Taking the long view

An introduction to Natural England's Long Term Monitoring Network 2009 - 2016

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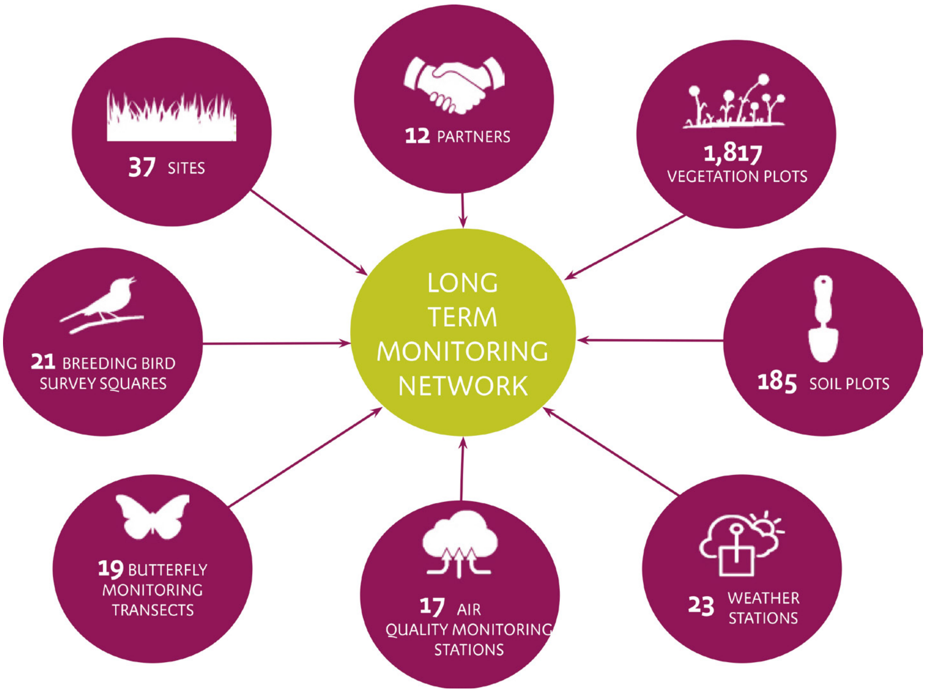

Figure 1 Natural England's Long Term Monitoring Network.

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Foreword

David Askew, Director of Evidence


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Long term monitoring is an incredibly important investment in our evidence base on the natural environment – an environment which always has and will continue to change. It is only by tracking changes consistently over the long term, using repeatable methods, that we can detect the important changes, identify signals of change early, and discriminate significant shifts from short term fluctuations. As we have done here, we can structure our evidence collection to also provide insight into what is driving change and therefore inform how we can respond.

Maintaining long term monitoring activities requires significant commitment to invest resources now that will realise benefits in future years and even decades. We are at the start of that journey now having established a baseline across our network of sites. This is our first report from this long term activity and the focus at this stage is on describing the scope of the network, the approach taken and some description of the environment covered by the network.

I hope it is clear from this report that a great many people from Natural England and elsewhere have been involved in establishing the network and collecting and analysing the evidence. Indeed, having been directly involved in fieldwork on a number of sites myself one of the great pleasures of long term monitoring has been working alongside staff and volunteers from across the country brought together to deliver a common long term environmental goal. This has been by turns a wet, windy, cold and sunny experience – but always fulfilling, educational and engaging.

Finally, we have worked in partnership on the long term monitoring network so far and hope to continue to do so as the evidence is analysed for trends and insight into change. The data from the network is being made openly available (**Natural England Long Term Monitoring Network**) and we encourage creative analysis and use of this data. Natural England, and more importantly the environment, will benefit from as wide a collaboration as possible on this.

Contents

Introduction

Andy Nisbet and Susie Smith

Climate change will significantly affect England's natural environment and biodiversity and there is strong evidence that this is already happening (Morecroft and Speakman 2015). These changes will be compounded by the long term effects of air pollution and changes in land management policy and practice.

Natural England's conservation strategy for the 21st century, Conservation 21, sets out an ambitious, long term vision of how we can work together to protect England's nature and landscapes. In order to achieve this we will need to understand the nature of environmental change so that we can advise others, develop shared plans for places and adapt our own interventions and decision making.

Monitoring lets us track changes and assess the effects of our activities on the environment. Long term datasets are necessary because many of the environmental processes affected are long term and real change cannot be judged in just a few years. A long term approach is needed to distinguish trends from annual variation. Long term monitoring provides the baseline against which the future state of the environment can be assessed in a reliable historical context and it allows unanticipated changes to be identified.

Natural England's Long Term Monitoring Network project (LTMN) began in 2009 with the aim of developing, with our partners, a cost effective network of sites to provide evidence on the effects of changing climate, air pollution and land management on the natural environment. It is a set of intensively monitored sites across England, selected to have a wide geographical spread and to include some of our most valuable habitats. LTMN extends and complements the UK Environmental Change Network (ECN) which was established in 1992. Figure 2 shows how this kind of intensive monitoring complements the other environmental monitoring and surveillance that Natural England carries out or supports.

LTMN (and ECN) measure multiple attributes on individual sites using common protocols. Table 1 summarises what is measured on our sites. This approach will enable us to draw stronger conclusions from a smaller number of sites than if these measurements were collected through separate, broad surveillance schemes. The ability to attribute change to the correct cause is important. This requires high quality, spatially explicit data on the potential causes of change. The integration of different types of data collection across a range of sites is essential to give a high degree of confidence and statistical power.

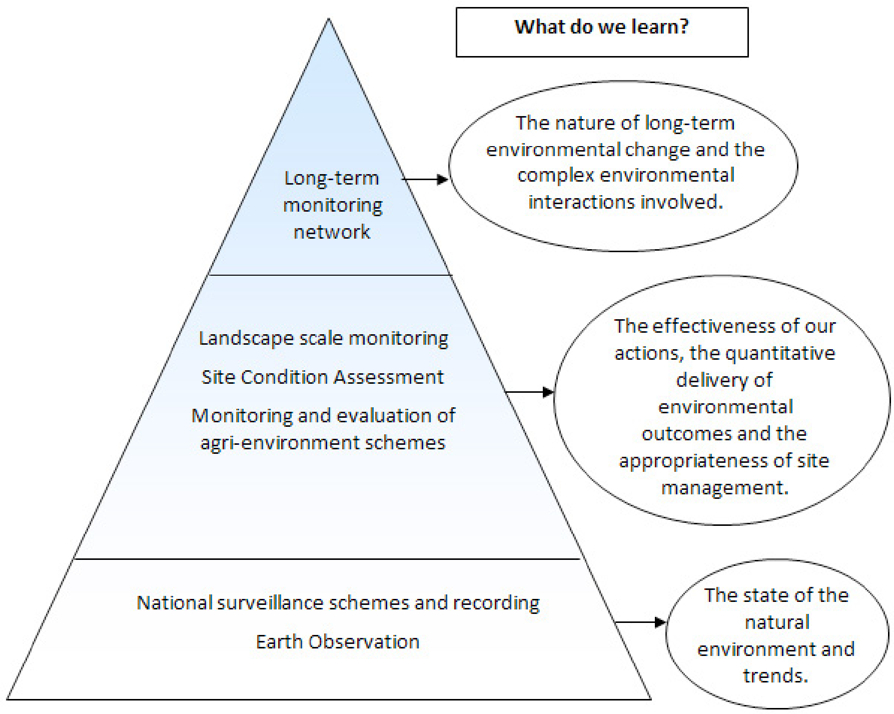

Figure 2 The relationship between different monitoring and surveillance activities.

LTMN now has 37 fixed sites across England. It covers ten habitats and similar habitats can be compared in areas with contrasting climate and pollution conditions. In 2016 we completed all the baseline surveys and will now be comparing data sets over time. Most of the data collected are already openly available for others to analyse and use under an Open Government Licence.

About this report

We have produced this report to:

- Raise awareness of Natural England's Long Term Monitoring Network and enable people to appreciate the value of our investment in this evidence.
- Publicise the data sets that are now, or soon will be, openly available and promote their use and analysis by others including researchers and universities.
- Provide an introduction, support and context for future reports that we will publish which will focus on detailed analyses of specific LTMN data sets.
- Demonstrate to our own staff, partners and the many volunteers who have contributed to LTMN the value of, and our appreciation of, their work.

This is not a definitive research report; instead it is a mixture of background information, explanations, some analysis of data, case studies and sign posts to more detailed information on methodologies and the raw data.

- **Chapter 1** sets the context for understanding and measuring the long term changes associated with climate change and air pollution.

- **Chapter 2** provides information about the LTMN sites, most of which are on our National Nature Reserves (NNRs). The chapter provides some background on the history of monitoring and research on NNRs.

- **Chapter 3** is about our partners. LTMN is part of a wider national and international partnership. It is an ambitious project, and gathering and analysing all the data is a huge task. It would be impossible to deliver without partners.

- **Chapter 4** looks at the vegetation surveys. It explains the methodology and presents some summaries of the baseline data.

- **Chapter 5** introduces and explains the soils monitoring and presents some results from the baseline surveys.

- **Chapter 6** is a case study of Thursley NNR in Surrey that brings together some of the different aspects of LTMN monitoring and discusses site management in a changing environment.

- **Chapter 7** introduces the protocols and data and includes links to published data.

- **Chapter 8** considers the future. New techniques may help us to gather environmental data more efficiently and effectively, but these opportunities must be balanced with the value of maintaining consistent long term data sets.

The report concludes with some reflections from Natural England's Chief Scientist, Tim Hill, on the value and future of LTMN.

Meet the people

LTMN uses scientific methods and modern technology, but people and team work have been at the heart of its success. Throughout the report there are profiles of a few of the people who have been involved. In fact, hundreds of people have contributed from our partners, NNR managers, specialists and the many members of staff and volunteers who have collected the data. We are grateful to all of them for making this possible.

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Figure 3 Ready for the 2016 vegetation survey on Fenn's, Whixall and Bettisfield Mosses NNR.

What	Why	How	When
Weather	A driver of change. Rising temperature is changing the timing of seasonal events and disrupting the interactions between species. It is also affecting rainfall patterns and is likely to lead to an increase in the frequency of extreme weather events.	Automatic weather stations	Continuously
Air quality	A driver of change. Air pollution is a significant threat to the natural environment. There are numerous air pollutants that have different impacts in different conditions.	Field samples and laboratory analysis of samples	Continuously
Vegetation	An indicator of change. Plant communities are an indicator for wider biodiversity and changes in species composition and abundance will help identify what is driving change and what the impact of that change might be.	Field based vegetation surveys	Once every four years
Soils	An indicator of change. Soils provide ecosystem services such as flood prevention and clean water and host a significant proportion of our terrestrial biodiversity. Monitoring will help us understand how soils work and how changes to land management, climate and pollution may change soil properties and communities.	Soil sampling and laboratory analysis	Once every six to nine years
Birds	An indicator of change. Wild bird populations are an important indicator of the health of the countryside. Knowledge of the trends in bird populations is fundamental to the conservation of birds as well as an indicator of wider biodiversity.	Field surveys using British Trust for Ornithology methodology	Twice a year
Butterflies	An indicator of change. Butterflies are indicator species with rapid lifecycles and, in many cases, high sensitivity to environmental conditions. There are strong volunteer recording and monitoring networks for butterflies, with datasets built up since 1975 by Butterfly Conservation (BC) and the Centre for Ecology and Hydrology (CEH) which enable accurate assessment of trends.	Field surveys of transects using Butterfly Monitoring Scheme methodology	Weekly during the flying season
Site management	A driver of change. The management activities on a site can greatly influence the character of the site, and records of management activities undertaken help our understanding of changes to site biodiversity.	Reserve manager records	Ad hoc

Table 1 A summary of the monitoring on LTMN sites.

1 Understanding long term environmental change

Mike Morecroft and Zoe Russell

The environment has always changed but since the industrial revolution, the rate of change caused by people has rapidly increased, with profound implications for ecosystems, the species they support and the benefits they provide to society. The impacts of air pollution and climate change are more widespread and more complex than many of the impacts that conservationists have historically addressed, such as habitat destruction and changing land management.

Natural England's Long Term Monitoring Network is helping us to unravel some of these complex changes and make better decisions about how to manage the environment for the long term.

Rises in temperature, of approximately 1°C in the UK, are the clearest changes in the climate and have the clearest impacts. This has led to species ranges shifting northwards and the balance between different species in ecological communities changing (Morecroft and Speakman 2015). Long term monitoring has been essential to identifying these changes and the evidence is much clearer in well monitored groups, particularly butterflies and birds in which it has also been possible to identify interactions with land use (Oliver et al 2017). Rising temperature is also changing the timing of seasonal events (phenology) and disrupting the interactions between species (Thackeray et al 2016).

Climate change is also affecting rainfall patterns and is likely to lead to an increase in the frequency of extreme weather events, including droughts and floods. These can have profound implications for ecosystems, including change or loss of wetlands and death of dominant trees in woodlands. At the coast rising sea level is accelerating coastal erosion, leading to the loss of coastal habitats where hard flood defences hold the coastline static, or a loss of terrestrial habitats where coastal habitats shift inland.

Air pollution remains a significant threat to the natural environment. There are numerous air pollutants and these have different impacts. The impacts of acid rain on ecosystems are probably the most well-known and have been studied since the 1970s. Soils and waters have acidified compared to pre-industrial levels leading to loss of species, changing biological communities and changes in soil and water chemistry. Reductions in sulphur dioxide concentrations from power stations and, to a lesser extent, nitrogen dioxide from vehicle exhausts, power stations and domestic emissions have led to a reduction in acidity and partial recovery in soils and waters (Monteith et al 2016). Long term monitoring at ECN sites has showed early signs that soil is becoming less acidic (Figure 4; Morecroft et al 2009) and more recently there is evidence that vegetation too is starting to respond (Rose et al 2016).

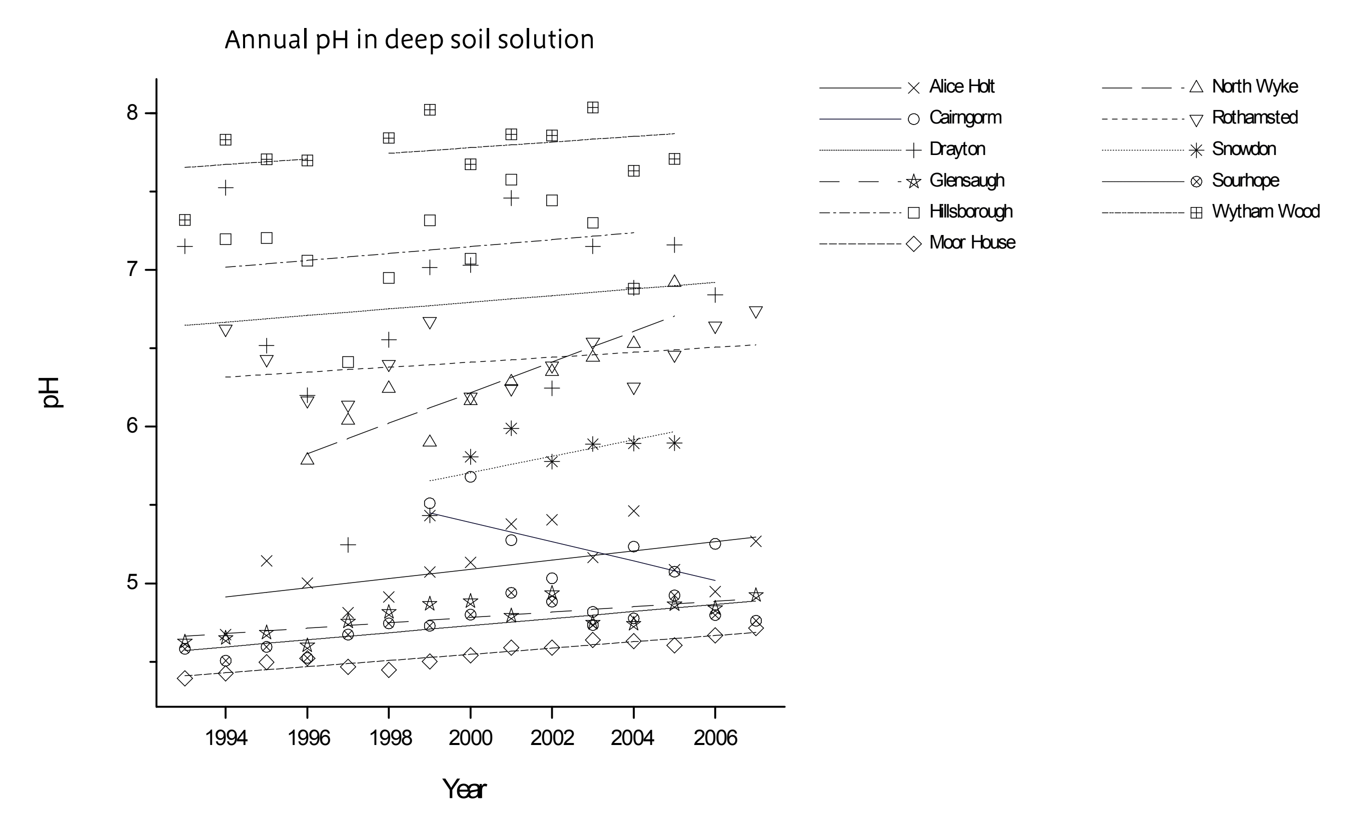


Figure 4 Trends in pH of soil water at Environmental Change Network sites. Different symbols represent different sites. pH is a logarithmic scale: an increase of 1 pH unit indicates 10 times less hydrogen ions. (Reproduced from Morecroft et al 2009).

The input of reactive nitrogen from the atmosphere remains a major problem. Ammonia, produced from a range of sources, but especially livestock production, is an important element of this, alongside nitrogen dioxide. Plants need nitrogen to grow and an increase in atmospheric deposition has a fertilising effect on some species. However, stimulating the growth of these species, typically common, fast growing species, has led to them excluding other, smaller, often rarer plants and therefore reducing overall diversity.

Whilst these broad patterns of impacts from climate change and air pollution are well known, there remain significant uncertainties. As well as identifying changes we need to understand what factors are causing change in specific cases if our actions are to be effectively targeted. For example increasing nitrogen supply and rising temperatures may both benefit the growth of competitive plant species, but which is most important in different places? To find this out we need to be able to build up a picture of geographical and habitat differences. Some factors are much more spatially variable than others. Ammonia emissions reflect land use and management, particularly livestock farming whereas nitrogen dioxide is higher around towns and near the major road network. Rainfall can vary with topography – with much higher levels on high ground and lower in the lee of upland areas. LTMN monitoring provides rigorous data to quantify these factors and by monitoring key biological variables, including vegetation composition, bird and butterfly populations in the same place as the drivers of change (such as climate and air quality), it allows us to test causes of change with confidence.

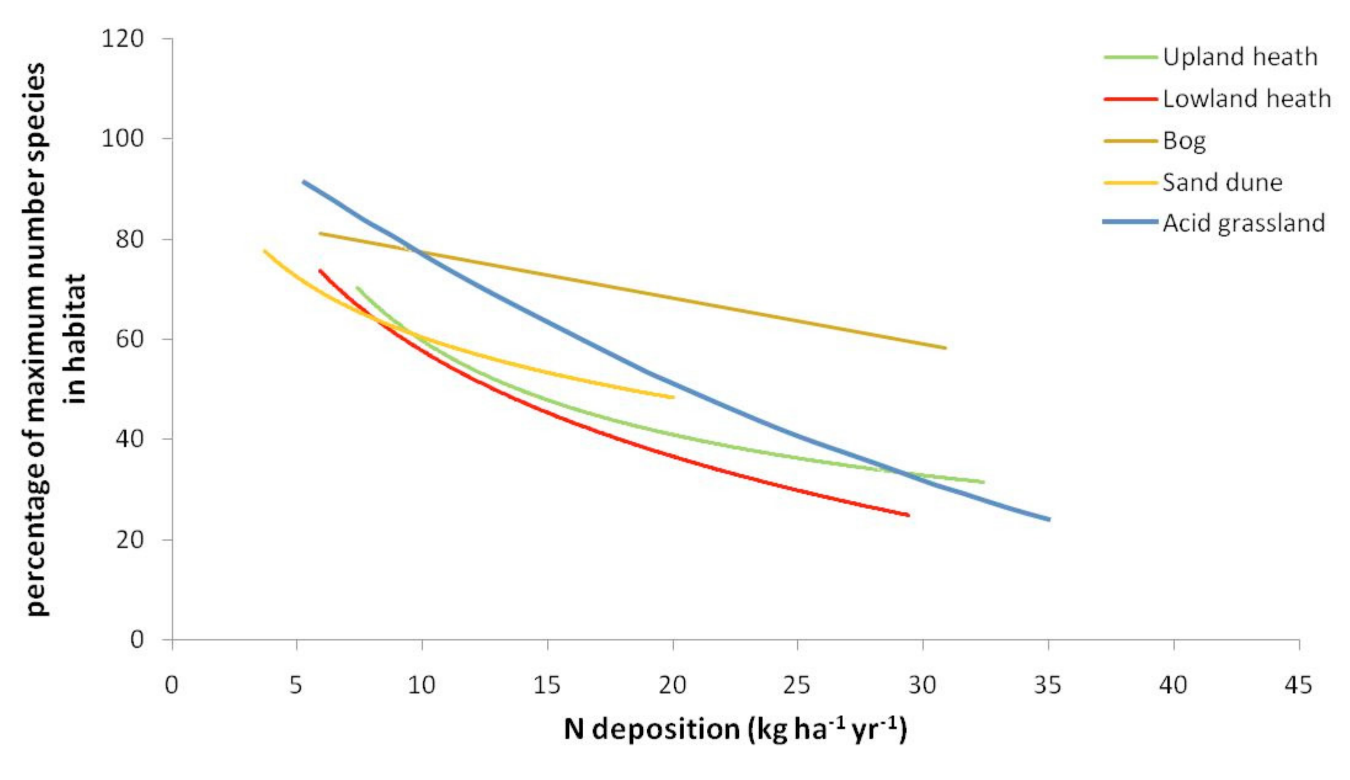


Figure 5 Modelled response curves showing the rate of change in species richness across habitats in response to nitrogen deposition (from Caporn et al 2016).

Another important aspect is that the effects of climate change and air pollution may be mediated by the soil. For example, the effects of acidification can be buffered in a base rich soil, but not a soil that is already acidic. An extreme climatic event may lead to a change in soil chemistry, such as release of nitrogen, which affects the plant community in addition to the direct effects of the extreme event. Monitoring of soil chemistry and biodiversity doesn't normally take place at conservation sites so LTMN offers insight into these factors. It establishes the chain of cause and effect as well as being an important aspect of the environment in their own right.

LTMN is helping us to understand causes and effects of environmental change that will inform how we build resilient landscapes, ecosystems and biodiversity. One key issue is what makes plant communities resilient to change. Long term monitoring starts to give us the evidence to address this. The ECN has been running for over 20 years now and is starting to build up a picture of plant community resilience. It has shown that vegetation plots with more species and species typical of low nitrogen environments show less change in response to year to year fluctuations in the weather (Figure 6; Morecroft et al 2009). This suggests they may be more resilient to some of the shocks that climate change is likely to bring, such as droughts.

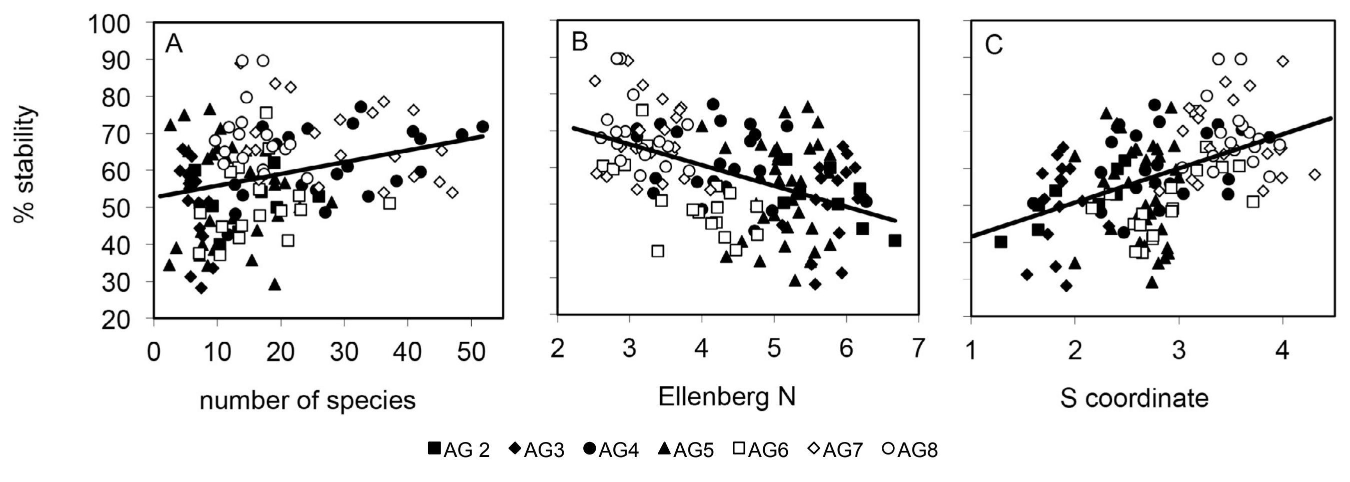
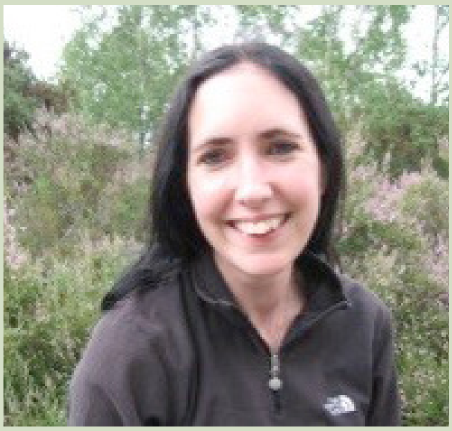


Figure 6 Relationship between the stability of composition of species in the plant community between years and (a) species richness, (b) An index of the extent to which vegetation is composed of species adapted to high nitrogen levels (Ellenberg N value) and (c) Grime S-coordinate and indicator of stress tolerance of species. (Reproduced from Morecroft et al 2009).

The involvement of NNR site managers and their practical experience in LTMN will be critical in making sure that practical lessons are learnt from LTMN and help to ensure good decision making. We can't monitor all conservation areas to the extent that we are monitoring those in the LTMN, but they can act as demonstration sites and pioneers with an influence far beyond their immediate boundaries.

Meet the people – Zoe Russell, Natural England's Senior Specialist for Air Quality

"I work for Natural England as an Air Quality Senior Specialist. My role includes assessing air pollution impacts in England and working with others to find and implement solutions - at national and local levels. One of the best things about my job is that I get to work with lots of different people, both internally and externally, and on lots of different habitat types.



I provide technical advice on the air quality monitoring aspects of the LTMN and also sit on the steering group. One of the great things about the LTMN is the co-location of monitoring because much of our other air quality work has to rely on modelled estimates of air pollution. LTMN is also allowing us to look at the interactions with climate change. It's great news that our LTMN air quality monitoring is being integrated with the wider Defra UKEAP network. Our LTMN air quality data are being 'cleaned' and quality assured and then we will be able to analyse them alongside the vegetation, soils and climate data.

Best of all, I get to volunteer for at least one LTMN vegetation survey each year. In 2016 it was Thursley; this year I grabbed a quadrat and hand lens and headed to Chobham Common. Not only do I get to spend a few days studying one of our many wonderful National Nature Reserves, but I also get to meet so many enthusiastic and incredibly knowledgeable staff and volunteers. The surveys are lots of fun, really well organised and a great excuse to get outdoors and refresh/boost your botanical skills. I look forward to them every year."

2 Sites

Ben Le Bas and Andy Nisbet

Selecting the sites

The Long Term Monitoring Network is made up of 37 sites across England and extends from Lindisfarne in Northumbria and Ludham - Potter Heigham Marshes in Norfolk to The Lizard in Cornwall. Figure 7 shows this geographical spread and some of the environmental variation across the network.

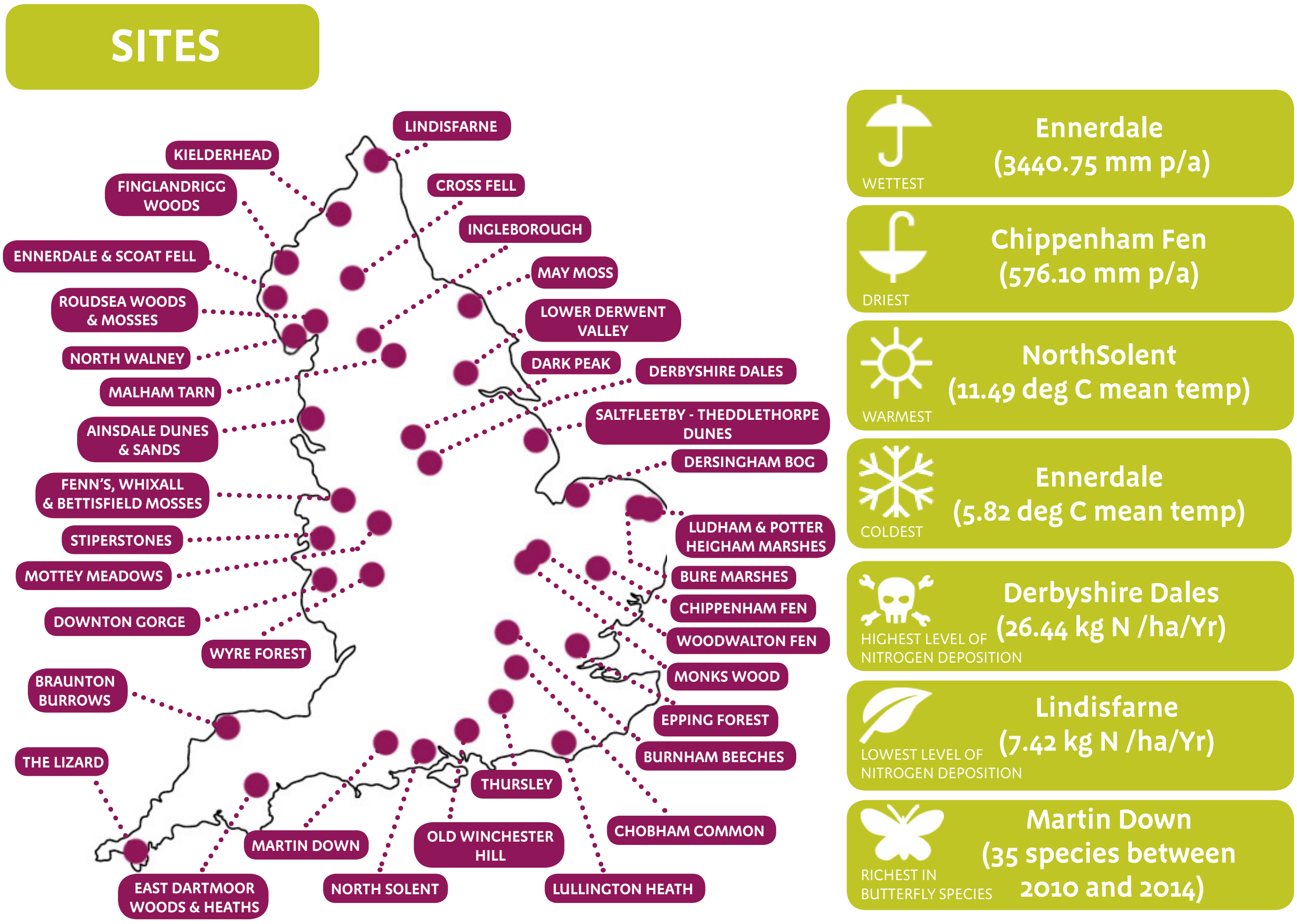


Figure 7 LTMN sites in England.

Site selection was a balance of scientific and practical considerations, such as:

- The need for a broad geographical spread covering a range of different air pollution impacts, predicted changes in climate and landscape types to increase the chances of detecting significant relationships.
- The sites needed to have sufficient area to be representative of one or more of the target habitats as well as the ability to carry out all the different aspects of site monitoring.
- A need for long term security and stability of site management.
- Safe and easy access to set up the plots and return to them to resurvey (eg sites subject to coastal erosion are not suitable).
- The interest from partner organisations and/or site managers was also important in making some choices.
- Sites that were already part of long term studies were chosen where possible, in particular studies that measured the LTMN attributes.

Habitats monitored

There are 56 habitats of principle importance for the conservation of biodiversity in England as listed for Section 41 of the Natural Environment and Rural Communities Act 2006. These are often referred to as priority habitats. The habitats selected for LTMN monitoring were the more widespread, semi-natural, terrestrial habitats found in England. This excluded freshwater habitats, arable field margins and hedgerows and habitats of inland and maritime cliffs. There are ten LTMN target habitats which include seven priority habitats and three broader categories that may include more than one priority type. For example, heathland includes both lowland and upland heath while broadleaved woodland includes a number of woodland priority habitats. Figure 8 shows the number of sites with each of the habitats.

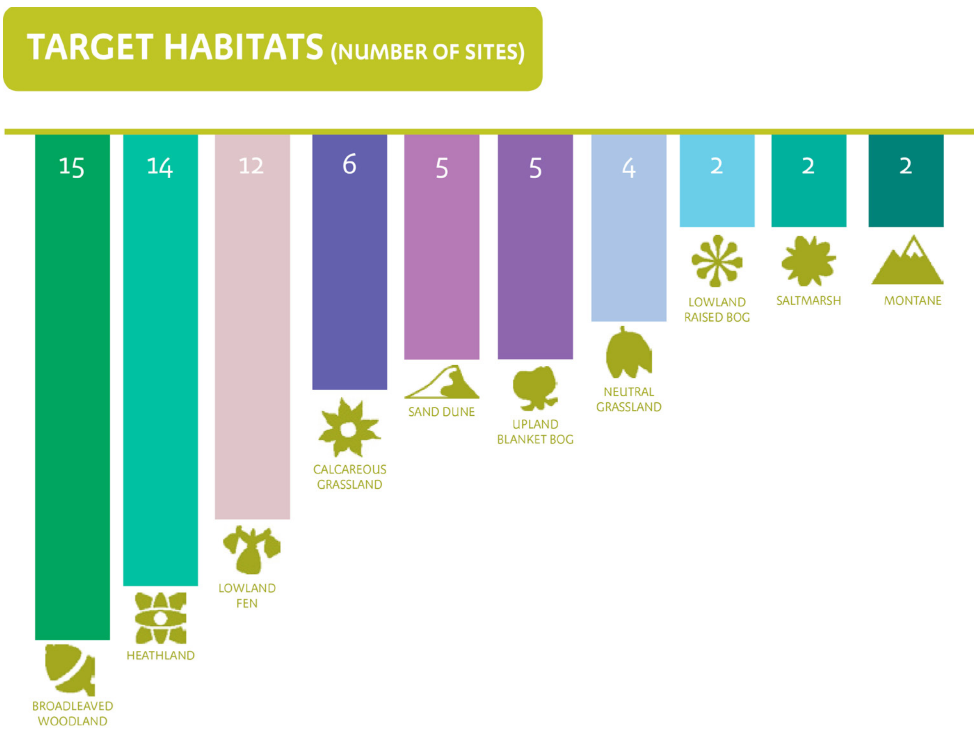


Figure 8 Number of sites with each target habitat.

National Nature Reserves, research and long term monitoring

Our NNRs protect some of our most important habitats, species and geology and, since their inception in 1949 under the National Parks and Access to the Countryside Act, they have had an environmental research purpose. There are 224 NNRs in England today, with a total area of around 94,000ha. All broad categories of SSSI interests and habitat types are represented (**National Nature Reserves open data - NNR001**). Natural England has management responsibility for 143 of the reserves, comprising over 60,000 ha.

The 1949 Act defined the purposes of NNRs as either preservation of wildlife or earth science, or study and research into the same, or both. In fact, some of the first NNRs, such as Monks Wood, were adjacent to environmental research stations and were selected as much for their research value as on their nature conservation merits.

NNRs form the majority of sites in the LTMN for both scientific and practical reasons. They have stability and longevity, they are managed for nature conservation and research is part of their basic purpose. A number also have existing long term monitoring programmes that complement the LTMN.

Monks Wood NNR

© Natural England/Peter Wakely

Figure 9 Monks Wood NNR, Cambridgeshire.

Monks Wood is an exceptionally well-studied 156 hectare reserve in Cambridgeshire and has been a key site in our understanding of the impact of deer on woodland vegetation. The Deer Initiative's widely used Woodland Impact Survey is based on research from Monks Wood NNR (Cooke 2006). The reserve has an extensive bibliography of many hundreds of research publications, everything from pioneering the use of LiDAR remote sensing technology for woodland structure to variations in the territorial hoot of the tawny owl (Gardiner & Sparks 2003; Massey & Welch 1993; Steele & Welch 1973). It was the site of one of the very first UK Butterfly Monitoring Scheme transects; the route was established in the early 1970s and is still walked today. Now operating on over a thousand sites, the UKBMS is one of the complementary datasets used by the LTMN.

Yarner Wood, East Dartmoor Woods and Heaths NNR

Yarner Wood in Devon was the first NNR established in England, in 1952. Now part of a larger reserve known as East Dartmoor Woods and Heaths NNR, Yarner Wood has been used for scientific study from its earliest days. Vegetation survey plots were set up at various times from the 1950s and data collected at intervals since, allowing statistical analysis of trends (Bealey 2015). Some of the LTMN survey areas have been superimposed on woodland plots which were first surveyed in 1974. Yarner Wood is also well known for its long-running study of pied flycatchers. Nest boxes were erected in the 1950s. They were intended for the study of other hole-nesting species, because pied flycatchers were not then present on the site, but the pied flycatchers using them have been studied ever since they moved in.

© Mark Taylor

Figure 10 Pied flycatcher in East Dartmoor Woods and Heaths NNR, Devon.

Not only are there detailed breeding records going back to the early days, but the population is also used for other research. For instance, there is a current study comparing the migratory routes and West African wintering grounds of several north western European pied flycatcher populations using small geolocators weighing just over half a gram. Data indicate that flycatchers from different breeding populations use different wintering sites, despite using similar routes during most of the autumn migration, perhaps resulting from variation in breeding times and in food availability prior to their return to their breeding locations (Ouwehand et al 2015).

Moor House - Upper Teesdale NNR

The roots of the evidence function of NNRs are in national-level studies; some are international, such as the major study of the ecology of peatlands at Moor House - Upper Teesdale NNR that was the UK's major contribution to the International Biological Programme (1964 – 1974). This was a cross-continent collaboration exploring the relationships between habitat productivity and human welfare in which the reserve was grouped with tundra sites in Russia, America and northern Europe. This intensive study added significantly to the scientific understanding of our uplands (Heal & Perkins 1968).

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Figure 11 Long term experimental plots on Moor House - Upper Teesdale NNR, County Durham.

Like Yarner Wood and Monks Wood, current research at Moor House builds on and demonstrates the value of data collected in the past, such as the study of the relationship of sheep grazing and vegetation which analyses nine long term experiments undertaken between 1954 and 2000. The results indicate that, on the one hand, grazing homogenises upland plant communities but, on the other, simply reducing sheep numbers does not necessarily deliver the right conditions for key plant species groups (Milligan et al 2016).

Similarly, the reserve has a series of plots that have been burned on 10 and 20 year rotations since 1954, providing invaluable data for the study of the impact of burning on upland ecosystems. The results have been described in an extensive series of reports and papers (summarised in Glaves et al 2013). Results indicate that differences in frequency of burning affect the vegetation composition and structure of blanket bog. At Moor House, more frequent burning has stimulated dominance by hare's-tail cotton grass, whilst heather achieves higher cover under the longer rotation. The reserve is an important component of the Environmental Change Network; important recent research includes work on the influence of different moorland plant communities on greenhouse gas emissions, revealing how heather-dominated vegetation increases the amount of CO_2 taken up in a warming climate whilst cotton grass has the opposite effect (Ward 2013).

Meet the people – Dave Mercer, Senior Reserve Manager, Ainsdale Sand Dunes NNR

Dave Mercer is the Senior Reserve Manager on the Ainsdale Sand Dunes NNR on the Sefton Coast in Merseyside. The open dunes are the priority habitat on this 508 hectare site for the diverse range of species they support and much of Dave's effort is spent managing this habitat to prevent scrub invading. This is done by cutting down young scrub and winter grazing with Shetland cattle and Herdwick sheep brought down from the Lake District. As well as the open dunes the reserve has 170 ha of pine forest, which is loved by many visitors to the site and is a sanctuary for red squirrels. There is also a site for a Forest School, which is used by local schools and a number of teachers are training for their Forest School Skills qualifications.

© Tony Meadow

Dave gets help from the NNR team, 70 registered volunteers and a range of organised groups including a mental health group and a group recovering from drug addiction. There are plenty of visitors and Dave also works with partners such as the National Trust, Wildlife Trust, Sefton Council and others. Dave and the NNR team hosted the LTMN vegetation surveys in 2012 and 2016:

"There is a lot of preparation before the survey starts. First we need to locate the permanent markers which can be tricky. After the experience of the 2012 survey, in 2016 we located all the plots before the survey team arrived. Even with volunteers and student placements this took time and the plots in the woodland were particularly difficult. People also needed accommodation organising as they came from all over the country. Some camped and others stayed in local hotels. There were also evening events to organise, hot drinks, particularly when it was cold, as well as risk assessments and logistics. For example: Where would people park their cars that wouldn't block emergency routes or the door to the Land Rover used to fight forest fires?"

But for Dave it was worth it: *"It was great to be involved in the survey and to have the opportunity to see the reserve 'through the lens of botany'. Although I'm responsible for the management of the reserve, a lot of my time is spent the office or attending meetings. Spending time studying the species growing on the reserve in the company of botanists and other experts reminded me just how diverse and important the reserve is. The survey gave me the chance to improve my identification skills and at the same time teach other people. I particularly enjoy the camaraderie of the surveys, it was fun to have the office packed with people at the start and finish of each day, even if they were a bit damp and drank all the coffee!"*

3 Partnerships and investment

Susie Smith, John Holdsworth and Rob Keane

LTMN is a complex project and gathering and analysing the data requires significant co-operation across Natural England and with our many partners. The group effort includes partners who are involved in managing sites, gathering and managing the data, as well as providing specialist advice on survey methods and quality assurance of data. Some data can only be collected using highly technical equipment, other data is collected by volunteers walking the site with pencil and paper. Here are a few examples of some of the partnerships that make up the network.

Partner sites

Figure 12 Burnham Beeches NNR, managed by the Corporation of the City of London.

Most of the sites that make up the network are owned and managed by Natural England, but to get the right sample of habitats across the country the network includes eleven sites that are partly or wholly owned or managed by other organisations. The enthusiasm of these organisations and their site managers has been crucial to the success of the network. LTMN partners include the Forestry Commission, who own and manage parts of the Wyre Forest, May Moss and part of Kielderhead, the National Trust (Dark Peak and part of Malham Tarn), the Field Studies Council (part of Malham Tarn), the Corporation of the City of London (Epping Forest and Burnham Beeches), the Christie Devon Estates Trust (Braunton Burrows), Surrey Wildlife Trust (Chobham Common), Yorkshire Wildlife Trust (Lower Derwent Valley), Northumberland Wildlife Trust (part of Kielderhead), and Natural Resources Wales (part of Fenn's Whixall and Bettisfield Mosses).

The Met Office and meteorological data

Figure 13 Automatic Weather Station managed by the Met Office at Kielderhead NNR, Northumberland.

Most of the LTMN sites have an Automatic Weather Station (AWS) which records different meteorological variables. Some sites are already close enough to Met Office weather stations for those data to be representative of the LTMN site.

Natural England originally maintained its own weather stations on LTMN sites but in 2014 we entered into a partnership with the Met Office, who now deliver, install and manage the LTMN weather monitoring network. Both organisations want a better understanding of how ecosystems are responding to changing climate, to what extent these changes vary across the country and what mechanisms underlie these changes. This information will help us better model, predict and mitigate the impacts of climate change on ecosystems and on ecosystem services.

Data from AWSs are automatically uploaded to **Weather Observations Website (WOW)**. This website allows for the sharing of current weather observations from all around the globe. The data should also be available on data.gov in 2018.

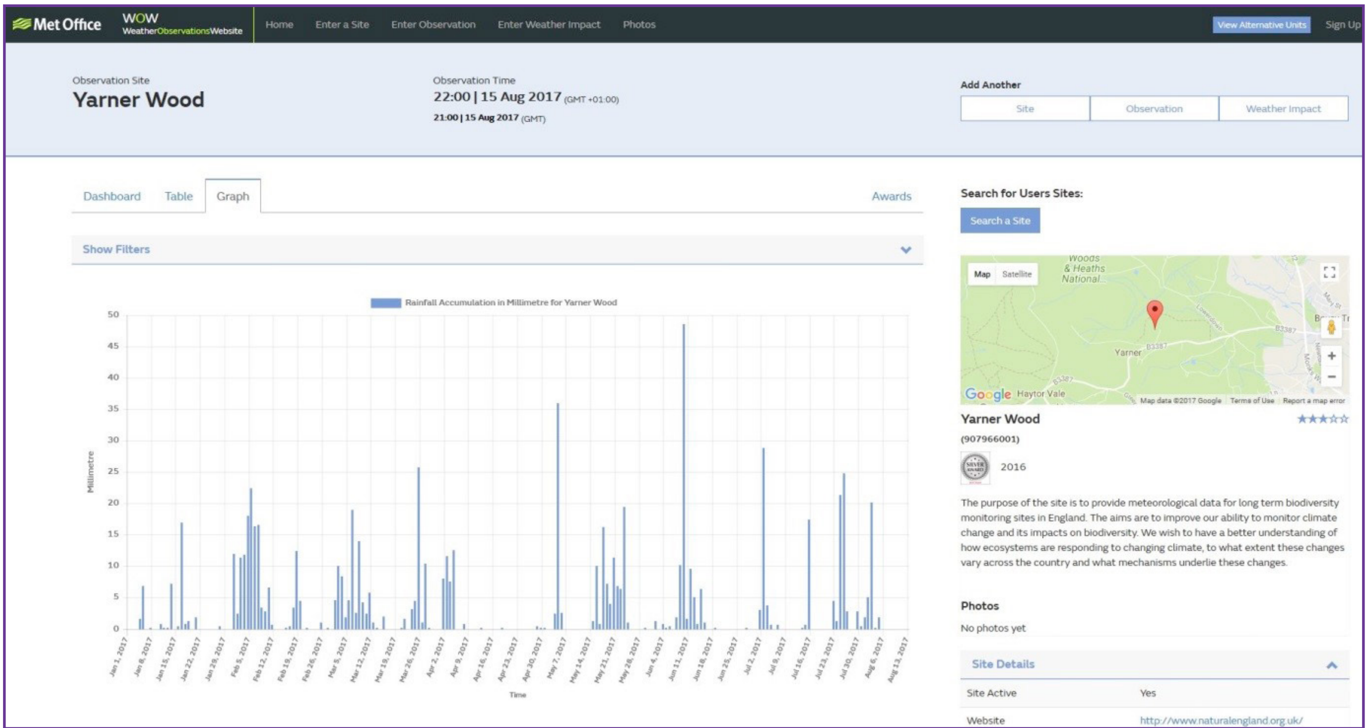
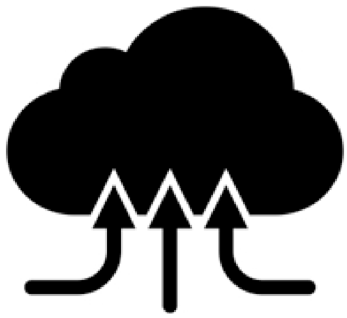


Figure 14 Rainfall rate (mm/hour) from 1 January to 15 August 2017 at Yarner Wood (East Dartmoor Woods and Heaths NNR) LTMN weather station; viewed on the Met Office's WOW site.

"Managing a network of automatic weather stations on behalf of Natural England has benefited the Met Office by increasing the number of high quality meteorological observations available to inform our world-leading weather and climate services. Managing these sites as part of our own observation network has worked very well for both the Met Office and Natural England, ensuring that observations taken at the LTMN sites are reliable, timely and accurate."

Jake Brown, Observations Partnership Manager, Met Office

UK Eutrophying and Acidifying Pollutants Network



LTMN collects atmospheric ammonia, ammonium, precipitation and soil chemistry readings to help understand nitrogen deposition and how it influences plant and soil communities in the long term. Measuring both precipitation and soil chemistry, combined with some other data, allows us to track the total nitrogen deposition from the atmosphere through into the soil as nitrates.

The UK Eutrophying and Acidifying Pollutants (UKEAP) Network brings together a number of atmospheric pollution monitoring networks run by Defra and the Environment Agency. In 2016 LTMN sites became part of UKEAP. Integrating the air quality element of LTMN into UKEAP has led to efficiencies in data collection and also improved the quality of data. Being part of UKEAP also allows LTMN data to be more easily shared as open data using the **UK AIR data portal**. The data can contribute to model outputs and supports wider research and collaboration to help improve our understanding of the long term impacts and interactions of air pollution and climate change on biodiversity. Working in partnership with the Environment Agency and UKEAP helps us to ensure our data is quality assured to UKEAP standards and to understand the robustness of our air quality data.

"This Partnership with Natural England has added extra air quality monitoring sites to the UKEAP network. This will contribute to the data needs of both the Environment Agency and Natural England and is a great example of how our two organisations can work together to deliver cost efficiencies whilst meeting our individual organisation's required outcomes"

Jo Scully UKEAP Project Manager

International

Since 2009 LTMN has contributed to and complemented the wider Environmental Change Network. ECN is the UK node of the International Long Term Ecological Research Network (ILTER) and its European regional network, LTER-Europe.

Resources and investment

In 2011 a LTMN project report (Nisbet at el 2011) presented a business case for Natural England's development of a LTMN with 40 sites. Table 2 shows the projected and actual programme costs from 2011 to 2016 (excluding the cost of staff time).

Year	Projected costs (2011)	Actual costs
2011	£97,580	£142,000
2012	£127,893	£164,446
2013	£145,688	£182,723
2014	£168,760	£178,976
2015	£168,760	£87,485
2016	£168,760	£107,871
Total	£877,441	£863,501

Table 2 Projected and actual programme cost of LTMN development (2011 to 2016).

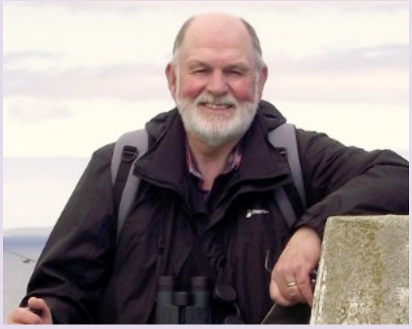
The actual programme costs have been very similar to the projected costs although for a current network of 37 rather than 40 sites. Costs were higher initially but have been lower in recent years. There was also significant capital expenditure of £156,000 in 2012 on weather stations as part of the partnership agreement with the Met Office.

The recent lower levels of expenditure has been partly in response to the pressures on public sector spending which have affected Natural England's Evidence Programme budget and, as a consequence, funding for LTMN. However, this has also been a driver for managing the network and delivering the monitoring more efficiently, eg by developing the UKEAP partnership. In 2016 the total programme spend equated to a unit cost of £2,915 per site.

Natural England staff, partner organisations and volunteers are also essential to delivering LTMN. The work is led and managed by a small team within Natural England's Evidence Services Team and relies on time from NNR site managers. Time from Natural England staff (including site managers but excluding volunteers on the in-house surveys) is approximately 4 FTE per year.

Meet the people – Ron Moyes is a volunteer who monitors the butterflies at Ainsdale Sand Dunes NNR

"I survey butterfly species and numbers which involves walking a transect (a set route) each week from the beginning of April to the end of the season, (the end of the season at Ainsdale is usually late September) and recording what I see. The transect has 13 "legs" of varying lengths matching the changes in the habitat along the route to give a cross-section of what the reserve is about; eg leg 1 is mainly along a firebreak cut through pine woodland, whilst leg 10 is on top of the frontal dunes, at the coast. Different habitats usually hold different species, but some species can be found anywhere on the reserve.



© Christine Moyes

I try and pick a day of the week with sunny weather forecast, but sometimes this doesn't work out and I just make the best of it. As I walk along I record numbers against species on a standard recording form and other relevant information, eg percentage of sunshine and average temperature, wind speed and direction, start time and finish. At the end of each leg I also enter notes on any other observations. In spring, this is often noting migrating birds. This year I was worried I had missed the wheatears on passage, but joy I clocked one! In summer, more usually I record sightings of day flying moths and that other speciality of the Sefton Coast, the northern dune tiger beetle. Red squirrels are always a pleasure to see and earlier this year I had a wonderful face to face with a stoat.

© Natural England/Julian Dowse

Figure 15 Dark green fritillary butterfly.

Butterfly numbers fluctuate considerably. In 2016, which was considered a poor year, I recorded 21 different species and 1435 individuals. The most uncommon butterfly was a single brimstone and the most plentiful was gatekeeper at 446 records. Our speciality butterflies at Ainsdale are dark green fritillary (55) and grayling (15). It was quite a good year for the immigrant painted lady (15) and we recorded ringlet on the Reserve for the first time in 2016. It wasn't on the transect, but was quite close. Hopefully it has come to stay. Sometimes I meet someone who has seen something I've not seen on the transect.....I just grit my teeth, think dark thoughts and press on!

I volunteer because I feel that I am giving something back to nature, the reserve and the reserve staff for the pleasure I get from spending time on the reserve and in the countryside in general. I trust that my records, and all those from other recorders, will help to ensure that correct decisions are made for our countryside for future generations to enjoy. I didn't volunteer for any benefit but I now realise that there are tremendous benefits in health, in social contact, in knowledge, in enjoyment, in contentment. For me it is a win-win. I recommend volunteering and where better than on a National Nature Reserve?"

4 Monitoring vegetation

Andy Nisbet and Christoph Kratz

The species composition of vegetation is an important aspect of biodiversity and vegetation provides the habitat for animal species. Monitoring the changes in abundance of individual plant species and the makeup of the community as a whole will provide valuable information on what is driving change and what that change means for the conservation value of the site.

How do we monitor vegetation?

Every site in the LTMN has permanently marked plots located within one or more of the target habitats. Permanently marking the plots means that the same area is examined each time and this is a more efficient way of detecting consistent change. Most sites have 50 plots and the vegetation is surveyed every 4-5 years. Baseline surveys were completed between 2010 and 2015 and repeat surveys began in 2013. Figure 17 shows the proportion of plots in each target habitat (out of a total of 1,803 plots across the network).

Figure 16 Recording plant species present in vegetation monitoring plots, Malham Tarn NNR.

Broadleaved woodland is the best represented habitat and is present in 19% of all plots. Heathland, lowland fen, sand dune, calcareous grassland and blanket bog all occur on 10% or more of the plots and at five or more sites. Neutral grassland, lowland raised bog, montane habitats and saltmarsh are only monitored at two or three sites each, although they are intensively sampled on those sites. The least well sampled habitat is saltmarsh, with 43 plots on two sites.

Nearly 8% of plots are in 'non-target habitat'. These plots are often included to provide site managers with information on the condition of other important habitats or on the effects of management activities, eg there are plots in the coniferous woodland at Ainsdale, on limestone pavement at Malham Tarn and in wetland restoration areas on Woodwalton Fen.

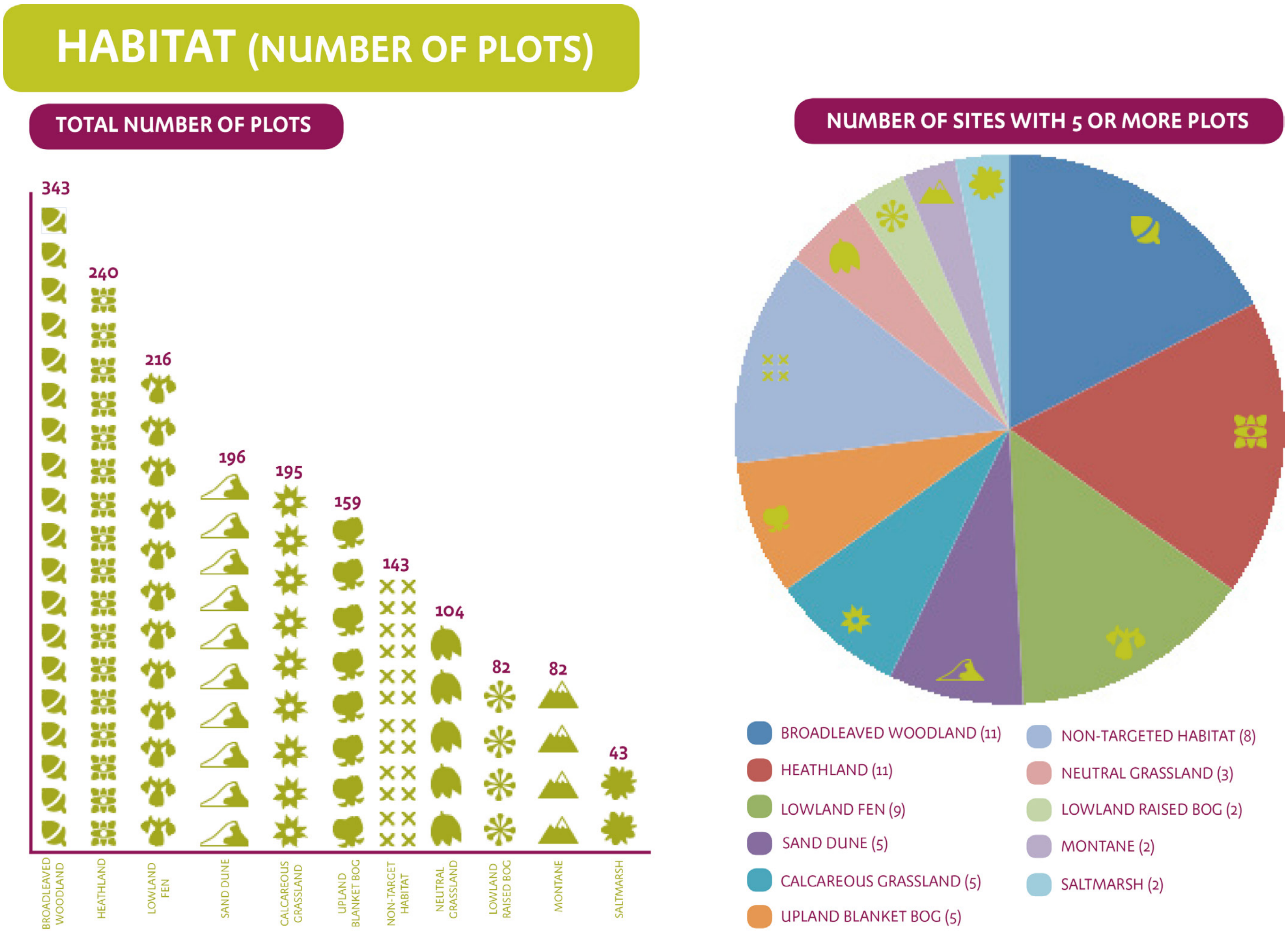


Figure 17 Frequency of habitats in the vegetation monitoring plots.

Each plot is a 2m by 2m square which is divided into 25 cells of 40cm by 40cm. The vascular plants and bryophytes present in each cell are recorded and then the proportion of the 2m square covered by each species is estimated (percentage cover). Surveyors record bare ground, vegetation height, slope and aspect. Additional information is recorded in woodland from a larger area around each plot. The full methodology is published on our Access to Evidence Catalogue **Long Term Monitoring Network Methodologies (LTMN001)**.

Analysing the data

The data recorded during the surveys can be analysed in a number of ways to characterise the vegetation, assess its condition and identify changes. We can do this at different spatial scales - for individual sites, target habitats and the network as a whole.

Vegetation structure and physical characteristics

As well as the detailed data on composition, the surveys also collect data on physical characteristics (such as altitude, slope and aspect) and vegetation structure (such as vegetation height and the amount of bare ground and litter present). Some attributes, such as slope angle, will vary between plots and vegetation types but are not expected to change over time. Others may vary between vegetation types and change over time in response to changes in climate, air pollution or management, eg vegetation height.

Species richness

The baseline surveys recorded 1,071 separate species of vascular plants (838) and bryophytes (233). The vast majority of species are found at low levels across the network. A few species are recorded much more frequently but these are often associated with particular sites or habitat types. For example, there is no overlap between the ten most frequently recorded species on calcareous habitats and on bog habitats (see Tables 3 and 4).

Scientific name	Common name
Eriophorum vaginatum	Hare's-tail cotton-grass
Calluna vulgaris	Heather
Eriophorum angustifolium	Common cotton-grass
Erica tetralix	Cross-leaved heath
Hypnum jutlandicum	Heath plait-moss
Vaccinium oxycoccus	Cranberry
Empetrum nigrum	Crowberry
Calypogeia muelleriana	Mueller's pouchwort (a liverwort)
Andromeda polifolia	Bog rosemary
Deschampsia flexuosa	Wavy hair-grass

Table 3 Ten most frequently recorded species on bog habitats.

Figure 18 Hare's-tail cotton-grass at Malham Tarn NNR, Yorkshire.

Figure 19 Heather at Dersingham Bog NNR, Norfolk.

Scientific name	Common name
Festuca rubra	Red fescue
Carex flacca	Glaucous sedge
Plantago lanceolata	Ribwort plantain
Sanguisorba minor	Salad burnet
Agrostis capillaris	Common bent
Leontodon hispidus	Rough hawkbit
Lotus corniculatus	Bird's-foot trefoil
Rubus fruticosus	Bramble
Festuca ovina	Sheep's fescue
Veronica chamaedrys	Germander speedwell
Galium verum	Ladies bedstraw
Holcus lanatus	Yorkshire fog

Table 4 Ten most frequently recorded species on calcareous habitats.

Figure 20 Calcareous grassland species at Old Winchester Hill NNR.

The number of plant species recorded in each survey varied from 348 species at Ingleborough to only 49 at Dark Peak. This is primarily related to habitat, with calcareous habitats (eg Ingleborough, Martin Down, Malham Tarn and Old Winchester Hill) being the richest, and bog habitats (Dark Peak, Fenn's, Whixall and Bettisfield Mosses) the poorest. The richest individual plot was on Old Winchester Hill which contained 64 species. Geographical variation within habitats is also noticeable, such as among sand dune sites (from 231 species on Braunton Burrows to only 121 species at North Walney).

Indicator species

Changes in abundance of individual species or groups of species provide valuable information on sites and their condition. In Chapter 6 the changes in abundance of individual species between surveys show how vegetation on Thursley NNR is recovering from a damaging fire.

The frequency of occurrence of groups of species can be used as positive or negative indicators of habitat quality. Positive indicators are species that are often frequent or occasional in vegetation that is in good condition. Negative indicators are often more ubiquitous species that indicate a decline in quality through disturbance or nutrient enrichment eg nettles or docks. Figure 21 shows the frequency of abundance at the plot scale of selected positive indicator species recorded on two surveys, ie the proportion of cells within a plot in which a species was recorded.

Indicator species are often part of Common Standards Monitoring guidance (JNCC 2003) which is used by Natural England when assessing the condition of features on Sites of Special Scientific Interest. Data from LTMN surveys contributes to these assessments.

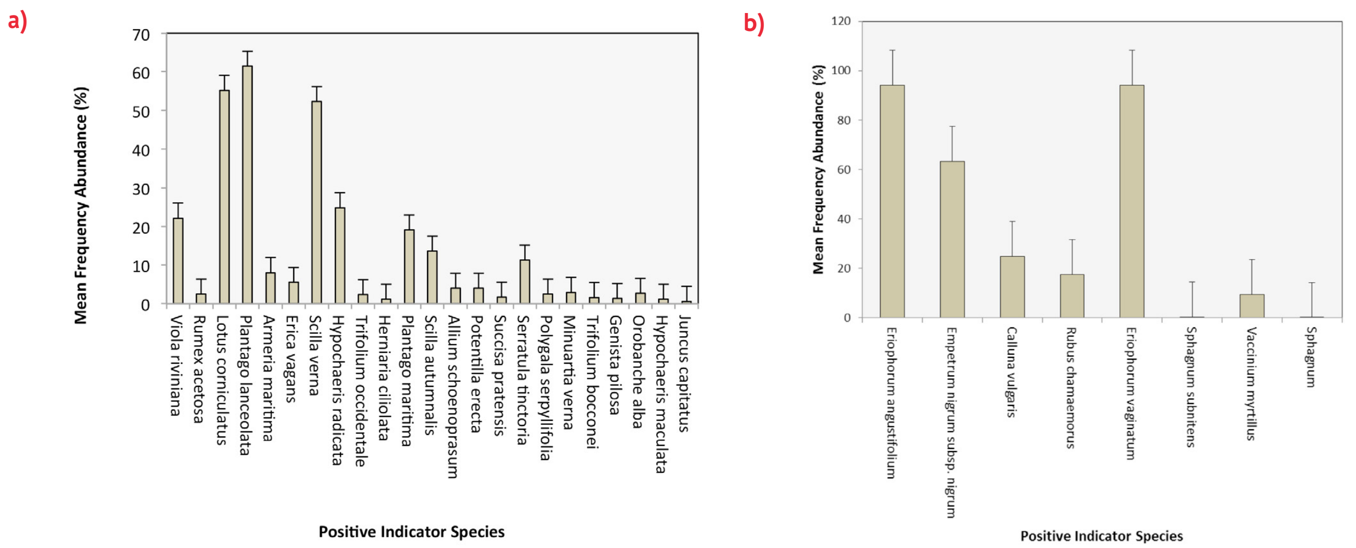


Figure 21 The mean frequency abundance of selected positive indicator species at a) the maritime grassland habitat at The Lizard NNR (2013) and b) blanket bog habitat at the Dark Peak (2014).

Vegetation communities

The species composition of the plots can be analysed to assign them to a vegetation community in the National Vegetation Classification (NVC) and the distribution of these communities can be mapped. Figure 22 shows the distribution of NVC mire (M) (Rodwell 1991) and swamp and tall-herb fen (S) (Rodwell 1995) communities and sub-communities on Chippenham Fen NNR in 2013. NVC analysis was done using the Modular Analysis of Vegetation Information System (MAVIS) (Centre for Ecology and Hydrology 2013).

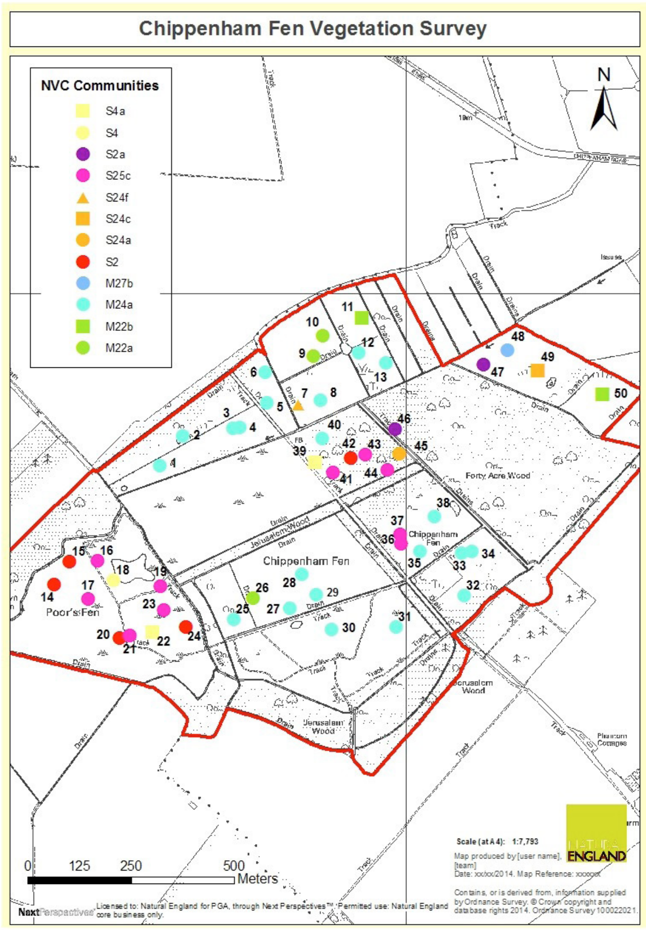


Figure 22 Map showing positions of quadrats in Chippenham Fen NNR and their NVC classifications based on results from MAVIS.

Analysing vegetation data across habitats

Analysing data on individual species, groups of indicators and vegetation type is useful when considering individual sites or habitats. However, as Tables 3 and 4 illustrate, there is a large variation in community composition between habitats and that makes it difficult to make network wide comparisons.

It is possible to make such comparisons by looking at the environmental preferences shown by different species. Plant trait indices are very powerful when used in conjunction with environmental information about a site. One way of doing that uses the Ellenberg scheme (modified for the UK by Hill et al 1999) which classifies plants according to their observed preference for environmental factors such as fertility, wetness, acidity and light. The higher the Ellenberg score for a species then the stronger its preference is for that parameter. This approach brings all species into the same index so that mean values can be calculated for each plot. It allows comparisons to be made between vegetation on very different sites.

Species can also be classified according to basic strategies of competitor, stress tolerator and ruderal (Grimes 1977). Competitors will do better in areas with low levels of environmental stress and disturbance. Stress tolerators will live in habitats with high levels of stress but low levels of disturbance. Ruderal species will favour areas with high disturbance but lower levels of environmental stress.

Figure 6 (in Section 1) illustrates how different ways of characterising vegetation (species richness, Ellenberg and Grimes) have been used to look at relationships with the stability of plant community composition.

Ellenberg indices can help us examine habitats on individual sites and the differences between them. Figure 23 shows mean Ellenberg values for plots on lowland heathland and maritime grassland plots on The Lizard in 2013. These show similarities in mean values for light and fertility but differences in wetness and pH.

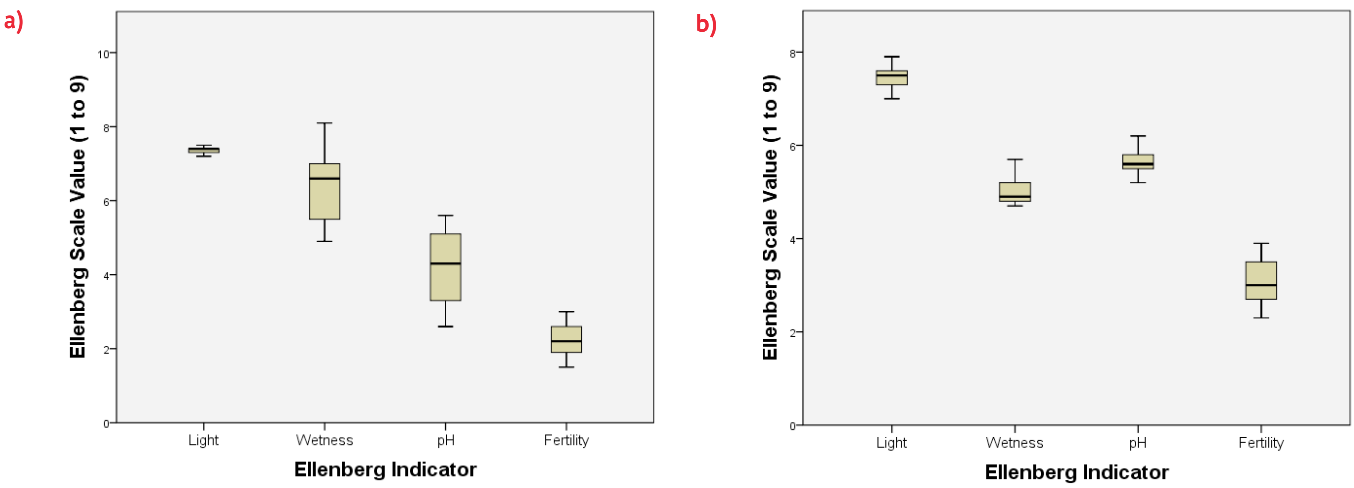


Figure 23 Boxplot showing the Ellenberg Indicator values for variables in the a) Lowland Heath habitat and b) Maritime grassland habitat on The Lizard NNR.

This approach also helps us understand differences in the same habitat on different sites. For instance, Figure 24 shows that the Ellenberg moisture index on heathland plots is highest in the coastal and more westerly sites, and lowest on inland and easterly sites. It is also noticeable that some sites (eg Chobham Common (CHB) and Dersingham Bog (DRS)) have a wide range of Ellenberg moisture values, whereas others (eg May Moss (MAY)) have a very narrow range. This may change if changing climatic conditions affect the vegetation composition.

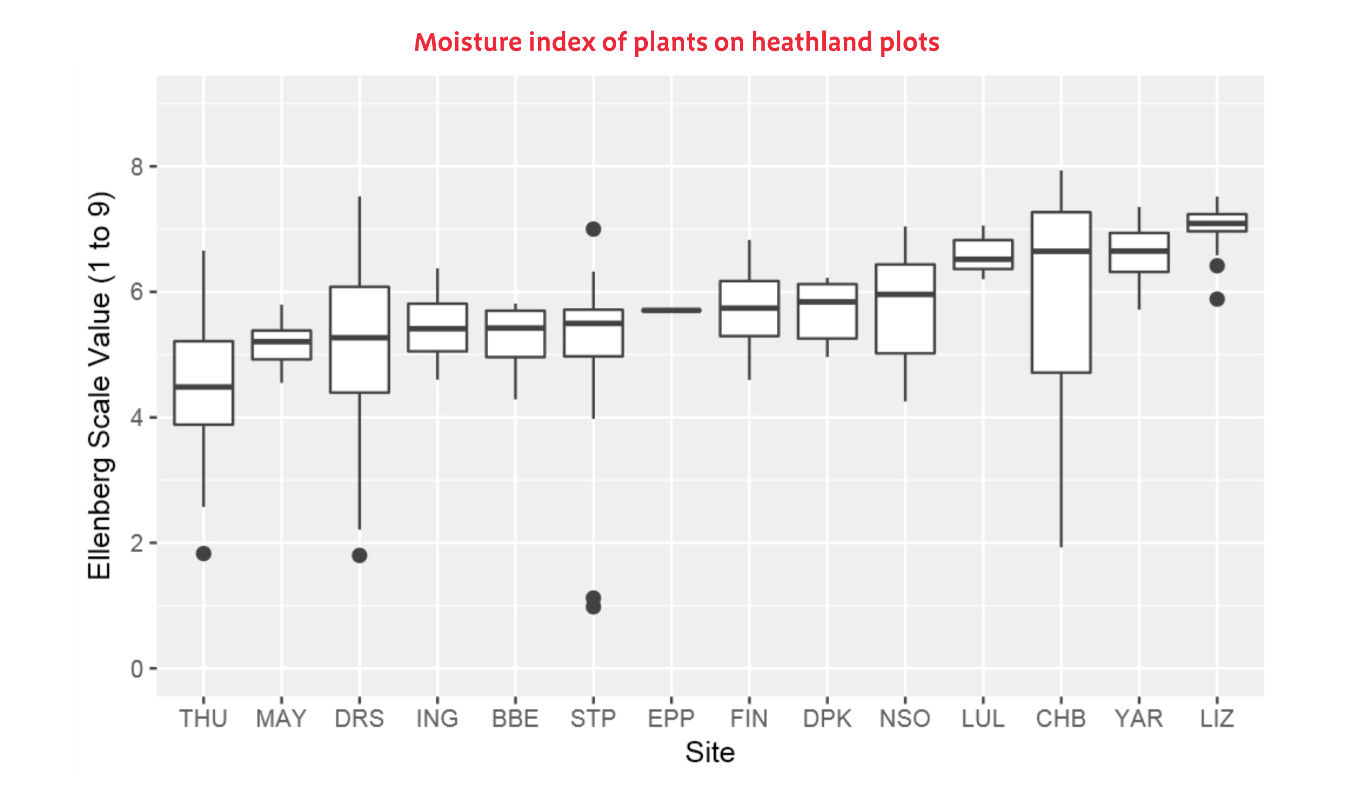


Figure 24 Boxplot showing the Ellenberg moisture index on heathland plots across 14 sites.

Meet the people – Dan Pedley helps out with the vegetation surveys

© Natural England/Rob Keane

Dan first volunteered as a surveyor on a Long Term Monitoring Network (LTMN) survey in 2013, when he was a Natural England Support Adviser in Technical Services. He had an ecology degree, some botanical knowledge, and career aspirations to move into terrestrial biodiversity work.

"On my first survey at Malham Tarn I quickly discovered the limitations of my botanical skills, but also found the survey was a great way to improve these through repeated and detailed recording of all the plants in the cells, helped by knowledgeable team leads and 'roaming' experts. I also picked up other skills, such as how to measure slope angle using a clinometer, and how to use the GPS to locate the permanent markers.

I subsequently became a regular volunteer on LTMN surveys – in the process learning the methodology inside-out – and began to help with organising survey kit and logistics. I learnt what paperwork is needed, how the field guide library system works, and what box the radio chargers are kept in, amongst other things. My botanical skill level increased over time, along with my confidence in coaching others in ID skills and survey methods, and I now regularly lead survey teams on surveys.

The skills I have developed as a surveyor (and later a team lead and helper) on LTMN surveys have played an important role in my career progression. In 2015 I moved from Technical Services to be a Terrestrial Biodiversity Adviser in our Cheshire to Lancashire Team, a role in which I use my botanical knowledge and survey experience to help deliver the Area Team's fieldwork and site assessments. I continue to volunteer on LTMN surveys, both as a way to refresh and further develop my field skills, and also to catch up and share skills with old friends and new volunteers."

5 Monitoring soils

Matthew Shepherd

Why are we monitoring soils?

Soils are a structured mixture of mineral material, air, water, organic matter and organisms. They underpin, and are part of, all terrestrial ecosystems. The ecosystem services delivered by soils and the organisms that inhabit them are hugely important for life on land, and include the cycling, storage and release of carbon, nutrients and water. Soils mediate the flow of water through landscapes, and provide a growing medium for crops.

Soil biodiversity is astonishing. Approximately one quarter of all animal species are thought to be soil dwellers, as are most plants. Many animal species rely on the soil as much as we do. The microbial diversity of soil is vast and its genetic and chemical diversity provides numerous medicines, pesticides and industrial biochemicals.

Monitoring our soils can help us understand how soils work, how soil characteristics are related to each other and how soil conditions differ between different habitats. Future monitoring should help us assess whether changes in soil properties can be related to changes in climate, pollutant deposition and land management, and enable us to identify the most sensitive indicators of these changes in the soil.

The monitoring data will also provide an understanding of the range of soil biodiversity in England associated with our most valued conservation habitats, and help us identify whether rare and unusual habitats are associated with rare and unusual soil organisms. It should help reveal whether our soil biodiversity is declining, or keeping pace with environmental change, and how it may be responding to changes, such as the reduction of acid deposition.

Comparing the LTMN soils data with the vegetation data should help us understand the soil conditions required by the plants in our valued habitats, and how these interact with the soil biological community.

How we monitor soils

Soils are monitored on a rolling programme that began in 2011. In 2016 the programme completed its first baseline monitoring of all 37 sites.

A wide range of chemical, physical and biological parameters are monitored. To ensure our data is both reliable and compatible with past efforts, the measurements used for LTMN soils monitoring were selected for their reliability and their extensive use in other surveys and the samples are taken in ways that are compatible with previous surveys.

For the baseline soil surveys the vegetation data and aerial photos were used to select a shortlist of sampling points that aim to represent a single vegetation type on each site. Five sampling points were selected and sampled using the protocol below.

Each sampling point is visited within the period September 15th and October 15th for field assessment and soil sampling. The yellow marker that indicates the associated vegetation plot is relocated, a 20m by 20m soil plot offset from this location is laid out and an additional permanent marker is placed at its most distant corner.

Plot photos are taken, and four 2m by 2m subplots are marked out. Photos are taken of the vegetation on the subplots and a quick vegetation survey completed. For each sampling plot a soil auger is used to extract, photograph and describe the soil profile to up to 1 m depth (texture, colour and depth of horizons) at one subplot. From all other subplots soil samples are collected and bulked together for analysis.

Plastic tubes of various sizes are cut into the ground to retrieve intact samples of topsoil for soil mesofauna (visible invertebrates that can pass through a 2mm diameter hole) and nitrogen mineralisation and further samples from 0-15 cm and 15-30 cm depths are collected for analysis of physico-chemical soil properties. A long narrow trowel is used to collect 2 further samples for microbial community and nematode community analysis. On peaty sites a Russian auger is used to collect intact peat samples down the peat profile and peat depth is measured using metal rods for all 4 sub plots.

All the samples are transferred to cold storage to help slow microbial changes, and then sent to the James Hutton Institute for analysis. The chemical analysis includes:

- moisture content;
- bulk density;
- loss on ignition (soil organic matter content);
- pH;
- total carbon and nitrogen;
- extractable cations Fe, Al, Mg, Mn, K, Ca, Na, H;
- mineralisable nitrogen using the method developed for the Countryside Survey.

Biological measurements include indications of:

- soil microbial biomass and community composition;
- soil microbial genetic diversity;
- soil mesofauna;
- soil nematodes.

All data are collated into a spreadsheet and the protocols used and the results are publicly available at **Long Term Monitoring Network soils data (LTMN002)**.

Figure 25 Field sampling a) lateral photo of subplot showing vegetation height (North Walney, 2015); b) sampling for physico-chemical characteristics at 15 to 30cm (Mottey Meadows, 2014); c) taking an auger for soil profile description (Dark Peak, 2016); d) a podzolic gley soil profile ready for description (Chobham Common, 2014).

Results

So far only baseline surveys have been completed, so we are not yet able to detect changes in the soils monitored over time. However, the wide range of different semi-natural habitats sampled has provided a broad overview of the nature of soils in England that have enabled some conclusions to be drawn.

Organic matter

- Many soil physical and chemical conditions are clearly correlated with organic matter content (% of dry weight) as measured by loss on ignition.
- Around 85% of the variability of soil water content can be predicted from organic matter content despite different weather conditions during the 6 years of baseline surveys.
- The soils with the highest organic matter content represent waterlogged peat with almost no volume of air or mineral material. The density of both topsoils and subsoils was negatively correlated with organic matter.
- The ability of soil to hold onto plant nutrients increases with increasing organic matter.

Soil microbial communities

Soil biological communities are driven by organic matter content and by soil chemistry, in particular by pH. The amount and composition of microbial cell wall constituents (Phospholipid Fatty Acids: PLFAs) are used alongside microbial genetic techniques to indicate the diversity of the microbial community. Analysis of these results from all 37 sites has shown:

- Microbial communities are distinctive between many of the sites, although there are some clear areas of overlap between sites with similar vegetation or soil chemistry.
- Sites that have more similar communities are generally those with sandy soils with low organic matter content, low water content and high bulk density.
- Sites with peaty soils generally have more variable communities.
- Fungi are likely to be more prevalent in low-nutrient substrates (see Figure 26).

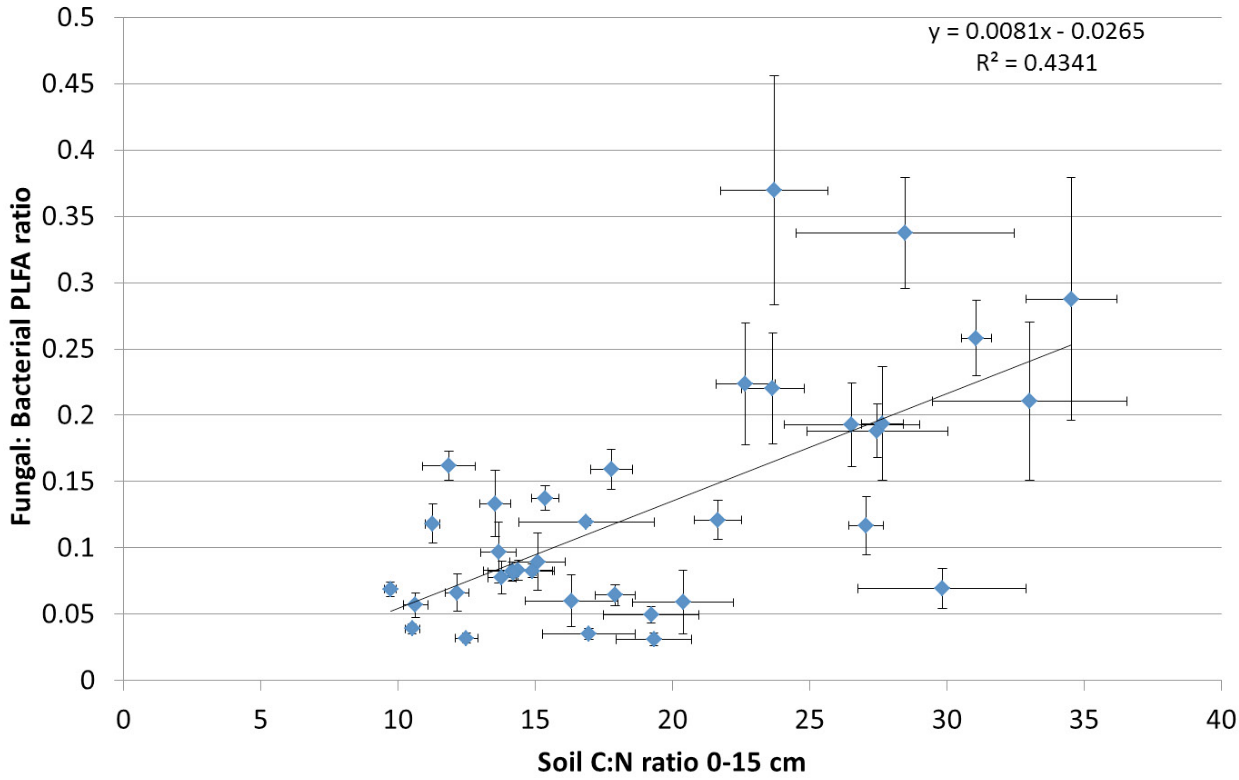


Figure 26 The relationship between ratio of fungal to bacterial-derived PFLAs and the soil carbon to nitrogen ratio, showing how high carbon, low nitrogen compounds are associated with greater fungal biomass, while substrates containing more nitrogen are associated with more bacteria. Bars show variability within sites (standard error, n=5).

Multivariate analysis indicated that soil bacterial communities are most strongly influenced by pH and that communities in acidic sites are more variable between sites than those in more alkaline soils, although there is an outlier group representing five plots at North Walney, which is the only saltmarsh site in the series.

Soil mesofauna

Bacterial communities may respond to changes in conditions within hours or days, but soil mesofauna typically reflect conditions between monthly to multi-annual timescales. Only a few soil mesofauna samples have been processed so far and only one site (Finglandrigg Woods) has all five samples analysed. The initial results suggest that in the top 8cm of a square metre of soil, mesofauna animals number between 20,690 and 216,450 (average 79,100) at Finglandrigg Woods, 142,443 at Lullington Heath and 316,718 East Dartmoor Woods and Heaths NNR (Yarner Wood).

The numbers at Finglandrigg Wood are close to the averages measured by the Countryside Surveys 1998 and 2007 for broadleaved woodland (~73,000 to 82,000 per square metre), while the numbers measured for Lullington Heath and Yarner Wood are considerably higher than the countryside survey averages for these habitats (60,240 and 94,856 for heathland).

The 1998 and 2007 Countryside Surveys grouped animals into "broad taxa" and found average values for number of these "broad taxa" ranging between 3.28 and 5.81. Again, while Finglandrigg Wood's diversity of broad taxa is comparable (average 4.4 broad taxa), the two samples assessed at Yarner Wood and one sample at Lullington Heath supported 8, 9 and 7 broad taxa, respectively. These results may indicate that our NNRs are supporting an unusually high population and diversity of soil organisms compared to the national picture.

So far, the soil mesofauna communities analysed have been dominated by mites, and approximately half to three quarters of all animals being decomposer oribatid mites (Figure 27). There are clear differences between communities even at low levels of taxonomic resolution, but analysing the communities at higher levels of detail shows greater differentiation between the habitats processed so far suggesting that the composition of these communities may be sensitive indicators of environmental change, as demonstrated in previous studies (Behan-Pelletier, 1999).

The early results from this analysis suggest that different components of the mesofauna communities in the top 8cm of soil are associated with different soil conditions. Lower density soils support more mites, soils with more calcium have fewer well-armoured oribatid decomposer mites but more softer-bodied prostigmata mites, and wetter soils supported fewer predatory mesostigmata mites. These patterns are based on analysis of very few samples and should be investigated further, but support the idea that these tiny animals closely reflect the soil habitat in which they live.

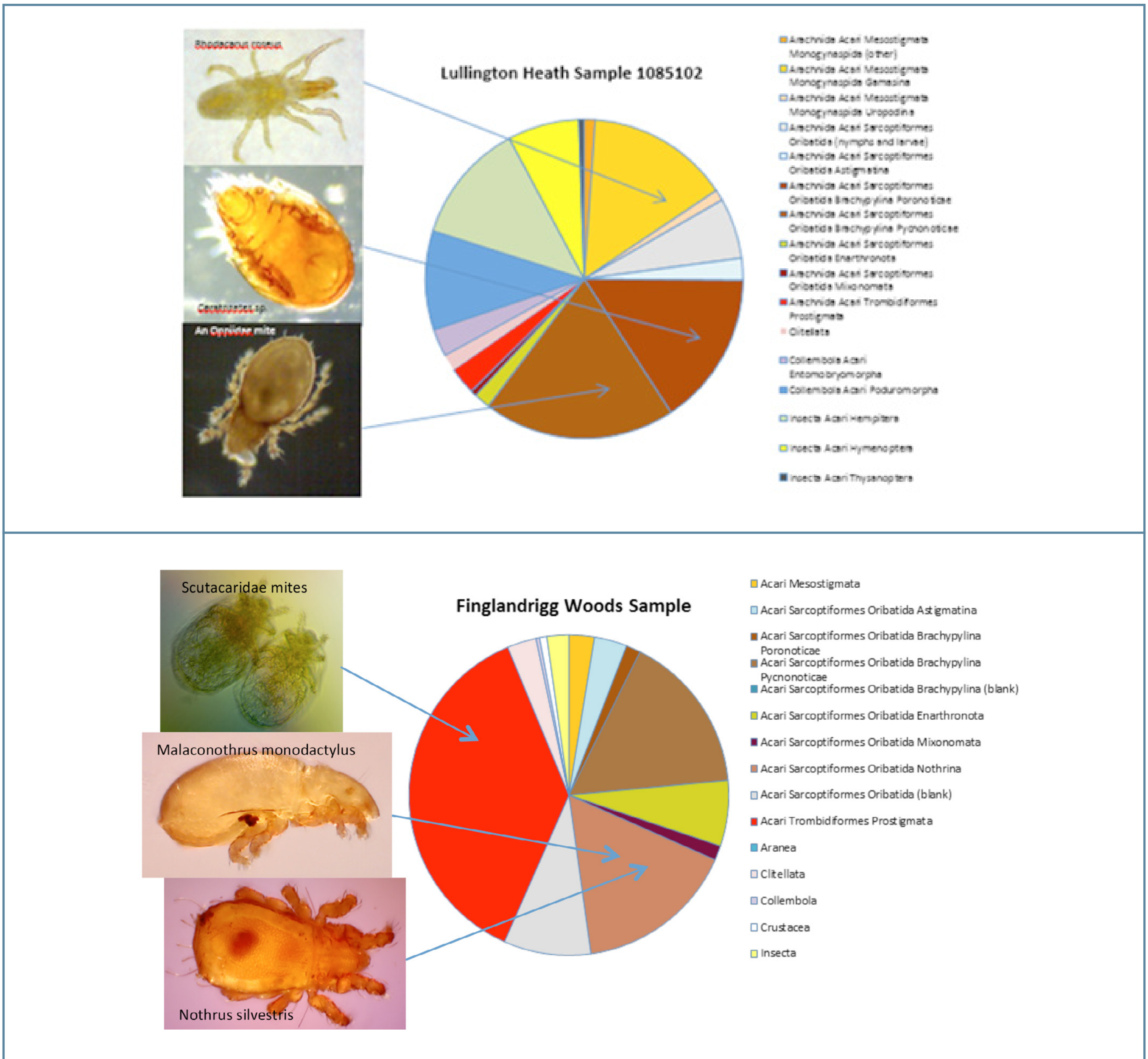


Figure 27 Soil mesofauna communities from Lullington Heath and Finglandrigg Wood showing clear differences in the nature of the dominant Oribatid mite communities, and also the localised prevalence of scutacarid mites in one Finglandrigg sample.

Further analysis

All the above-ground and below ground field and soil analytical attributes from the LTMN soils monitoring can be included in one analysis, to identify and visualise broad patterns in the natural environment. It's possible to draw graphs not only of the similarities and differences among the different sites, but to use the same axes to map out how the different attributes measured relate to this space (Figures 28 and 29). As the vegetation and soil conditions change during the course of the monitoring scheme, we should be able to track the path of these sites across this conceptual landscape, enabling us to identify their trajectory of change and the possible nature of their destination.

Figures 28 & 29 Loadings of a range of different soil and vegetation parameters on the axes of a principle components analysis for all LTMN soils monitoring data (above) and score on these 2 principle axes (which explain over 40% of the variance in the full data) for the sampling plots from each site. The position of each sampling plot on Figure 28 indicates its likely characteristics as described by Figure 29.

Figure 28

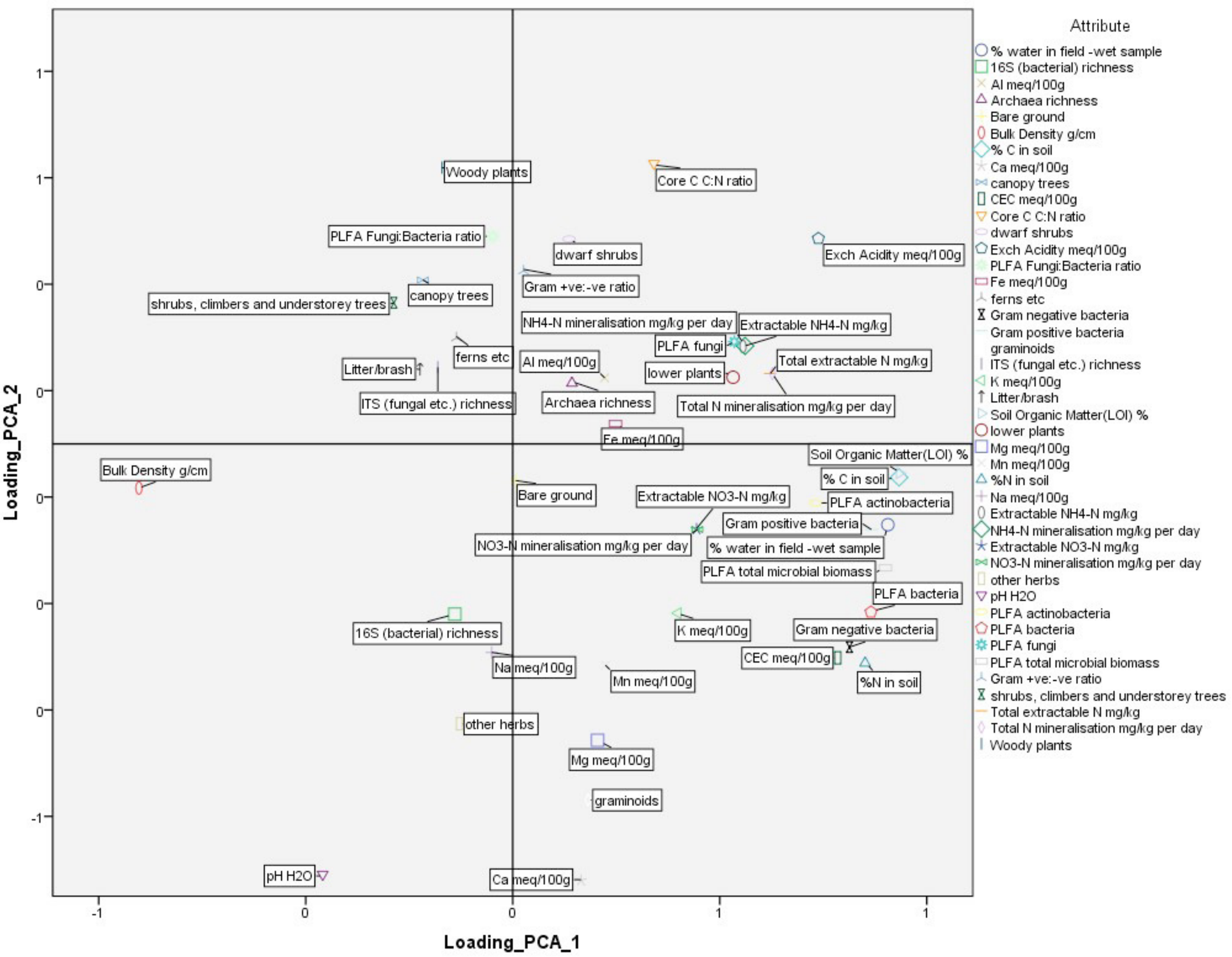
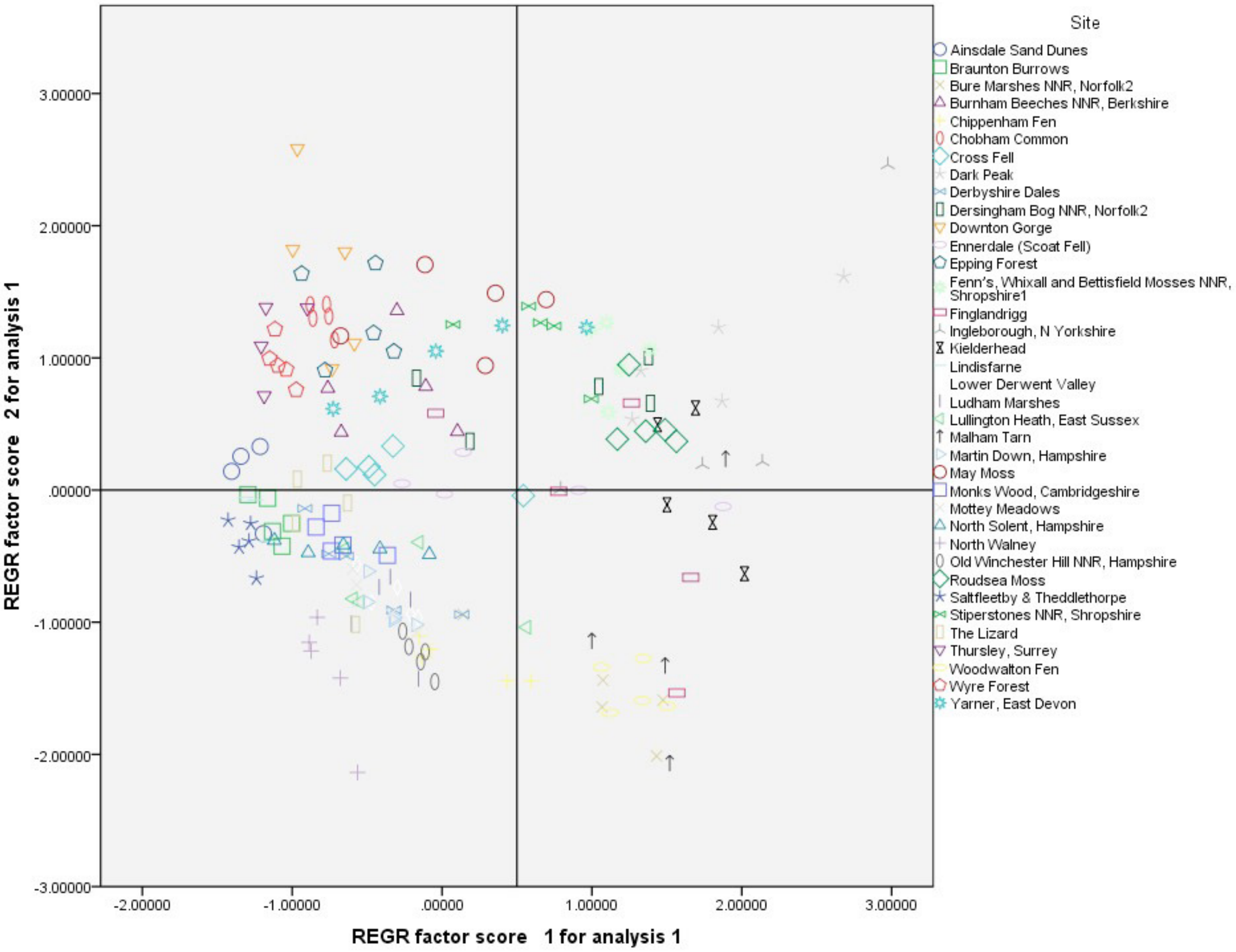


Figure 29



Conclusions

The LTMN soils monitoring data collected to date has helped us to:

- Describe how soil conditions vary across our semi-natural habitats.
- Identify interactions between these conditions.
- Indicate the relationship of these conditions with the organisms that carry out the functions of the soil.

The data and analysis are compatible with those collected by the Countryside Survey, and further exploration of the relationship between these two data sets is likely to yield greater insight into the relationship between soils in some of our most valued semi-natural habitats and soils in the wider countryside.

The assessment of microbial communities, and the early results from the analysis of the soil mesofauna communities, show a promising ability to distinguish sites, making these potentially sensitive tools to detect change. Furthermore, the data from this survey is contributing hugely to our scant knowledge of the composition and distribution of soil communities in England.

From 2017 onwards we will revisit the sites to determine changes over the last 6 years. This will present a new set of challenges, not least relocating the sampling plots in dense and ever-changing vegetation, but it should enable us to understand how environmental change is affecting the condition of our soils, the vital functions they carry out and the fascinating soil communities that inhabit them.

For details of the survey methods, initial analysis and results see Evidence Information Note EIN024 *Long Term Monitoring Network: soils monitoring 2011 to 2016*. A more detailed scientific paper is due to be published in 2018.

6 Thursley NNR: a case study

Andy Nisbet, Zoe Russell, Matthew Shepherd and Susie Smith

Thursley NNR is one of the largest remaining fragments of heathland in Surrey and its 325 hectares hold extensive areas of open dry heathland, peat bogs, ponds and woodlands. All six native species of reptile can be found on the drier heath along with Dartford warblers, stone chats, long-tailed tits, goldcrests, redstarts, whitethroats and wheatears. The nationally rare marsh clubmoss occurs on bare exposed peat in the mire areas alongside three different species of carnivorous plants. Twenty species of dragonflies and damselflies live around the open ponds and ditches of the reserve and the areas of open water also support the bog raft spider.

The climate at Thursley is typical of south east England, with mild winters and relatively low annual rainfall. The north-facing topography creates a microclimate which moderates these factors, but the site is still subject to frequent prolonged periods of low rainfall, which creates a high risk of heath fires.

In June 2006 the reserve suffered a devastating, uncontrolled fire that damaged 211 ha of the heathland. It is recovering, but the consequences of the fire can still be seen. Climate change is predicted to increase the frequency and severity of summer fires in the UK. After the fire Natural England's management has sought to reduce the risk of further large fires by reducing the fuel available, increasing fire breaks and raising awareness among visitors, volunteers and staff. One of the ways the fuel is being reduced is by reintroducing cattle grazing.

Figure 30 Thursley NNR, Surrey.

Studies have shown that the effects of fire, such as the one in 2006 on ecosystem processes are likely to depend on the 'pre-burn' vegetation characteristics, soil chemistry and microbiology - all of which are known to be affected by changes in atmospheric nitrogen deposition.

Wildfires have the potential to remove a large proportion of the accumulated nitrogen stores, potentially slowing the process of nutrient build up associated with atmospheric nitrogen deposition.

LTMN at Thursley

Thursley has been contributing data to LTMN since 2009. The heathland is the main target habitat for LTMN vegetation plots, along with a few plots in the mire and woodland habitats.

Air quality

Thursley is located in a densely populated area close to Guildford with the busy A3 road running just to the east of the site. The air quality is monitored as part of our UKEAP partnership. Figure 31 shows ammonia levels from 2000 to 2010 and Figure 32 shows a more detailed picture of levels during 2014.

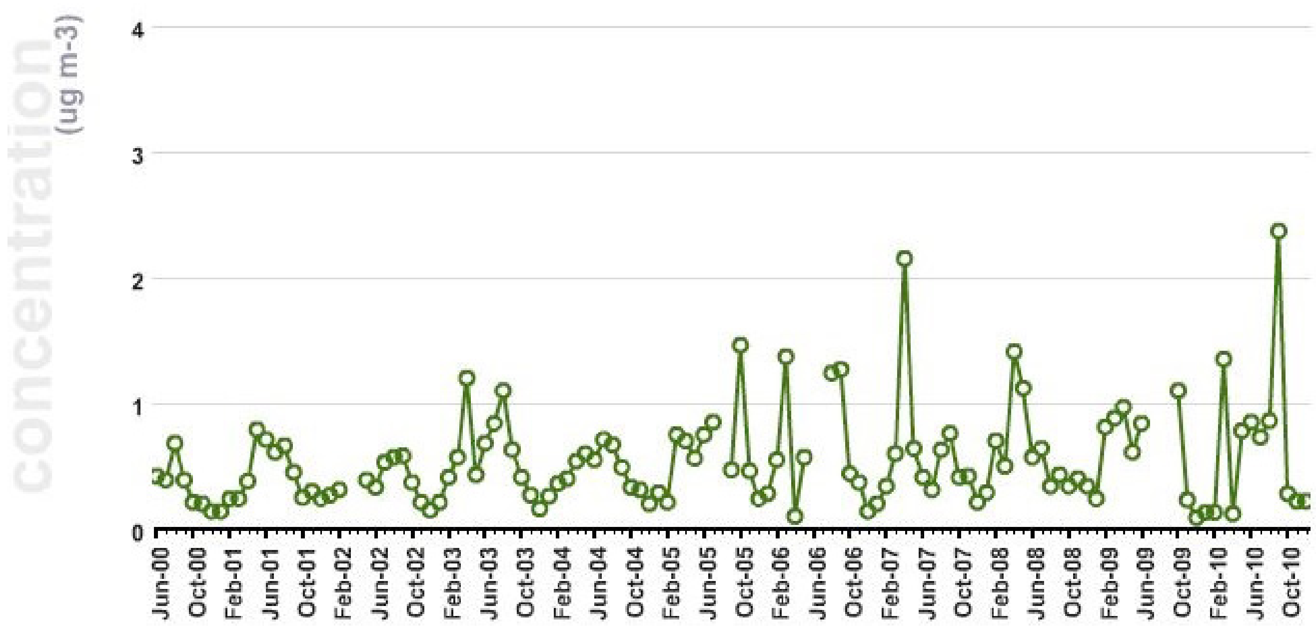


Figure 31 Ammonia levels at Thursley NNR from 2000 to 2010.

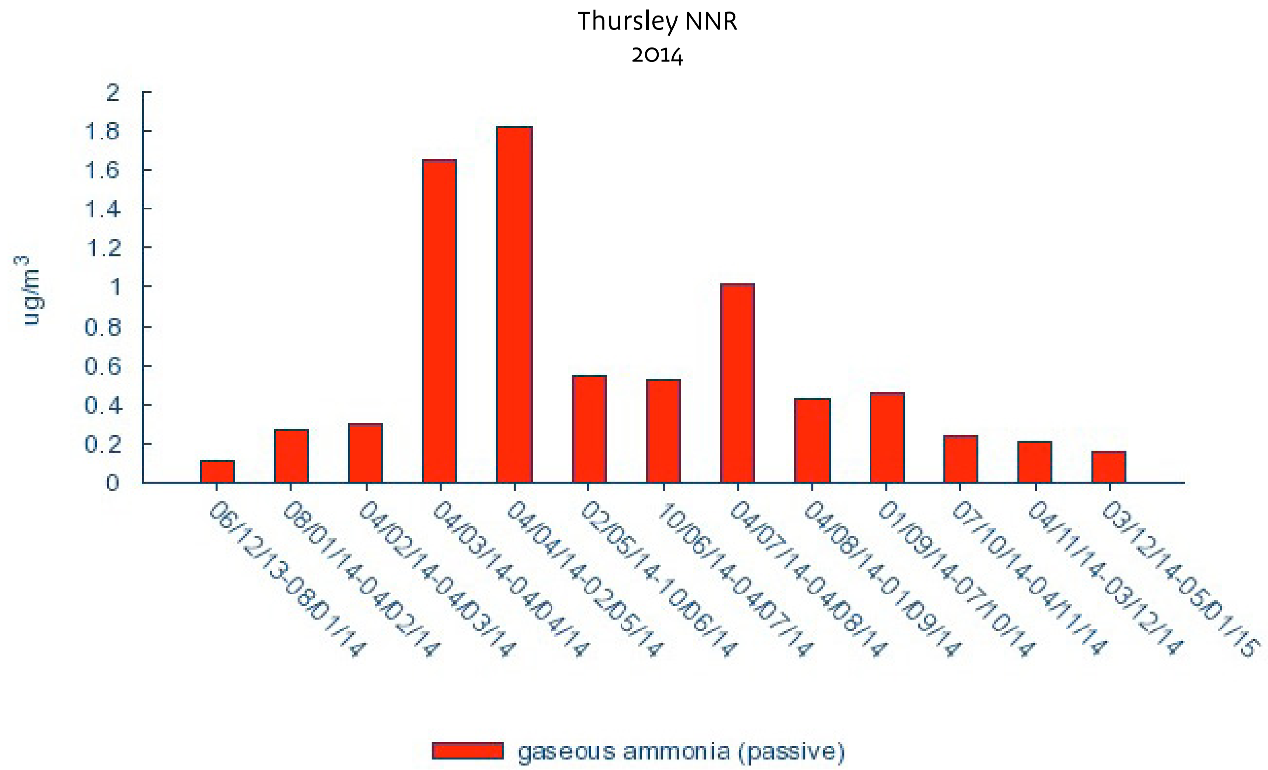


Figure 32 Ammonia levels at Thursley NNR during 2014.

Data on air quality are used to model deposition across the country and data on nitrogen deposition are particularly important to Natural England. Modelled deposition is combined with calculated critical loads to identify 'critical load exceedance'. The atmospheric nitrogen deposition at Thursley is predicted to be around 15.5 kgN/ha/yr, which is above the relevant environmental benchmarks (called 'critical loads') for the mire, dry heath and wet heath vegetation.

Research at Thursley has included manipulation experiments to study the effects of air pollution on lowland heaths and the rates of recovery.

Vegetation

LTMN vegetation surveys began on Thursley in 2011 and the first repeat survey was carried out in 2015, by 32 volunteers from Natural England, partners and the NNR. A comparison of data from these surveys shows changes over this period, but also illustrates that the impact of changing climate or air pollution will take time to become apparent. Figure 34 shows changes in cover for some characteristic species and leaf litter. The results indicate an increase in heather (*Calluna vulgaris*) cover and decrease in the cover of the invasive heath star-moss (*Campylopus introflexus*). These changes reflect the recovery of the vegetation from the fire.

Figure 33 Permanent vegetation monitoring plot on dry heath at Thursley NNR.

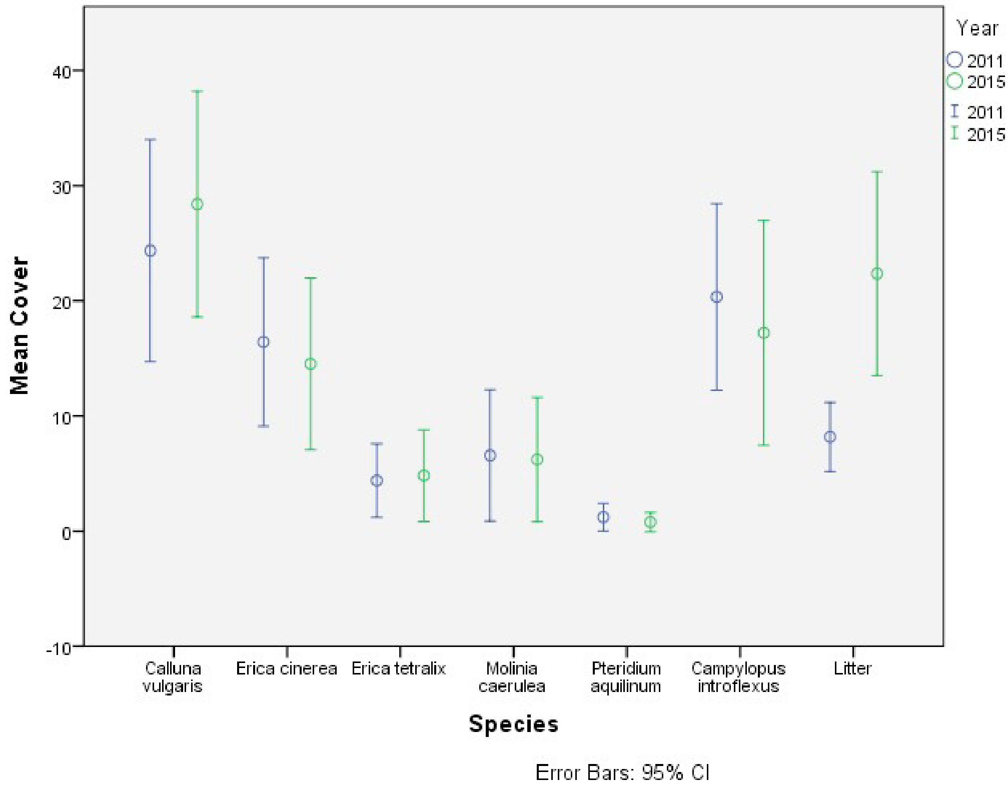


Figure 34 Mean cover of selected plant species (and litter) at Thursley in 2011 and 2015.

Although there were some changes for some species, there were no significant changes in the mean Ellenberg indicator values over these 4 years. Figure 35 shows the mean values for vascular plants on the same 33 plots. We expect that in the medium term, and across the full network of LTMN sites, changes resulting from climate change and air pollution will become apparent using this method.

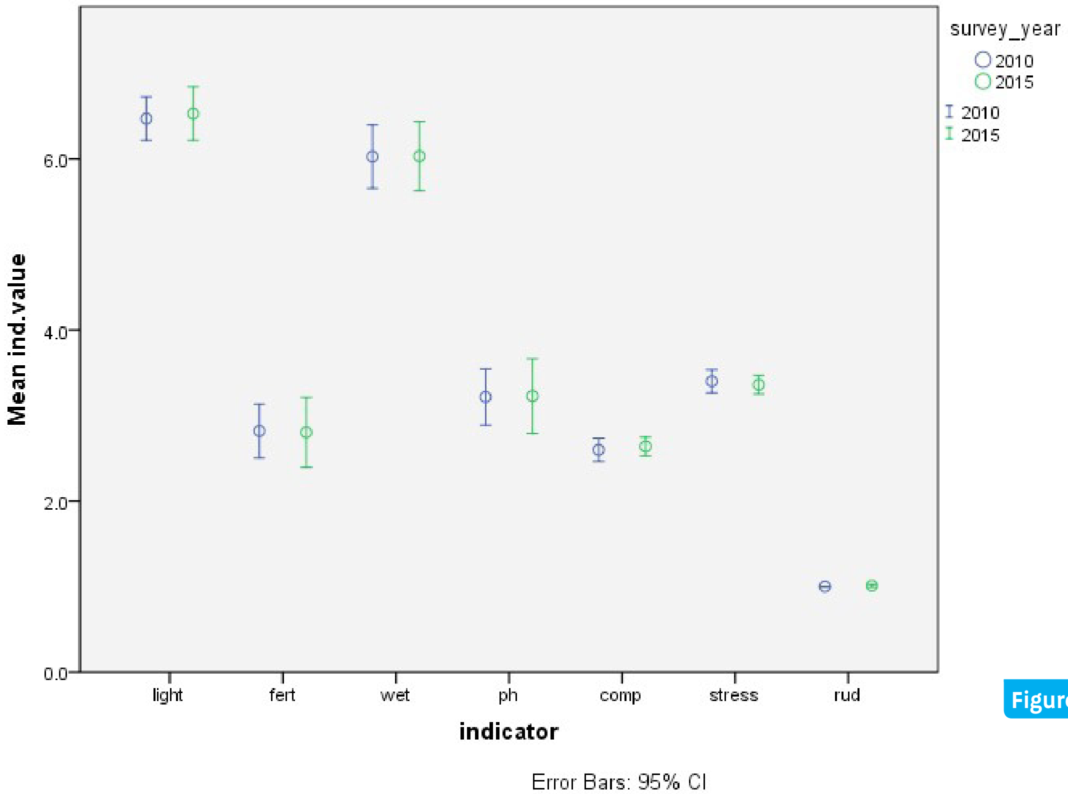


Figure 35 Mean indicators of plant traits at Thursley in 2011 and 2015.

Soils

The impact of the fire in 2006 continues to be reflected in the soils. The 2011 soil monitoring results suggest that many features of the soils here are close to those found in sand dunes, although the site still has affinities with other lowland heathlands and also with some acid woodland sites. The microbial community, as characterised by its cell membrane constituents, is more similar to that found in the fixed dune habitats of Ainsdale than it is to the lowland heath at nearby Chobham Common, although it also resembles that found in the acid woodlands of Wyre Forest. The organic matter content of the soil is the lowest of all non-dune sites, reflecting the burning off of the organic topsoil during the fire. This has resulted in the densest (least porous) soil recorded in the programme, with a low capacity to retain plant nutrients and water as indicated by extremely low water content and cation exchange capacity.

These conditions, however, along with the naturally acidic soil conditions, are often associated with lowland heaths, many of which have a long history of burning, turf stripping, and nutrient removal by livestock which historically would have grazed and foraged in the heathland. The vegetation data from the soil monitoring at Thursley gives rise to the lowest Ellenberg scores for nutrient affinity of all sites in the baseline assessment and these plants produce tough litter, as indicated by the high ~28:1 ratio of carbon to nitrogen found in the topsoil. Continued monitoring should show how long it will take for the tough, low nutrient litter of the recovering heath plants to accumulate soil organic matter again as a surface "mor" humus.

Bird and butterfly monitoring

Figure 36 shows trends in selected bird species on Thursley from 1995 to 2014 (from the bird census carried out over the Special Protection Area (SPA)). The 2006 fire appears to have had a significant effect on the population of Dartford Warbler which has only recently shown signs of recovering. Impacts on other ground nesting species are not obvious.

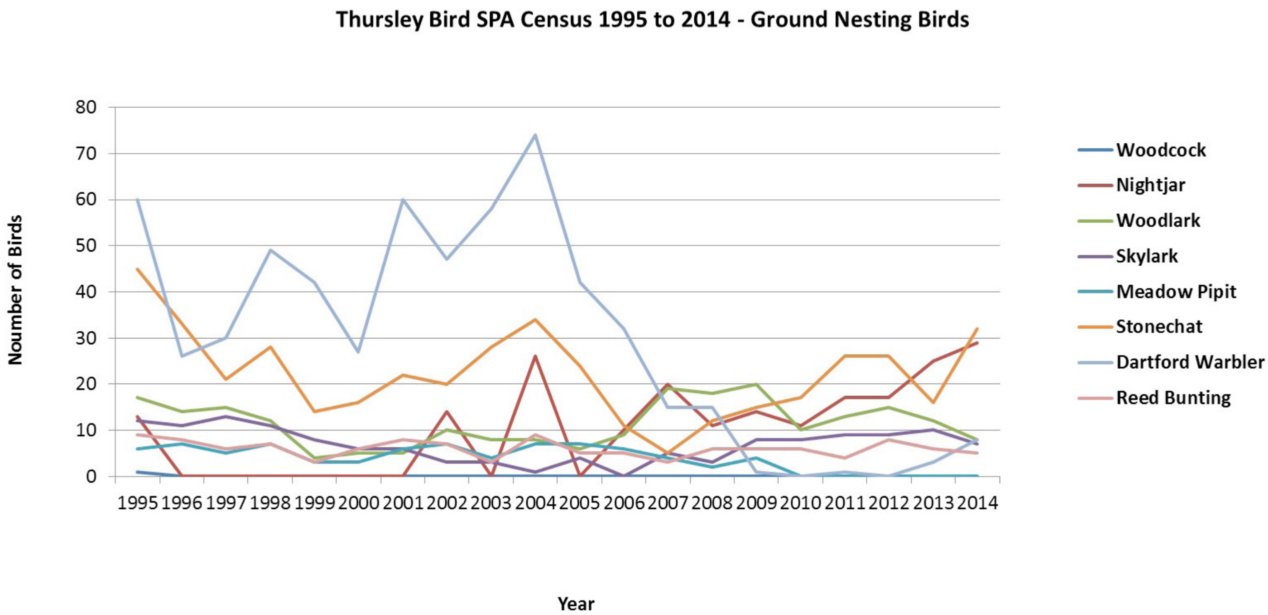


Figure 36 Ground nesting birds on Thursley SPA from 1995 to 2014.

Meadow brown butterflies are the species most frequently encountered during butterfly monitoring followed by Silver Studded Blue and Gatekeeper. Figure 37 shows the maximum numbers recorded during any single transect walk each month from 2013 to 2015 along with the mean monthly temperature.

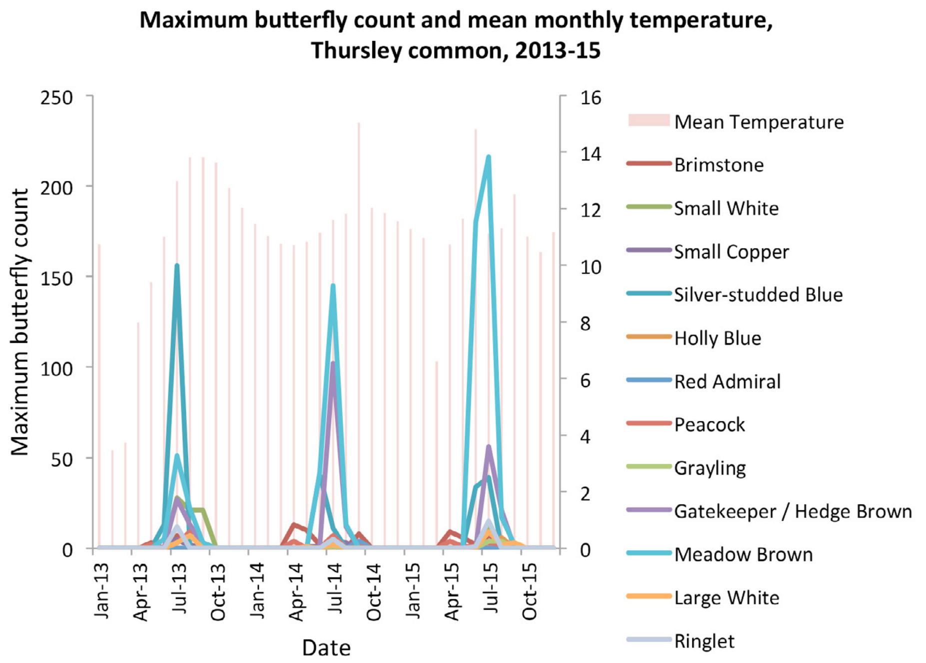


Figure 37 Maximum number of individual recorded during any one transect walk in a month and mean monthly temperature at Thursley from 2013 to 2015.

Conclusions

As well as contributing to our national long term monitoring, the work on Thursley has value for this site. Firstly, the monitoring shows the impact of and recovery from the 2006 fire with some interesting data on the impact on the soils. It will be useful in determining the effect of management on the site, especially the effect of grazing and other measures to reduce the fuel available and diversify the heathland structure. Finally the monitoring will help us understand the effect of climate change on this site and the ongoing effects of air pollution in this populated part of Surrey.

Reserve manager James Giles appreciates the work done to monitor the changes in plant communities, species diversity and how active management and limited intervention can affect our NNRs. *"As well as being a great resource for long term study this database of knowledge helps us to prioritise and implement the day-to-day management of Thursley."*

In 2015 the government's Chief Scientific Adviser, Sir Mark Walport, visited Thursley and afterwards said *"I am impressed by the science that goes on at Thursley. There is a wealth of activity from break-through research to volunteer wildlife recording. I saw for myself the practical outcomes on the ground that can arise from science and practice being brought together."*

Lichens on Thursley NNR

Lichens don't have any roots and they get their nutrients from the air, which makes them highly susceptible to changes in atmospheric chemistry and a good indicator of air quality. They are slow growing and tend to be found where there is little or no competition for light and moisture. Open heathlands are known for their lichen flora and some of these were recorded during the vegetation surveys.

Figure 38 Selected Cladonia species found on Thursley National Nature Reserve: a) *Cladonia portentosa* a relatively easy species to identify; b) *Cladonia grayi* one of the pixie cup or golf tee lichens, which are a particularly tricky group to identify; c) *Cladonia floerkeana* also known as devil's matchstick.

In the 2011 survey the lichens were generically identified as either lichens or Cladonias, a particular group of lichens, but in 2015 we tried to identify the individual Cladonia species. Some of these are particularly tricky to identify. In 2015 we recorded 13 species of Cladonia in 39 out of the 50 plots surveyed. We collected some samples during the survey, and had those identified by an expert lichenologist. He identified 15 species of lichen from the samples. He also found a rare lichen parasite on one of the samples, the fungus *Scutula epicladonia*, which is the first ever record of this species in England.

The 2015 survey indicated that the lichens appeared to have recovered, and even to have benefitted from the 2006 fire, because it had opened up the peat and reduced competition from other vegetation as well as reduced the nitrogen build up in the soil. The management actions to reduce fuel build up should also benefit the lichens in the future.

7 Protocols and data

Rob Keane and Susie Smith

One of the main aims of this report is to raise awareness of the vast amount of data that has been, and will continue to be collected by LTMN. It is a fantastic resource and we want it to be shared, analysed and used for a wide range of different purposes.

This section summarises the data that has been collected up until 2016, and provides a link to the protocols so you can find out how the data has been collected, quality assured and managed. There are also links to published data.

Collecting the data

It is crucial that LTMN data is collected using standard, repeatable protocols. As far as possible the protocols used are the same as, or are consistent with, the original ECN protocols.

Butterflies are monitored using the Butterfly Monitoring Scheme (BMS) standard methodology. Birds are monitored using standard methods developed by the British Trust for Ornithology (BTO). On most sites this involves recording birds within a 1km square using the Breeding Bird Survey (BBS) method. Some sites are continuing to carry out surveys using the Common Bird Census (CBC) method as well as (or instead of) BBS. The vegetation survey method is based on the ECN coarse-grain vegetation monitoring protocol.

Some protocols have been revised following developments, such as improvements to the standards of the weather stations by working in partnership with the Met Office to collect real time data and meet their Meteorological Monitoring Standards. The LTMN soil sampling and analysis protocol is significantly different from any of the ECN soil monitoring protocols and includes analysis of soil microbial communities. Initially air quality data was collected using ECN methods, but these were replaced by UKEAP protocols as part of the UKEAP partnership work to meet higher standards and to facilitate data sharing. The ECN and UKEAP protocols for air quality differ slightly in the methods used and intervals between samples.

A LTMN protocol has yet to be developed to record land management activities although site managers do keep records of management activities. The plan is to develop a protocol that incorporates the spatial mapping of information outlined in site management plans, to enable analysis of land management activities with other LTMN datasets.

The main protocols used for the data collected up to 2016 can be accessed at:
Long Term Monitoring Network Protocols.

Meet the people – Rob Keane's story from developing LTMN protocols to publishing data

"I first became involved in monitoring in 2003 when I was part of the team that monitored the possible effects of open access in the uplands on the breeding success of moorland birds. I joined Natural England's Integrated Monitoring Team in 2010 when we got the go-ahead in 2009 to establish LTMN and were starting to monitor air quality and climate on a small number of sites.

When I first started I was part of the team identifying and bringing the sites into the network, this included liaising with reserve staff to set up the monitoring. When a new site came into the network the first thing we would set up was the vegetation survey, although some sites were included in the network because they already had existing long term monitoring programmes in place. These were mainly butterfly and bird surveys, some of the woodlands also had long term surveys that have now been incorporated into LTMN.

After the vegetation monitoring had been established all the other monitoring planned for the site would be set up. Thursley NNR was the first in-house vegetation survey in 2011. At the time there was a lot to consider and establish, both in-house and with partners. In many cases we needed to develop the partnerships before we could set up the monitoring programmes. We were learning how to run climate and air quality monitoring networks and understand what we needed to do to ease the data gathering and improve data quality. We worked with the Met Office on setting up climate monitoring on new sites and improving the weather station network as a whole and how we quality assured the data. I concentrated on running and expanding the air quality monitoring sites working with **UKEAP** *partnership to improve standards in how we collect rainfall chemistry samples and monitor ammonia.*

Now that LTMN has been established, the focus of my work has moved to developing and implementing the data protocols and preparing data for publication. Each of the different attributes being monitored have different data protocols, formats, storage requirements and quality assurance processes that we have had to develop and agree. There is a lot to be done, and it wouldn't be possible without the help of placement students, agency staff and partners such as UKEAP and the Met Office.

Once the data is ready to be published it is sent to the Centre for Ecology and Hydrology (CEH) Lancaster to be added to the ECN database. In this way it is incorporated into that wider project. To further improve access, the LTMN data is also made available as Open Data on Data.Gov and on our Access to Evidence Catalogue (A2EC).

The vegetation data was the first to be published in 2016 and we will continue to make new data sets available after the end of each survey season. The soil survey data was also published in 2016 having been collated and quality assured by Matthew Shepherd and it will be updated regularly as new data sets become available. Since 2014, the climate data for 13 *of the 23 sites in the network with Automatic Weather Stations (AWS) is available through the Met Office* **Weather Observation Website** *(WOW) but we are working to collate and QA data from the original AWSs that collected data between 2009 to 2014 into one data set and publish it on the A2EC in 2018. We are also currently checking and cleaning the air quality data from 2009 to 2014 onwards and plan to publish it on the A2EC in early 2018.*

Our current placement student, Morgan Smith will be helping to get the bird data ready to be published, but as some of this dates back to the 1970s and is still in paper format, this may take some time. The volunteers that carry out the butterfly monitoring add the data online.

It is so exciting to see the data now being released to the world and available for people to analyse. I am looking forward to starting to understand how climate change and air quality are affecting our biodiversity and the natural environment. I am also very excited about new developments in LTMN monitoring such as Earth Observation and DNA sampling."

What has been collected?

Figure 39 shows what has been collected. For annual or continuous monitoring the date is the year the surveys started and it is followed by an > to show it is from that date onwards. For one-off surveys the dates are shown. In brief:

Figure 39 shows when automatic weather stations were installed on LTMN sites. Some sites have longer weather records from earlier manual weather stations. Sites marked with "R" do not have a weather station, but the data collected from the Met Office automatic weather station listed in table 5 is in the same climate envelop as the LTMN site.

LTMN site	Representative AWS
Braunton Burrows	Coastal Dune RAF Chivenor
Chippenham Fen	Brooms Barns
Cross Fell	Great Dun Fell 2
Lower Derwent Valley	Linton-on-Ouse
May Moss	Fylingdales
Saltfleetby-Theddlethorpe Dunes	Donna Nook 2
Woodwalton Fen	Monks Wood
North Walney	RAF Walney Island

Table 5 Representative AWS.

Initially the AWSs were Campbell Scientific weather stations and in 2013 these were mostly replaced by Met Office ones. The data is continuously collected. Note, some stations are due to be discontinued from 2017 onwards. The data collected by the Met Office can be seen here **Weather Observations Website** (WOW). The LTMN data is uploaded a day after it was collected, so to find the LTMN sites users need to look at historic data, at least 24 hours old. All the weather data is due to be published together on our Access to Evidence Catalogue after it has been quality assured and reviewed.

Air quality data first started to be collected in 1996 and has been collected on 20 LTMN sites, either as atmospheric ammonia (a) or as wet deposition or precipitation (p). Atmospheric ammonia is measured using passive sampling ammonia diffusion tubes. Wet deposition is measured in rainfall collected using standard precipitation bottles and analysed for pH, nitrate, ammonium, sulphate, chloride, calcium, magnesium, sodium, potassium, phosphate, alkalinity and conductivity. On most sites both atmospheric ammonia and wet deposition have been monitored, but on sites where only one data set has been collected there is an (a) or a (p) in front of the date in the summary table to denote the type. Air quality monitoring stopped in March 2015 for a year, partly because of budget constraints but also because we were developing our partnership agreement with UKEAP.

Air quality data is made available through the **UK AIR data portal**. It is due to be published as one data set on the Access to Evidence Catalogue in 2017 once it has passed all the quality assurance checks.

Butterflies are monitored on 19 sites and the table shows when this started on each site. We are working to bring all the butterfly data together into one spreadsheet and this should be available in 2018.

Vegetation is monitored on all 37 sites. All sites have now had the baseline survey and by 2016 twelve sites have had a repeat survey. The intention is to repeat the vegetation survey once every four years, but sometimes it may take longer. The data from the vegetation surveys is available on the Access to Evidence catalogue once it has been through the relevant quality assurance processes. See **Long Term Monitoring Network core sites and data**.

Soils are monitored on every site in the network. In 2016 the all baseline surveys were completed. Resurveys are due every six years.

SUMMARY OF COLLECTED DATA

SITES	HABITAT	WEATHER	AIR QUALITY	VEGETATION	SOIL	BIRDS	BUTTERFIES
BURNHAM BEECHES		1989>	2009 - 2015	2012	2012	2007>	1989>
DOWNTON GORGE		2009>	2013 - 2015	2012	2013	-	-
EPPING FOREST		2011>	-	2013	2013	2012>	2012>
MONKS WOOD		2014>	2009 - 2015	2012	2012	2007>	2006>
WYRE FOREST		2013>	-	2014	2014	-	-
CHOBHAM COMMON		2015>	-	2012	2013	-	-
EAST DARTMOOR WOODS & HEATHS		2008>	1996>	2010 & 2013	2011	2003>	1976>
KIELDERHEAD		2013>	-	2013	2013	-	-
STIPERSTONES		2008>	2009 - 2015	2010 & 2014	2012	2002>	2006>
THURSLEY		2008>	2000>	2011 & 2015	2011	2012>	2012>
THE LIZARD		2013>	2006>	2013	2014	2012>	2012>
BURE MARSHES		2009>	2009 - 2015	2010 & 2014	2012	2010>	1976>
CHIPPENHAM FEN		R	-	2013	2014	2013>	1980>
DERSINGHAM BOG		2013>	-	2013	2012	-	-
LUDHAM & POTTER HEIGHAM MARSHES		R	-	2013	2014	2012>	2012>
NORTH SOLENT		2013>	2009 - 2015	2011 & 2015	2011	-	-
WOODWALTON FEN		R	-	2014	2016	1980>	1980>
AINSDALE DUNES & SANDS		2006>	2009 - 2015	2012 & 2016	2013	2014>	2013>
BRAUNTON BURROWS		R	-	2015	2016	-	-
LINDISFARNE		2010>	2009 - 2015	2012	2013	-	-
NORTH WALNEY		R	-	2015	2015	2014>	-
SALTFLEETBY - THEDDLETHORPE DUNES		R	-	2013	2014	-	-
DERBYSHIRE DALES		2006>	2010>	2012 & 2016	2012	2007>	2004>
INGLEBOROUGH		2005>	2009 - 2015	2010 & 2014	2011	2004>	2004>
LULLINGTON HEATH		2006>	1996 - 2009	2011 & 2014	2011	1991>	1991>
MARTIN DOWN		2008>	2009 -2015	2010 & 2014	2011	2007>	1982>
OLD WINCHESTER HILL		2008>	2009 - 2015	2012 & 2016	2012	1976>	-
DARK PEAK		-	-	2014	2016	-	-
MALHAM TARN		Manual	(A) 2014 - 2015 (P) 2013 - 2015	2013	2013	2012>	2012>
MAY MOSS		R	-	2015	2015	-	-
LOWER DERWENT VALLEY		R	(P) 1994>	2013	2014	2013>	2013>
MOTTEY MEADOWS		2013>	-	2014	2014	-	-
FINGLANDRIGG WOODS		2008>	2009 - 2015	2012	2012	2007>	2006>
FENN'S, WHIXALL & BETTISFIELD MOSSES		2009>	(A) 1996> (P) 2009 - 2015	2012 & 2016	2012	1994>	1994>
ROUDSEA WOODS & MOSSES		2015>	-	2015	2015	-	-
CROSS FELL		R	-	2015	2016	-	-
ENNERDALE & SCOAT FELL		-	-	2015	2015	-	-

Primary ***Habitat*** - *Secondary* ***Habitat***

Figure 39 Data collected on LTMN sites up to the end of 2016. Note: There was a break in air quality monitoring in 2015 but monitoring resumed on selected sites in late 2016 under the UKEAP contract.

Published data

The datasets generated by the LTMN have been, or are due to be, published under the Government Open Data initiative. The Government Open Data initiative aims to be an engine of economic growth, social wellbeing, political accountability and public service improvement by making data accessible to enable people to learn more about how government works, carry out research and build applications and services. The LTMN datasets are listed on Data.Gov.UK at - **https://data.gov.uk/data/search?q=LTMN**

Details of **Natural England's Long Term Monitoring Network Project** can be seen on our Access to Evidence Catalogue. This page has links to the various data sets and protocols already published and in due course it will provide links to regular newsletters with up-dates on LTMN developments and the publication of new data sets, protocols and analysis.

Meet the people – Martin Godfrey's story about quality assuring LTMN data

Martin was a roaming an expert on mosses and liverworts during the 2016 survey of Fenn's, Whixall & Bettisfield Mosses.

© Natural England/Andy Nisbet

"Many of the surveyors working on LTMN are very experienced and can identify a wide range of species, but LTMN covers a diverse range of habitats with some specialist and tricky species. For example at Fenn's, Whixall & Bettisfield Mosses a substantial proportion of the ground flora is composed of sphagnum mosses and small liverworts. These are a specialist group of species that can be difficult to identify and tend to make botanists rather nervous. So Natural England brought me in to provide advice to the surveyors and identify any difficult samples.

© Natural England/Jacqueline Ogden

Figure 40 *Sphagnum cuspidatum* and *Sphagnum fallax*.

It was great fun although it involved rather a lot of trekking between quadrats over rather dodgy bog. I must say that it is a great tribute to the skills of the recorders that after about a day most of them had sorted out the main bryophyte species. This allowed me to confirm the species for the less confident surveyors and identify the really small liverworts and scruffy bits of moss – frequently in the evening with the microscope, and in my case with an accompanying glass of wine. The four days of recording passed smoothly, and in good weather - I certainly enjoyed myself and judging from the general chat so did everyone else.

I find that there is a great deal of satisfaction to be had in recording in this way, not just from the seeing and identifying of interesting plant material, but in knowing that what you are doing is contributing to robust data on long term change and site-management effectiveness. I would recommend it."

8 The future

Andy Nisbet and Rob Keane

The greatest strength of this intensive, site based monitoring network is that it will give us a better understanding of the reasons for change and the environmental processes underlying these. We can gain a better understanding through LTMN because we are monitoring the physical and biological environment in the same place. This allows us to go beyond trends and correlations to start to tease out the details of cause and effect. Being able to do that depends on building up a time series of data as well as having co-located monitoring. By the end of 2017 we will have completed the second round of vegetation surveys on 20 sites and even done the third survey at East Dartmoor Woods and Heaths. In 2017 we also started the first resurveys of our soil plots.

Long term monitoring by its nature requires investment for the future and it will, inevitably, take time to build up the data sets and for their full value to be realised. The analysis of the first 20 years of data collected by the ECN has provided valuable insights into the impacts of changes in weather, acid deposition and soil acidity on vegetation (Rose et al 2016). However the data generated from LTMN can also give us useful evidence in the short-term, eg into soil health, the impact of air pollution on soils and vegetation, and how these factors can vary geographically and between habitats.

The LTMN is also one of the main ways in which our NNRs contribute to meeting their national and strategic science and evidence purpose in an integrated way. By designing the LTMN around NNRs and involving our partners we have been hugely successful in engaging and involving a large number of people. The 'in-house' delivery of vegetation surveys is a great way for staff to refresh and develop their field skills and the benefits of wide participation go well beyond technical skills. The surveys bring together Natural England staff from different parts of the organisation with colleagues from partner organisations and the volunteer community; improving individual morale and our collective understanding of work within the conservation sector. Together we can share our passions and enthusiasms and learn from each other.

LTMN sites supporting innovation

The wealth of monitoring and data on these sites means that they are great places to test out new technologies and develop new monitoring techniques. In the last few years Natural England has used LTMN sites to trial the use of DNA techniques and remote sensing applications.

DNA analysis to categorise vegetation communities

DNA technologies have the potential to significantly change environmental monitoring in terms of cost, the ease with which species can be detected and new ways of monitoring functional groups and communities. Natural England has a number of projects looking at different applications in a range of habitats.

In 2016 we used the Derbyshire Dales NNR and LTMN site to compare the data collected by expert botanists from Natural England's Field Unit to the results from DNA analysis of above ground vegetation and soil samples.

All images © Natural England/Christoph Kratz

Figure 41 Vegetation and soil sampling on Derbyshire Dales NNR in 2016 for DNA study.

The field survey was based on the LTMN vegetation survey methodology and recorded the species present and their cover in 40cms cells within a plot. After recording percentage cover the vegetation was harvested and soil cores taken. The vegetation from one cell was analysed and root material was separated from the soil samples and analysed for all cells.

Preliminary results show a good correspondence between conventional field survey and the species identified from the DNA analysis of above ground vegetation. An initial comparison of the field survey data with the analysis of soil samples showed that fewer species were recorded from each soil sample than from the cell from which they were taken. This is not surprising since the area of soil sampled was much smaller. The soil analysis also frequently recorded some species that were not recorded by the above ground survey.

Findings from last year's DNA projects will be published and our programme of work is continuing with the further development of some applications and the exploration of new ones. This includes further work on vegetation and soils in conjunction with some of the 2017 LTMN in-house vegetation surveys.

Earth Observation and UAV Piloting

A second area of innovation being trialled on LTMN sites is the use of Earth Observation and remote sensing technology. Satellite imagery (particularly from Sentinel Satellites) will provide regular observations of sites that will improve our understanding of temporal variation. Unmanned Aerial Vehicle (UAV) technology is also improving and becoming more affordable. These developments should enable us to gather more data on our sites more frequently and use remotely sensed data in conjunction with our traditional vegetation survey approach.

The LTMN team is working with our Cheshire to Lancashire Area Team to develop and evaluate Earth Observation capability to map broad habitats and plant communities at larger spatial scales across landscapes and in Natural England's Focus Areas. The pilot project across Ainsdale Sand Dunes NNR and the Sefton coast is comparing the use of Sentinel Satellite imagery, outputs from airborne CASI and LIDAR sensors, UAVs and the LTMN ground vegetation survey data, collected in 2012 and 2016.

The UAV flights will include hovering over selected locations at different heights to assess whether plant communities and even individual species can be identified using these technologies.

© Natural England/Alexandra Kilcoyne

Figure 42 Getting ready to fly Natural England's drone.

Challenges for long term monitoring

New technologies offer exciting opportunities to improve environmental monitoring but also represent a challenge to traditional long term monitoring. New technologies may be more effective or efficient than traditional techniques or provide more and different data. However long term monitoring depends on having consistent time series of data over long periods. Programmes such as LTMN must try to reconcile the need for continuity in long term data sets with the opportunity to innovate. This will be one thing that Natural England will address in our planned evaluation of LTMN.

A second challenge is the need to meet changing evidence requirements. On one level the evidence needs that LTMN was designed to meet are still critical. We still need to understand the detail of how our natural environment is changing as a result of climate change and air pollution. However, Conservation 21 asks us to think at larger scales (to create resilient landscapes and seas) and to understand the benefits to society (to grow our natural capital). LTMN as a national network provides us with evidence beyond the site scale. It allows us to look at our most valuable habitats and consider the larger scale drivers of change and how these vary between locations and landscape types. NNRs have a crucial role as core sites within resilient landscapes and LTMN will provide evidence to support this. We need to focus our subsequent analysis on meeting these changing needs.

The co-location of physical and biological monitoring provides us with a better understanding of environmental processes and the health of natural capital assets such as soil. LTMN is providing valuable data on soil health and processes. Habitat data derived from LTMN vegetation surveys can input to activities such as modelling ecological connectivity to help us better understand resilience, natural capital assets and climate change.

Meet the people – Anna Harris was a student volunteer in 2016

In 2016 Anna Harris joined the LTMN at Ainsdale NNR with Dave Mercer and the week contributed towards her Duke of Edinburgh Gold award. Anna describes what she gained from the experience:

© Lisa Harris

I contacted Natural England to ask if I could be considered as a volunteer and Rob Keane managed to arrange for me to join one of the survey teams and camp with other volunteers. The data collection took place over four days and included training to become familiar with the species and the sampling methods.

I helped identify plant species, measure slope aspect and gradient and calculate percentage coverage. I learnt a lot from the other volunteers and staff, many of which were excellent botanists, much of this knowledge will be helpful towards my Biology degree. Despite some days of terrible weather I really enjoyed the whole experience, especially the BBQ night featuring one of my survey teammates' band!

9 Conclusions

Tim Hill, Chief Scientist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I hope that you have found this insight into Natural England's Long Term Monitoring Network as interesting, and thought provoking, as I have done.

Although still relatively young for a long term monitoring programme, the adolescent LTMN now has a firmly established baseline from which we can monitor changes. This baseline has already begun to reveal new insights into the make-up and composition of our semi-natural habitats. We have, for example, developed a comprehensive understanding of how soil conditions vary across the different semi-natural habitats, and we have developed a better understanding of the relationship between different soils conditions, and the organisms that carry out the functions of the soil.

Over time, I anticipate that we will be able to develop an ever-more comprehensive understanding of how different aspects of England's natural environment are changing in response to climate change, air pollution and land management practices. We should, for example, be able to detect and study the pace and types of changes in vegetation of semi-natural habitats that are occurring as soils become less acidic in response to improvements in air quality. Changes in seasonal weather patterns, droughts, floods and increasing temperatures will also impact on the viability of species populations, their interactions with one another, and the adaptation of our precious semi-natural habitats. Understanding these changes will be crucial in informing how best we can respond.

Perhaps inevitably with a report such as this, we have only been able to offer a snap-shot of the data and information that the LTMN currently has to offer. With the continued support from our partners, researchers, volunteers and staff, this information resource is set to grow and grow. Every single aspect of this information will be freely available (**Natural England Long Term Monitoring Network**) for viewing and use for any purpose.

I would be really pleased to hear from you about what information you're using from this resource, what further analysis you've done and insights gained.

As a final thought, my own PhD study involved monitoring changes in algal communities over several years. I can't help wonder what more I could have done if I'd been able to draw upon a comprehensive data series such as is being created through the LTMN. Food for thought for anyone planning future ecological studies of our semi-natural environment? If so, we'd be delighted to hear from you. Maybe even our future conservation scientists and environmental leaders will one day look back and reflect on the value and their use of data from England's Long Term Monitoring Network.

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