Natural England Chief Scientist Report 2019: Monitoring and Indicators

First edition – December 2019

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NATURAL ENGLAND

Contents

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This report should be cited as: Hill, T., Stone, D., & Stevenson, N.M. (Eds) 2020. *Natural England Chief Scientist Report 2019: Monitoring and Indicators*. Natural England Report NE759

Foreword

Science and evidence work in Natural England underpins our integrity and our authority. It has never been more important than it is now as we strive to meet the challenge of the twin biodiversity and climate crises. As the Board Member with responsibility for chairing Natural England's Science Advisory Committee (NESAC) I am privileged to work with many of our specialist staff who make this report possible, and whose contributions ensure our reputation. In addition, the participation of many independent academic minds from a variety of disciplines, including other Board members, provides a high-level of scrutiny and encouragement to our science.

Recovering nature is dependent on knowing its current state, and the trends that put it there, understanding the pressures that are causing change, and addressing them through informed and targeted action. That is why this second Chief Scientist Report is focusing on monitoring and indicators, and on how in Natural England this sits alongside a growing paradigm of evaluation. At a time of scarce resources we are sometimes criticised by others in the sector for a reduced basic monitoring effort across the piece. Whilst our huge reduction in funding does have consequences for what we can do, it also charges us to move with the times and do things differently. The schemes that feature in this report demonstrate the importance of consistency of approach over decades – the Long Term Monitoring Network - and, at the other end of the spectrum, cutting edge technology revolutionising the power of monitoring through, for example, eDNA work and Earth Observation.

Science can occasionally leave people behind. And to ensure we know about people's behaviour and connection to nature, Natural England has been driving the report, Monitoring Engagement in the Natural Environment (MENE), which is also featured here. This is world-class knowledge that can inform future policy and practice to improve the public's connection to nature and, hopefully, their participation in acting on behalf of nature's recovery.

2020 has become known as the super year for nature with a new Government ready to implement the 25 Year Environment Plan, and both the global Biodiversity and Climate Conferences of the Parties in September and November. The importance of indicators will be paramount at the Biodiversity COP where new indicators that incorporate nature-based solutions to address the climate crisis will set a decadal agenda for action. Natural England's monitoring, indicators and evaluation work has a strong role in helping to set and drive this challenging agenda.

Dr Andy Clements

Natural England Board Member, Chair of Natural England Science Advisory Committee (NESAC)

Welcome and introduction

Welcome to Natural England's second Chief Scientist Report. The focus of my first report was to shine a spotlight on the breadth and depth of the science & evidence work that we do, and to show how it underpins and supports all of our work. In the three years since that report we have continued to build upon the contribution and influence of our science and evidence work. The impressive bibliography of peer reviewed papers, books and in-house reports published over the last couple of years illustrates the quality of our scientific work, and the strength of our partnership working, very well. I am particularly proud that the work of some staff has been published in major scientific journals, whilst others have received prestigious awards (e.g. the John Hoy economics award and an outstanding publication award). This gives an insight into breadth, depth, and multi-disciplinarity of our science and evidence work that is the major foundation upon which Natural England's work is built.

The past three years have seen something of a transformation in Natural England too as the importance of being an evidence-led organisation has been widely recognised. The quality of our advice and the legality of our decisions fundamentally depend upon our use and understanding of the evidence base, from understanding how and why the natural world is changing to notifying SSSIs and protecting landscapes to advising on the design of agri-environment schemes and creating opportunities for people to enjoy nature.

So, rather than try to cover everything we do in this report, we have decided to give a flavour of our work around monitoring and indicators. Natural England has developed a clear vision for the future – to achieve **Thriving nature for people and planet**. In setting this vision we were keen to demonstrate our ambition to go beyond simply making improvements in nature. We want to see nature thriving everywhere - because a healthy natural environment is fundamental to everyone's wealth, health and happiness.

The State of Nature Report 2019[1] and IPCC assessment reports[2], amongst others, have highlighted pressures and drivers of environmental change and some of the effects of that such as threats to species populations and declines in habitat quality and the Government's 25 Year Environment Plan[3] sets out ambitious goals to achieve a healthy functioning environment. In this context, understanding the changes in our environment and the effects of our actions have never been more

[1] Hayhow DB, Eaton MA, Stanbury AJ, Burns F, Kirby WB, Bailey N, Beckmann B, Bedford J, Boersch-Supan PH, Coomber F, Dennis EB, Dolman SJ, Dunn E, Hall J, Harrower C, Hatfield JH, Hawley J, Haysom K, Hughes J, Johns DG, Mathews F, McQuatters-Gollop A, Noble DG, Outhwaite CL, Pearce-Higgins JW, Pescott OL, Powney GD and Symes N (2019) The State of Nature 2019. The State of Nature partnership. https://nbn.org.uk/wp-content/uploads/2019/09/State-of-Nature-2019-UK-full-report.pdf

[2] www.ipcc.ch/2019/

[3] A Green Future: Our 25 Year Plan to Improve the Environment (2018), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/693158/25-year-environment-plan.pdf

important. How we do that is through monitoring, data analysis, and evaluation. So, for this second report, we have focussed on the theme of monitoring and the development of indicators.

You will see in this report how we have refreshed and modernised our monitoring strategy to reflect technological developments and the increased focus on recovering nature. We also show how we are increasingly using environmental DNA in monitoring across a range of habitats; and about our ground-breaking development of natural capital indicators and their use in developing a new approach to natural capital accounting.

The past couple of years have also seen rapid developments in earth observation techniques and we report on how we've enhanced our capability and developed pioneering methodologies that will transform our habitat mapping by, for example, combining machine learning, habitat records and satellite data to produce a map that predicts the likelihood of the presence of a specific habitat type.

Two of our major monitoring programmes have had their tenth birthday this year too, and so this report marks the occasion by looking at the impact and influence that the Monitoring Engagement with the Natural Environment (MENE) survey has had across both the environmental and health sectors. This survey has been described as the best survey of its kind in the world, and looking at the breadth and quality of the scientific studies that it underpins it is not hard to see why. Finally, the Long Term Monitoring Network (LTMN) has also been running for ten years, and is offering us invaluable insights into how plant and soil communities, and species populations, are responding to changes in the climate and air quality, as well as the role that land management interventions might be having in mitigating or amplifying the changes.

Dr Tim Hill MIEnvSc MIoD

Chief Scientist, Natural England

December 2019

To keep up to date with science and evidence developments in Natural England, you can follow me on Twitter @NEChiefSci.

Natural England Monitoring Strategy

Andy Nisbet and Oliver Grafton

Natural England's Monitoring Strategy 2019 sets out how we will monitor the natural environment and its benefits across England's land and sea. It provides a framework to guide our investment to efficiently gather the evidence we need to support our ambitions for land and sea management, people and nature, sustainable development and nature recovery.

The new strategy aligns our monitoring ambitions and activities more closely with those of the 25 Year Environment Plan and takes advantage of new technologies and approaches.

The strategy explains why we monitor, what we will monitor and how we will monitor. It sets out a series of key questions, describes a tiered programme approach and outlines a set of founding evidence services which underpin efficient monitoring.

Our key questions

We need answers to fundamental questions about nationally important features, assets and functions of the natural environment and landscapes, their benefits and how people use and value them (see Figure 1). The core purpose of our monitoring programme is to gather the evidence we need to answer these questions and track change over time.

Figure 1: Our key evidence questions within a knowledge management cycle

What We Will Monitor

Natural England has an interest in all the evidence society needs to sustain and enhance the health, benefit and enjoyment of the natural environment and landscapes of England. Our role will vary across the breadth of this interest.

Natural England has an accumulated knowledge of and responsibility for the nation's network of protected sites. We also lead on the monitoring and evaluation of land management agreements across England and the monitoring of people's use of and engagement with the natural environment. In addition to directly commissioning and conducting monitoring, we positively advise on, support and influence the monitoring activity and contribution of others, setting standards and describing best practice.

Our investment in monitoring will help us better understand and describe to others the following:

Species: The distribution, status, trends and threats to species that occur throughout England to help inform and prioritise the work needed to protect, recover and enhance nature.

Habitats: The distribution, extent and condition of important habitat types to help maintain, restore nature and increase the amount of healthy functional ecosystems and the services they provide.

Landscape: Important aesthetic, cultural and historic landscapes across England and how these are changing.

People: What people understand and value about the natural environment across England, how they access and enjoy it and how this is changing.

Recovery: The pressures, opportunities and risks for important features of the natural environment, to inform tactical plans and guide collaborative efforts to protect, enhance and recover them (e.g. in Protected Sites and a Nature Recovery Network).

Outcomes: The impacts and effectiveness of our decisions and interventions. This is critical to determine how successful we are being at protecting and enhancing the natural environment (e.g. Environmental Land Management and Biodiversity Net Gain).

A three tiered programme

Our strategy describes three distinct tiers of monitoring activity; Sentinel, Outcome and Agile (see Figure 2). These are fundamental to ensuring our monitoring is scientifically sound, progressive, impactful and efficient.

The Sentinel Tier comprises long-term activity designed to maintain a watch over the natural environment and landscapes of England, their benefits and how people use and value them. These activities form our programme of structured monitoring

designed to answer key monitoring questions at national and more local scales as far as we are able.

The Outcome Tier covers monitoring activities intended to help evaluate our interventions and projects. These will be designed to suit the scale and duration of the projects being assessed.

The Agile Tier covers monitoring activity needed in response to opportunities and risks as these emerge. Typically these activities will be planned and delivered over shorter periods. They may be exploratory, important one off investigations or in response to increasing risks.

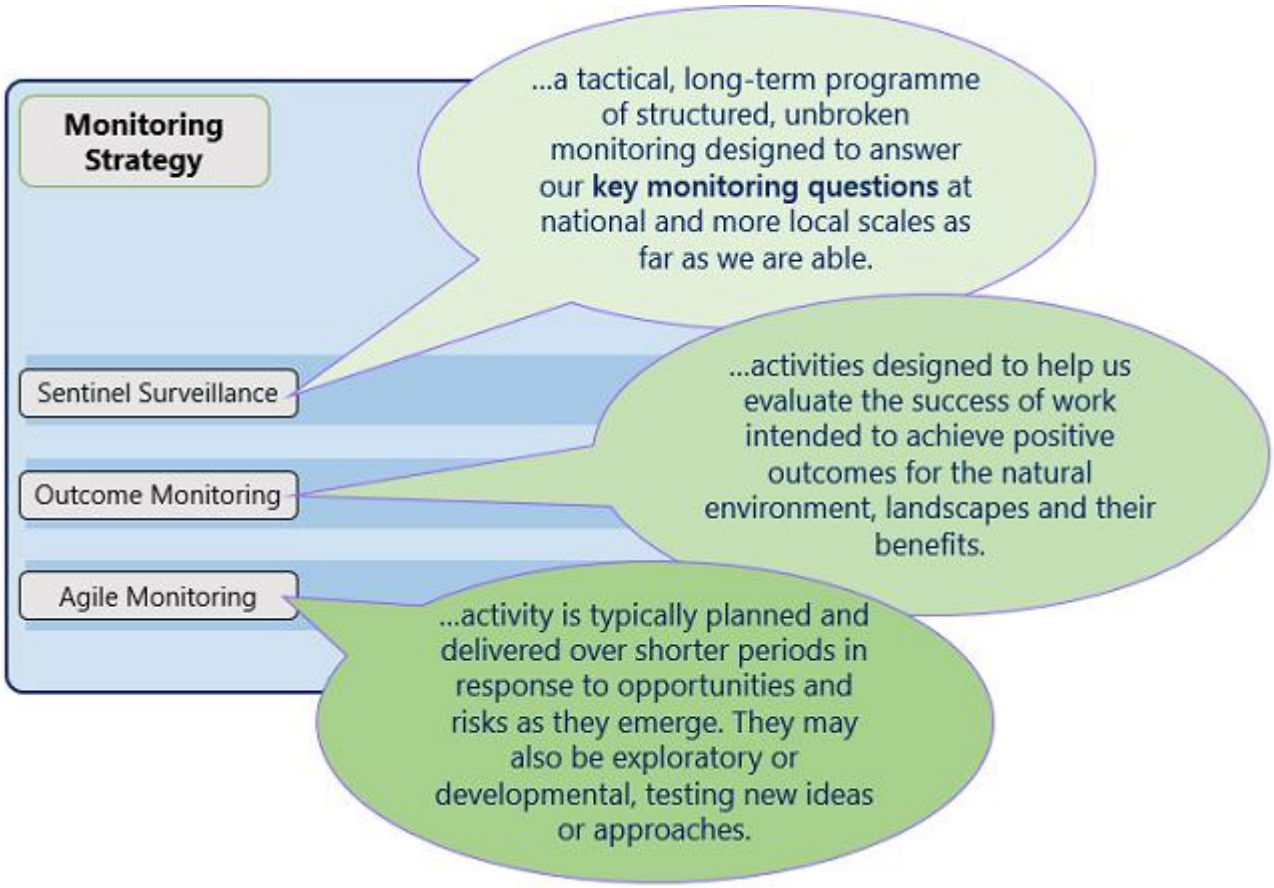

Figure 2: A tiered monitoring programme

Using DNA for environmental monitoring

Katie Clark, Debbie Leatherland, Andy Nisbet, Jon Webb

Deoxyribonucleic acid (DNA), an organism's genetic material, holds many clues that can be used to enhance our understanding of the natural environment.

DNA– based technology is developing at a rapid pace. This technology uses DNA obtained directly from living organisms and DNA shed into the environment (eDNA). It can be used to identify species and communities of interest, and offers a significant opportunity to monitor ecosystems cost-effectively in novel ways; particularly for species which are challenging to monitor using traditional methods. This enhances our understanding of protected sites and species and how we report on the progress of the government's 25 Year Environment Plan.

Natural England has been leading the drive to apply DNA technology within the Defra group, building on the success of eDNA methods we developed monitoring approaches to identify the presence and absence of great crested newts. We are working to make the use of DNA methods mainstream, identifying opportunities in our monitoring programs for:

- Terrestrial invertebrates: Traditional methods are very time consuming and highly specialist, but DNA technology offers us the opportunity to identify species, and potentially their prey and parasites, to understand functional networks

- Fish communities: eDNA from fresh and seawater can be used to identify fish communities, making community analysis much more comprehensive

- Marine invasive species: Developing tests for seawater using eDNA as a frontline test for newly established invasive species, where targeted removal can be very effective for management

- Crayfish: Developing eDNA assays to detect both white clawed and signal crayfish, and crayfish plague in rivers, to monitor the spread of disease

- Fungi: Using DNA present in soil samples to identify fungi of conservation interest

We are building exciting partnerships with organisations such as the Natural History Museum (NHM). With our partners we are identifying and testing new opportunities such as the development of DNA tools for ecosystem-level assessments. We are also considering what emerging DNA technologies Natural England can make use of in the future to improve the environment, in line with the 25 year Environment Plan.

Figure 3: White-clawed crayfish

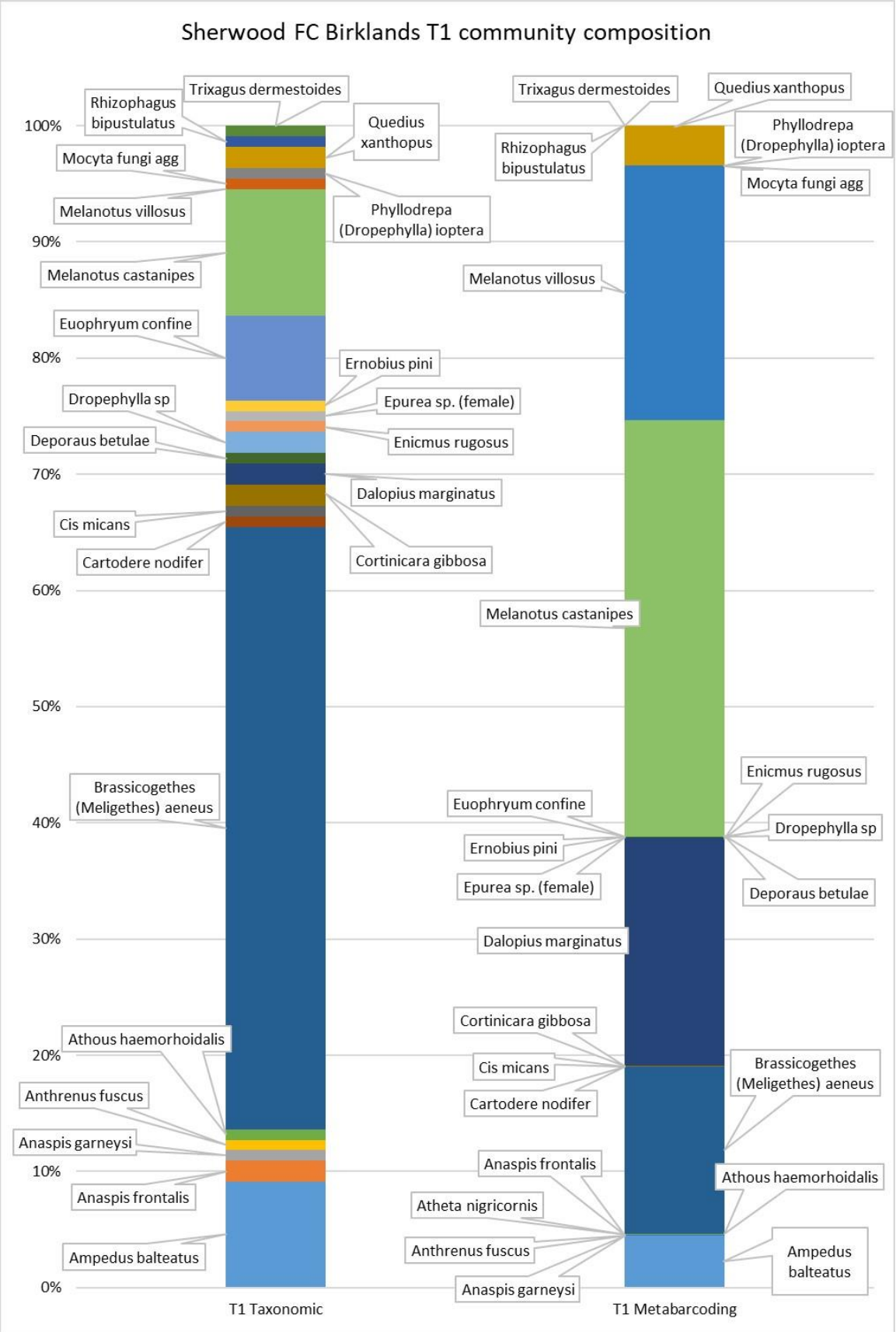

Figure 4: A comparison of traditional taxonomic terrestrial invertebrate identification with DNA metabarcoding from one survey station in Sherwood Forest4.

Figure © Helen Rees/ RSK

Case Study: A DNA Bioblitz

Figure 5: The pop-up DNA lab for the DNA Bioblitz

DNA ‘barcodes’ are critical to using DNA technology ‘. These are short regions of DNA that can be used to identify a species. However, the reliable results depend on having a trusted reference library of species DNA barcodes, and these are currently not available for all species. Natural England has been identifying priority gaps in the barcode reference libraries for critical taxa, starting with terrestrial invertebrates, but we are also partnering with the Natural History Museum to fill some of the gaps by hosting DNA bioblitzes on National Nature Reserves, starting at Ainsdale NNR.

On the 1st July 2019, Natural England and the NHM embarked on a ground-breaking mission to pilot a new approach to DNA analysis - by filling gaps in DNA barcode libraries to improve our understanding of life on earth. This first joint mission was to collect genetic material from invertebrates (either a full specimen or just a leg) for both the Darwin Tree of Life Project and to augment the NHM DNA barcoding library.

Ainsdale Sand Dunes National Nature Reserve was the base of operations, with visits to the Ribble Estuary NNR and Cabin Hill NNR, and River Ribble. Entomologists and invertebrate ecologists were invited from museums, NGOs,

universities and local volunteers and the NHM set up their pop-up molecular lab full of high tech, pioneering equipment for sequencing DNA.

Three days of sampling and sequencing generated the following headline Information:

- 59 participants throughout the week
- 14 partner organisations
- 846 specimens databased
- 531 identified to genus
- 469 identified to species
- 285 unique species identified
- 384 specimens sequenced
- 12 micro-litre final sample size for DNA analysis
- 573,000 sequences generated in first 80 minutes

The event was a huge success, and Natural England benefitted not only from the large number of DNA sequences of species of interest generated for use in environmental monitoring, but the sharing of expertise from both entomologists and geneticists.

Earth Observation and UAS

Paul Cox and Alexandra Kilcoyne

Introduction

Over the last 10 years, exploiting Earth observation (EO) data has become easier than ever. Commercial satellite data and Unmanned Aerial Systems (UAS) have reduced in cost and increased in availability, while cloud computing platforms have become more flexible and scalable. To capitalise on these opportunities, Natural England has made significant investments in its EO capability. These timely investments complement and enhance Natural England's field-based monitoring techniques, improve the evidence base and support the delivery of positive environmental outcomes.

Current progress (2014 – present)

Since 2014, Natural England has significantly increased its capability and reputation for environmental EO applications. Natural England routinely use cloud computing to combine data from the European Space Agency Sentinel satellites with a wide range of other data sources to produce: Visualisation, mapping, modelling and monitoring products in support of local delivery.

Natural England is at the forefront of using Unmanned Aerial Systems (UAS) and now owns and operates nine UAS under a Permission for Commercial Operation, granted by the Civil Aviation Authority. The use of UAS enables the organisation to become an EO 'data producer' as well as a user. UAS have been used for a wide range of applications, from in-field assessment of large, challenging sites, to habitat mapping and species counts. This investment in hardware has enabled Natural England to capture data where previous approaches would have been either cost- or time-prohibitive.

Figure 6. A fixed-wing UAS

One of the greatest achievements to come out of the expansion of EO services is the Living Maps methodology. This uses machine learning, habitat records and satellite data to produce a map that predicts the likelihood of the presence of a specific habitat type. The Living Maps methodology was published under an Open Government Licence (OGL) and has been used by government and commercial agencies for habitat mapping, both within the UK and internationally. In recognition of the value of the Living Maps methodology, Natural England has been commissioned to produce a national habitat map (Living England) that will support the monitoring and evaluation of changes in the natural environment, future agri-environment schemes, and provide a baseline habitat quantity dataset for the government's 25 year plan indicators.

Another major benefit of EO-based approaches is the ability to cover large areas, using standardised data and methodologies. Natural England has been developing two strategic monitoring products that take advantage of this. Firstly, the Moorland Change Map (MCM), which uses satellite data to map change in heather extent across areas of blanket bog. Secondly, the Space to Eye Lens project, which is developing an EO-based assessment of bog quality. Both of these projects are ongoing; there are future plans to make them operational.

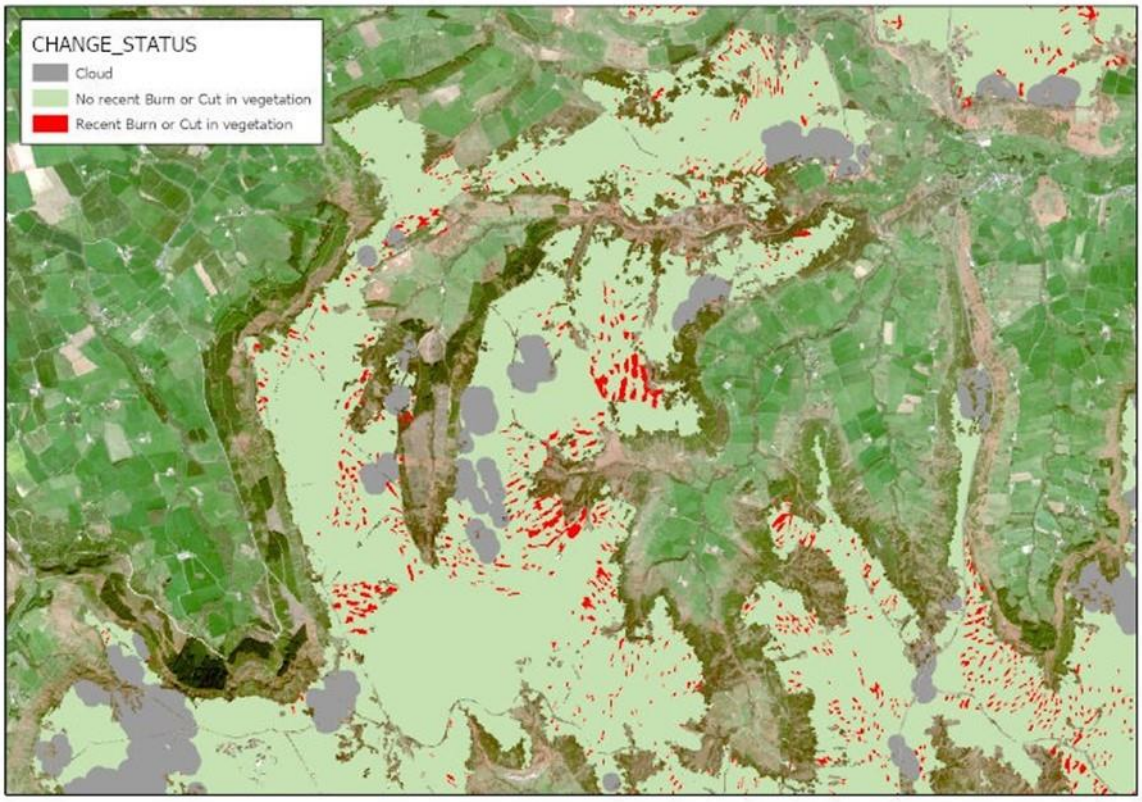

Figure 7: Example output from the Moorland Change Map from the 2018/19 burn season

Long Term Monitoring Network – the first ten years.

Sarah Grinsted and John Holdsworth

The Long Term Monitoring Network (LTMN) project has completed its first ten years of looking at the effects of climate change, air pollution and land management on our best wildlife habitats and species. The project is long term, using multiple monitoring protocols and covering a range of target habitats across the country. It sits in the sentinel surveillance tier of the Natural England Monitoring Strategy. The LTMN sites, which are largely on National Nature Reserves (NNRs), can be regarded as beacons or reference sites representing our wider network of valued wildlife sites; LTMN contributes to meeting a key purpose of NNRs for study and research.

The project aims to answer the over-arching question: How are plants, soil communities and species populations changing due to climatic change (e.g. increasing temperature, changing rainfall, extreme events) and air quality (e.g. nitrogen deposition and/or recovery from acidification), and what is the role of land management interventions?

LTMN activities

The project is based on thirty-seven sites where we implement seven monitoring protocols covering vegetation, soils, birds, butterflies, weather, air quality and land management.

For example, fifty 2m by 2m permanent plots are located on target habitats across a reserve and surveyed every four years for the presence and abundance of plant species. This year we completed the 80th vegetation survey, with eight sites having had a third survey. Some early analysis explored the use of variables such as vegetation structure, plant species cover, Common Standards Monitoring indicator species and Ellenberg plant trait values (preferences for fertility, wetness, acidity and light) to characterise the vegetation, and assess condition and change[5,6].

[5] Hicks, D. (2018) *'Short term use of long term monitoring data: LTMN upland vegetation'.* Unpublished.

[6] Nisbet, A., Smith, S.J., & Holdsworth, J. (Eds) (2017) Taking the long view - an introduction to Natural England's Long Term Monitoring Network 2009 - 2016. Natural England Report NERR070.

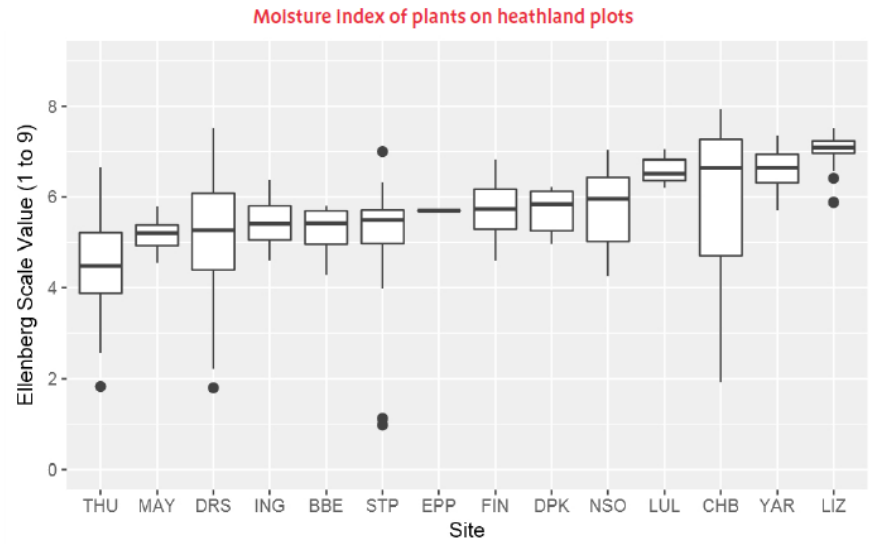

Figure 8: Boxplot showing the Ellenberg moisture index on heathland plots across 14 sites.

To monitor soils, five 20m by 20m plots are located near the vegetation plots, which are monitored every six to nine years. A range of soil samples are collected and analysed for a range of physical, chemical and biological properties. After the first round of sampling across the sites, analysis revealed that soil microbial communities are driven by organic matter content and soil chemistry, particularly pH. Microbial community diversity was measured through the amount and composition of microbial cell membrane constituents (Phospholipid Fatty Acids: PLFAs) and a genetic technique - bacterial tRFLP (terminal Restriction Fragment Length Polymorphism). It was found that microbial communities were distinctive between many of the sites, although there were clear areas of overlap between sites with similar vegetation or soil chemistry. Sites with sandy soils (low organic matter, low water content and high bulk density) tended to have a separate set of highly distinctive communities, whilst those with peaty soils had a broad range of varying communities.

Subsamples of soil mesofauna communities from 15 sites were analysed using genetic metabarcoding – a technique that uses distinctive genetic barcodes found in their mitochondrial DNA. This revealed a range of different animal communities across the sites, and future work will explore how these differences link to other soil and vegetation attributes. Both microbial and mesofauna communities showed promise as tools to distinguish sites and detect change[7].

[7] Shepherd M. (2016) *Long Term Monitoring Network: monitoring soils 2011 to 2016.* Natural England Evidence Information Note EIN024.

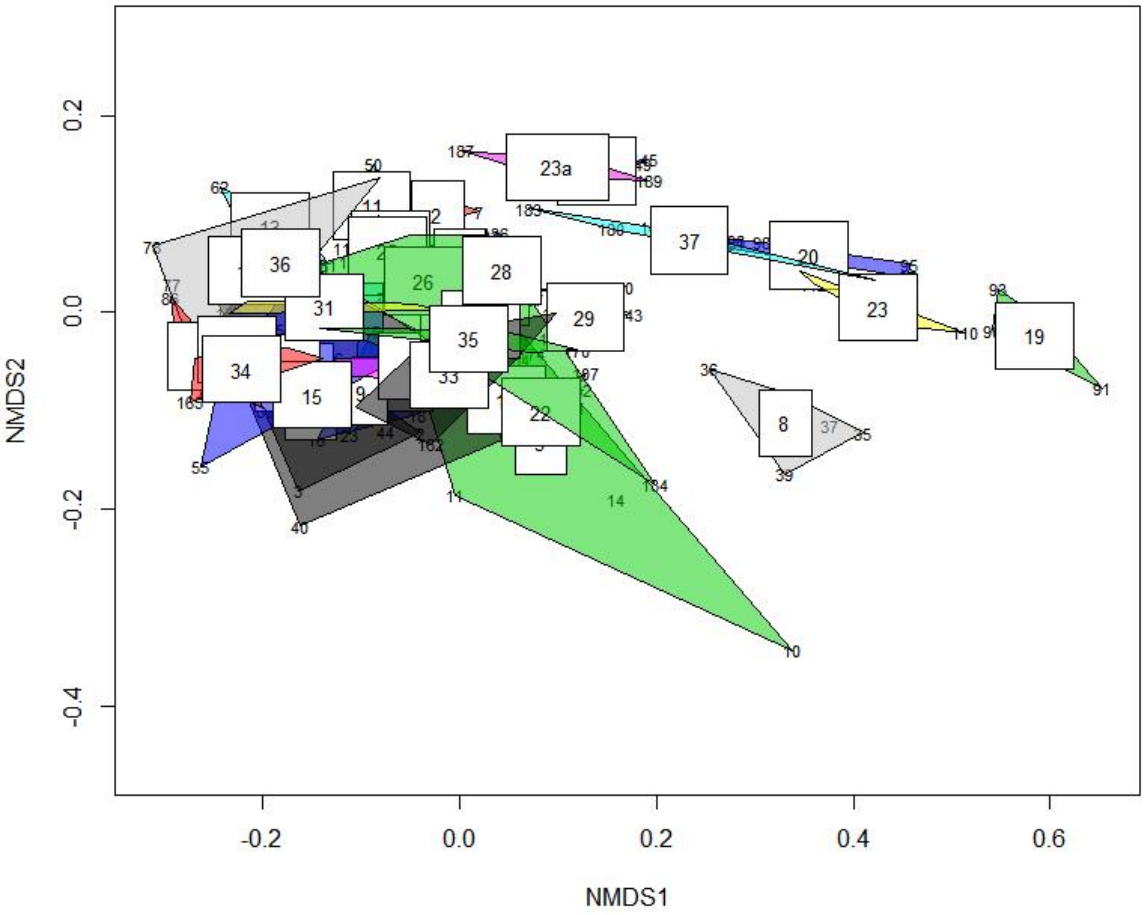

Figure 9: Diversity of microbial PLFAs (cell membrane components) found across 37 sites during soil monitoring. The x axis (NMDS1) explains most of the variability of the data and is correlated negatively with soil organic matter content and positively with soil bulk density. The y axis (NMDS2) explains the next most variability among PLFAs and is correlated positively with soil pH. Sites 19, 20, 23 and 37 are sand dune sites: Ainsdale, Lindisfarne, Saltfleetby Theddlethorpe and Braunton Burrows. Site 8 is Thursley Common – the distinctive microbial community here may reflect a widespread fire at the site shortly before sampling.

Crucial to the success of the LTMN project has been the support and enthusiasm of partner organisations who wholly or partly own or manage 11 of the LTMN sites, that is the Forestry Commission, National Trust, Field Studies Council, Corporation of the City of London, Christie Devon Estates, three Wildlife Trusts and Natural Resources Wales. On-going collaboration with Manchester Metropolitan University has used LTMN vegetation data in combination with satellite imagery, for mapping habitats and detecting change, and informing our increased use of Earth Observation techniques. We are working with Defra and the Centre for Ecology & Hydrology looking at the integrated analysis of LTMN data with UK Environmental Change Network, Countryside Survey and National Plant Monitoring Scheme data.

For Natural England staff and external volunteers, the vegetation and soils monitoring are eagerly anticipated each year, giving opportunities for adventure,

comradery and developing botanical identification and other survey skills. All levels of expertise are welcomed, from national specialists, through to intermediates and beginners.

Figure 10: Braunton Burrows vegetation survey 2019.

The LTMN data is Open Data and available for you to use. Are you a student, researcher or partner organisation with a project in mind? Perhaps there is scope for collaboration? The vegetation and soils data in particular are ready to use having completed each step of collation, Quality Assurance and publication. If you would like to know more or to sign up for our newsletter please contact us at

LTMN@naturalengland.org.uk, or you can go direct to the LTMN pages on Natural England's Access to Evidence catalogue.

Looking forward, Natural England has ambitions to add further sites to the network. Continued investment in the LTMN will provide a critical evidence base to inform the understanding of environmental change which will be vital to shaping the delivery of government's 25 Year Environment Plan.

MENE: insights into people and the environment

Amy Greenwood, Claire Gray, Rose O'Neill, Nathan Shaw, Cheryl Willis

From March 2009 to February 2019, Natural England ran the Monitor of Engagement of the Natural Environment (MENE) survey[8,9]. Half a million adults from all over England participated in face-to-face interviews about their experiences and attitudes of nature and the things they do to protect it. The MENE dataset is the largest of its kind and allows us to track how visits to the natural environment have changed over the last decade. Statistics derived from MENE have been designated as National Statistics. They meet the highest standards of public value, trustworthiness and quality. It was estimated there were 4 billion visits to the natural environment in 2019, up from 2.9 billion over 10 years. Clearly, we are visiting the natural environment in greater numbers, but what else have we learned?

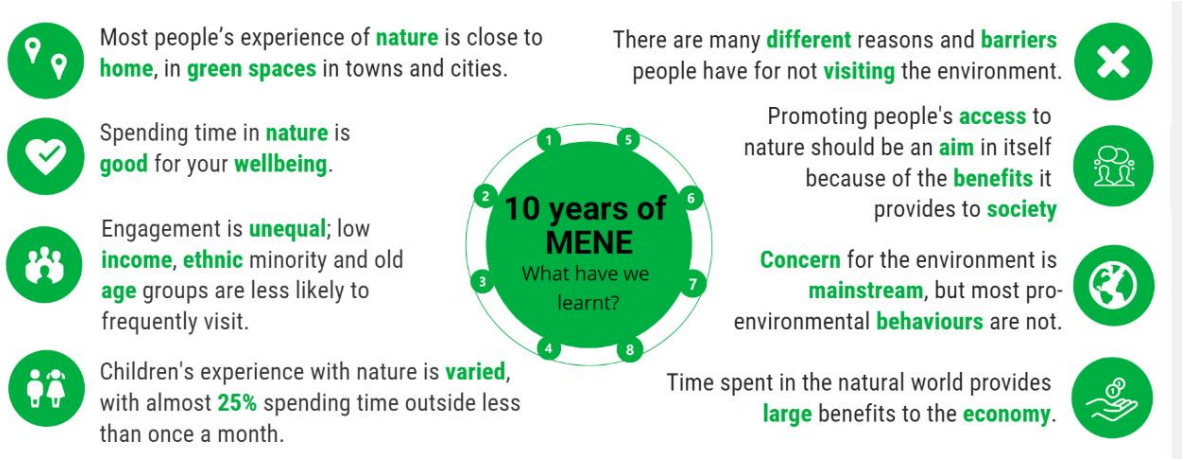

Figure 11: 10 years of MENE

Nature on our doorstep

Most people's experiences with nature are close to home, with people making more use of nature on their doorstep. Over the last decade, the numbers of visits to urban greenspaces, such as parks, playing fields and woods, almost doubled. More generally, the average distance travelled decreased. More of the population are getting outside regularly, taking shorter visits to nature closer to home.

[8] https://www.gov.uk/government/collections/monitor-of-engagement-with-the-natural-environment-survey-purpose-and-results

[9] http://publications.naturalengland.org.uk/publication/2248731

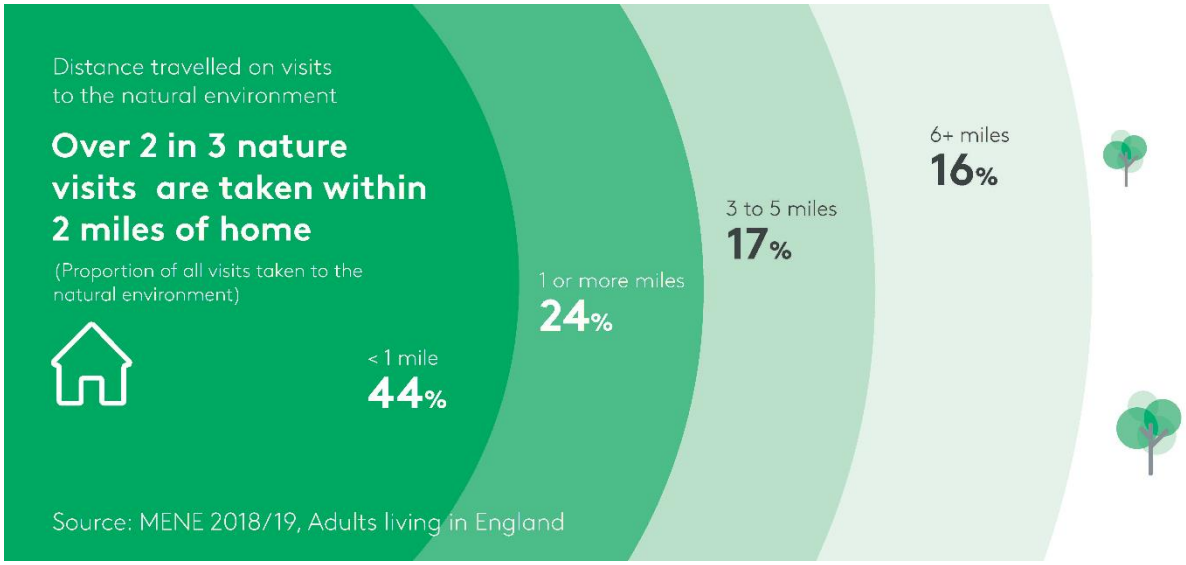

Figure 12: Distances travelled on visits to the natural environment

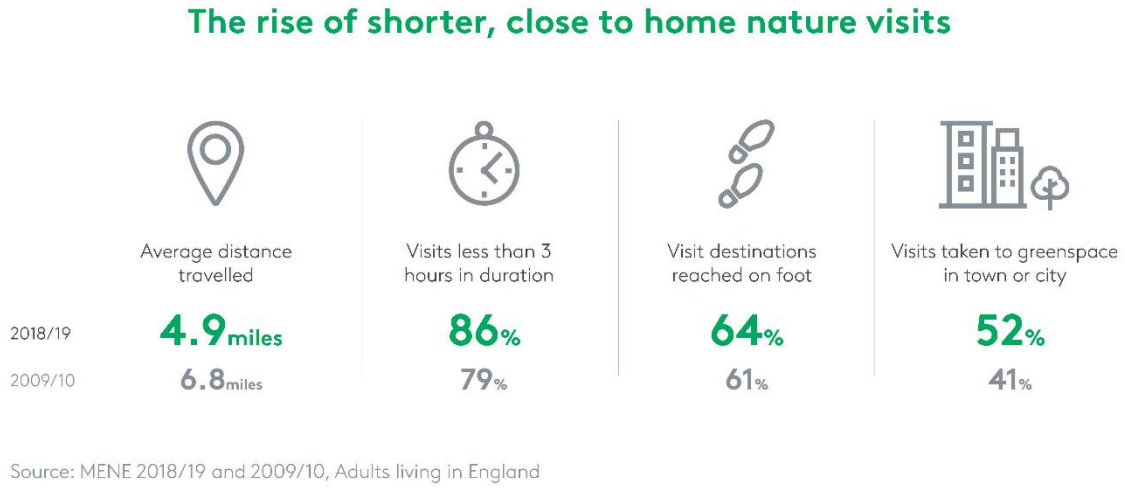

Figure 13: Nature visits

Nature is good for you

The survey shows that nature not only provides a source of enjoyment but is associated with relaxation, feeling refreshed and revitalised.

In 2012, we added the Office of National Statistics wellbeing measures to MENE. We found that people who visited the natural environment the most often (several times a week) have the greatest life satisfaction, more self-worth, more happiness and less anxiety[10] .

[10] Monitor of Engagement with the Natural Environment: The national survey on people and the natural environment - Wellbeing and the natural environment (NECR129)
http://publications.naturalengland.org.uk/publication/6710511932538880?category=47018

Additional analysis of the MENE dataset has shown that spending at least 120 minutes a week in nature is associated with good health and high psychological wellbeing[11].

However, MENE has shown clear inequalities between different age, ethnic and socio-economic groups, and those with different states of health, in how they use and experience the natural environment.

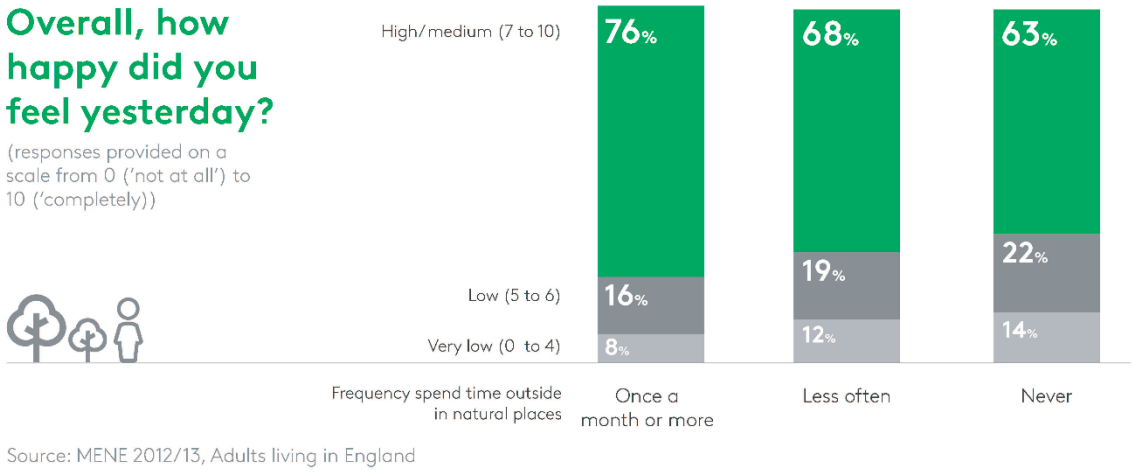

Figure 14: MENE: Happiness, plotted against the frequency of visits to the natural environment

Over the last 10 years, health and exercise has become the main reason for spending time in the natural environment

Older people (65+) reported that 64% of their visits were for health and exercise; a rise of 21% over 10 years.

Among the lowest income areas of England, health and exercise as a reason for visiting increased from 23% to 52% over the last 10 years.

Children and Nature

In 2013, we started asking adults about their children's time in nature. They reported that three quarters of children spent time outside in an average month in 2018/19.

Most children, even in older age groups, spend time outside with adults present.

We also ask how often children spend time in natural places away from home. In 2018/19, just over two thirds of children spent time outside at least once a week; almost a quarter did so less than once a month or never.

Values and actions

[11] White, M.P., Alcock, I., Grellier, J. *et al.* Spending at least 120 minutes a week in nature is associated with good health and wellbeing. *Sci Rep* **9,** 7730 (2019) doi:10.1038/s41598-019-44097-3

Most people (nine out of ten) agree that they are “concerned about damage to the natural environment”. MENE has tracked awareness and concern for biodiversity decline since 2014. Latest results show levels of awareness of, and concern about, biodiversity loss in England has increased significantly over this time, from 49% adults both aware of biodiversity loss and concerned about it in 2014/15, rising to 62% in 2018/19. While attitudes seem to be changing, participation in pro-environmental behaviours has been largely static over the last decade, with a gap between the proportion of people who report concern for nature and the proportion who take multiple actions to protect it.

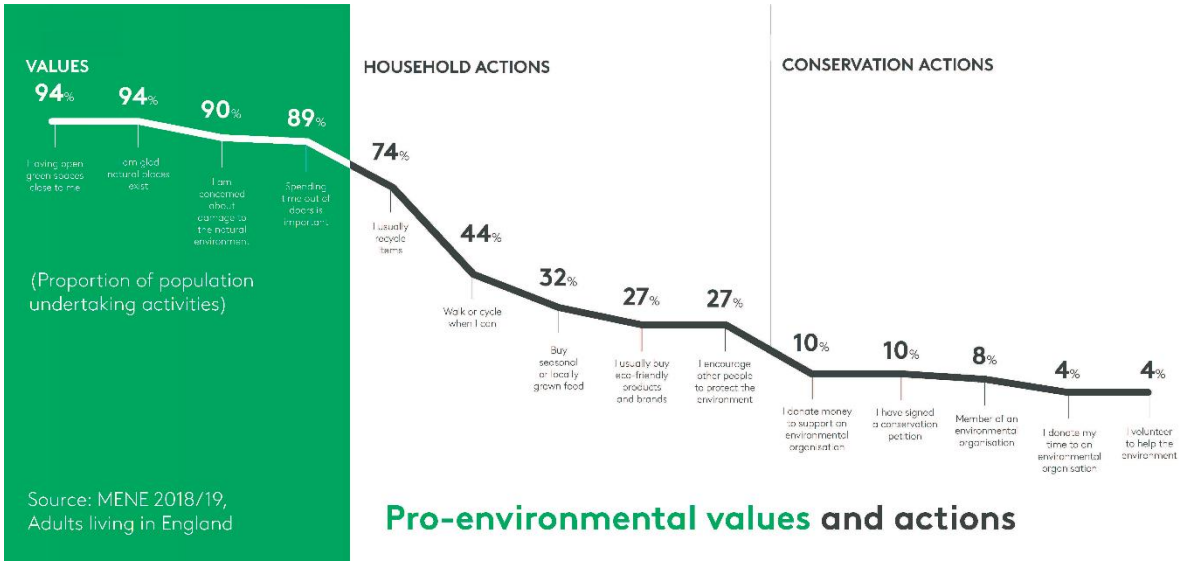

Figure 15: MENE, tracking values and actions

Natural Capital Accounts

Around a third of visits involve some form of expenditure. MENE has been used to inform the UK natural capital ecosystem accounts, which estimates the value of recreational visits in nature

Spend values collected in MENE are likely to be underestimated as, for example, expenditure made in preparation for visits (e.g. on fuel, food and drink) is not accounted for. Visits to nature which incur no expenditure are likely to also have an economic value which is not captured - for example, estimated savings to the NHS relating to health and wellbeing benefits.

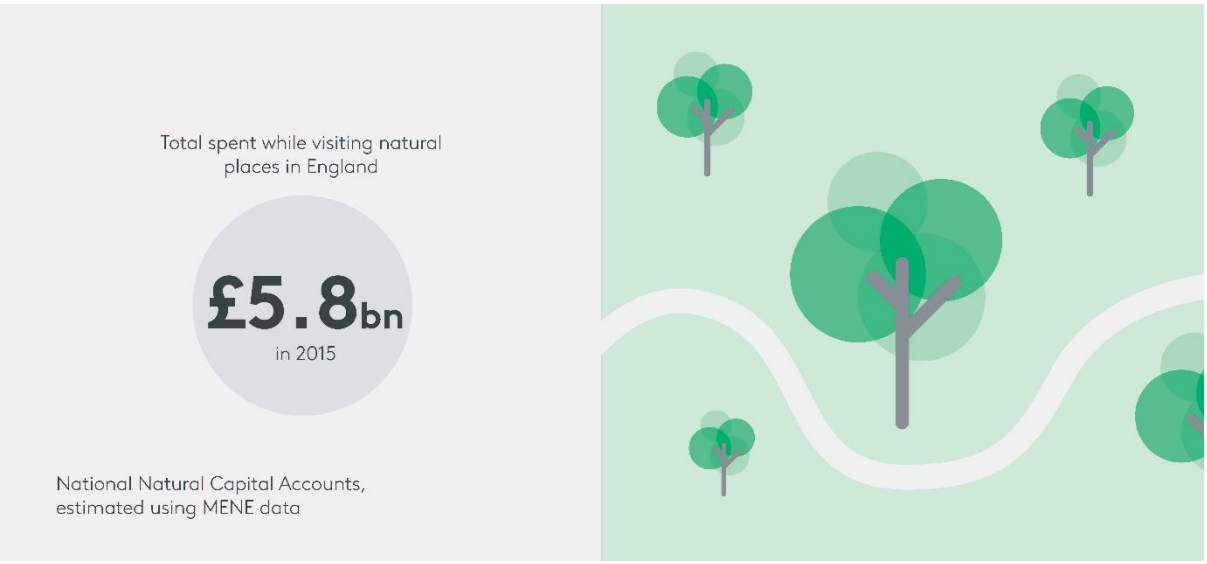

Figure 16: MENE

People and Nature Survey – the new MENE

MENE has answered many of the original questions it was set up to address and lots more besides. Our understanding of people's engagement with the natural environment has grown, and with that has come a new questions. In 2020 MENE will be replaced by the People and Nature Survey (PNS). This will be an online survey, retaining the core the MENE but also enabling us to explore new areas in greater depth, such as health and wellbeing. It will also be a key data source to inform progress on the government's 25 Year Environment Plan.

Development of natural capital indicators and their use in natural capital accounts.

Ruth Waters

Natural Capital frames the environment as a productive asset in order to include it in economic decision-making. It asks the same questions about land or sea that we might ask about other material assets, for example: What state is the asset in? What benefits does it provide? For how long? How well? What maintenance and investment is required?

Natural England has used a logic chains approach to understand the assets and flow of ecosystem services to people who benefit from them and therefore value them. This is a simplistic representation of a system that in reality is highly complex and multi-dimensional. This simplistic approach helps us to tease out some of these relationships in a systematic way and to identify important attributes of the assets, the consequential services, benefits and values. This flow of services from natural capital assets to people is represented in figure 17:

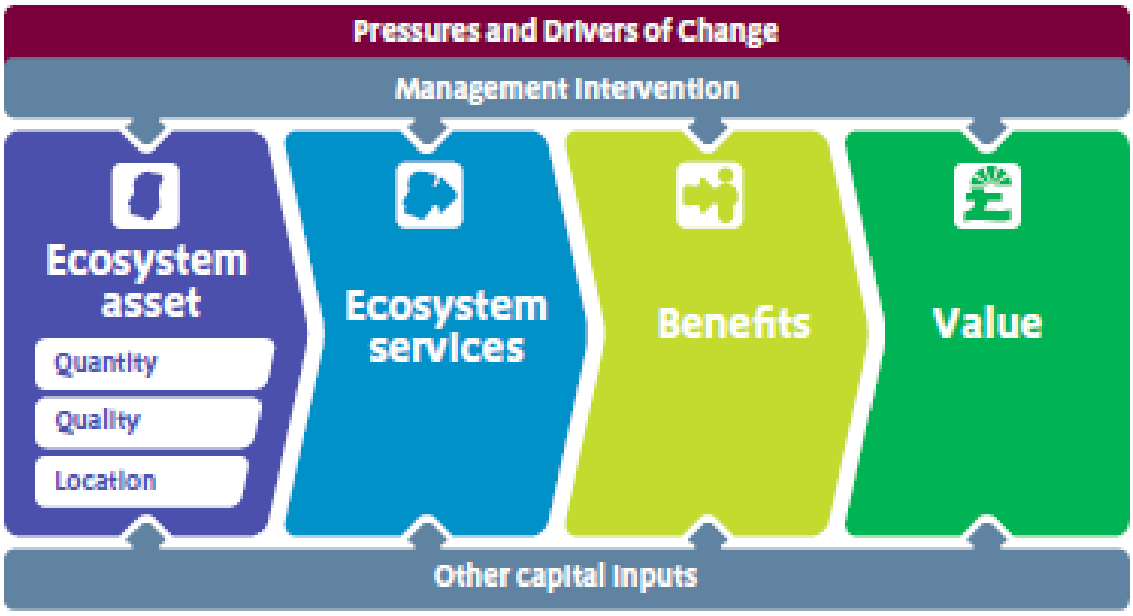

Figure 17: Logic chain diagram showing the link between ecosystem quantity, quality and location and the provision of ecosystem services, benefits and value (from Sunderland *et al.* 2020)

Natural England also did a review of natural capital indicators to understand the critical attributes to monitor in each part of the logic chain. These attributes were matched with best available data and indicators. Fifty one logic chains were done for eight broad habitat types and eighteen ecosystem services[12]. Figure 18 illustrates

[12] Natural Capital Indicators: for defining and measuring change in natural capital NERR076 http://publications.naturalengland.org.uk/publication/6742480364240896

the key attributes of the quality of our natural capital in the roots that enables the flows, benefits to society and values in the canopy. This work was used to support the development of the 25 Year Environment Plan indicator framework which is being used to assess progress on protection and improvement to our natural environment.

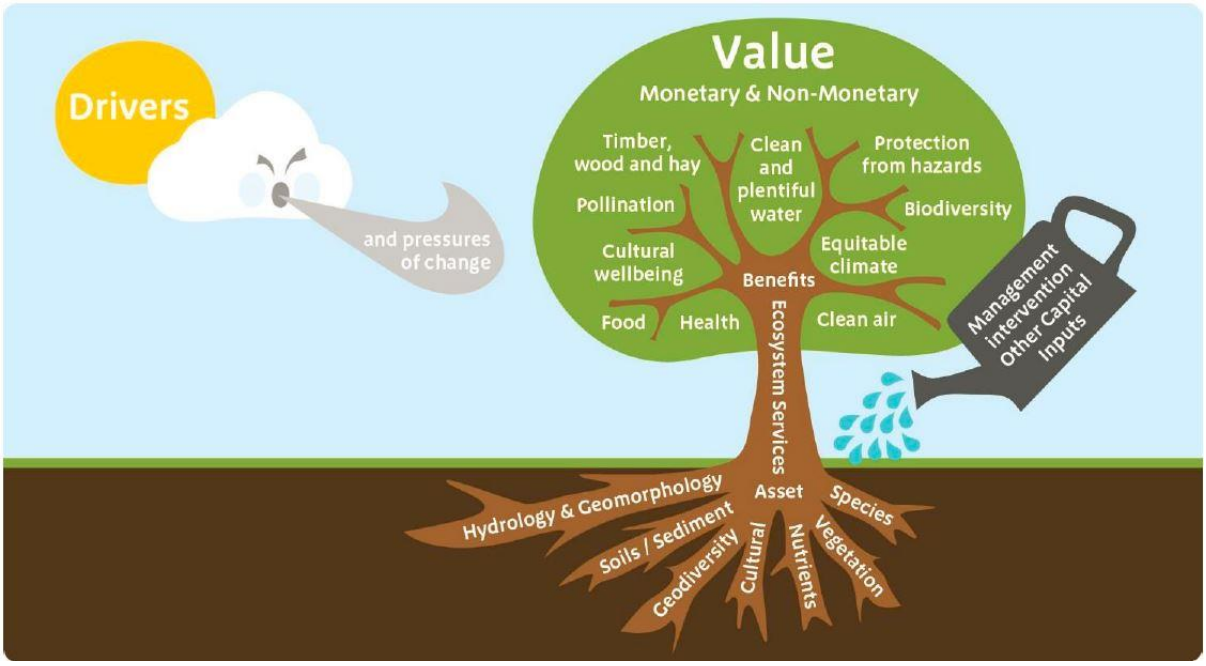

Figure 18: Ecosystem attributes underpinning the provision of multiple benefits (from Sunderland *et al.* 2020)

Natural England has used the natural capital logic chain as the basis for our natural capital accounts on National Nature Reserves (NNRs), seeking to report on each part of the chain: assets, services, benefits and values using the indicators identified through the logic chains. This approach provides decision makers with a more complete picture of the state of the assets, flows, benefits and the values derived from them. Often, understanding values is insufficient to know whether or not the asset is able to continue to provide benefits into the future. Figure 19 shows us that typically we lose information as we go from left to right along the logic chains, from assets through to values. This is particularly important for assets such as NNRs whose purpose is to provide a range of public goods such as biodiversity that we know is difficult to value. Values on their own, may not relate closely to the quality of the asset.

We have also developed an extended balance sheet which reports on the quantity and quality of the assets, the ecosystem services, benefits and values alongside each other. Where quantified data is missing, we have estimated the significance of ecosystem service provision and benefits qualitatively using expert judgement to avoid partial accounts and to present a more complete picture[13]. The accounts and

[13] Accounting for National Nature Reserves: A Natural Capital Account of the National Nature Reserves managed by Natural England (NERR078) http://publications.naturalengland.org.uk/publication/4535403835293696.

the indicators work won the 2019 John Hoy prize for best piece of economic analysis across government.

Figure 19: Loss of information across the logic chain (from Sunderland *et al.* 2020)

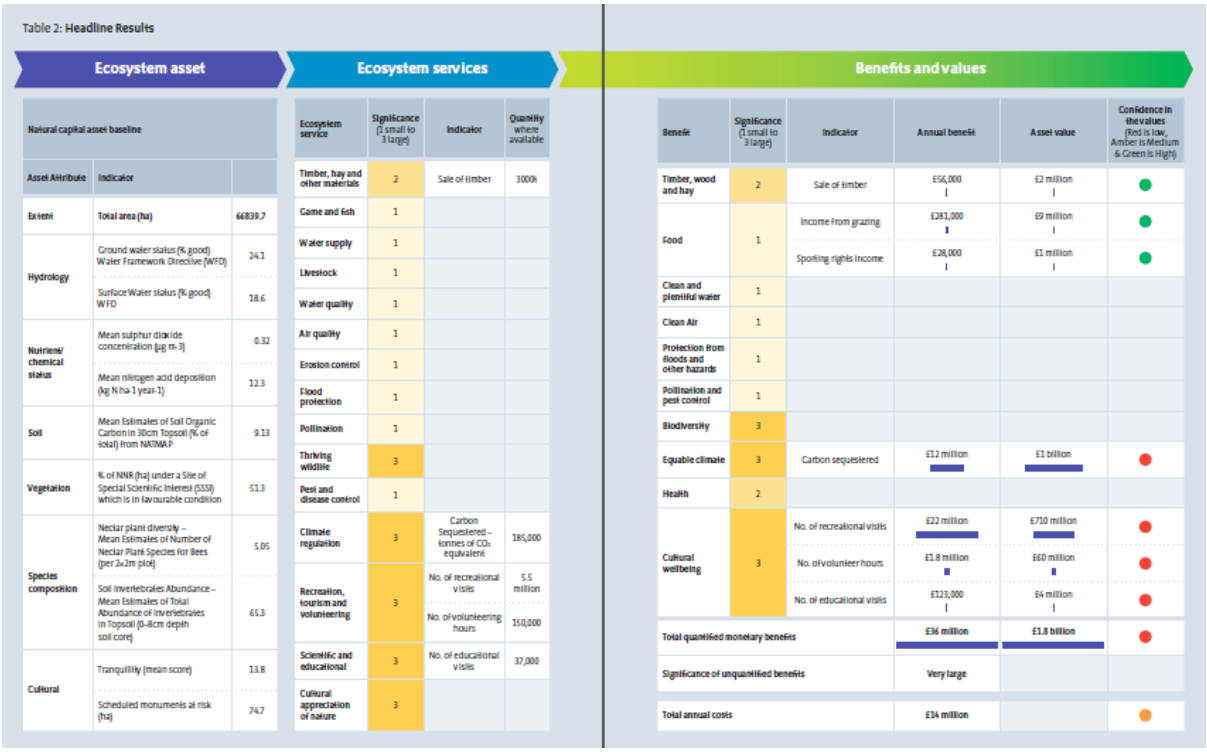

Table 2: **Headline Results**

Ecosystem asset

Natural capital asset baseline		
Asset Attribute	Indicator	
Extent	Total area (ha)	66839.7
Hydrology	Ground water status (% good) Water Framework Directive (WFD)	24.1
	Surface Water status (% good) WFD	18.6
Nutrient/ chemical status	Mean sulphur dioxide concentration (µg m-3)	0.32
	Mean nitrogen acid deposition (kg N ha-1 year-1)	12.3
Soil	Mean Estimates of Soil Organic Carbon in 30cm Topsoil (% of total) from NATMAP	9.13
Vegetation	% of NNR (ha) under a Site of Special Scientific Interest (SSSI) which is in favourable condition	51.3
Species composition	Nectar plant diversity – Mean Estimates of Number of Nectar Plant Species for Bees (per 2x2m plot)	5.05
	Soil invertebrates Abundance – Mean Estimates of Total Abundance of invertebrates in Topsoil (0-8cm depth soil core)	65.3
Cultural	Tranquillity (mean score)	13.8
	Scheduled monuments at risk (ha)	74.7

Ecosystem services

Ecosystem service	Significance (1 small to 3 large)	Indicator	Quantity where available
Timber, hay and other materials	2	Sale of timber	3000t
Game and fish	1		
Water supply	1		
Livestock	1		
Water quality	1		
Air quality	1		
Erosion control	1		
Flood protection	1		
Pollination	1		
Thriving wildlife	3		
Pest and disease control	1		
Climate regulation	3	Carbon Sequestered – tonnes of CO_2 equivalent	185,000
Recreation, tourism and volunteering	3	No. of recreational visits	5.5 million
		No. of volunteering hours	150,000
Scientific and educational	3	No. of educational visits	37,000
Cultural appreciation of nature	3		

Benefits and values

Benefit	Significance (1 small to 3 large)	Indicator	Annual benefit	Asset value	Confidence in the values (Red is low, Amber is Medium & Green is High)
Timber, wood and hay	2	Sale of timber	£56,000	£2 million	
Food	1	Income from grazing	£281,000	£9 million	
		Sporting rights income	£28,000	£1 million	
Clean and plentiful water	1				
Clean Air	1				
Protection from floods and other hazards	1				
Pollination and pest control	1				
Biodiversity	3				
Equable climate	3	Carbon sequestered	£12 million	£1 billion	
Health	2				
Cultural wellbeing	3	No. of recreational visits	£22 million	£710 million	
		No. of volunteer hours	£1.8 million	£60 million	
		No. of educational visits	£123,000	£4 million	
Total quantified monetary benefits			£36 million	£1.8 billion	
Significance of unquantified benefits			Very large		
Total annual costs			£14 million		

Figure 20: Example of an extended natural capital account balance sheet (from Sunderland *et al.* 2020)

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Humphrey Crick

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ISBN 978-1-84754-348-3

Catalogue Code: NE759

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