Monitoring the Natural World

Introduction

It is essential that Natural England develops its evidence base to ensure it can operate effectively and efficiently - both as an environmental delivery organisation and as a statutory adviser to government. Our single evidence programme coordinates the evidence work across Natural England and encompasses all the monitoring and research projects we undertake or directly fund.

Our monitoring work covers biodiversity, geodiversity and people engagement in relation to both terrestrial and marine environments. We also collect data on the marine environment and our articles in this section include the work of our dive team and use of novel survey techniques to estimate populations of red-throated divers. Examples of our terrestrial monitoring include the Geological Conservation Review, which systematically identifies key geological sites for scientific research and underpins the network of geological Sites of Special Scientific Interest in England. Assessments are ongoing and we discuss the tufa review towards the end of this section. Our Long Term Monitoring Network covers 37 terrestrial sites and is key to our understanding of the effects of climate change, air pollution and land management on the natural environment. We also monitor people's engagement with the natural environment in both urban and rural places through our flagship project Monitor of the Engagement with the Natural Environment (MENE). We present the headlines from the sixth survey at the start of this section.

Monitoring on Pewsey Downs NNR

We participate in partner-led long-term monitoring schemes to understand specific environmental changes such as how harmful substances can affect wildlife. The Predatory Bird Monitoring Scheme is one of the best examples of influential long-term monitoring.

We also develop new monitoring methods to understand the impact of financial or policy interventions on the natural environment. Our approach to investigating how Environmental Stewardship affects the quality and character of landscapes uses a new spatial framework design to assess the landscape effects of agri-environment schemes. Citizen science is also becoming increasingly important to gather data and engage people with the natural world. This can also be a lot of fun as our mini citizen scientists, the Bog Hoppers, found out through their survey of crickets and grasshoppers on a National Nature Reserve.

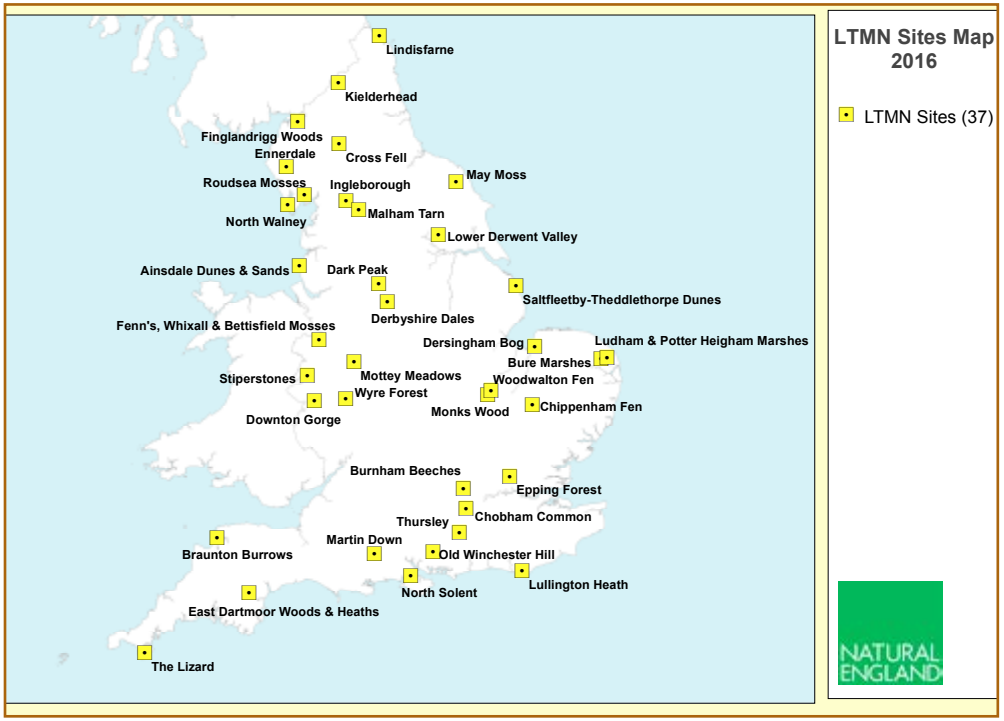
Long term monitoring of the natural environment

by John Holdsworth and Christoph Kratz

The long term monitoring network helps Natural England understand the effects of climate change, air pollution and land management on the natural environment.

Since 2009 Natural England has contributed to the **Environmental Change Biodiversity Network** through its Long Term Monitoring Network (LTMN), which currently stands at 37 sites across England. The sites are shown on Figure 1, the LTMN sites map 2015. On these sites we monitor weather, air and soil chemistry, plant and soil biodiversity and bird and butterfly populations using standard methods, to allow us to compare target habitats on a range of sites across the network.

As part of the programme vegetation surveys are carried out every four years to monitor the change in plant communities, over time. Soil surveys are repeated every six years, bird and butterfly surveys are carried out annually, and on sites where we record weather and air quality, this is done continuously. The results are available as open data, published on **Data.gov.uk**, and via our **Access to Evidence catalogue**. Natural England uses the survey outputs to advise others (such as Defra) on mitigation or adaptation actions and to allow us to adapt our own interventions and activities. Some surveys have been contracted out but others are done in-house which, since 2011, has resulted in over 850 volunteers from Natural England and our partner organisations participating in vegetation surveys on LTMN sites.



CLICK MAP TO ENLARGE

Figure 1: Long Term Monitoring Network sites map.

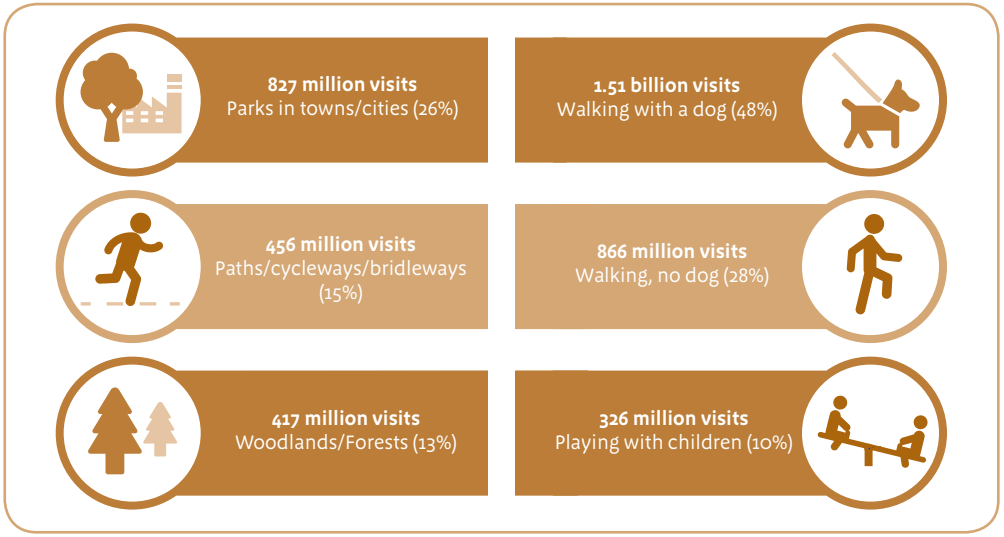
As part of our 2016 programme we completed four in-house vegetation surveys during which 176 volunteers from National Nature Reserves, Natural England and partner organisations surveyed 179 plots. We also carried out in-house surveys for soil biodiversity, sampling 80 plots on four sites.

We love the great outdoors and our survey shows it: Monitor of the Engagement with the Natural Environment (MENE)

by Hazel Thomas and Katie Allen

MENE is Natural England's annual survey which looks at the English population's engagement with the natural environment – all green open spaces in and around towns and cities, the countryside and coastline. The MENE survey was recognised as a National Statistic by The UK Statistics Authority in October 2014 because of its high quality data.

Family on a footpath in Blanchland, Northumberland



The sixth **MENE survey results**[1] released on 2 December 2015, show the public's enthusiasm for spending time outside relaxing and unwinding, watching wildlife, enjoying the scenery, or keeping healthy is the highest it's been since records began.

A record three billion visits were made to England's great outdoors, showing interest in our natural environment is on the rise.

The survey – supported by Defra and the Forestry Commission – interviews approximately 800 people weekly who are a representative sample of the population. Crucially it also collects detailed information regarding actual 'visits', including location; meaning we now have information that is statistically robust down to local authority level.

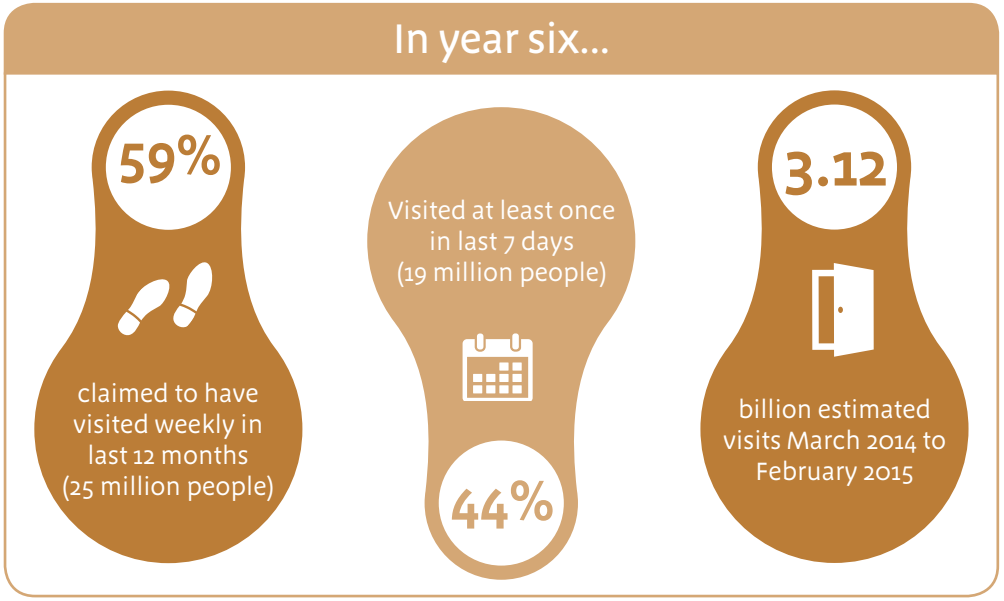
Using MENE data:

- We produce themed as well as annual reports, for example, attitudes to the marine environment, outdoor learning and play, **visits to the natural environment in East London**[2] and the forthcoming report on the importance of urban greenspace for outdoor recreation.

- Pennine Prospects, a partnership of local authorities, water companies, and the heritage and voluntary sector, commissioned an **analysis of MENE data**[3] to understand the profile of visits to the South Pennines. This contributes to their decision making about local infrastructure investment and small business support in rural areas.

- To support a number of national indicators including Biodiversity 2020's Indicator 13; Public Enjoyment of the Natural Environment, and Public Health England's Outcomes Framework Indicator 1.16: percentage of people using outdoor places for health/exercise reasons in Upper Tier Local Authority areas.

- In 2015 the survey was extended to reveal the scale and scope of the **visits children**[4] in England make to natural environments, including parks, playgrounds and woodlands. The results show a link between social inequalities and the opportunities that children have to experience their natural environment. It highlights the importance of local greenspace to all children - especially those who visit less frequently.



MENE data assists our work nationally and locally:

- It allows us to work with partners to make choices about what priorities might be needed in terms of sectors of the population.

- It enables us to prioritise if and where we focus effort to maximum effect, for example, in and around urban areas.

- It enables us to identify what activities may be most appropriate to increase engagement with the natural environment.

Citizen science on National Nature Reserves:
Bog Hoppers, crickets and grasshoppers

by Ash Murray

Of the 17 species of grasshopper and cricket that have been recorded in Norfolk, in total, 14 have been recorded from Dersingham Bog National Nature Reserve. In 2015, as part of a joint project with the British Trust for Ornithology, NNR staff joined forces with a Natural England led children's science group, the Dersingham Bog Hoppers, to carry out a survey of grasshoppers and crickets.

Bog bush cricket

Before 2015, all of the data on crickets and grasshoppers (*Orthoptera*) at the reserve came from informal records, rather than any systematic survey. Our understanding of species distributions and relative abundance on the site was therefore very limited.

In 2015, a Natural England children's science group, the Dersingham Bog Hoppers, assisted by reserve staff and the British Trust for Ornithology, helped to survey grasshoppers and crickets on the reserve. As well as helping the children understand more about these insects and how to recognise them, we wanted to use their unique abilities (low centre of gravity, acute eye-sight and excellent hearing) to help find the insects in the first place! We were particularly interested in whether the reserve still supports the rare bog bush cricket and even rarer large marsh grasshopper.

The survey dovetailed neatly with an exciting opportunity, identified by the British Trust for Ornithology. This involved using our data to help colleagues from the Paris Museum develop computer software that could transform our understanding of Orthoptera distribution and ecology. Staff at the museum are developing automatic call recognition software which will, for the first time, allow the broad-scale, systematic surveying of Orthoptera. If successful, surveyors could record calls using recording devices fitted to broad-spectrum bat detectors. The recordings could then be analysed using the call recognition software to identify species.

The Bog Hoppers helped reserve staff deploy the recorders at a series of randomised locations across the site. They also carried out sight and sound surveys using line transects between the randomised points which provided supplementary information to the recorded call data. The sound data were then used to field test the call recognition software created by the Paris Museum. Since Britain has a smaller Orthopteran fauna than France, field testing the software in Britain makes it easier to detect identification errors.

Once analysed, the data confirmed that Dersingham Bog currently supports 12 species of grasshopper and cricket and, unfortunately, confirmed our suspicion that it is highly unlikely that the bog bush cricket and large marsh grasshopper survive on the site.

In the future, the data may be used as evidence to support a reintroduction programme for large marsh grasshopper or bog bush cricket. The remote sampling will be repeated to determine population abundance and distribution changes over time at Dersingham Bog National Nature Reserve.

Natural England's Dive team

by Kevan Cook

To determine the condition of designated sites we require sound evidence on the various features within a site to assist both our reporting of site condition and advice on management operations. Acquiring sound evidence for our underwater maritime sites presents many challenges, as techniques such as remote sensing, aerial photography and multi-beam surveys can only provide a limited and top-down view of the sea floor. Often, the best way to collect the evidence we need is to deploy divers.

Natural England's dive unit consists of 16 highly skilled and experienced marine survey divers and the data they collect makes an essential contribution to our statutory reporting on the condition of our European designated sites and features. Over the last four years, the dive team has carried out over 300 dives surveying (among other things): eelgrass beds, maerl (coralline red algae)beds, kelp forests, faunal turf communities and rocky reefs.

A particular example of their work was the sea-grass survey of the Fal and Helford Special Area of Conservation and Poole Harbour Special Protection Area in 2015. The data collected (in conjunction with video surveys carried out by external contractors) were used to inform our condition assessment of these sites.

Recording seagrass plant densities in Cornwall

With the forthcoming Marine Conservation Zone (MCZ) Tranche 3 designations, the dive team will be able to undertake further verification surveys to fill some of the gaps in our evidence base.

Using novel survey techniques to estimate populations of red-throated divers in Marine Protected Areas

by Richard Caldow

High altitude aerial photography reveals that the Thames Estuary has a much larger population of red-throated divers than previously thought.

Red-throated diver

The Outer Thames Estuary Special Protection Area (SPA) is the most important site for wintering red-throated divers in Great Britain. When it was designated in 2010 it was estimated to support a population of 6,466 over-wintering birds.

The figure of 6,466 birds was not, however, the result of a census of all birds within the site (which covers some 3,800 km^2). Rather, it was an estimate derived from a series of partial sampling surveys of the wider Greater Thames area over a number of years (1989-2007). These surveys were carried out using what at the time was the only viable survey method - human observers conducting visual surveys from low-flying aeroplanes. Since then, advances in technology have allowed aerial surveys to be carried out using aeroplanes flying at greater altitude and using high resolution digital cameras to capture images of the sea surface. Survey work within the SPA by one of the country's leading providers of digital aerial surveys (APEM Limited) indicated that the previous population estimates were likely to be significant underestimates.

Reasons for underestimation include:

- the speed at which survey aircraft travel and the limited time observers have to detect and identify birds
- the escape reaction of divers to approaching low-flying aircraft (they may dive or take flight)
- low-flying survey aeroplanes need to gain altitude close to shore for safety reasons, making it harder to record birds in such locations.

Digital aerial surveys do not suffer from these problems as photographs can be examined at leisure rather than at speed and because the aeroplanes fly at greater altitude, reducing escape reactions by birds and allowing transects to be carried out right into shore. Digital aerial surveys also generate a permanent record of survey images which can be reanalysed if needed and used to answer future questions of biological interest.

For all of these reasons, we commissioned digital aerial surveys of the entire SPA to derive an up to date, geographically comprehensive, and probably truer estimate of the numbers of red-throated divers supported by the SPA.

Methods

Two aerial surveys using high-resolution digital photography were undertaken in January and February 2013. Some 63 transect lines were surveyed, spaced 1.8 km apart and evenly distributed across the SPA (Figure 2). The same lines were flown on both surveys. High-resolution digital photographs (Figure 3) were taken through an opening in the floor of the plane.

The images were collected with a 3 cm ground sampling distance resolution (i.e. each pixel represents an area of 3 cm × 3 cm at ground level). Red-throated divers were distinguished from other species on each image and the location, time and date of each individual bird was recorded.. The number of red-throated divers present in the sample area was extrapolated to the entire SPA using design-based modelling.

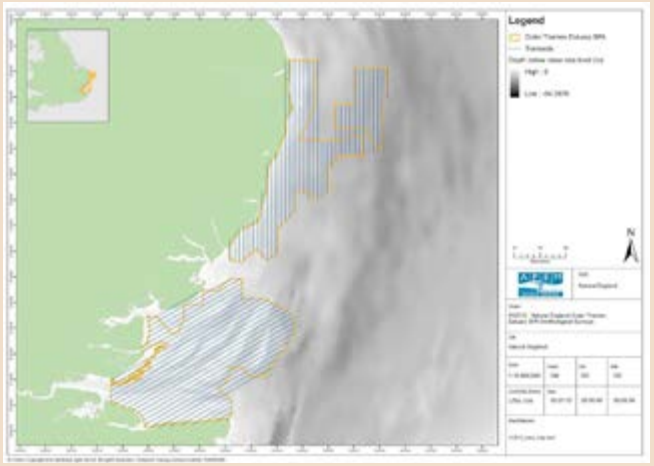


Figure 2: The Outer Thames Estuary SPA with bathymetry and aerial survey transect lines.

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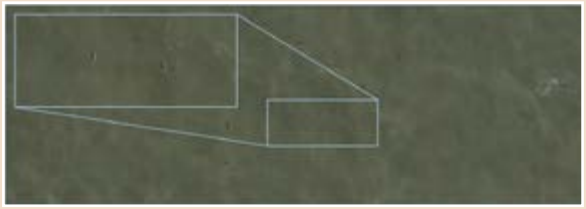

Figure 3: Digital aerial survey photograph of red-throated divers Gavia stellata sitting on the sea surface with two divers enlarged in top left-hand corner. This is a 3 cm GSD image.

Results and conclusions

The population in January and February 2013 was estimated to be 11,248 and 14,161 respectively. These numbers represent the largest aggregation of red-throated divers ever observed in a single site in UK waters or elsewhere in Europe. Red-throated divers were recorded throughout the SPA in both months, although the highest densities were recorded in the southern part, especially in February, and especially towards the centre and northeast of that area.

Although the Outer Thames Estuary SPA covers only about 40% of the Greater Thames area, the peak estimate recorded by these 2013 surveys was generally higher than peaks recorded in the Greater Thames area in previous years. While diver numbers within the SPA clearly vary from year to year and may do so considerably, it is highly likely that the results of these digital aerial surveys are a truer reflection of the numbers of birds that typically use the area than the figure of 6,466 individuals for which the site is notified. If a repeat digital aerial survey in the near future yields similarly high numbers, it would provide a sound evidence-basis for revising the baseline population of this SPA.

Given the many advantages of the digital aerial survey method it is likely that Natural England will use this method in future monitoring of marine SPAs designated for over-wintering aggregations of birds such as divers, seaducks and grebes.

The Predatory Bird Monitoring Scheme

by Susan Zappala and Alastair Burn

Long-term monitoring of contaminants in wildlife is essential for understanding the effects of chemicals released into the environment and to ensure that use of harmful substances is properly regulated. Natural England makes an important contribution to this.

Barn owl

The Predatory Bird Monitoring Scheme (PBMS) is a national, long-term programme that records the amount of selected contaminants in the livers and eggs of some British predatory and fish-eating birds. It is the longest-running monitoring scheme of its kind in the world, having been in operation since it started investigating chemicals such as DDT in 1962. PBMS is managed by the Centre for Ecology and Hydrology (CEH) and funded primarily by the Natural Environment Research Council (NERC), with support from a partnership of Defra and other government bodies including Natural England, NGOs and manufacturers. Citizen science contributes to the scheme, with volunteers submitting 300 to 400 birds annually through the PBMS postal collection service for autopsy and tissue analysis or archiving.

A question of particular interest for the scheme is how new or currently regulated substances such as pesticides and metals end up in wildlife, their food sources and the wider environment. The PBMS targets sentinel predators such as barn owl, sparrowhawk, gannet and (in collaboration with the Cardiff University Otter Project) otter. These provide an indication of how contaminants move through terrestrial, marine and freshwater food-chains, respectively. Substances of concern that have recently been included in the scheme are anticoagulant rodenticides, flame retardants and metals such as lead and mercury. The findings are used to determine geographic and temporal trends in exposure, which helps in understanding impacts on populations.

Recent analysis and findings

The PBMS holds a tissue archive for many predatory birds back to the 1960s and from some predatory bird eggs back to the 1970s[5]. This has enabled trends in a range of contaminants to be detected and monitored, including:

Second generation anticoagulant rodenticides (SGARs)

The PBMS has been instrumental in identifying that SGARs move through multiple food-chains and result in widespread exposure of a wide spectrum of predators[6]. For example, recent work showed that SGARs occurred in more than 80% of barn owls and sparrowhawks sampled by the PBMS between 2010 and 2013[7]. The PBMS has developed a method, using barn owls as a sentinel, for monitoring the impact of the 2016 Anticoagulant Rodenticide Stewardship Scheme on exposure of non-target wildlife[8]. Natural England is a member of the Government Oversight Group that is monitoring progress of the stewardship scheme which started in 2015 and will continue to monitor progress. Barn owls may be exposed to SGARs by consuming live non-target rodents (wood mice, voles) that have fed on these rodenticides. PBMS monitoring has shown that England has twice the number of owls with SGAR detectable residues than Scotland or Wales. Adult owls and sparrowhawks have more likelihood of having detectable SGARs, with adult owls having significantly greater tissue concentrations than adult sparrowhawks (Figure 4).

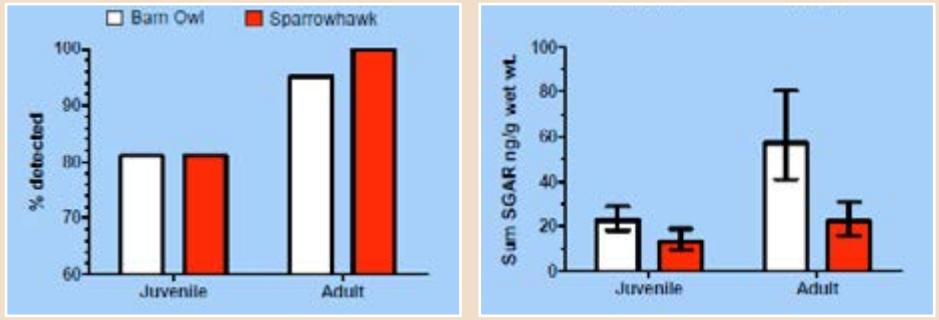

Figure 4: Second Generation Anticoagulant rodenticides (SGARs) were detected in over 80% of barn owls and nearly 90% of sparrowhawks (left panel) submitted to the Predatory Bird Monitoring Scheme (PBMS) between 2010 and 2013. Adult barn owls had significantly higher SGAR tissue levels (right panel), showing how SGARs move through the avian food-chain. From Walker and others 2015.

Red kite

More recently, the PBMS has included red kites in its SGAR investigations as, unlike barn owls, kites are exposed by scavenging dead rodents, particularly rats which are the targets of control.

Flame retardants and other organic contaminants

The PBMS has assessed the exposure of wildlife to a range of organic contaminants, including polychlorinated biphenyls (PCBs), poly-brominated flame retardants (PBDEs) including deca-brominated diphenyl ether (DBDE), and perfluorinated compounds (PFs). Studies on PBDEs show that concentrations have fallen in gannet eggs (marine sentinel), closely reflecting declines in use following European regulation, but remain relatively high in sparrowhawks in some locations' (terrestrial sentinel); this indicates how the impact of regulatory mitigation may vary significantly between ecosystems[9, 10, 11, 12].

Recent work on PFs has indicated that wildlife contamination by Perfluorooctanesulfonic acid (PFOS), the most abundant compound, has fallen recently following regulatory intervention on use, but concentrations of perfluorinated carboxylates are rising[13]. Overall, such work provides both early warnings of increasing threats from pollutants and assessment of whether mitigation has reduced risk to wildlife.

Polychlorinated biphenyls (PCBs)

Gannet eggs have shown a significant decline in PCB concentrations between 1969 and 2009. Generally PCB contamination recorded in eggs of most birds has declined, with the exception of coastal nesting golden eagles[14].

Gannet eggs have shown a significant decline in PCB concentrations since 1969

PBMS in the future: regulation, research and monitoring

PBMS provides ongoing evidence of exposure in sentinel species and helps assess the success of any voluntary or mandatory changes. For example, Defra used PBMS data[15] to inform mercury monitoring under the **Minimata Convention on Mercury**, which aims to control anthropogenic sources of mercury to protect human health as well as global air, soil and water resources. Information generated by PBMS about mercury and anticoagulant rodenticides has been used for Natural England's contribution to the State of the Environment reports[16]. The PBMS format is flexible and can adapt to changing evidence needs and emerging risks, as it has done in the past.

Data from PBMS are made available in a number of ways. A series of **reports** have been published and are publically available[17]. PBMS data also contribute to numerous research projects on contaminants as well as wider research on wildlife fitness and survival[18].

PBMS also contributes to a UK-wide effort to understand contaminant exposure of vertebrates such as fish and otters through the **WILDCOMS** (Wildlife Disease & Contaminant Monitoring and Surveillance) network; the PBMS was instrumental in establishing WILDCOMS. These approaches and data are now being incorporated into a wider European raptor monitoring network called **EURAPMON**.

Monitoring how environmental stewardship affects landscape character and quality

by David Vose, Chris Bolton, Andrew Baker and Sarah Manning

We have developed a new approach to investigating whether Environmental Stewardship (ES) is improving the character and quality of our landscapes. This work involved:

- a new method for monitoring the impacts of Environmental Stewardship on landscape character;
- a database of indicators and thresholds;
- a rapid survey method to extend the evidence base.

Methodology

Spatial framework design

Developing a consistent, repeatable and rigorous method for assessing the landscape effects of agri-environment schemes required a clear spatial framework allowing selection of a representative sample of survey areas, taking account of the variation in character of farmed landscapes. A nested hierarchy of sample areas was developed, operating at three levels from national to local (Figure 5).

Field surveys

The spatial framework was used to select 79 sample survey squares (each of 1km^2). Within each square, the landscape impact of each ES option and any classic scheme options still in operation was assessed using a five-point scale of *enhancing, conserving, maintaining, neutral or detracting* effect on landscape character and quality.

Figure 5: The spatial framework hierarchy.

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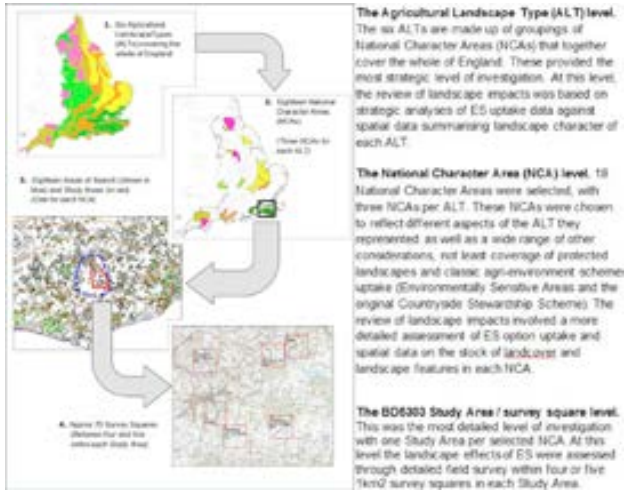

The field survey relied on answers to specific qualitative and quantitative questions. The result was a baseline recording the presence of all visible landscape features (land cover, linear features and point features such as individual field trees) and the condition of all those features covered by the agri-environment scheme against three condition classes.

Using counterfactuals

The assessment of counterfactual scenarios, tested through results of the field survey, allowed comparisons between the impacts of Environmental Stewardship, the previous 'classic' agri-environment schemes (Environmentally Sensitive Areas and the original Countryside Stewardship Scheme) and a 'do-nothing' situation. These counterfactual scenarios were described in four hypotheses that reflected the nature of the data that had been collected in the field.

Creating a database

The database captured and brought together:

- a comprehensive list of every ES option, together with the potential landscape effects of each;
- the uptake of each option within each National Character Area (NCA); and
- the key landscape characteristics of each NCA (the first time this information had been brought together in a simplified format).

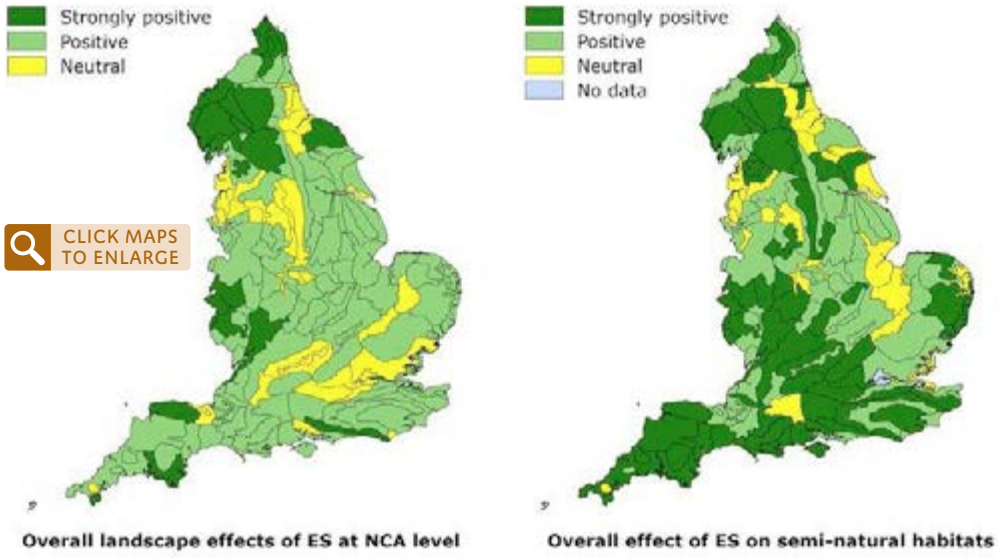

Figure 6: The spatial distribution of overall landscape effects (left hand map) and an example of the effects of ES against one of the landscape themes (semi-natural habitats).

ES options were categorised into 80 groups and sub-groups. These brought together those ES options which, as judged from field work and descriptions in the ES Handbooks, contribute to the same landscape outcome(s).

A comprehensive set of indicators and thresholds was developed to help judge the significance of the change in landscape introduced by ES uptake and which can be used for the consistent and repeatable monitoring and assessment of the landscape impact of agri-environment activity. A database was developed under the seven landscape themes of woodland and trees; boundary features; agricultural land uses; traditional farm buildings; the historic environment; semi-natural habitats; and the coast.

Thresholds were set in the database and a result was produced against each indicator for each NCA. The database allowed the assessor to select a NCA, select a theme and undertake the assessment (Figure 6). This:

- provided a consistent framework against which to consider the landscape effects of ES.
- allowed the balance of landscape effects to be quickly and easily understood.
- enabled quick identification of where the emphasis of ES uptake should be focused in the future for the benefit of the landscape.
- helped to identify which options that particularly benefit the landscape are being poorly utilised.
- illustrated which options and their level of uptake were having a strongly beneficial effect on the landscape and, conversely, which were not.

The rapid survey approach

The rapid survey approach was developed to provide a comprehensive 'broad and shallow' survey approach that collects a large amount of relatively simple data over a large area which can be calibrated by the 'narrow and deep' survey findings. It provides an efficient approach to collecting and storing data in the field, using tablet computers to record the scheme options that contribute most to landscape character and quality and the landscape types which receive most benefit from ES. The results from both approaches can be directly compared because they share common characteristics.

The survey method maximises the number of squares surveyed (Figure 7) by adopting a largely 'tick box' approach to recording the results. This approach has now been followed by Land Use Consultants during 2014, 2015 and 2016. A robust baseline for future landscape monitoring work has therefore been established, enabling statistically reliable comparisons between ALTs, NCAs and time periods.

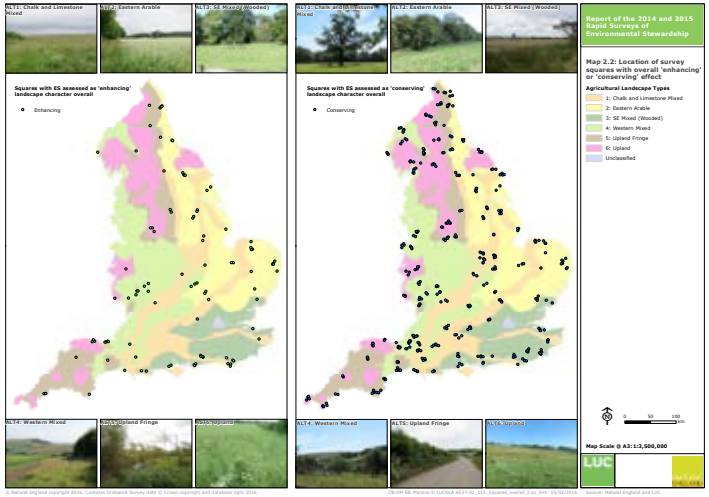

Figure 7: Location of survey squares with overall 'enhancing' or 'conserving' effect in relation to ALTs.

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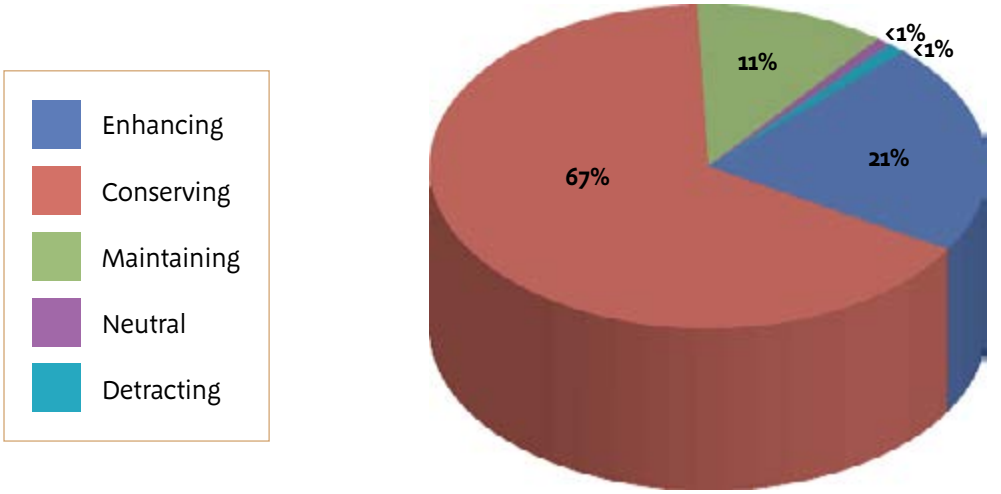

Figure 8: Overall impact of Environmental Stewardship on landscape character in the survey squares.

Results (Figure 8)

Conservation of landscape character (defined as maintaining traditional features that have declined significantly in the wider landscape) occurred in the majority (67%) of areas surveyed, largely through the management and restoration of hedgerows and through the retention of permanent grassland with low or very low levels of agricultural inputs.

Enhancement of landscape character most frequently resulted from the creation of appropriately sited field margin buffer strips on cultivated land and through the creation or restoration of semi-natural grassland. For some other forms of landscape enhancement, such as the creation or restoration of woodland and traditional orchards, greatest benefit occurs in areas where these features are considered to be characteristic but where their stock in the

landscape is low. Maintenance of landscape character frequently involved retaining the mixed or pastoral character of livestock farming areas. Few *neutral* or *detracting* effects were found. *Neutral* effects tended to be found in the urban fringe and some western pastoral areas.

The contribution of ES to landscape quality, (as defined by the condition of landscape features) could not be proved. Although a causal link between the options and the condition of features could not be established there is some evidence that options assessed as enhancing landscape character also create features of high quality, in contrast to options that simply maintain landscape character.

The results also suggest that ES helped to:

- Conserve features of taller vegetation (e.g. trees and hedgerows) that create scale and pattern in the landscape.
- Conserve and reintroduce traditional landscape patterns, colours and textures through field management such as hay cutting and conserving wild flower meadows.
- Help reinforce local distinctiveness and sense of place though use of traditional techniques and materials.
- Conserve, restore and help reveal historic features in the landscape.

Entry Level Stewardship particularly favoured the conservation of field trees, boundary features, permanent pasture, and aspects of archaeology, while Higher Level Stewardship supported the conservation of woodland and orchards, wet and rough grasslands, archaeology and the conservation of habitats. It was the combination of ELS and HLS working together that delivered most for landscape.

CLICK MAPS TO ENLARGE

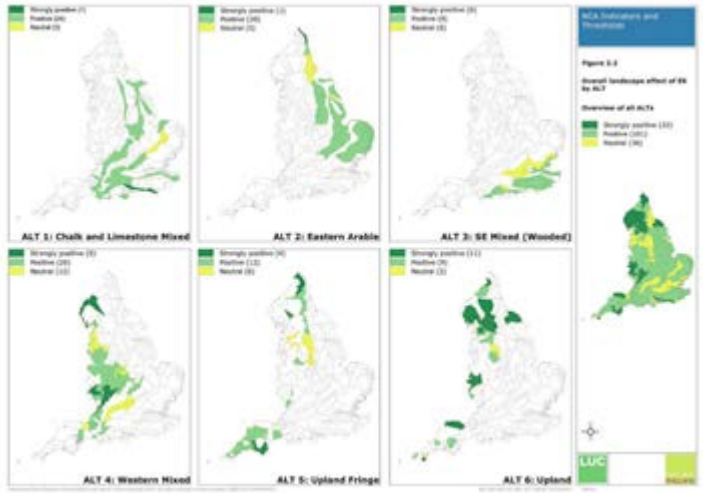

Figure 9: Summary of overall effects by Agricultural Landscape Type.

The analysis of thresholds and indicators indicates that ES had:

- A Strongly Positive effect on the landscape of 21 NCAs (13%)
- A Positive effect on the landscape of 102 NCAs (64%)
- A Neutral effect on the landscape of 36 NCAs (23%)

The NCAs benefitting from a strongly positive landscape effect under ES tended to be concentrated in the north of England, primarily in upland areas. The spatial distribution of these results is illustrated in a series of ALT maps (Figure 9).

The survey results confirm that ES was largely meeting the objective of maintaining and enhancing landscape character but that it had by far the most strongly positive effect in the uplands, with ES assessed as having a strongly positive effect in 50% of the NCAs in this ALT. This is followed by the Upland Fringe, with more varied and less positive results across the lowland ALTs.

The location of options can be very influential in defining their impact on the landscape, both strategically and at the local scale. Arable options, in particular, can significantly enhance the landscape if in the right location. For example, they help define the boundary of large-scale field systems, but in the wrong location can detract from the landscape, as when placed in blocks randomly imposed on the established field pattern. Advice that promotes arable options should take account of potential adverse effects and encourage the appropriate scale, design and location of these options.

Maintenance of a traditional farm building under ED1. This feature was assessed as having a 'conserving' effect on landscape

ES would have benefited from new ELS options for the restoration of boundary features outside the Upland Severely Disadvantaged Areas. New HLS options to restore locally significant lines of trees and ELS options targeted to conserve wet or floodplain grasslands would also have increased potential landscape benefits.

Overall, the research shows that ELS and HLS support the conservation of different landscape features and working in combination they deliver most for the landscape. Two broad potential landscape themes for future agri-environment options are highlighted:

- for pastoral and mixed farming areas, including the uplands, the primary need is to *conserve and restore* characteristic landscape features such as hedgerows; hedgebanks; walls; small farm woodlands and trees; and semi-natural habitats.
- for intensively managed, large scale arable landscapes the need is to *enhance* the landscape by reinforcing or reintroducing landscape structure and diversity. This can be achieved through the use of wide buffer strips to strengthen field boundaries and the reintroduction of semi-natural and non-arable habitat for wildlife to create localised areas of diversity and interest.

The Geological Conservation Review:
Underpinning geological and geomorphological SSSIs with evidence

by Jonathan Larwood and Hannah Townley

The Geological Conservation Review (GCR), launched in 1977, was the world's first systematic assessment of the geological heritage of an entire country [20, 21]. This Great Britain wide assessment systematically identified the key geological sites for scientific research and to understand Britain's Earth history. GCR sites are the basis for the network of geological and geomorphological Sites of Special Scientific Interest (SSSI) in England.

The GCR series is considered to be a dynamic network to reflect current and future scientific thinking and advances. As a consequence, a number of further GCR assessments are currently under way with expert advice from partners. These include an analysis of recent advances in Palaeolithic studies, a review of the latest research into the last glacial advance and a review of active tufa sites. The tufa review is the most advanced.

Active tufa

Tufa forms when carbonate minerals precipitate in a range of freshwater environments. Up until 2015, only one site in the GCR had been selected for the geomorphological processes associated with actively forming tufa, which is being increasingly researched by scientists as a possible carbon sink, as a mechanism for metal remediation, and to understand ancient tufa forming processes.

Actively forming tufa sites are vulnerable to changes in water chemistry, changes in land management, and removal for rockery stone and so the gap in the GCR, and SSSI series, was seen as a potentially significant omission.

During 2014 and 2015 a review of actively forming tufa sites was initiated to determine if additional GCR sites were needed. Initially, the existing GCR and SSSI series were reviewed, which produced a list of relict inactive tufa sites and sites where actively forming tufa was likely to be found. This was followed by a literature search to determine the level of current research on actively forming tufa sites and to produce a list of external scientific experts with an interest in these sites.

International value and collaboration

In October 2014 a workshop with eight external scientific experts from British universities and interagency geological staff was held to review 28 sites. Of these, 13 sites were short-listed for commissioned scientific descriptions from the scientific experts as potential new GCR sites. During 2015 these reports were peer-reviewed by the group of external scientific experts, who recommended a final list of 10 sites for addition to the GCR.

Tufa cascade at Janet's Foss, Gordale Beck, North Yorkshire

Of these sites, two are within existing SSSIs. The Gordale Tufas potential GCR site is within Malham-Arncliffe SSSI. Here, the tufas are of international significance as they demonstrate an active upland 'cascade-barrage system', considered to be one of the best of its kind in Northern Europe.

Lathkill Cave, Derbyshire

The Lathkill Dale Tufas potential GCR site, within Lathkill Dale SSSI, form the most extensive tufa system in Britain, comprising sites of active deposition and relict sites that date back to the 'Ipswichian interglacial' (approximately 130,000 years ago) . The site contains many important examples of active principal and secondary barrage constructions and pool tufa deposits; Britain's only example of an interglacial barrage tufa complex; and globally rare extensive tufa caves. Collectively, the Lathkill deposits represent Britain's finest active and fossil tufa systems connected in both space and time.

From this research we now know a lot more about some of our existing relict ancient tufa SSSIs and have a small network of potential new GCR sites important for actively forming tufa.

In addition, we have a new network of external specialists who can provide us with advice and understand the GCR and SSSI process and the importance of site conservation. It has also provided the opportunity for Natural England to become a project partner in an international programme, which will research and monitor a network of tufa sites across Europe through a number of PhD research projects.