with those identified from the species hotspot mapping; the Dart Valley, Haytor and Warren House/Soussons areas show a substantial predicted growth in footfall in locations of SSSI sites, archaeological sites and rare bird nesting areas.

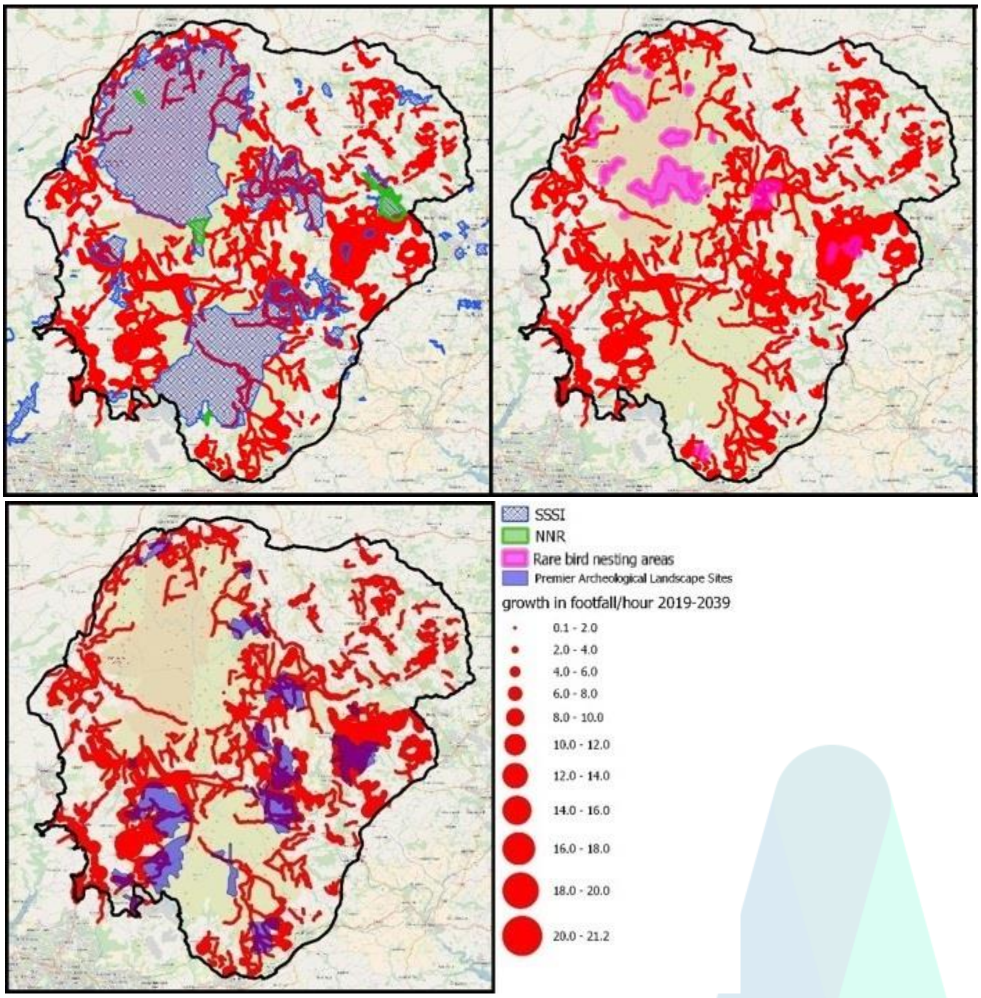


Figure 33. Increased hourly footfall 2019-39, mapped with the locations of SSSIs, NNRs, rare bird nesting areas and Premier Archaeological Landscape sites.

It is perhaps unsurprising that many of the sites of interest in Figure 33 are predicted to show some of the largest increases in visitor pressure, as such sites are popular with visitors due to their special features. To ensure successful protection and continued enjoyment of the National Park's unique assets, it will be key to ensure appropriate protections are put in place in order to prevent damage to the archaeology, flora and fauna. The impacts of increased footfall on archaeological features were not investigated for the purposes of this report, and therefore further investigation into this topic would be beneficial in aiding management decision-making.

5.3 MITIGATION MEASURES

Table 13 below provides an overview of potential measures to mitigate the impacts of recreational pressures. These mitigation measures (presented in no particular order) were suggested by species experts in the key species questionnaires. Additional mitigation measures, as suggested in relevant studies in the scientific literature, can be found in section 5.2.2.

Table 13. Mitigation measures to minimise impacts of recreational activities on key wildlife species.

MITIGATION MEASURE	BENEFITS	LOCATION	TIMING
No large events (e.g. runs/walks) during bird breeding season	Dunlin, Cuckoo, Red Grouse, Wood Warbler, Skylark other breeding bird species. Plants.	Any known or suspected breeding hotspots on the moor. Wood Warbler woodlands. On tors to prevent plant damage.	March-August bird breeding period. Year-round on sensitive tors to prevent plant damage
Strictly enforcing dogs on leads policy during bird breeding season	Adder, Breeding birds (e.g. Cuckoo, Nightjar, Skylark, Whinchat),	Across Dartmoor with particular focus on bird and Adder hotspots	Particularly during bird breeding period (March-August)
Encourage walkers to stick to paths	Prevents trampling of plants and bird nests, reduces bird disturbance	Across Dartmoor, including open moor (e.g. Cuckoo, Whinchat) and woodland/forestry (Nightjar, Wood Warbler). Particularly in sites with hotspots for breeding birds and sensitive plants	Always but particularly during large events and during bird breeding season

MITIGATION MEASURE	BENEFITS	LOCATION	TIMING
Re-design right of way and reserve paths to avoid sensitive areas for Wood Warbler	Wood Warbler	Key Wood Warbler sites (see full report version)	Late April-mid June for temporary closures
Discourage visitors to (remote) tors in spring	Raven, Ring Ouzel, other breeding birds	Key sites (see full report version)	Particularly early to mid-spring for Raven, until summer for other breeding birds
Access restriction E.g. limiting access or re-directing paths. Can also use vegetation management to create habitat barriers (e.g. no burn areas).[3]	Breeding birds (e.g. Dartford Warbler, Nightjar, ground-nesting passerines), Adder, butterflies	Where feasible in bird breeding and Adder hotspots and butterfly sites. For Dartford Warblers, areas with >13 visitors/hour (see species factsheet)	Could be a year-round infrastructure consideration, or seasonal access restriction during sensitive months
Restrict access indirectly by discouraging visitor increases through not adding any additional car parking facilities	Breeding birds, butterflies	Any butterfly and bird breeding hotspots	Year-round infrastructure consideration
Continue existing "Rare Bird Nesting Area" mitigation	Ring Ouzel, waders (and other birds in those areas)	All Ring Ouzel and wader breeding sites	All year, reviewed annually
Restrict and reduce night-time lighting, avoid future increase in lighting	Greater Horseshoe Bats (and other nocturnal species)	Maintain year-round dark corridors around all bat priority areas, reduce lighting around key sites (see full report) from May-September	Year-round
Outreach on reduction of disturbance. Explain when birds are disturbed (e.g. alarm calls) and how to reduce disturbance, rather than only highlighting presence of birds.	Breeding birds (including Ring Ouzel, Dartford Warbler and other ground-nesting passerines and waders)	Park rangers and volunteer wardens when coming across public on key wildlife sites (see full report). Potentially online and in visitor centres.	Bird breeding season
Continue to keep information on Hen	Prevent disturbance to Hen Harrier roosts	All sites	Permanently

MITIGATION MEASURE	BENEFITS	LOCATION	TIMING
Harrier roosting sites out of public domain			
Ensure adequate ecological impact assessments are completed. For Otter, potential site use for breeding should be assessed.	Otter, and other protected species more broadly	All sites	Before planning permission is sought
Vegetation management to maximise available suitable breeding habitat	Whinchat	At known Whinchat breeding sites, allow Bracken and heather in areas with sloping ground, gullies and ditches	Year-round
Allowing existing woodland to creep up slopes	Increase breeding habitat for e.g. Wood Warbler away from recreational disturbance	For example Dendles Wood	Year-round
Limit letterboxing and geocaching	Plants	Tors	Year-round
Restrict or ban barbeques	Plants (and birds by preventing prolonged disturbance at one site)	Open moor	Year-round
Continued prevention of illegal raves	Nightjar and other wildlife	Nightjar hotspots (and other wildlife hotspots)	Particularly during bird breeding season
Install roadside boulders to prevent damage to spring feeding Southern Damselfly runnel	Southern Damselfly	Known sites (see full report)	Permanent installation
Prevent off-road cycling off bridleways	Plants, birds	All habitats	Year-round
Campaign for cleaner cars, provide better public transport	Air quality (to support plants)	Across moor	Year-round
Generate improved mapping of Adder	Adder	Across Dartmoor, implement education	March - August

MITIGATION MEASURE	BENEFITS	LOCATION	TIMING
hotspots and educate public to avoid Adder sites		for Adder hotspots	
Research into how human and dog presence affects bird settlement. Local Wood Warbler/RSPB project has study system and expertise in place to undertake this, funding needed to implement study	Wood Warbler as focal species, other birds from wider implications of findings	Key breeding sites (see full report)	
Encourage monitoring of Dipper territory sites and hotspots to ensure birds are successfully breeding	Dipper	Particularly sites with high kayaking activity	Dipper breeding season
Install nestboxes in habitats suitable to Dipper	Dipper	Sites where no natural nesting opportunities currently exist	Before Dipper breeding commences

Several existing mitigation measures which are currently used by DNPA were listed by species experts as desirable. These include the existing policy around discouraging access to rare bird nesting area, prevention of illegal raves, and the policy of keeping details of nesting and/or roosting locations of rare birds (such as Hen Harrier) out of the public domain. The regulation of large events was also identified as an important policy; several bird species experts expressed serious concerns over the possible impacts on breeding birds resulting from the prolonged disturbance arising from such events. While a paucity of scientific data means it is currently difficult to evidence the causal link from disturbance to population outcomes, there are sufficient grounds for concern to support the continued regulation and limitation of large events, particularly at bird breeding hotspots during the March to April breeding period. It is important to note that this should not only cover events on the open moor; consideration should also be given to woodland species where experts also expressed concerns regarding disturbance from events such as busy woodland visit days.

Our literature review revealed several past studies that have highlighted the disturbance of birds by dogs. Both the consulted Dartmoor species experts and the reviewed scientific literature raised "dogs on leads" policies as an important mitigation measure. In addition to preventing disturbance to breeding birds and livestock, it might also help minimise dog-Adder conflict and associated negative perception of Adders. A "dogs on leads" policy is already in existence and can benefit a wide range of ground-nesting bird species. Again the evidence, while still limited, supports the spatially and temporally targeted continuation of this policy, reinforced by outreach programs and, where feasible, enforcement.

Our analysis also revealed a number of targeted, smaller scale interventions which would be relatively straightforward to implement and are likely to benefit a number of key species. In suitable Dipper habitats where no natural nesting areas currently exist, the installation of Dipper nestboxes could add valuable breeding opportunities. Likewise, an outreach initiative to help the general public understand how to recognise and reduce disturbance could benefit wildlife, and would educate and engage the public in taking an active role in wildlife protection. Such an initiative might include online materials and flyers on recognising the behaviour of disturbed birds (e.g. alarm calling), and recommendations on how to reduce disturbance (e.g. targeting picnickers, geocachers, campers and climbers). Rangers and wardens could also contribute to outreach initiatives by actively educating the public on these issues at key sites (e.g. Ring Ouzel hotspots). A final targeted mitigation measure is the use of temporary path closures and path network re-designs to avoid sensitive areas for Wood Warbler, particularly in East Dartmoor NNR, Dunsford Woods and Fingle Bridge. Such access restrictions should also be considered in other areas where recreation and wildlife come into conflict; for example, our literature overview highlighted access restrictions as a recommended mitigation measure for Nightjar.

In addition to the targeted mitigation measures outlined above, wider habitat management is key in providing sufficient suitable habitats for wildlife. Habitat enhancement or habitat creation can be used in strategic locations away from recreation hotspots in order to maximise the availability of habitat for key species. For example, Whinchat are known to show affinity for sloping ground, gullies and ditches with Bracken and heather cover. Therefore, encouraging such vegetation in areas with those geographical features will increase breeding site options for this species. On woodland edges, some allowance for vegetation to creep up the slopes can increase the availability of Wood Warbler breeding sites away from highly-used footpaths in the woodland valleys (for example in Dendles Wood). More generally, encouraging a rich diversity of vegetation types across the moor will ensure the availability of suitable habitat for a wide range of species. For example, avoiding burning in selected patches can create a mosaic of higher shrubbery to support a range of invertebrates and birds. Where used in targeted locations, this could also help reduce habitat penetrability for dogs and humans, and can therefore be used strategically to discourage recreational activity and prevent footpath creation or footpath widening in areas of concern.

A further broad mitigation measure is the active creation of "wildlife refuge areas" where recreation is discouraged. Temporary path closures can be used to prevent visitors entering sites where vulnerable species are found. However, full access restrictions are often not a management option, and a range of alternative techniques can be used to discourage visitation to particular areas. As mentioned above, using patches of higher vegetation around key wildlife sites can reduce visitor numbers by reducing the accessibility of sites. Reduction (or prevention of expansion) of parking availability, and the provision of alternative access points can have similar effects. Signposting along access points and footpaths can be used to encourage visitors to take specific routes, thereby taking a land-sparing approach to recreational activities. The active creation of such "wildlife refuge areas" is not recommended to be necessary on the high open moors, which are natural refuges due to their inaccessibility and subsequent low levels of footfall. Areas which may be particularly suitable for the interventions outlined above are sites which are important for wildlife whilst not showing high predicted levels of increased footfall. Examples include the Tavy Teign and Bovey Valleys. On key conflict sites such as Warren House and Venford/Dart Valley, vegetation management and signposting could be used to encourage visitors towards certain areas whilst maintaining local wildlife refuges in these areas. A big honeypot site such as Haytor, which is predicted to experience large increases in visitor numbers over coming decades, may be a site of choice for the encouragement of recreation through promotion and the provision of additional access and facilities to draw visitors to this area, thereby sparing other sites. This can of course be combined with further access management (e.g. higher vegetation, footpath closures) at this site in order to discourage visitors from straying into nearby areas of conservation importance.

6 SUMMARY AND CONCLUSIONS

The findings presented in this report provide a detailed assessment of the likely impacts on Dartmoor of future population growth in the region. The first major contribution of this work has been to construct spatialized predictions of population change in the Dartmoor hinterland from 2014 to 2039. Those predictions draw on Office of National Statistics population projections augmented by details of property developments that are expected in the region that are described in the Local Plans of the eight Local Authority Districts (LADs) that surround the National Park.

To understand how these new residents of the region might use Dartmoor, the spatialised population projections have been coupled with the Outdoor Recreation Valuation (ORVal) tool. ORVal is a sophisticated recreation demand model developed by the LEEP institute at the University of Exeter using data from the Monitor of Engagement with the Natural Environment survey. With the help of local experts, a bespoke calibration of the ORVal tool has been developed for this project that allowed for the prediction of expected visitation to the array of recreation sites across Dartmoor National Park. That model indicates that Dartmoor is currently the backdrop for over 7 million day trips per year from residents of the eight neighbouring LADs. Moreover, increased populations in those LADs will result in a predicted additional 870,000 annual visits to Dartmoor per year, a rise of some 12%.

A further novel modelling exercise was undertaken that sought to extend the ORVal estimates of visitation into estimates of intensity of footfall through the National Park. That model used evidence from various sources to approximate how far visitors might travel through the paths network during their visits. The resulting estimates of the spatial dispersion of visitors and the intensity of footfall across the National Park allows us to address a number of questions regarding the impact of recreation on Dartmoor.

While the modelling framework developed for this project provides a sophisticated toolkit with which to address the primary objectives of the research, one weakness is that the models lack solid primary evidence that could be used to verify their predictions. One area of future research that DNPA might consider pursuing is the structured quantification of recreation demand and activities across the National Park.

The report addresses both the benefits and the costs of increased recreation activity on Dartmoor. With regards to benefits, a key measure is that of economic welfare, a monetary estimate of the enjoyment that visitors realise from their visits. Economic welfare can be directly estimated using the calibrated ORVAl tool. Indeed the model estimates suggest that Dartmoor is currently the source of £25.6 million of welfare benefits to the residents of the 8 neighbouring LADs each year and that as a result of population increases that number will likely rise by £2.5 million by 2039. Those benefits are not evenly distributed across the neighbouring LADs. Rather the largest welfare values are realised in those LADs with significant populations in and around Dartmoor including Teignbridge, West Devon and Plymouth.

The report also attempts to quantify the health benefits of the physical activity enabled by recreational access to the National Park. The footfall model provides prediction as to how far visitors to Dartmoor might be expected to walk in the National Park. Translating walking distances into energy expenditure provides an estimate the level of fat burned by visitors. Those estimates suggest that residents of the eight local LADs burn around 100,000 kg of fat each year as a result of their physical activities on Dartmoor.

Of course, these recreational benefits do not come without cost. As per the projects objectives, here we have focused on environmental costs particularly those that arise from the physical erosion of and the disturbance of Dartmoor's wildlife.

Transferring findings from a detailed study of the English Lake District, the report uses the footfall intensity estimates along with measures of path slope and altitude to predict rates of footpath erosion. Our analyses suggest that increasing recreational pressure on Dartmoor may result in 10,854 m^2 of bare ground being exposed along the path network and increased gullying along 42km of path.

Again the analyses suffer from a paucity of data on path erosion on Dartmoor. Another area where improved information would be valuable for management purposes would be in the form of a structured analysis of recreation pressure and path erosion, a study that might employ developing technologies such as drones or remotely-sensed Lidar data sets.

In the context of impacts on wildlife disturbance, this report gives an overview of scientific studies which have recorded a wide range of impacts of recreational activities, including changes to animal behaviour, distribution and reproductive success. Questionnaires conducted with local species experts indicate cause for concern on the impacts of recreation on a wide range of key Dartmoor plant and animal species. Examples of species of particular concern include Cuckoo, Nightjar, Ring Ouzel and Wood Warbler. Activity types which have negative effects differ between species, but walking, dog-walking and large events are key concerns across many of the investigated key species.

Once again, the detailed science regarding threshold levels of recreation at which species incur disturbance that might impact on reproductive success is lacking. Indeed, more species-specific research in a Dartmoor context is needed to understand the footfall levels at which negative effects occur.

All the same, four sites of conservation importance have been identified where large increases in footfall are predicted over the coming years. These sites are the areas around i) Burrator, ii) the Dart Valley and Venford Reservoir, iii) Haytor, iv) Warren House, Soussons and Fernworthy. At these sites, an increased conflict between recreation and wildlife can be expected, and mitigation measures could therefore be prioritised there. Mitigation measures derived from both expert opinion and past research are outlined in the report. Measures suggested to be beneficial to a broad range of species include (temporary) access restrictions, management of large events, enforcement of the dogs on lead policy and public education.

In addition to this report, an accompanying assessment on planning and legal systems was conducted in order to identify potential alternative income streams to fund mitigation measures. Further details can be found in the assessment report by Green Balance and Kristina Kenworthy.[9]

---

[9] Planning and legal advice – informing assessment of recreational impacts on Dartmoor National Park. Green Balance and Kristina Kenworthy. March 2018.

REFERENCES

Botsch, Y., Tablado, Z., Jenni, L. (2017). Experimental evidence of human recreational disturbance effects on bird-territory establishment. *Proceedings of the Royal Society B.* 284: 20170846.

Brambilla, M., Rubolini, D., Guidali, F. (2004). Rock climbing and Raven *Corvus corax* occurrence depress breeding success of cliff-nesting Peregrines *Falco peregrinus*. *Ardeola*. 51(2), pp. 425-430.

Bravata DM, Smith-Spangler C, Sundaram V, et al. Using Pedometers to Increase Physical Activity and Improve Health: A Systematic Review JAMA 2007; 298: pp. 2296-2304

Breeding Bird Survey of Dartmoor Training Area (2006).

Buckley, R. (2013). Next steps in recreation ecology. *Frontiers in Ecology and the Environment.* 11(8), p. 399

Coleman, R., (1981). Footpath erosion in the English Lake District. *Applied Geography*, 1(2), pp. 121-131.

Davies, N, (2016). *Investigating route-choice by recreational walkers in the English Lake District*, A thesis submitted in partial fulfilment for the requirements for the degree of Doctor of Philosophy, at the University of Central Lancashire.

Day, B. H., and G. Smith (2016). Outdoor Recreation Valuation (ORVal) Data Set Construction. *Report to the Department of Food and Rural Affairs*.

Day, B. H., and G. Smith (2018). The Orval Recreation Demand Model. *Report to the Department of Food and Rural Affairs*.

DNPA (2018). Naturally Healthy Project. Summary Report April 2018.

DCC, 2017. Plymouth Housing Market Area Population & Housing Projections 2014 to 2034. Devon County Council Local Modelling Report. Available online: https://www.plymouth.gov.uk/sites/default/files/PlymouthHousingMarketAreaPopulationHousingProjections20142034.pdf

DCLG, 2016. *2014-based household projections: detailed data for modelling and analytical purposes*. Housing and Planning Analysis Division, Department for Communities and Local Government. Available online: https://www.gov.uk/government/statistical-data-sets/2014-based-household-projections-detailed-data-for-modelling-and-analytical-purposes

East Devon, 2013. East Devon Local Plan 2013-2031. Available online: http://eastdevon.gov.uk/planning/planning-policy/local-plan-2013-2031/

Exeter City Council (2012). Exeter Core Strategy 2012-2026. Available online: https://exeter.gov.uk/media/1636/adopted-core-strategy.pdf

Finney, S.K., Pearce-Higgins, J.W., Yalden, D.W. (2005). The effect of recreational disturbance on an upland breeding bird, the golden plover *Pluvialis apricaria. Biological Conservation*. 121, pp. 53-63

Gill, J.A. (2007). Approaches to measuring the effects of human disturbance on birds. *Ibis*. 149, pp. 9-14.

Jayakody, S., Sibbald, A.M., Mayes, R.W., Hooper, R.J., Gordon, I.J., Lambin, X. (2011). *European Journal of Wildlife Research*. 57, pp. 939-948.

JLP, 2017. *Plymouth and South West Devon Joint Local Plan 2014-2034.* Produced by West Devon Borough Council, South Hams District Council and Plymouth City Council. Available online: https://www.plymouth.gov.uk/planningandbuildingcontrol/plymouthandsouthwestdevonjointlocalplan

Korkanç, S. Y., (2014). Impacts of recreational human trampling on selected soil and vegetation properties of Aladag Natural Park, Turkey. *CATENA*,113, pp. 219-225,

Langston, R.H.W., Liley, D., Murison, G., Woodfield, E., Clarke, R.T. (2007). What effects do walkers and dogs have on the distribution and productivity of breeding European Nightjar *Caprimulgus europaeus*? *Ibis.* 149, pp. 27-36.

LeCheminant, J.D., Heden, T., Smith, J. et al. (2009). "Comparison of energy expenditure, economy, and pedometer counts between normal weight and overweight or obese women during a walking and jogging activity", Eur J Appl Physiol, 106, pp. 675-682. https://doi.org/10.1007/s00421-009-1059-9

Liley, D., Clarke, R.T. (2003). The impact of urban development and human disturbance on the numbers of nightjar *Caprimulgus europaeus* on heathlands in Dorset, England. *Biological Conservation.* 114, pp. 219-230

Mallord, J.W., Dolman, P.M., Brown, A.F., Sutherland, W.J. (2007). Linking recreational disturbance to population size in a ground-nesting passerine. *Journal of Applied Ecology.* 44, pp. 185-195.

Marion, J. (2016a).A review and synthesis of recreation ecology research research findings on visitor impacts to wilderness and protected natural areas. *Journal of Forestry*. 114(3), pp. 352-362

Marion, J. (2016b).A review and synthesis of recreation ecology research supporting carrying capacity and visitor use management decisionmaking. *Journal of Forestry.* 114(3), pp. 339-351

Mid Devon District Council, 2006. Core Strategy 2006-2016. (pages 29-30, 38-49) Available online: https://www.middevon.gov.uk/media/103617/core_strategy_adopted.pdf

Monz, C. A., Pickering, C.M., Hadwen, W.L. (2013). Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. *Frontiers in Ecology and the Environment*. 11(8), pp. 441-446.

Murison et al. (2007) Habitat type determines the effects of disturbance on the breeding productivity of the Dartford Warbler *Sylvia undata. Ibis.* 149. pp. 16-26

ONS (2011) Output Area to Lower Layer Super Output Area to Middle Layer Super Output Area to Local Authority District (December 2011) Lookup in England and Wales. Office for National Statistics. DATASET. Available online: http://geoportal.statistics.gov.uk/datasets?q=OA_LSOA_MSOA_2011_LU&sort=name

ONS (2014) *SNPP Z1: 2014-based Subnational Population Projections.* Local Authorities in England, mid-2014 to mid-2039. DATASET and REPORT. Available online: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/subnationalpopulationprojectionsforengland/2014basedprojections

Pearce-Higgins, J.W., Finney, S.K., Yalden, D.W., Langston, R.H.W. (2007). Testing the effects of recreational disturbance on two upland breeding waders. *Ibis*. 149, pp. 45-50

Pescott, O.L., Stewart, G.B. (2014). Assessing the impact of human trampling on vegetation: a systematic review and meta-analysis of experimental evidence. *PeerJ.* 2: e360.

Rodway-Dyer, S., Ellis, N. (2018). Combining remote sensing and on-site monitoring methods to investigate footpath erosion within a popular recreational heathland environment. *Journal of Environmental Management*. 251, pp. 68-78.

Roovers, P. , K. Verheyen, M. Hermy, H. Gulinck, and Bakker, J.P. (2004). Experimental trampling and vegetation recovery in some forest and heathland communities, Applied Vegetation Science, 7 (1), pp. 111-118.

Rouifed, S., Piola, F., Spiegelberger, T. (2014). Invasion by *Fallopia* spp. in a French upland region is related to anthropogenic disturbances. *Basic and Applied Ecology.* 15, pp. 435-443.

SHMNA, 2017. *Strategic Housing Market Assessment Part 2 – Objectively Assessed Need for Affordable Housing.* Report compiled by HDH Planning and Development Ltd for Plymouth, South Hams and West Devon Councils. Available online: https://www.plymouth.gov.uk/sites/default/files/StrategicHousingMarketNeedsAssessmentPart2.pdf

Showler, D.A., Stewart, G.B., Sutherland, W.J., Pullin, A.S. (2010). What is the impact of public access on the breeding success of ground-nesting and cliff-nesting birds? CEE review 05-010 (SR16).

Sibbald, A.M., Hooper, R.J., McLeod, J.E., Gordon, I.J. (2011). Responses of red deer (*Cervus elaphus*) to regular disturbance by hill walkers. *European Journal of Wildlife Research.* 57, pp. 817-825.

Steven, R., Pickering, C., Castley, J.G. (2011) A review of the impacts of nature based recreation on birds. *Journal of Environmental Management.* 92, pp. 2287-2294.

Teignbridge District Council, 2014. Teignbridge Local Plan 2033. Available online: https://www.teignbridge.gov.uk/planning/local-plans-and-policy/teignbridge-local-plan-2033/

Torbay Council, 2012. New Local Plan 2012-2030. Available online: http://www.torbay.gov.uk/council/policies/planning-policies/local-plan/new-local-plan/

Vangansbeke, P., Blondeel, H., Landuyt, D., De Frenne, P., Gorissen, L., Verheyen, K. (2017). Spatially combining wood production and recreation with biodiversity conservation. *Biodiversity Conservation.* 26, pp. 3213-3239.

Votruba, S.B., Atkinson, R.L., Hirvonen, M.D., Schoeller, D.A. (2002). Prior exercise increases subsequent utilization of dietary fat. *Medicine & Science in Sports & Exercise.* 34(11), pp. 1757-1765.

Whinam, J. ,Chilcott, N.M. (2003). Impacts after four years of experimental trampling on alpine/sub-alpine environments in western Tasmania. *Journal of Environmental Management*. 67(4), pp.339-351.

Yalden, D.W. (1992). The influence of recreational disturbance on common sandpipers *Actitis hypoleucus* breeding by an upland reservoir, in England. *Biological Conservation.* 61, pp. 41-49.

Yang, Y., and Diez-Roux, A. V. (2012). Walking distance by trip purpose and population subgroups. *American Journal of Preventive Medicine*. 43(1), pp. 11–19.

APPENDICES

Appendix 1. Population Projections

Every two years, the Office for National Statistics (ONS), release national population projections by age and sex. The current release[10] is based on the estimated population on 30 June 2014 and uses demographic assumptions about fertility, mortality and migration to project 25 years into the future (see ONS, 2014). Annual population figures for mid-2014 to mid-2039 for persons, males and females, are released by single year of age at a local government area level in England. *ONS projections use past trends but do not take into account future government policies.* Projections become increasingly uncertain the further they are carried forward (ONS, 2014).

The Department for Communities and Local Government (DCLG) release future projections of household structure and headship rates (at local government area level from 2014 to 2039) (DCLG, 2016). ONS now maintain most of the statistics on households (HH) in England (https://www.gov.uk/government/statistical-data-sets/live-tables-on-household-projections). These include, at a local government area level, total HH, number of dependent children in HH and average HH size. Temporal resolution for these statistics is variable (annual, five-year time step and base to 2039 only).

Other spatially-explicit population data are either both spatially and thematically coarse (e.g. Eurostat), or do not provide projections (e.g. GHSL)[11].

All regions of England are expected to see an increase in their population size over the 25-year period (ONS, 2014) and the population is also ageing (Figure A1).

---

[10] The next release is due 26 October 2017, but likely not at the subnational level.

[11] Global Human Settlement Layer, GHSL, (source: European Commission) – 250 m resolution for target years 1975, 1990, 2000 and 2015. Derived from 1 km resolution Gridded Population of the World (GPW4).

Eurostat, the statistical office of the European Union, provide population projections at a national level using 2015 as the baseline and projecting to 2081. Demographic age groups are coarse (e.g. children, working age, elderly and oldest old persons).

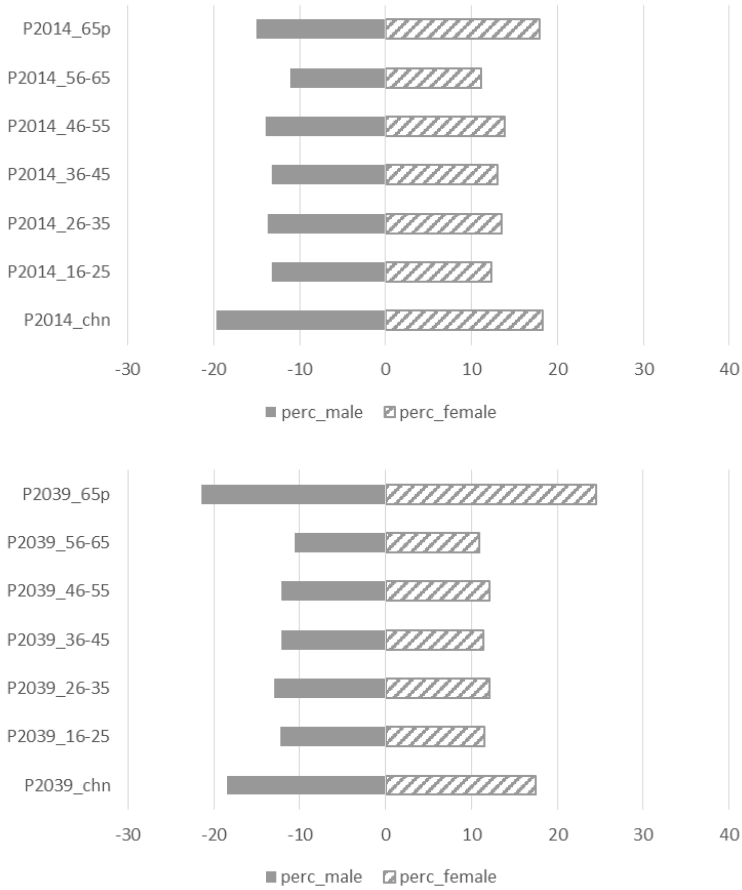


Figure A1. Population structure across England for 2014 baseline (top panel) and 2039 (bottom panel). (Source: ONS 2014, SNPP Z1

Appendix 2. Population changes in Dartmoor's hinterland

Tables B1, B2 and Figure B1 show population increases, and changes to population structure, in the hinterland (see also Table 1 and Figure 2 of the main document). Figure B2 and Table B3 show changes to household (HH) numbers and size.

Table B1. Population change mid-2014 to mid-2039 for local government areas in Dartmoor's hinterland. (Source: ONS 2014, SNPP Z1, rounded nearest thousand)

Area Name	Area Code	Area (km^2)	Persons 2014	Persons 2019	Persons 2024	Persons 2029	Persons 2034	Persons 2039	Overall change (%)
East Devon	E07000040	814	262,000	268,000	272,000	278,000	283,000	287,000	17.9
Exeter	E07000041	47	133,000	136,000	139,000	142,000	146,000	148,000	17
Teignbridge	E07000045	674	136,000	141,000	147,000	152,000	157,000	161,000	16.7
West Devon	E07000047	1161	124,000	130,000	133,000	138,000	142,000	145,000	15.9
Mid Devon	E07000042	913	79,000	81,000	84,000	86,000	88,000	89,000	12.7
Torbay	E06000027	63	84,000	85,000	87,000	89,000	91,000	92,000	11.7
Plymouth	E06000026	80	127,000	132,000	137,000	141,000	145,000	149,000	9.7
South Hams	E07000044	886	54,000	56,000	58,000	60,000	62,000	63,000	9.1

Table B2. Sub-national population projections for Dartmoor's hinterland, male and female for ORVal age structure groupings (base mid-2014 and mid-2039 shown; annual data available). Source: ONS, SNPP Z1.

Area_code	M2014_chn	M2014_16-25	M2014_26-35	M2014_36-45	M2014_46-55	M2014_56-65	M2014_65p	M2014_all	M2039_chn	M2039_16-25	M2039_26-35	M2039_36-45	M2039_46-55	M2039_56-65	M2039_65p	M2039_all
E06000026	23407	23295	17824	15377	16918	13907	19230	129958	25131.918	26281.066	19928.695	16144.998	15105.52	12991.094	29361.644	144944.932
E06000027	11243	7242	6449	7093	9306	8755	14244	64332	12074.851	7327.706	7282.358	6833.506	7987.499	8364.504	23167.855	73038.279
E07000040	11014	6879	5772	7006	9027	9054	17102	65854	12209.017	7468.638	6610.945	7554.873	8936.548	9213.93	27270.048	79264.002
E07000041	10049	13521	9565	7495	7272	5622	7754	61278	11261.369	14928.299	12119.503	9388.315	8296.284	6318.794	12340.608	74653.171
E07000042	7534	4277	3803	4656	5620	5247	7684	38821	8127.638	4411.843	4505.584	4786.538	5227.47	4935.803	12393.955	44388.83
E07000044	6836	4310	3353	4196	6143	6274	9518	40630	7237.296	4272.369	3586.366	4058.273	5022.232	5452.633	14591.406	44220.571
E07000045	10770	6409	6015	6951	9315	8540	13562	61562	12357.012	6708.943	6908.658	7741.676	8730.283	8409.385	21703.446	72559.405
E07000047	4480	2578	2462	2862	4131	3892	6046	26451	4920.171	2455.792	2651.747	3013.196	3688.894	3834.679	10067.704	30632.182

Area_code	F2014_chn	F2014_16-25	F2014_26-35	F2014_36-45	F2014_46-55	F2014_56-65	F2014_65p	F2014_all	F2039_chn	F2039_16-25	F2039_26-35	F2039_36-45	F2039_46-55	F2039_56-65	F2039_65p	F2039_all
E06000026	22487	20792	17315	15720	17400	14335	23539	131588	24304.569	22908.646	17061.008	14765.346	15474.603	13965.554	33537.283	142017.012
E06000027	10783	6769	6843	7714	9809	9233	17501	68652	11605.35	6895.474	6960.454	6984.828	8450.781	9043.309	25511.349	75451.546
E07000040	10165	5875	5696	7755	9804	10022	21203	70520	11671.127	6087.3	5965.453	7368.062	9285.645	10275.741	30814.32	81467.651
E07000041	9423	13279	8954	7137	7425	6105	10727	63050	10656.056	14386.26	9274.645	7541.637	7519.965	6267.724	15125.528	70771.815
E07000042	7080	3914	4078	4919	6045	5437	8904	40377	7628.956	3927.261	4298.81	4646.148	5321.96	5243.364	13818.404	44884.905
E07000044	6609	3522	3456	4841	6936	6832	11282	43478	7113.378	3604.795	3494.002	4509.951	5826.949	6225.517	16739.565	47514.155
E07000045	9933	6107	6086	7568	9953	9379	16769	65795	11301.549	6015.38	6778.114	7632.411	9019.813	9218.763	26047.586	76013.617
E07000047	4218	2403	2401	3139	4360	4194	7094	27809	4633.06	2334.913	2631.172	3028.525	3804.44	4130.16	11700.138	32262.408

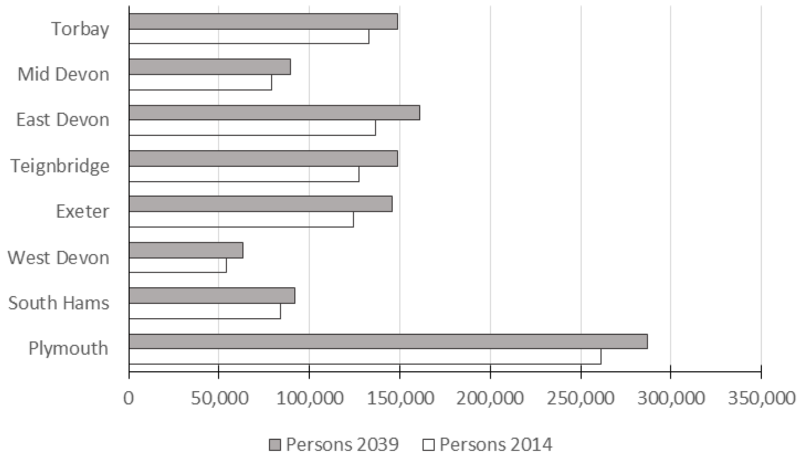


Figure B1. Population change mid-2014 to mid-2039 for local government areas in Dartmoor's hinterland. (Source: ONS 2014, SNPP Z1)

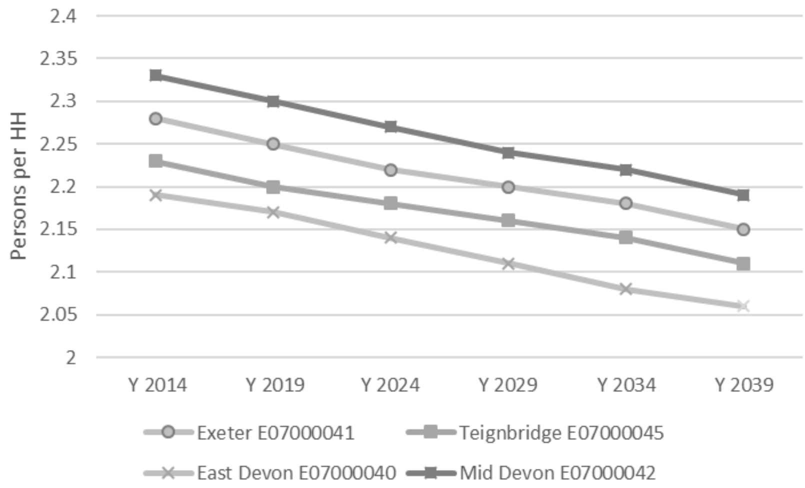


Figure B2. Household (HH) size in Exeter and surrounds decreases over time (source: DCLG 2016).

Table B3. Household (HH) information at a local government area level (HH available at an annual resolution, HH size on a five-year time step and HH with children (derived) available for 2014 and 2039 only). Source: ONS Live tables on household projection (2014-based). *Dartmoor's hinterland

Area code	Area name1	Area name2	Area name3	HH_2014 (000s)	Pop_2014 (000s)	HH_w_chn_2014 (000s)	Av_HH_Size_2014	HH_2039 (000s)	Pop_2039 (000s)	HH_w_chn_2039 (000s)	Av_HH_Size_2039
E92000001	ENGLAND			22746.487	53351.232	6555.474	2.35	28003.598	62026.7	7554.744	2.21
E06000026		Plymouth UA*		111.987	256.174	30.207	2.29	126.068	280.341	33.906	2.22
E06000027		Torbay UA*		60.307	129.949	14.634	2.15	71.276	144.18	16.586	2.02
E10000008		Devon		332.864	746.504	80.714	2.24	402.909	853.717	92.899	2.12
E07000040			East Devon*	60.972	133.393	13.802	2.19	76.147	156.64	16.067	2.06
E07000041			Exeter*	51.837	118.408	12.321	2.28	64.558	138.994	14.623	2.15
E07000042			Mid Devon*	33.602	78.288	9.084	2.33	40.16	87.935	9.974	2.19
E07000043			North Devon	40.663	91.97	10.397	2.26	46.144	99.538	11.457	2.16
E07000044			South Hams*	37.69	82.774	8.988	2.2	42.897	89.799	9.945	2.09
E07000045			Teignbridge*	55.788	124.422	13.804	2.23	68.303	144.313	16.351	2.11
E07000046			Torridge	28.922	64.643	6.859	2.24	36.081	75.934	8.294	2.1
E07000047			West Devon*	23.39	52.606	5.459	2.25	28.619	60.564	6.188	2.12

Appendix 3. Key species questionnaire

sweep

Recreation Impacts Project
Dartmoor key wildlife species questionnaire

Background information:
This questionnaire is part of a project between SWEEP (sweep.ac.uk) and the Dartmoor National Park Authority. In order to assess potential conflicts between key species and recreational activities, we are aiming to map locations of particular importance for key wildlife, and aim to understand potential impacts of recreational activities. In this questionnaire, we ask you to give us your expert opinion on key Dartmoor sites for "your" species on Dartmoor, and ask you to describe any potential impacts and possible mitigation measures for a range of recreational activities. Thank you very much for your help in this project.
For any questions or to submit this questionnaire, please email Sara Zonneveld: s.zonneveld@exeter.ac.uk

Species: ....

Species expert name: ....

Date: ....

SECTION 1: HABITAT AND DISTRIBUTION

What are the site-specific requirements of this species relevant to Dartmoor? Describe habitat and vegetation requirements, altitude, food resources, etc.
What is the current population size and population trend on Dartmoor?

What is this species' distribution on Dartmoor? Please describe. If you are able/willing to share any openly availably GIS data, please send this to s.zonneveld@exeter.ac.uk.
Are there specific areas on Dartmoor which are of particular importance for this species? If so, *where* (exact location and size of area) and *why* (e.g. higher numbers, better reproductive success)? Note: we are aiming to use the information for this question to produce species "hotspot" maps to indicate sites of wildlife importance. Please describe sites in detail, and if possible include grid reference or share any available data by emailing s.zonneveld@exeter.ac.uk

SECTION 2: RECREATION IMPACTS

Which, if any, recreational activities currently impact on this species, and
- **what effects are these recreational activities having (e.g. mortality/reduced population size, behavioural changes/displacement, reduced reproductive success, positive effects)**
- **are there any specific sites on Dartmoor at which this impact is more severe, or is it the same across this species' Dartmoor range?**

ACTIVITY	IMPACTS ON SPECIES	SITES OF IMPACT
Cars on roads		
Walking/hiking (no dogs)		

Dog-walking		
Running		
Mountain biking (off-road)		
Horse-riding		
Kayaking		
Any **indirect effects**, for example an effect on food sources or associated habitat) (please describe)		
Large organised events such as walks/runs (please describe) …………………………		
Other (please list) e.g. camping, picnics, barbecues, on-road cycling, climbing, swimming, fishing …………………………		
Other (please list) …………………………		
Other (please list) …………………………		

Could future changes in recreation pressure affect this species (e.g. increased visitor numbers, changes in the recreational hotspot sites, changes in nature of recreation such as more large events)? Please describe these changes and potential impacts on this species.

SECTION 3: MITIGATION MEASURES

MITIGATION MEASURE: Please identify and describe any mitigation measures that could be put in place to prevent impacts of recreation on this species on Dartmoor. What are these measures and where might they be effectively applied? Examples of mitigation measures include changes/restrictions to access, change in location of facilities such as car parks/toilets, outreach activities.
IMPLEMENTATION LOCATION: For each mitigation measure, please indicate where this mitigation measure should be implemented, e.g. across the entire Dartmoor range, in certain hotspots, in areas of particular concern. Please name specific locations on Dartmoor wherever possible.
WHEN: When should these mitigation measures be implemented? E.g. as soon as possible, or when visitor pressure changes in the future. Should these measure be implemented year-round, or in specific months?

MITIGATION MEASURE	IMPLEMENTATION LOCATION	WHEN

SECTION 4: OTHER

Are there any threats, other than recreational impacts, which you think need to be considered for this species on Dartmoor, either currently or in the future? This could include for example future climate change and habitat/land-use change.

Any other comments and/or concerns.

Appendix 4. Species case studies

On the following pages case studies on recreational impacts, derived from questionnaires with local species experts, are presented for each key species. For plants and butterflies, all key species are combined into one plant section and one butterfly section due to high similarity in recreation impacts for these groups of species. Species or species groups are presented in alphabetical order. NOTE: sensitive information on, such as maps and references to specific hotspot sites has been retracted. Full information was made available to DNPA in a full version of this report. Names of experts and organisations who provided information and data can be found in the full version of this report.

ADDER

Requirements and distribution

On Dartmoor, habitat requirements for adders are mature heathland areas, stands of mature gorse and bramble patches. This provides the requirements for shelter, overwintering and breeding sites, but adders forage more widely over Dartmoor. Adders overwinter in underground retreats often in areas of raised ground. Adders feed on lizards, small mammals, ground-nesting bird eggs and nestlings. The population size of Adder is not well established and needs further researching. The highest population densities are found on the lower reaches of Dartmoor where suitable habitats are located.

Recreation impacts

Most recreation activities are unlikely to strongly impact on Adder. Walking and hiking are unlikely to disturb adders as they are usually not found on paths. Where roads are located near suitable Adder habitats, adders are occasionally killed by cars, but strong impacts from increased numbers of cars on roads are unlikely. Some disturbance from large events is possible if large numbers of individuals visit key Adder breeding areas. The only other disturbance to adders is caused by dog-walking, with individual adders being disturbed by dogs during the spring and summer season. As dog-walking increases with increasing visitor numbers, dog-adder interactions are likely to increase, which may result in associated bad press, with adders being perceived as a threat to dogs and people. Conflict between adders and people can be reduced by restricting access to known breeding/overwintering areas, and by educating the public to avoid areas where Adder are known to occur. Keeping dogs on leads would avoid dog-adder conflict. Better mapping of adder populations across Dartmoor would help public education and management decision-making by identifying sites of potential conflict.

Other threats

The main threat to adders on Dartmoor is likely to be poor vegetation management. In areas known to harbour Adder, extensive burning of mature gorse and bramble patches needs to be avoided, and over-wintering sites need to be protected.

Hotspots

Examples of areas important for Adder include Bone Hill, Holne Moor, Haytor and Warren House. These are just examples of areas of importance for Adder, many other hotspot sites are likely to exist across the moor.

BOG HOVERFLY

Requirements and distribution

UK records for Bog Hoverfly are restricted to Dartmoor, with 17 sites currently known within the National Park. The species is elusive due to its low population density and fast flight, making population monitoring difficult. Anecdotal evidence from observations on Dartmoor since 1998 suggest that the species may have declined significantly, but this has not been proven due to surveying challenges. The species is not found on high exposed moorland; all known sites are on the eastern and southern fringes of the moor. The site characteristics consist of sphagnum bogs, particularly runnels, and spots with some shrub shelter. Adult Bog Hoverfly require a succession of bog flowers from May to September for nectar, key plant species are bog bean, bog pimpernel, common heather, marsh marigold and devils-bit scabious. Habitats grazed by cattle and ponies may be an essential requirement for this species. The larval ecology, and relationships to predators and parasitoids are currently poorly understood.

Recreation impacts

The Bog Hoverfly is found in wet habitat which are less frequented by visitors. Current recreational activities in the National Park are unlikely to have any direct impacts on this species.

Other threats

The species is associated with dung, and dung-associated flies may be particularly susceptible to the use of avermectins for de-worming livestock. On Dartmoor, levels of use of these chemicals are currently unknown, and further studies would be needed to understand the possible effects on Bog Hoverfly and other invertebrate species.

Hotspot map

Provided in full report

BLUE GROUND BEETLE

Requirements and distribution

This flightless beetle is found in humid, ancient oak and beech woodland with extensive moss cover. Within these woodlands, the species is usually found in wood pastures with little vegetation on the ground, managed by light grazing from sheep, ponies and cattle. Warmer, south-facing slopes are favoured. It feeds on slugs, and therefore requires good populations of *Limax* and *Lehmannia* spp. The Blue Ground Beetle is currently known to occur on six woodland sites on Dartmoor. The current population size is unknown, local monitoring since 1996 suggests populations on the six known sites appear to be stable.

Recreation impacts

It is unlikely that the Blue Ground Beetle suffers any significant direct effects from current recreational activities on Dartmoor, particularly when considering that most visitors in ancient oak woodland stay on paths.

Other threats

A spread of tree diseases, such as sudden oak death, to Dartmoor would have a severely detrimental effects on the Blue Ground Beetle.

Hotspot map

Provided in full report

BUTTERFLIES & MOTHS

Key species on Dartmoor include High Brown Fritillary, Marsh Fritillary, Pearl-bordered Fritillary and Narrow-bordered Bee Hawkmoth. This section combines information on these four species.

Requirements

The two main habitat types in which these species are found are Bracken slopes (**High Brown Fritillary** and **Pearl-Bordered Fritillary**) and wet grassland/rhôs pasture (**Marsh Fritillary** and **Narrow-Bordered Bee Hawkmoth**). Important features in Bracken habitats include steep, south-facing sides of valleys, as well as a Bracken vegetation interspersed with open areas and tracks (created by grazing animals). The presence of Violets, the food plant of these species, is a key requirement[1]. Marsh Fritillary and Narrow-Bordered Bee Hawkmoth are often found in the bottom of valleys in wet grassland. Sites need to have tussocky vegetation and some scrub or rush cover. Key plant species are Purple Moor Grass and Devil's-Bit Scabious.

Local distribution and trend

- **High Brown Fritillary** (stable but signs of recent declines): 12 sites across two areas of Dartmoor
- **Pearl-Bordered Fritillary** (stable): 40 sites across much of Dartmoor
- **Marsh Fritillary** (stable but signs of recent declines): 36 sites in multiple valley networks
- **Narrow-Bordered Bee Hawkmoth** (trend unknown): 8 sites across one area of Dartmoor

Recreation impacts

Generally, impacts of recreation are not a major concern for these species, but under substantial increases in visitor pressure the following impacts should be considered:

ACTIVITY	IMPACT
Collecting butterflies	On Dartmoor, (illegal) collection of butterflies has been reported and could pose a threat to these species
Cars on roads	Impact likely minimal, potential for mortality for small number of individuals flying across roads
Walking, dog-walking, running, horse-riding	There is potential for low levels of disturbance to individual butterflies, but unlikely to have population-level implications
Indirect effects - trampling	Under high visitor pressure, trampling of key vegetation or main foodplants could occur
Indirect effects - fire	Burning butterfly habitat through arson or fires could negatively affect these species

Other threats

Changes in habitat and land-use have had large negative effects on these species on Dartmoor. Appropriate grazing and habitat management is essential to ensure habitat connectivity. Changes in policy, such as future changes to agri-environment schemes are a key concern in the conservation of these species. Furthermore, climate change and eutrophication could impact these species through changes in vegetation and soils.

Hotspot map

Provided in full report

[1]*Fritillary Butterflies of Dartmoor, A practical guide to managing Bracken and Rhôs pasture habitats for Fritillaries on Dartmoor. Butterfly Conservation*

CUCKOO

Requirements and distribution

National surveys and the Devon Birds Atlas indicate rapid rates declines in recent decades. Declines in lowland areas have been faster, resulting in Dartmoor being of key importance to local Cuckoo populations. The main Dartmoor host of the Cuckoo is the Meadow Pipit, and Cuckoos are therefore generally found across open moorland habitats suitable to Meadow Pipit, although an additional requirement is the availability of perches (trees or high scrub) for calling and observing Meadow Pipit nests. This need for perches means that Cuckoo are generally not found breeding on the highest, most open parts of the moor. Cuckoos can also be found foraging in woodland areas.

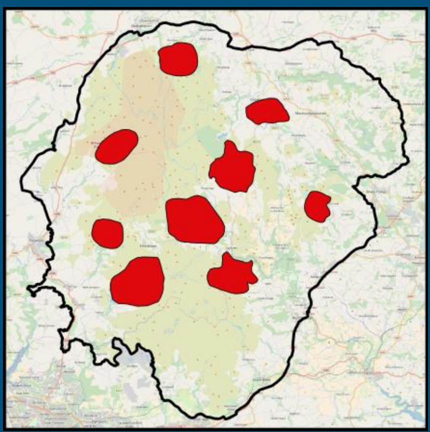
Recreation impacts

Increased visitor numbers would result in a higher frequency of disturbance. If this disturbance is constant throughout the day, for example along popular footpaths, this may interfere significantly with Cuckoo breeding and foraging behaviour.

ACTIVITY	IMPACT	SITES OF IMPACT
Cars on roads	A small chance of road collisions	Cuckoo hotspots near roads
Walking and hiking	Disturbance. Compared to other bird species, Cuckoos are relatively easily disturbed, and can flush at distances of 100+ meters, with some individuals much more sensitive from disturbance	Particularly on open moor, Cuckoos are less likely to flush from large distances in areas of high cover
Dog-walking	Cuckoos are much more sensitive to disturbance when dogs are present, increasing flushing distance. Young fledgling Cuckoos may be particularly vulnerable due to poor flight abilities	At Cuckoo breeding hotspots, where "dogs on lead" policy should be particularly strongly enforced
Running	Effects are likely similar to walking	Breeding sites
Mountain-biking	Causes less disturbance than walking	Breeding sites
Large organised events	Prolonged disturbance from walkers and runners could lead to prolonged Cuckoo displacement, which is likely to interfere with foraging and nest observation	Breeding sites

Hotspot map

The map shows known hotspots for breeding Cuckoo.



Other threats

Land management changes, such as increased grazing and burning pressures result in a reduction of essential Cuckoo landscape features like perches and heather-rich foraging sites. Habitat diversity should be encouraged to support this fast-declining species

DARTFORD WARBLER

Requirements and distribution

Dartford Warbler are a nationally important breeding bird species. They are classed as Near Threatened on the global IUCN red list. Populations of Dartford Warbler are increasing strongly in the UK and their range is expanding.[1] It is predicted that the UK will become an increasingly important stronghold for this species due to climate change causing a loss of suitable habitat in Europe.[1]. In 2006, 31 territories on Dartmoor represented a nationally important population, but in line with Dartford Warbler nationally, this number crashed due to cold winters of 2009/10 and 2010/11.[1] Dartmoor currently holds a small population.

Recreation impacts

Dartford Warbler is a species which is known to be impacted by recreation. Studies have shown that human disturbance can prevent multiple breeding attempts, thereby reducing reproductive output.[3] Increased footfall is therefore likely to cause increased pressure on Dartford Warbler populations. Large events and activities such as picnics and camping are likely to have additional harmful effects by causing prolonged disturbance when carried out near Dartford Warbler territories. These activities may also impact on range expansion, preventing birds from settling in areas of suitable habitat when footfall levels are high. To ensure recreation impacts to Dartford Warbler (and other breeding birds) are minimised, the public needs to be educated to avoid areas where birds are alarming. Access restrictions can be used at known breeding sites (e.g. as known from Devon Birds Atlas) to prevent reduced breeding success. Murison (2007)[3] found that 13-16 individuals passing through a heath territory per hour would prevent multiple broods. Although this result was not based on Dartmoor data, and only covers a specific habitat type, this number could be used as an indicator for sites where access restrictions may be needed (i.e. breeding areas where footfall exceeds this number).

Hotspot map

Dartford Warbler are found mostly around the southern, south-western and south-eastern edges of the moor. The population size is very small, and therefore this species currently has no specific hotspots with high densities of Dartford Warbler.

Other threats

Dartford Warbler require heathland and mature gorse, and therefore active habitat management is needed. In areas where Dartford Warbler have been known to occur, extensive burning of mature gorse needs to be avoided. To protect and enhance the population of this rare breeding birds, and to ensure range expansion, habitat management is needed to ensure improved habitat connectivity across Dartmoor.

[1]*The State of the UK's Birds 2017*

[2] *http://devonbirdatlas.org*

[3] *Murison (2007) Ibis 149 (s1)*

DIPPER

Requirements and distribution

Dipper are found along fast-flowing streams and rivers. Their main requirements are the availability of suitable nesting sites, as well as clean water to fulfil feeding requirements. They are highly territorial species, regularly found nesting in man-made structures such as bridges. Purpose-built Dipper nestboxes are available, for example for use on bridges which lack existing nesting opportunities. On Dartmoor, Dipper are found along all larger rivers, and birds are known to also spend time at higher altitudes, including along leats on the open moor. The 2016 State of the UK Birds report indicates population declines of 28% across the country, which is in line with breeding declines seen locally (see for example devonbirdatlas.org).

Recreation impacts

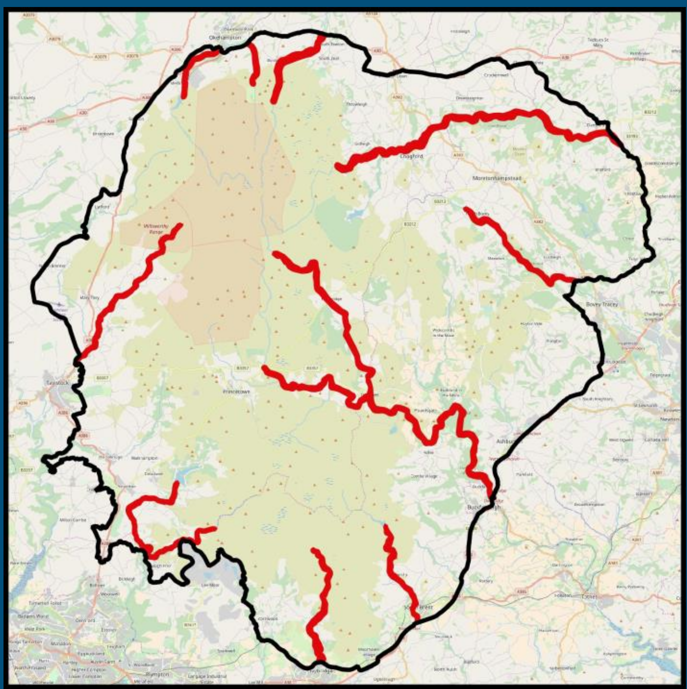
Dipper frequently breed on foot bridges and in areas frequented by humans, and appear relatively tolerant to people, for example walkers crossing over bridges with nest-sites. As dipper typically nest over flowing water, they are relatively undisturbed by dogs, especially when nesting on Dartmoor bridges. The main recreation impact for dipper is likely to result from water-based activities such as kayaking; the Dipper's territorial nature means that kayaking could disrupt territorial behaviour and foraging, and could disturb young fledgling birds. Threshold levels of disturbance are currently unknown, but increased intensity of kayaking could lead to prolonged disturbance and therefore have negative effects on this species.

Other threats

Clean water is essential for Dipper and therefore any deterioration in water quality, including increases in sediment load, would be a cause for concern.

Hotspot map

All major rivers on Dartmoor support Dipper.



DUNLIN

Requirements and distribution

Dunlin are small waders found breeding in the uplands. They used to be red-listed in the UK but was recently moved to Amber status following improvements in their population status.[1] A small population of around 20 pairs is found on Dartmoor from April to September.[2] Their breeding habitat generally consists of very wet, boggy ground with open water pools and peaty hollows at the higher altitudes on Dartmoor. They are site-faithful and return to breeding sites across years.

Recreation impacts

ACTIVITY	IMPACT
Walking	Walking could cause disturbance to breeding pairs. Due to the remoteness of Dunlin breeding sites, current recreation levels are not an issue as only small numbers of individuals frequent Dunlin breeding areas.
Dog-walking	As with other Dartmoor ground-nesting bird species, dogs have the potential to cause breeding disturbance in this species, although this is not currently thought to be a concern due to the remoteness of Dunlin breeding sites.
Large events	Large events could cause serious disturbance. Policy to prevent disturbance from organised events to breeding sites from April – August is essential

Other threats

Short vegetation is necessary and should be maintained through grazing. Mire restoration work has been beneficial. Crow predation is a concern; crows may be observing and targeting Dunlin (and potentially other moorland bird) nests.

Hotspots

Provided in full report

[1] *The State of the UK's Birds 2016*

[2] *http://devonbirdatlas.org*

FAIRY SHRIMP

Requirements and distribution

Fairy Shrimp are Crustaceans found in temporary pools which tend to have little aquatic vegetation and muddy bottoms. These pools can be dips in open grassland, but also wheel ruts and puddles by car parks. Fairy Shrimp are found on Dartmoor, mostly in pools located at 180-200 meters in altitude. Relatively high grazing levels, particularly by ponies, appears to be important for pool maintenance and egg transfer. No exact population estimates are available, but 20 years of intermittent recording has shown Fairy Shrimp have occurred in pools in 10 localised areas. The species is protected under the Wildlife and Countryside Act 1981.

Recreation impacts

Activities such as cars, mountain biking and large organised events may have mixed effects. These activities may help the species by keeping pools open. On the other hand, too much disturbance, such as cars driving through pools, could have adverse effects. It is unlikely that moderate changes in recreation pressure will affect this species, although localised effects at specific sites could result from recreation-related changes in pool creation and disturbance rate.

Other threats

Appropriate grazing levels need to be maintained to ensure habitat availability and egg dispersal for Fairy Shrimp.

Hotspots

Provided in full report

[1]*https://www.legislation.gov.uk/ukpga/1981/69/schedule/5*

GREATER HORSESHOE BAT

Requirements and distribution

Greater Horseshoe Bats can be found roosting in caves, mines, old slate-roofed barns and buildings with gaps of more than approximately 45cm. Their foraging and commuting requirements include linear features, woodland edges, hedgerows, meadows and cattle-crazed habitats. They feed on a range of insects such as moths, dung beetles and craneflies.[1] There are limited numbers of maternity colonies in the UK. In Devon 11 priority areas were identified, with the South Hams holding a significant proportion of the UK population.[2] Greater Horseshoe Bats are found along most of the edge of Dartmoor, and within the boundary of the National Park are a number of larger towns.

Recreation impacts

ACTIVITY	IMPACT
Caving	Potential negative impacts from disturbance at sites where bats are roosting or hibernating
Cars on roads - collision	Greater Horseshoe Bat fly close to the ground and are therefore vulnerable to vehicle mortality[3]
Cars on roads - disturbance	As Greater Horseshoe Bats are light-sensitive, traffic at night can cause disturbance to commuting bats
Other activities (e.g. walking, cycling, kayaking)	Although generally these activities are unlikely to cause issues, any activities close to roosts or at night with torches would be a potential concern

Other threats

Increases in night-time lighting, for example during large events or through changes in infrastructure and street-lighting, can cause severe detrimental effects by impacting bat commuting routes. Land-use change resulting in losses of foraging sites and commuting routes are a further threat. Loss of meadows, pastures and grazed areas could have negative effects by causing a reduction in important invertebrate prey species.

Hotspot map

Provided in full report

[1] *Greater Horseshoe Bats factsheet. Devon Greater Horseshoe Bat Project. www.devonbatproject.org*

[2] *South Hams SAC - Greater horseshoe bat consultation zone planning guidance. Natural England (2010)*

[3]*Medinas (2013). Ecological research. 28 (2)*

HEN HARRIER

Requirements and distribution

The Hen Harrier is a rare and declining bird of prey. Population surveys estimated approximately 575 pairs across the UK.[1] On Dartmoor, Hen Harrier are almost exclusively a winter visitor; up to eight birds are generally seen between September and April. Hen Harrier forage over much of the open moor; they tend to prefer areas of heath and lightly grazed grass moor. Their prey includes small mammals, as well as passerine species such as Meadow Pipit[2].

Recreation impacts

As a wintering species, Hen Harrier are perhaps less affected by recreational pressures by using the moors at a time of year when visitor pressure is generally lower. Generally, Hen Harrier and recreational activities do not come into conflict. The only serious threat to this species is disturbance of roost sites by birdwatching activity. Such disturbance has been known to occur on Dartmoor. Therefore, roost site information is currently only shared with organisations and individuals involved in the management of this species and its sites.

Other threats

Should Hen Harrier start breeding on Dartmoor, recreation impacts would need to be re-considered and appropriate protection put in place. Continued appropriate vegetation management (prevention of swaling) at roost sites is also key.

Hotspots

Hen Harrier use large areas and can forage across most of Dartmoor. The central area of the moor provides important hunting sites. Disturbance to roost sites by members of the public is a key concern. Information on current and past roost sites is not included in this report, but is already known by key organisations and land owners to ensure appropriate land management and protection.

[1] *The State of the UK's Birds 2017*

[2] *Clarke (1997) Ibis 139 (1)*

NIGHTJAR

Requirements and distribution

Nightjar are ground-nesting birds breeding mostly on heathland and in forestry plantations.[1] The species has showed declines across the UK, but conservation action in recent years has resulted in it being moved from Red to Amber status.[2] The Devon Birds Atlas indicates a range increase over recent decades. On Dartmoor Nightjar particularly thrive in recent clear fells within forestry plantations.

Recreation impacts

Human impacts on Nightjar have been established in several studies. It has been shown that human disturbance can cause nest failure by through predation when adults are flushed and nests are left exposed; a Dorset study showed that failed nests were located closer to paths.[3]

ACTIVITY	IMPACT	SITES OF IMPACT
Walking and hiking	Disturbance by walkers can lead to an increase in nest failure (see further detail in study by Langston)[3]	Breeding sites
Dog-walking	See above link between flushing increased nest predation, dogs could potentially exacerbate disturbance effects. Flushing of Nightjar by dogs has been confirmed on nest cameras [3]	Breeding sites
Running	Effects are likely similar to walking, potentially less severe due shorter disturbance time	Breeding sites
Mountain-biking	Disturbance caused by increased intensity of off-road cycling in conifer plantations is a concern	Breeding sites
Illegal parties	Illegal raves with very large numbers of individuals (1000+) have previously taken place at known Nightjar hotspot sites, leading to severe night-time disturbance and potential nest destruction from trampling	Particular hotspot sites

Other threats

Habitat and land-use change are a threat to this species; Nightjar require specific vegetation types within heathland and forestry, and the maintenance of appropriate vegetation conditions is essential for this species.

Hotspot map

Provided in full report

[1] *BTO Research Report No. 398.*
[2] *The State of the UK's Birds 2016*
[3] *Langston et al. (2007) Ibis. 149.*

OTTER

Requirements and distribution

Otters are found on rivers, streams and lakes across Dartmoor. Their main requirement is the availability of fish prey (although they are known to prey also on frogs, riparian birds and rabbits). The population is thought to have been at carrying capacity for the last 20-30 years, having recovered from a previous nationwide decline. The exact number of individuals on Dartmoor is unknown; the Otter's territorial nature and large home ranges (up to 40km for males) means that total numbers are not high.

Recreation Impacts

Otters generally are tolerant of human activity, and can habituate to human recreational activities. Otters are killed on roads, but it is thought that casualty rates are not currently impacting on long-term population trends. Excessive levels of traffic around water reaches is likely to lead to increased road casualties. Potential indirect effects, such as effects on fish supply or the effects of toxic chemicals, should be kept in mind. Current requirements for ecological impact assessments are in place as part of the planning system, and the Mammal Society is currently preparing further guidance which is expected to be published in 2019.

Other threats

Any factor which may lead to a reduction in fish populations, as well as any introductions of new forms of toxic chemicals, for example through changes in farming practices.

Hotspots

There are no known particular hotspots for this species, although it is worth noting that there will be specific sites of importance where Otters give birth and rear young.

PEREGRINE FALCON

Requirements and distribution

A small number of Peregrine Falcon pairs breed in and around Dartmoor, for example in some quarries. The UK population size was estimated to be around 1769 pairs[1] in 2014, with the Dartmoor population currently stable at around seven pairs (pers. comm.).

Recreation impacts

Scientific research has shown Peregrine Falcon breeding success is impacted by disturbance, for example from climbing activities.[2] However, as Peregrine Falcon on Dartmoor mostly breed on private site with no public access, climbing impacts are not currently a concern. Change of land-use, for example use of quarries for outdoor activities, could impact Peregrine Falcon breeding activity and success. A large reduction of recreational activity could result in Peregrine breeding on some of the larger tors on the open moor.

Other threats

In addition to rock climbing, the IUCN red list describes persecution, habitat degradation and wind energy developments as key threats.[3]

Hotspots

Birds breed in and around Dartmoor. Information on exact breeding sites is kept out of the public domain due to the risk of illegal persecutions.

[1]*Wilson (2018) Bird Study (online)*
[2]*Brambilla (2004) Ardeola. 51 (2)*
[3] *www.iucnredlist.org Peregrine Falcon*

PLANTS

Dartmoor National Park is home to a wide range of scarce and/or ecologically important plant species. On the open moors, bogs and grasslands, important species such as Vigur's Eyebright and Bog Orchid are found growing. Flax-leaved St John's Wort, for which Dartmoor holds the majority of the British population, is found on rocky slopes.[1] Mosses, liverworts and lichen thrive on bare, unburn heathland, on tors and rocks (e.g. *Bryoria* spp.) and on isolated Hawthorn trees. In woodland environments, lit conditions, glades and ride edges are important (e.g. *Lobaria* and *Stricta* spp.). Examples of notable lower plant species on Dartmoor include the charismatic String of Sausage lichen and the UK BAP species *Graphina pauciloculata*.

Recreation impacts[2]

The potential impacts of recreational activities on plant species were not investigated on a species by species basis for this project, the table below provides a generic overview of recreational activities and their potential impacts on Dartmoor plants. Low levels of recreational activity are unlikely to cause significant impacts, but sensitive species and habitats could be severely impacted by increased recreational activities. Large organised events could lead to particularly severe damage due to sustained, increased trampling effects on event routes. Increased recreational pressures could lead to increased damage to lower plant species growing on tors.

ACTIVITY	IMPACT
Cars on roads	Increased numbers of cars would detrimentally affect air quality
Walking, hiking and running	Trampling damage. Large events may result in particularly severe trampling damage
Dog-walking	Nutrification and trampling
Mountain-biking	Off-road cycling is likely to be one of the most damaging activity types for a range of plants due to "trampling" pressure
Horse-riding	Trampling damage
Kayaking, swimming & fishing	Trampling at access points and partial loss of lower plant species from stones
Letterboxing and geocaching	Partial loss of lower plants from stones
Fires and barbecues	Complete loss of plants at burning sites

Other threats

Changes in grazing regime can negatively impact plant communities, long term low-level grazing is to be preferred over heavy grazing. Furthermore, decreased air quality and changes in agricultural practices can have negative impacts. Other concerns include increased shading and ivy growth on trees and tors, as well as scrubbing up of open heath and tors. A lack of management of important plant sites was highlighted as a further threat in species questionnaires.

Hotspots

Key plant species are found across all moorland habitat types. Species-specific distribution information can be found for example in A New Flora of Devon (Smith, Hodgson & Ison 2016).

[1] *The State of Dartmoor's Key Wildlife 2011*

RAVEN

Requirements and distribution

These large omnivorous corvids are widespread on Dartmoor, and populations are increasing.[1] They feed on a wide range of prey items, including carrion, rabbits, eggs and birds, and have been reported to occasionally kill lambs. Raven nest on tall trees in woodlands, as well as on remote tors.

Recreation impacts

The only recreational activity that is of any significant concern is rock climbing. Climbing on tors with breeding Raven during spring causes disturbance to breeding Raven. Most hiking and dog-walking is thought to have little effects, although increasing numbers of visitors to woods and remote tors during spring is a concern and the potential for future impacts should be highlighted. This is of particular concern because Raven start breeding early in the season when few people are visiting, resulting in nest desertion when visitor disturbance at remote breeding sites increases later in the breeding season.

Hotspots

Raven are widespread across Dartmoor. During the breeding season, birds are found breeding in woodlands, on remote tors and likely also in quarries.

Map with examples of breeding tors provided in full report.

[1] *See The State of the UK's Birds 2016 and http://devonbirdatlas.org/*

RED GROUSE

Requirements and distribution

Red Grouse are a resident species on upland heather moorland. They are territorial through much of the year, and feed mostly on heather shoots, along with other plants (e.g. Cotton Grass and Bilberry), as well as invertebrates for chick-rearing.[1] The exact current population size on Dartmoor is not known and difficult to estimate, but is probably are in the region of a maximum of 50 breeding pairs. Birds are distributed relatively widely across Dartmoor, mostly found at altitudes of over 450m.

Recreation impacts

As most Red Grouse on Dartmoor are found mostly in the more remote areas, they are currently relatively protected from recreational impacts. In those areas, they are unaffected by cars on roads and unlikely to be affected by hikers, runners and horse-riders. However, Red Grouse are flushed by dogs, and dog-walking is a concern in some Dartmoor areas of high footfall where grouse are known to occur. Furthermore, large events during the breeding season with any off-track activity would be a concern for this species.

Other threats

Red Grouse require young heather for feeding, appropriate vegetation control is therefore needed to support this species.

Hotspots

Provided in full report

[1] *Martınez-Padilla (2013). Journal of Animal Ecology. 83 (1)*

RING OUZEL

Requirements and distribution

Dartmoor holds the UK's most southerly breeding population of Ring Ouzel , a UK red-listed species which is showing severe population declines.[1] Breeding habitat requirements include the presence of "steep sided river valleys, tracts of broken ground with boulders, bracken, gorse and bilberry".[2] On Dartmoor, they are mostly found on the north-west side of the moor. Long-term survey data on population trends on Dartmoor is limited, but suggests numbers are declining from a possible 20-25 pairs in the nineties. Monitoring efforts in recent years have showed numbers continuing to decline from 10-12 pairs in 2010-2012 to 6-7 pairs in 2017.

Recreation impacts

Extensive observations of Ring Ouzel breeding behaviour on Dartmoor has provided detailed insights into impacts of recreation on this species. Visitor pressure already impacts significantly on this species, and key concerns under future increased visitor numbers include:

- Expansion of climbing areas, new climbing areas being used and/or promoted in guides
- Increase in bouldering and river-related outdoor activities
- Increased commercial dog-walking, wild camping and geo-caching

ACTIVITY	IMPACT	SITES OF IMPACT
Walking and hiking	Nesting on tors appears to have decreased in recent years and is thought be linked to disturbance. Females are easily flushed (from within +-20m), and therefore on popular tors this result in substantial breeding disturbance. Regular flushing of birds has been observed to lead to nest failure through predation through birds revealing nest site to predators.	*Provided in full report*
Dog-walking	As above, bird behavioural change and disturbance is a major concern. Mortality has not been observed but direct nest disturbance has occurred. Particular concerns are around fast-moving and shoot-related breeds of dogs, as well as commercial dog-walking and/or owners exercising large numbers of dogs (up to 16 dogs with one owner observed on one Ring Ouzel breeding site)	*Provided in full report*
Climbing and bouldering	Current breeding distribution does not overlap with popular climbing sites, but would cause disturbance, displacement and/or reduced reproductive success. Bouldering has been observed occasionally near breeding sites, and high frequency bouldering during the breeding season should be avoided.	All breeding sites
Running and mountain-biking	Likely to be of lower impact due to fast, short-term disturbance, but larger numbers over prolonged would be a concern	All breeding sites
Drones and model airplanes	Currently unknown, but should be controlled to prevent potential impacts	All breeding sites

TABLE CONTINUED ON NEXT PAGE

[1] *The State of the UK's Birds 2017*

[2] *Emergency Action for Dartmoor's Ring Ouzels (Turdus torquatus). Productivity & habitat assessment Dartmoor 2011. Nick Baker & Fiona Freshney*

RING OUZEL (continued)

ACTIVITY	IMPACT (continued)	SITES OF IMPACT
Geocaching and letterboxing	Individuals can spend hours in one area, searching for caches in rocks and crevices where Ring Ouzel (and other species like Wheatear) would nest. Has been observed to lead to 1h+ disturbance of Ring Ouzel fledgling feeding. Small scale letterboxing likely minor issue.	Potential for disturbance across sites.
Large events	Current policies within DNPA ensure that disturbance from large organised events is minimised. Other unofficial events with large numbers of individuals are a concern, especially when time spent in breeding area is prolonged (e.g. group barbeques, camping)	All breeding sites
Camping, barbecues, picnics, swimming	Prolonged disturbance from these activities prevents the pair leaving and attending nest sites. Causes displacement and reduced breeding success. Camping has been observed near breeding sites (included at banned sites). On one instance, litter from party was jammed into a nesting crevice, in this instance this took place shortly after fledging but the anecdote reveals the potential implications of such activities.	All breeding sites
Naturalists and surveyors	Regularly observed. Can cause displacement and reduced breeding success. Individuals have been observed visiting nests, disturbing birds, and trampling vegetation around nest site.	All breeding sites.

Other threats

Other concerns for Ring Ouzel conservation are climate change and vegetation management. This includes continued (or increased) overgrazing of heathland habitat, undergrazing of forage grassland (resulting in *Molinia* dominance), and inappropriate swaling (e.g. of Western Gorse on steep breaks in slope). Army activity has both positive and negative effects. Army activity leads to temporary exclusion zones, thereby reducing disturbance from visitors. However, this has led to nest failure after birds have settled to breed in areas which were highly disturbed when sites were again open to the public. Therefore, the impact of army closures on Ring Ouzel settlement and success in relation to visitor hotspots needs to be considered. There have been occasional incidents from disturbance from firing and noise, resulting in reduced reproductive success and displacement of breeding birds.

Breeding sites

Provided in full report

[1] *https://data.gov.uk/dataset/rare-bird-nesting-areas*

SALMON

Requirements and distribution

Atlantic Salmon are found in all the main rivers of Dartmoor, and many areas of high spawning potential lie within the National Park. Salmon are of important economic value to the South West, for example, a study by the environment agency estimated that "*anglers' annual expenditure on fishing inland waters in the South West totalled about £100 million, supporting approximately 2,300 jobs and £50 million of household income*"[1]. The species has shown severe declines; numbers returning to English and Welsh rivers have declined by +-45% since the 1970s[2].

Recreation impacts

Rivers are an important recreational attraction on Dartmoor. Kayaking, wild swimming and river-side picnics are very popular along numerous areas of Dartmoor river. Previous research[3] highlighted that Salmon can "*be reluctant to pass obstacles that should not pose any physical problem*". Therefore, obstructions such as smaller dams created by visitors could potentially impact Salmon when built at sensitive locations. Canoeing and kayaking are often raised as having potential negative effects, for examples through disturbance of Salmon redds. However, a literature search using key words such as *kayak, canoe, watersport* and *recreation* revealed no relevant studies exploring this issue through direct scientific study (as also outlined in EA R&D technical report W266[4]). Further scientific research appears necessary to understand whether these activities could have impacts on Dartmoor's Salmon. Illegal fishing is a further potential threat.[5] Indirect recreation impacts, such as changes in water quality (see below), for example through pollution or toilet systems leaking into rivers, need to also be considered.

Other threats

Thorstad (2008)[3] outlines a wide range of factors affecting Salmon migration, including changes in water temperature, pH and pollutants. Any potential river management which alters river flow could affect Salmon breeding.

Hotspots

Map with areas of high Salmon spawning potential provided in full report (based on past work by EA).

[1]*Economic evaluation of inland fisheries (2009). Environment Agency*

[2]*Assessment of Salmon stocks and fisheries in England and Wales (2017). CEFAS, Environment Agency and Natural Resource Wales*

[3] *Thorstad (2008). Rev Fish Biol Fisheries. 18*

[4] *Environment Agency R&D Technical report W266. Effects of canoeing on fish stocks and angling*

[5] *Atlantic Salmon Devon Biodiversity and Geodiversity Action Plan. Devon Biodiversity Partnership 2009.*

SKYLARK

Requirements and distribution

Skylark are found on areas of moorland and grassland with low, open vegetation for nesting. They breed at a very broad range of altitudes, ranging from lowland grassland to high open moor. They are very widely distributed on Dartmoor across all areas of suitable low vegetation. Skylark have declined strongly across the country, and Dartmoor (and Exmoor) appear to be strongholds with relatively large populations. A 2006 survey[1] estimated a total of 4,593 individuals on the North Moor alone.

Recreation impacts

Given the broad distribution of Skylark across Dartmoor, only large changes in recreational activity levels would be likely to significantly affect the population as a whole. However, national declines and the importance of Dartmoor for breeding Skylark should be kept in mind, and therefore potential impacts in response to recreation should be re-considered periodically.

ACTIVITY	IMPACT	SITES OF IMPACT
Walking/hiking	Skylark nest in very low, open or grazed ground, and birds can nest near or along paths. Trampling of nests is therefore a higher risk compared to other moorland birds. Compared to other upland birds, adult Skylark generally appear to be less sensitive to disturbance from walkers	Breeding sites near paths
Dog-walking	As most moorland birds, tends to be more disturbed by walkers with dogs. Nesting near paths means nests are likely to be more susceptible to dog disturbance	Breeding sites near paths
Running	Sole, occasional runner is unlikely to cause any issues (but see note on large events below)	Running routes
Horse-riding	Only potential issue would be of trampling risk, but this is likely of low concern due to large Skylark populations and relatively low numbers of riders	Along riding routes
Large events	Large, organised events, especially cross-country runs, could increase risk of trampling	Any event locations

Other threats

Maintaining suitable habitat types and supporting insect populations, for example through targeted vegetation management, is essential for supporting a thriving Skylark population.

Hotspots

Skylark do not have particular breeding hotspots on Dartmoor, they are ubiquitous across suitable grassland and moorland habitats.

[1] *Breeding Bird Survey of Dartmoor Training Area, MoD and RSPB, 2006*

SNIPE

Requirements and distribution

Snipe are primarily found in wet, boggy habitats. They feed on a range of invertebrates, and earthworms and crane fly larvae are thought to make up a large part of their diet.[1] Snipe are amber-listed in the UK, and the far majority of Devon's Snipe breed on Dartmoor. Devon Bird Atlas data shows increases in breeding numbers over recent decades.[2] Due to the Snipe's secretive nature, population estimates for Dartmoor are difficult to obtain, but are thought to lie in the region of approximately 90-100 breeding pairs.

Recreation impacts

Due to the Snipe's dependence on wet, boggy habitats, there tends to be little overlap between recreation sites and Snipe habitats. Therefore, there are no recreation activities on Dartmoor which are currently thought to have significant effects on this species.

Other threats

The key requirement for Snipe is wet, boggy habitat, and therefore any draining of wet bogs would have adverse effects on this species. Snipe is one of the species shown to be negatively affected by upland wind farms[3], therefore future development of such wind infrastructure in or around Dartmoor could negatively affect breeding bird densities.

Hotspots

Snipe are widely distributed across Dartmoor's valley bogs and wet ground at all altitudes. Any wet areas are potential important breeding sites.

[1] *Hoodless (2007). Bird Study. 54 (2)*

[2] *http://devonbirdatlas.org*

[3] *Pearce-Higgins (2012). Journal of Applied Ecology. 49 (2)*

SOUTHERN DAMSELFLY

Requirements and distribution

Southern Damselfly is a declining, endangered species of damselfly. The species has very specific habitat requirements.[1] It requires continuously flowing, unshaded runnels with emergent vegetation such as Bog Pondweed and Marsh St John's Wort. Specific pH conditions (affected by geological site characteristics), as well as optimal grazing regimes and clean water are essential. The species is found on three sites on Dartmoor, which have been monitored for the past 12-22 years. Further details of Dartmoor populations, requirements and distribution can be found in DNPA reports by Norman Baldock and Dave Boyce.

Recreation impacts

This species is unlikely to be severely impacted by recreational activities. One notable exception is joy-riding with motorised vehicles at one known site, which potentially threatens a runnel by damaging the turf near the spring that feeds the runnel. Roadside boulders were suggested as a mitigation measure. Furthermore, large numbers of runners, mountain-bikers or horse-riders would have adverse effects, but should be avoided through the DNPA large event monitoring. Such disturbance is unlikely due to the wet nature of the Southern Damselfly sites.

Other threats

Sufficient grazing at the correct sites is essential and needs to be actively managed. Other threats could include weather-related events, such as summer droughts which could dry up runnels with larvae.

Hotspot map

Provided in full report

[1] *Southern Damselfly Management Handbook. British Dragonfly Society (2016).*

WHINCHAT

Requirements and distribution

Whinchat breed on open moor and heathland, and are generally found breeding on the moorland fringes, rather than on high exposed moorland. On Dartmoor they have a wide, but scattered distribution across the lower moorland sites with suitable habitats. The habitat tends to consist of sloping ground with some vegetation cover. They are often found associated with Bracken and sometimes, but not exclusively, with heather cover. Whinchat are now red-listed in the UK and have suffered very strong nationwide declines, and BTO atlas data[1] show a northward and upland shift. Dartmoor, along with Exmoor and Salisbury Plain, is now an important southern stronghold, although national and local atlas data[2] shows substantial declines in Devon also.

Recreation impacts

Occasional disturbance is unlikely to affect nesting success (see for example Border et al. 2018[3]), but where visitor hotspots or busy footpaths are close to breeding sites, potential effects of disturbance on predation or nest abandonment need to be considered.

ACTIVITY	IMPACT	SITES OF IMPACT
Walking/hiking	Whinchat are more "flighty" than other moorland passerines such as Stonechat and Skylark, and is subsequently more easily disturbed	Nesting areas
Dog-walking	As with other moorland birds, Whinchat tend to be more sensitive to disturbance when dogs are present	Nesting area
Running	Likely similar to walking. Single disturbance events are unlikely to cause concern, but continued disturbance, e.g. for birds nesting close to busy footpath, may affect breeding behaviour	Nesting areas

Other threats

Bracken growth can be an important landscape feature for Whinchat, and should therefore not be strongly controlled in areas of Whinchat breeding. To avoid nest destruction as a result of vegetation management, Bracken control should wherever possible avoid the bird breeding season.

Hotspots

A comprehensive knowledge of particular breeding hotspots is not currently available, although some known areas of breeding importance are known from targeted studies. Whinchat are very faithful to their breeding sites, and therefore a data collation effort which combines known breeding site data (e.g. from RSPB surveys, BBS data and Holne Moor bird study) would be helpful in informing locations of Whinchat conservation importance where specific habitat and disturbance protections should be put in place.

[1] *BTO Bird Atlas Mapstore https://bto.org/mapstore/*

[2] *http://devonbirdatlas.org*

[3] *Border (2018). Ibis (online)*

WOOD WARBLER

Requirements and distribution

Wood Warbler are ground-nesting birds, found breeding in woodland areas with high canopy cover and a relatively open understory. Nest sites are often located on sloped ground. On Dartmoor, birds are mostly found in oak woodland, but are also known to breed in plantation woodlands. Across 27 monitored woodlands on Dartmoor, the total population size has shown a continuous decline from 150 in 2012, down to 48 in 2017 (RSPB survey). Previous to this monitoring effort, the population is likely to have been declining for several decades.

Recreation impacts

A main concern is population growth and the promoting of visiting reserves leading to increased numbers of visitors at key breeding sites. In light of these increases, a (temporary) redesign of rights of way or reserve paths should be a consideration.

ACTIVITY	IMPACT	SITES OF IMPACT
Walking, hiking and dog-walking	Territory settlement may be negatively affected by the presence of walkers and dogs. Anecdotal evidence on Dartmoor shows that in woodlands with increasing visitor numbers, birds no longer breed in busy areas despite birds being seen there pre-breeding. Those areas in the past did support active Wood Warbler territories	*See full report*
Mountain-biking	Mountain-biking is frequent in territories around some breeding sites, exact effects not yet studied	*See full report*
Large events	Past woodland visit days with several hundred visitors took place during the breeding season. People strayed off paths and were seen walking close to nests, which are highly disguised and therefore vulnerable to trampling	*See full report*
Information-sharing among photographers	Single wildlife photographers have no negative effects. However, in recent years photographers have been known to intentionally or unintentionally share details of nest locations on social media, leading to continued disturbance near particular nests. This was also observed for other woodland species such as Redstart	Any breeding site

Hotspot map

Provided in full report