New Approaches

Introduction

Natural England is continuously seeking new approaches to pursuing and applying science and evidence. This section outlines two quite distinct areas in which we are exploring new approaches.

The first of these is using new technology to improve the quality of our science and evidence, and to undertake work that previously may have been prohibitively expensive. A series of articles showcase particularly innovative approaches and the use of new and pioneering technologies. Great crested newts feature on a number of occasions, as we describe three very different ways in which we are improving our knowledge of their populations and distribution; by using sniffer dogs, DNA analysis of pond water, and computer modelling techniques. We also discuss the more general potential that DNA has in biological surveying and recording. We describe how we are using social science to build relationships with the farmers and land managers who carry out these actions. We also consider unmanned aerial vehicles, known to most as drones: one of our conservation advisers talks about his quest to become a qualified drone pilot, and the opportunities this has opened up for him and his team.

The second part of the section has a different angle, focusing on work that Natural England has done to gather and interpret evidence that could inform new conservation strategies in the future. It opens with a summary of work being done by the Defra futures partnership to consider what future technologies and issues could affect our outcomes and the way we work. The next set of articles focus on the topic of climate change, an important area of research for Natural England. We describe research into which species might win and lose under climate change, followed by articles summarising an investigation of places where species might be better able to survive climate change and evidence that landscape-scale conservation also offers potential for increasing the resilience of species populations to climate change. The final four articles highlight a diverse range of other examples of gathering evidence (in many cases using innovative methods) to inform new approaches to conservation: research to improve our knowledge of an important and charismatic fish species; research into green transport corridors; exploring new ways of capturing and understanding what people value about their local landscapes; and, finally, the production of an important new evidence summary for managing freshwater ecosystems based on natural processes.

Great crested newt

The nose knows: great crested newt detection dogs

by Corrie Bruemmer

In 2015, as part of a Natural England funded PhD study we, **Conservation Dogs** and Salford University conducted the first great crested newt Sniffer Dog trial in the UK.

Kim and Ned, two springer spaniels, were trained by staff at Conservation Dogs to detect the scent of captive great crested newts. We were confident the dogs could detect the captive great crested newts, but would they be able to find a wild great crested newt in its natural habitat? In March 2015, a small trial was conducted at two known great crested newt sites in Cumbria. The trial found:

- The dogs successfully detected wild great crested newts
- On a number of occasions, both Kim and Ned independently detected the same potential resting places, such as a section of dry stone wall or a tussock of grass
- The dogs worked well during both the day and at night, but there was a greater chance of detection at night when great crested newts were active.

The trial raised further questions, in particular about resting sites. Both dogs clearly showed an interest in the same potential resting sites, but without destructive searches we could not determine whether they were detecting great crested newts currently within the resting sites, previously occupied resting sites or whether the dogs were showing interest in a different scent. Further trials are also needed to determine how far scent will penetrate if a great crested newt is, for example, deep in a dry stone wall or an artificial hibernacula.

There is clearly potential for using dogs to detect great crested newts, and the next step is to assess the effectiveness and efficiency of this method compared to other more traditional survey techniques.

Happy dog Kim (with tennis ball reward) and proud handler Aran Clyne (with great crested newt) after the first great crested newt Sniffer Dog trial in March 2015, Cumbria

Using DNA in species identification

by Keith Porter

Novel techniques involving DNA analysis can revolutionise our approach to species identification.

Information on species status and location is the starting point for much of Natural England's work. We spend public money on maintaining, restoring or reinstating the places where our native species live. Knowing where to target work, and what is needed, is largely driven by our knowledge of where species occur, but gathering information on the presence of species can be an expensive and complex business.

Most of our species data comes from the activity of many thousands of volunteer recorders. While we claim to be the best recorded country in the world, not all species groups are equally represented. Considerable progress is being made to make better use of our existing data using the improvement in statistical analysis and modelling techniques. However this still leaves us with gaps in some increasingly important groups such as invertebrates, soil biodiversity and invasive alien species. In conservation, there is growing interest in looking at assemblages and communities of species, and their relationship to habitats, as a measure of quality and site condition. This is the next logical step forward from our traditional focus on individual species but needs a different approach to how we collect and use species data.

DNA as a conservation monitoring tool

In the past two years we have seen the successful application of so called 'environmental DNA' or eDNA to detect the presence of great crested newts in ponds. This technique is now being routinely used to confirm presence or absence of this species. The approach relies on the fact that all life stages of newts release fragments of DNA into the water through sloughed skin, excretion and during courtship. These fragments can be collected in water samples and amplified by molecular techniques before being sequenced by laboratories for their unique genetic code. Each species has a unique 'barcode' that helps to distinguish it from others. You can read more about our application of this technique in Woking, in the next article.

This same basic approach can be used on samples from whole organisms – plants or animals – and the derived code from the DNA is then used to provide a definitive name for a species through use of databases of 'barcodes'. International collaboration has already created extensive databases of unique codes for many of the species of interest to Natural England, with countries such as Germany and Canada funding a process to barcode all their fauna and flora. The techniques available extend from the humble single sample through to looking at mixed samples and even whole genome sequencing.

The strength of this approach is in its ability to detect the presence of species, either from mixed samples of individuals, or as traces in the environment. This provides the potential to check for the presence of traditionally elusive species such as violet click beetle or species that are difficult to identify such as the allis shad (a fish species). As the technology matures, it also offers the chance of identifying species from bulk samples of trap material far more rapidly and accurately than is currently possible, and at a reasonable cost. This is the route to analysing whole species assemblages and the routine use of biometrics in conservation practice.

Species identification in soil communities via DNA metabarcoding

DNA metabarcoding is a high throughput DNA-based method that can identify multiple species from a single complex environmental sample. The approach is used by ecologists interested in biodiversity assessment, using samples such as soil and water. Natural England has been exploring metabarcoding for assessing soil communities and soil mesofauna (mostly springtails and mites). Working with the Centre for Ecology and Hydrology, we took samples from three different grassland types at Parsonage Down National Nature Reserve. Soil cores from the three types were processed to extract DNA from the whole soil community, and additionally some of the individual mites and springtails were extracted, identified and barcoded to help interpret the DNA sequences found. The technique is still in development but appears to be a good way to characterise the composition of soil communities, with real differences found between the soil communities of the three different types of grassland.

Where next?

Natural England's use of these exciting new techniques has so far been restricted to two areas; great crested newts and soil biodiversity, but we are now looking to use the techniques on a few other simple test cases. DNA approaches provide the opportunity for a new way to look at habitat quality, both through soil biodiversity and above ground assemblages, and will help us find the elusive and enigmatic species in the landscape. The improvement in sequencing technology offers the benefit of cost reduction when thinking about identification, and the approach should provide large volumes of relevant data that can be explored using biometrics.

Late summer chalk flora, Parsonage Down National Nature Reserve

In exploring potential, we recognise our strengths and our weaknesses. We do not operate laboratory facilities. Therefore we will rely heavily upon practical partnerships with academia and commercial enterprise to carry out the analysis, as well as to understand the boundaries of the possible. Whatever the outcome of our first toe in the water, it is likely that the world of species surveillance will look very different in the next decade.

Predictive modelling of great crested newt distribution in Woking

by Richard Alexander

DNA analysis and predictive modelling have led to a greater understanding of great crested newt populations and distribution in Woking, Surrey.

In Autumn 2015 Natural England began pilot work with Woking Borough Council to establish new survey techniques for great crested newts. The approach being trialed involved testing for traces of great crested newt DNA from a sample of ponds across the borough. Under the trial spatial models were developed using environmental DNA (eDNA) test results, to predict areas of high suitability for great crested newts across the borough and the level of connectivity between these areas (Figures 1 and 2).

Data collection

Ordnance Survey's MasterMap was used to identify potentially suitable water bodies for newts, based on their shape and size. Samples from 48 of the 180 ponds identified across Woking borough, were tested for great crested newt DNA. The ponds visited were those on public land or where it was possible to contact the owners. Five of these ponds tested positive for great crested newt DNA. In addition to the DNA samples, variables for calculating Habitat Suitability Index scores (HSI) were collected from 101 ponds (36 of which were also sampled for DNA). Records of actual great crested newt presence were obtained from the Surrey Amphibian and Reptile Group and from Natural England's licensing data.

Modelling using DNA presence absence data

The advantage of using eDNA data for predictive modelling is that models requiring presence/absence data can be used. Such models can provide more statistically robust results than models using presence only data.

Two approaches were tested using the DNA results:

1. Pond level modelling, using detailed data collected for individual ponds, such as information on presence of fish and aquatic vegetation. (These models can also use spatial variables, such as pond density or distance to unimproved grassland, but can only be used to predict presence for locations where this information has been collected).

2. Spatial modelling, using variables that can be mapped over the whole area of interest (and predict great crested newt presence in that area). Spatial modelling is unable to take account of pond level variables.

The pond level model was tested for correlation with the individual pond variables as well as individual spatial variables. While the model only showed weak correlation with individual pond level variables that were tested, it did show a good level of correlation with the overall HSI score. This corroborates the use of HSI in determining habitat suitability for great crested newts.

To test the spatial models further, layers were created for:

- distance to different habitat classes
- area of these habitats within a 250m buffer

- pond density within 250m, 500m and 1km buffers
- maximum and minimum annual temperature and temperature annual range
- distance from floodzone.

Figure 1: Outputs from the pond level GLM using HSI score, shading and distance to arable land as explanatory variables. Blue circles show the probability of great crested newt occurrence (small to large). The purple circles represent the corresponding HSI scores (small to large).

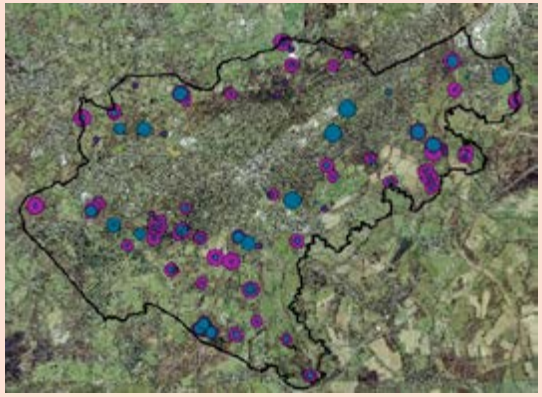
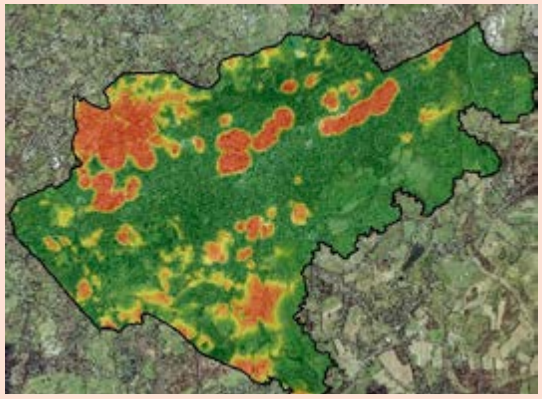


Figure 2: Results from the GLM using the 17 positive and 43 negative presence records for great crested newt . Areas of high suitability areas for great crested newt s are shown as red.



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Each variable was tested for correlation with the eDNA presence absence data. Using the 48 DNA presence/absence records, only a poor model fit could be achieved. A better fit was achieved by including the additional 12 verified presence records. Analysis of the standard errors produced by the model showed that these were highest for areas predicted as having a high probability of great crested newt being present. The absence of pond density data in the model and the low number of presence and absence records, are other likely factors in the poor fit of the modelling.

Modelling using presence only data

A more established approach to modelling great crested newt distributions involves using standard models such as Maxent [1]. Such models are popular as they only require presence data. The same variables used in the presence/absence modelling were used in the presence only modelling. Training the model using the 12 verified presence records and the 5 positive DNA records indicated a very good fit with the training data. Testing the predictions from the Maxent model against the presence records used for training and the DNA absence records showed a significant fit.

The difference in the fit between the two modelling approaches could be because of the differences in how the data were collected for the eDNA samples and the more random approach used in Maxent.

Connectivity analysis

Connectivity analysis for great crested newt populations across Woking was undertaken using the **Linkage Mapper** toolkit in ArcGIS (Figure 3).

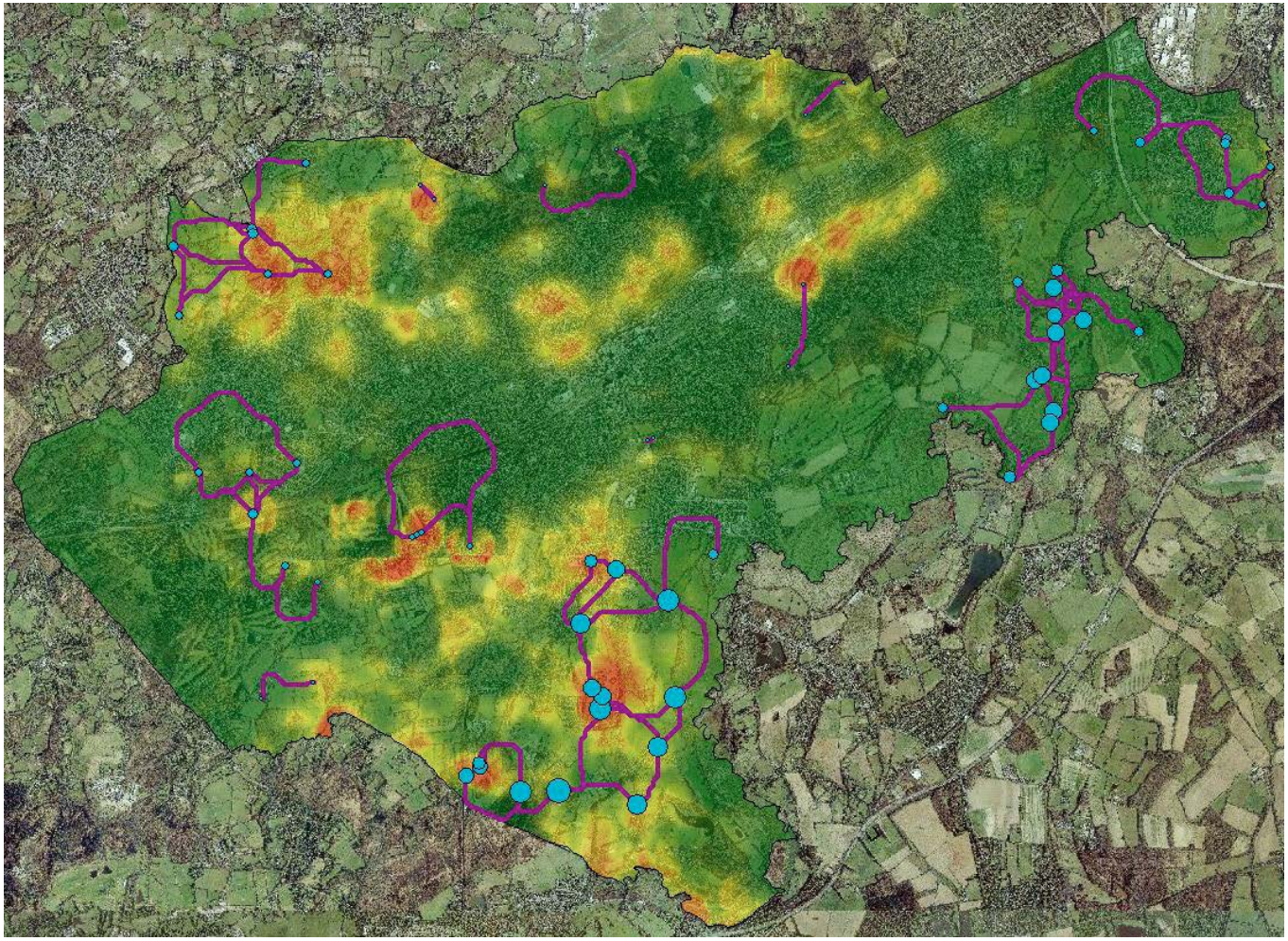

Figure 3: Output from the connectivity model showing ponds (pale blue circles) with size relative to their connectivity score and least coast paths (purple) overlaid against the habitat suitability predictions from Maxent.

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The outputs from the analysis highlight areas with high suitability for great crested newts and good connectivity and also areas of high suitability, but where connectivity is poor. As connectivity between ponds is shown even where these areas have been predicted to have low suitability for great crested newt, the results should be interpreted in conjunction with the habitat suitability modelling.

Next steps

The modelling work has been used to inform a conservation plan for great crested newts in Woking alongside field survey information. The results show a strong coincidence between the predictions from the modelling and the field records. As part of the pilot in Woking borough, developers are being invited to contribute to strategic measures for great crested newts which are to be provided by the Council. The strategy includes the creation or restoration of eight ponds to compensate for the potential residual impacts of development, as well as the retention of green corridors within development sites.

Changing behaviours to benefit farmers and wildlife: the importance of social science

by Jilly Hall

Social science can provide behavioural insights into the social mechanisms that underpin any shift towards (or away from) more sustainable land management. Capturing and analysing these insights gives us valuable information on how to build positive, long-lasting relationships with the farming community.

Traditionally science adopts a 'reductionist' approach to examine the relationship between two or three variables of interest. This can be illustrated by the relationship between wheat yield and nitrogen. The focus on yield variables provided by agricultural science has helped farm businesses to fine-tune agronomy, improve farm income and provide farmers with the cultural status attached to high-yielding crops. Ignoring the wider context can, however, lead to trouble. Important negative externalities such as nitrate leaching, pollution of surface and ground water, the impact on soil pH and fauna can be missed - with serious consequences for the natural environment.

The holistic philosophies, from which social science has grown, use wider understandings that embrace the messy complexity of 'real life' lived by 'real people'. Taking this wider view enables the social scientist to understand farmers' complex socio-cultural drivers such as: economic and moral imperatives ('making money'; 'feeding the world'), the personal desire for intellectual challenge; collaboration with agronomists; competition with other farmers; together with the status ascribed to high yields by the farming community.

Social science acknowledges the complexity of the target audience. The word 'farmer' is unhelpful in this respect. 'People-who-just-happen-to-Farm' are uniquely defined by their occupation from an early age – and are socially diverse.

For some, farming is the best of all occupations – for others it is a hard and stressful living. Unable to make money, but unable to leave the industry, for some farmers the behavioural barriers to change can include: a lack of personal confidence in the ability to change, a profound distrust of government (and especially environmental policies), social isolation in changing rural communities and finally, self-exclusion from virtually all sources of help.

Where farm pollution is an issue the success or failure of the behavioural change methods used by our staff are profoundly important to Defra's desire to reduce diffuse water pollution from agriculture.

'The landscape of any farm is the owner's portrait of himself'.
Aldo Leopold (1939)
The Farmer as a Conservationist

Minimum tillage: a low impact, cost effective system to enhance carbon retention and moisture in soil

Catchment sensitive farming officers and land management advisers have multiple, recent and readily-transferable understandings of behaviour change related to farmers and land managers. This invaluable experience is currently 'tacit' and undervalued: evidence is frequently lost when people change roles or leave the organisation. Social scientists in Natural England are working with officers and advisers to identify, analyse and share these behavioural insights to answer the research question:

'Which social mechanisms most effectively improve and sustain farmers': i) attitudes; ii) short-term and; iii) long-term behaviours towards the natural environment?'

Early findings from this informal study reveal valuable data on behaviour change related to power relationships, trust-building mechanisms, issues of loss and gender opportunities.

The research has the added benefit of allowing officers and advisers to share their experiences. This has encouraged them to see the behaviour insights they have identified as valuable data, raising morale and enabling them to discuss conflict and stress with their colleagues. Over 500 staff and 55 partners have attended training, providing an introduction to social science. As part of the training staff consider how to:

i) assess the social situation; ii) consider the best social mechanisms to use; iii) reflect upon the social outcomes; iv) identify causal linkages between social and environmental outcomes; and finally v) consider evidence to suggest a long-term culture shift. Virtually all staff have requested follow-on training to become 'Behaviour Change Practitioners'.

Gaining your wings: how to become a Natural England qualified drone pilot

by Paul Thomas

Unmanned Aerial Vehicles can revolutionise how we survey protected habitats and landscapes.

Paul Thomas, a conservation adviser in our Cheshire to Lancashire team describes how he became the first member of Natural England staff to 'gain his wings'.

One of the most useful tools our advisers have to support site monitoring and other SSSI work is aerial photos. These are one of my first ports of call when trying to assess how sites have changed over time or how effective management has been. One of the frustrating things is that even the most up-to-date photos available are six years old. This is not much help when you are looking at the impact of work done over the last few years.

Back in December 2014 a landowner requested consent to practice drone flying and capturing aerial photography on a SSSI and offered free up-to-date aerial photos of the site in return. Luckily this request coincided with the completion of a 4-year programme of re-wetting works and a follow up assessment of their impact on SSSI condition. This was an opportunity not to be missed; I was able to go out on site with the pilot and direct the images being taken, ensuring the most important parts of the site were captured.

This was a real eye opener with respect to the versatility and the usefulness of drone technology. Looking at the small screen on the controller showing the live feed from the camera gave me a new perspective of the site. I used the drone images for my condition assessment by comparing them with the older aerial photos taken before the re-wetting works had been completed. This illustrated the positive results the works had achieved and also highlighted areas where we needed to go back and have another look. Seeing the technology in action made me think that I could do the same; why not set-up a remote sensing capability within our local team? In the past, the drones available on the market have required a high level of technical experience and knowhow, not to mention the high cost, while commercially available aircraft still required self-assembly and programing skills to get the components to work together. However, things have moved on and you can now get an off-the-shelf drone - or unmanned aerial vehicle (UAV) as they are known - that is ready to fly and has an integral camera built-in.

Figure 4: NED's instruction manual

I discussed my plans and the potential for UAVs with colleagues, submitted a bid for funds and was very delighted to receive approval.

After much research we identified and bought a model that gave us the high quality photography and video capabilities we needed. We have named it Natural England Drone or NED for short.

As well as the UAV, a range of spare parts and safety equipment is needed to keep the aircraft up and running and the flight crew safe. For example, having more than one battery is essential to give us the flying time we need.

The other vital component for using any aircraft is the crew – for our drone we have two pilots. Acquiring the UAV was the easy part! The use of UAVs for aerial work and remote sensing for professional purposes is regulated by the Civil Aviation Authority (CAA). To demonstrate that we are competent and can fly safely the CAA requires us to become qualified UAV pilots. There are a number of approved qualifications that the CAA will accept; we chose the Basic Nation Unmanned Aerial System Certificate for Small Unmanned Aircraft (BNUC-S™).

The qualification was split into multiple parts. It started with a two day training course and examination, moved on to the development of an operations manual specific to Natural England (Figure 4) and ended with a flight examination. This not only tested our flying skills, but also the procedures developed in our operating manual. Now qualified, we still need to assess the risks associated with each flight before we get into the air. This includes a detailed series of checks of, among other things, the condition of the equipment, the hazards and restricted areas at the site and the weather forecast and sunset times.

We are now entering an exciting period where we will actually start using the drone for our work. At its simplest this will be detailed aerial geo-referenced photography to help with everything from assessing scrub cover to identifying drains in lowland raised bogs. The oblique aerial photographs are very good at giving an overall impression of a site, as they can give you a sense of depth and height. They allow you to see how scrub and woodland areas compare to open areas, which is really useful when assessing sites with a mix of features in a habitat mosaic. One of the most exiting capabilities is the video function.

It is amazing to be able to fly over a landscape and see how land and water levels affect the vegetation. This is the real game changer for me when it comes to understanding how a site works and how to intervene with management. The videos are also a great tool for engaging site managers and stakeholders; it really gets them on board with what we are trying to do when they see what they have achieved on the ground.

Working better together: the Defra futures partnership

by Helen Doran

To make the best use of our expertise and resources we need new approaches across the Defra group (Departments, agencies and non-departmental public bodies) to develop a shared evidence base. One of our successes is the Defra futures partnership, involving Defra, Natural England, Environment Agency, Welsh Government and Food Standards Agency. This group shares and analyses evidence of future change to take a forward look at what issues could impact on the natural environment and food systems in the future.

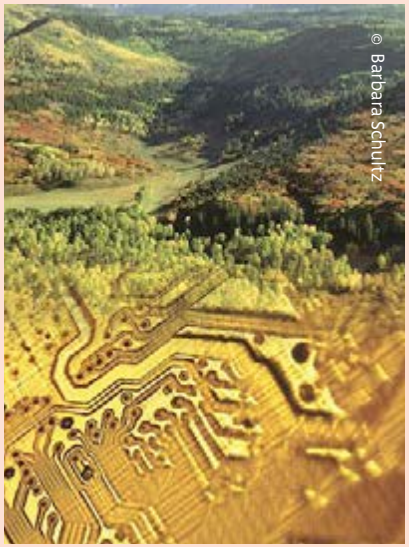
Evidence of future change – the Defra futures partnership

To get a better idea of what future issues could affect our outcomes and the way we work we need to keep an eye on what is changing in our external environment. This means we can spot issues earlier to adapt current or planned for work to minimise risks or maximise opportunities.

There is no 'evidence of the future' as it hasn't yet happened, but we can look ahead by monitoring trends and emerging issues through the technique of horizon scanning. This is the systematic capture and analysis of information related to existing trends and emerging issues and is a critical aspect of our broad evidence-base. During 2015, our horizon scanning evidence was developed through a partnership led by Defra. The partnership has produced five **Strategic evidence of future change reports**.

The issues the partnership identified in 2015 as having the potential to exert a significant impact on the natural environment over the medium-long term include:

- Gene editing has accelerated the biotechnology revolution and may spill over from the health sector to the environment.
- The evolving information communication revolution sweeping towns and cities may lead to a 'smart' countryside.
- Resources for the next industrial revolution, such as bio-mimicry, industrial ecology, circular economy and 3D printing may have direct application in nature conservation.
- Rising environmental activism may lead to new pressures for, and new forms of action to, safeguard the environment by governments, industry and civil society.



The Landscape Microchip: a smart countryside

Which species might win and which might lose under climate change?

by Humphrey Crick

A Natural England research project has assessed the potential risks and opportunities for over 3,000 species of plants and animals. This is the most comprehensive analysis of its kind ever done in England and helps us to understand how different species might be affected by a changing climate.

Cetti's warbler

We don't know for certain which species will be most badly affected by climate change and which species might benefit, but clear shifts have already been observed in the distributions of some species in the UK over the past 25 years (see section5). This suggests that species may be able to 'track' climate change, although evidence is beginning to show that some species may be limited from colonising suitable areas north of their current range due to poor dispersal abilities or habitat fragmentation creating barriers to dispersal. In order to target conservation resources, Natural England has to prioritise action based on the rarity of species, threats to them and current rates of decline. As part of this, we need to understand how we can help species to adapt to climate change, and to encourage species that might thrive if given appropriate management of their habitat or of places that they might potentially colonise. This requires an evidence base that can inform the design of appropriate adaptation strategies for as wide a range of species as possible. Adapting to climate change takes conservation into uncharted territory: we cannot rely solely on lessons learnt in the past.

A Natural England research project aimed to start to develop an evidence base to help conservation practitioners understand where species of conservation interest might survive and thrive under climate change. The project did this for over 3,000 species of plants and animals in England – the largest and most comprehensive analysis ever undertaken[2].

The research project was based on 'climate envelope' modelling. This is a technique that takes the known distribution of a species, relates it statistically to a range of climatic factors (e.g. temperature, rainfall, etc) and then projects where the climate will be suitable for the species in the future. There are assumptions and uncertainties behind the techniques that we need to be aware of, for example, the current distribution of a species might be determined more by soils or historical management than climate; local microclimates may allow a species to persist, even though the broader conditions appear unsuitable; and that other species that a species depends on may not shift distributions in a similar way. However, the projections do provide a useful guide to the likely nature and scale of changes that might occur for a species.

Examples of three species with contrasting projected changes in patterns of climate suitability across England.

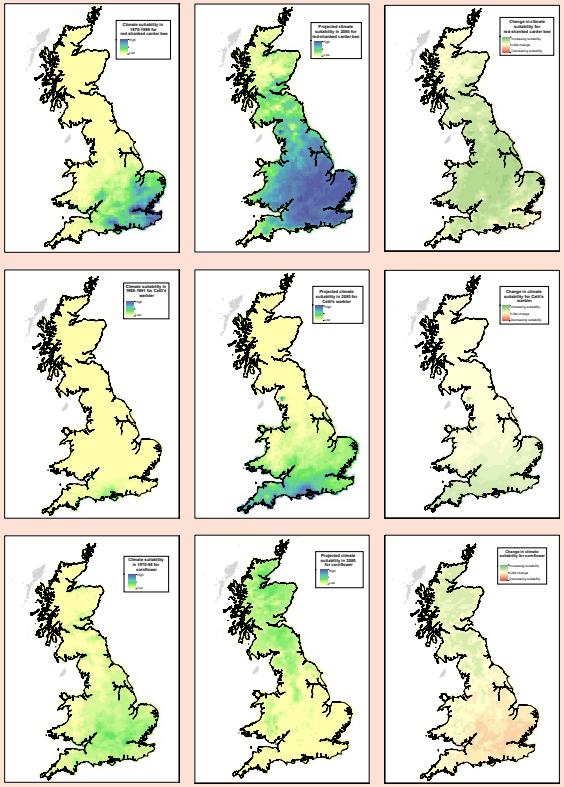
Models suggest that geographic patterns of climate suitability for different species might change in quite different ways as a result of climate change.

The maps opposite show three contrasting examples: the red-shanked carder bee (top row of maps); Cetti's warbler (middle row of maps); and cornflower (bottom row).

For each species, the map on the left shows modelled recent climate suitability (based on data from the 1970s and 1980s); the map in the middle shows the modelled climate suitability in 2080 (based on a scenario of a global 2^0C temperature increase), and the map on the right shows the change between the two.

These maps suggest that, if the species are able to move and if suitable habitat is present in the locations that are climatically suitable (neither of which can be taken for granted), the carder bee could benefit overall from climate change, expanding its range greatly with perhaps a small loss of its current range in the south; Cetti's warber could expand its range in southern England with no significant range retraction anywhere, and the cornflower's distribution could shift, with a large expansion in the north and large retraction in the south. Of these species, the cornflower is potentially threatened by climate change because it would be very uncertain whether the species could disperse to these new areas successfully, if its current areas really did become unsuitable.

CLICK MAPS TO ENLARGE



The research was led by the British Trust for Ornithology, bringing together skills and datasets from the Centre for Ecology and Hydrology/Biological Records Centre, the University of York, the RSPB and Natural England and was based on the vast datasets gathered by citizen scientists contributing to our national monitoring schemes. We aimed to cover as many species as possible across different taxonomic groups, particularly species listed as priority conservation species under section 41 of the Natural Environment and Rural Communities Act (Table 1).

Results

Having undertaken all this mapping work for just over 3,000 species, the project then assessed the overall risks and opportunities posed by climate change for each species, using information about recent changes in actual distribution. If distribution changes have already taken place and these are consistent with climate change projections, then it is reasonable to infer that climate change might affect the species in the future. Correspondingly if the current changes are inconsistent with the projections, then the risk or opportunity due to climate change is inferred to be reduced.

Looking at where suitable climatic conditions for different species are likely to be found in 2080, given a 2°C increase in average global temperature, we found:

- over a quarter (27%) of species were at high to medium risk of losing a substantial proportion of their currently suitable ranges.
- just over half (54%) could potentially expand their ranges , though this may not be possible in many cases because of limited mobility or a lack of suitable habitat in the future (Table 2).

Taxon	No of species included in the analysis	No of these species listed on s41 of the NERC Act
Native vascular plants	852	38
Bryophytes	520	1
Moths	422	58
Spiders	297	7
Coleoptera-Carabids	175	3
Diptera-Hoverflies	175	0
Bees	143	6
Wasps	133	1
Birds	180	41
Centipedes & Millipedes	39	0
Diptera-Craneflies	11	0
Coleoptera- Soldier Beetles and allies	22	0
Dragonflies & Damselflies	26	0
Coleoptera- Coccinnelids	17	0
Grasshoppers & Crickets	23	0
Ants	13	0
TOTAL	**3,048**	**155**

Table 1: Summary of the coverage of different species groups by the risk assessment.

OPPORTUNITY	RISK: VERY HIGH	HIGH	MEDIUM	LOW	TOTALS
LOW	25	1	7	6	39
MEDIUM	614	157	481	84	1336
HIGH	24	27	358	142	551
VERY HIGH	56	44	662	360	1122
TOTALS	**719**	**229**	**1508**	**592**	3048

Table 2: Numbers of species showing different gradations of risk of loss of suitable climate space and of potential opportunity to expand their ranges by 2080 under a 2°C warming scenario. Red and orange indicate a high to medium risk of losing a substantial proportion of currently suitable ranges; blue and purple show medium or high potential to expand ranges if mobility and habitat availability permit.

Kittiwake

Potential winners and losers

Mosses and lichens, vascular plants and spiders appeared to have the highest proportion of species at risk from future climatic change, whereas hymenoptera (ants, bees and wasps) species appear to be most likely to benefit from warming. Priority species for conservation (those listed on s41 of the NERC Act) appeared to be more likely to be at risk from climatic change than to benefit, compared with other species.

The species at greatest risk are often found in upland areas, such as twite, golden plover and mountain crowberry. Other wildlife expected to suffer include seabirds such as the kittiwake, and some lowland species such as lapwing, rare spring sedge, orange ladybird and the triangle hammock spider. In contrast, many species that have their northern range limit in southern England could flourish under a warmer climate. Further population increases are likely for birds such as avocet and the little egret. Other expected beneficiaries include the large wainscot and white line dart moths.

Conclusions

This research, for the first time, gives us a clear sense of the scale of the potential impact of climatic change on species distributions over the coming decades. It is also important to note the research depended on the observations of thousands of volunteers who submit sightings of wildlife to organisations like the BTO and the Biological Records Centres over many years. The findings are vital to help us target conservation at the species most in need and it will provide an important contribution to our wider work on climate change – such as the Climate Change Adaptation Manual (see the article in the Sharing our Science section) – designed to inform and prioritise action on the ground.

Natural England's report from this project also discusses how conservation action could increase our species' ability to adapt to climate change. For species whose range will expand, action is needed to enhance their habitat and the ecological links between areas to assist movement. At the same time, work is required to protect and create suitable habitat for colonisation by new species.

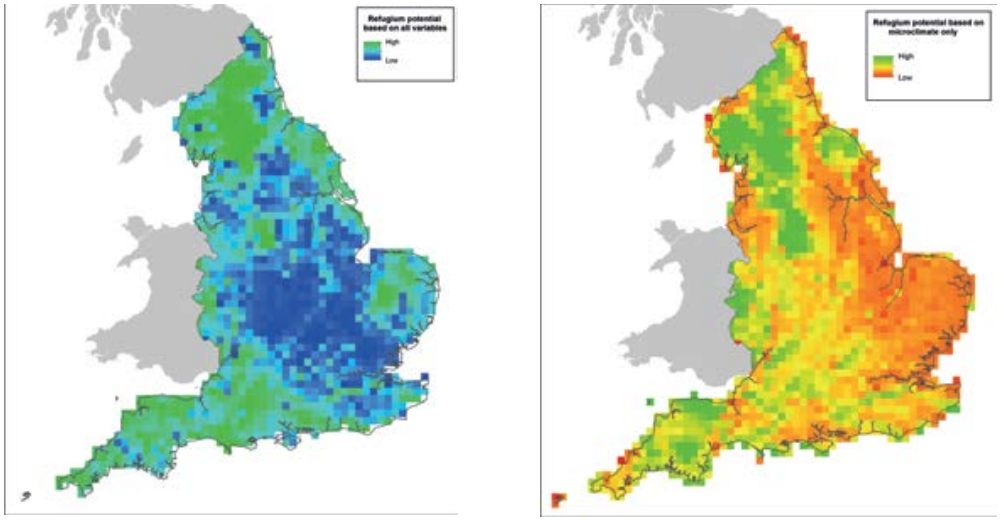
Investigating potential refugia from climate change

by Nicholas Macgregor

A Natural England research project has identified places that might protect a broad range of different species in England from current adverse climatic changes.

The research on 'winners and losers' outlined in the previous article focused on how species' ranges might change. But might there be places where species are able to persist locally? Through a project with the University of Exeter and other partners[3], we looked for evidence of potential 'refugia'; places that might enable species populations to persist despite climate change making the surrounding areas unsuitable. Refugia are a well-established feature of the last glaciation, harbouring many of the species occupying England today that are adapted to relatively warmer climates. But is the refugia concept also valid under current and future climate change?

To investigate this, the survival and extinction of over 1,000 species that retracted their range over the past 40 years was modelled against environmental characteristics (such as geology, elevation, water availability, exposure to solar radiation) thought likely (from a literature review) to influence refugium potential. The models also included agricultural intensity and level of recent climatic change.



CLICK MAPS TO ENLARGE

Figure 5: Maps showing refugium potential of 10km squares across England. The values correspond to the mean (across species) modelled probability of persistence over the last 40 years. Thus higher values indicate higher refugium potential. Refugium potential is calculated using different combinations of variables in the two maps: a) taking into consideration all variables that were identified as relevant by the analysis (microclimate, recent levels of climate change, geology and agricultural intensity) – green indicates areas species sensitive to climate change would have the highest likelihood of persisting; blue indicates lowest potential to persist; b) considering only microclimatic factors. green indicates areas where species sensitive to climate change would have the highest likelihood of persisting; red indicates areas of lowest potential to persist.

The results indicated that:

- local extinctions have been higher in areas of England that have experienced greater climatic change. This is further evidence that recent climate change is already affecting species;

- areas with more varied topography and a wider range of, or more stable, microclimates appear to give many species a better chance of persisting. In other words, refugia appear to exist under current climate change, just as they did in past glacial/interglacial cycles.

Knowledge about potential refugia could be useful when making future conservation decisions, for example about designating new protected areas. We have mapped the locations across England of conditions that appear to provide refugia (Figure 5). This provides a coarse-resolution picture of the areas in which species sensitive to climate change might be most likely to persist. It should be noted that refugia for many species are likely to act at a finer scale than the resolution of the maps, so even within areas with apparently low potential to provide refugia there could still be places, such as cool north-facing slopes and small gullies, that help some species to persist.

Our colleagues at the University of Exeter have extended this research to look at whether similar patterns of variability in microclimate and refugium potential exist at finer spatial scales. Focusing on the Lizard Peninsula in Cornwall, they found that fine-scale landscape variation can create significant variation in microclimates [4]. They also investigated whether changes in community composition and local patterns of colonisation and extinction of plants are related to microclimatic conditions. Overall, their results suggest that, at least over the last 30 years, north and east facing slopes, which have warmed less, have served as microrefugia for plant species associated with cooler climates [5].

The oak fern is a species that occupies cool, damp locations in north and west England. It has suffered highest rates of extinction in locations experiencing the highest rates of warming, but extinction risk has been reduced in areas with the greatest microclimatic heterogeneity

Can we increase species resilience to climate change through landscape-scale conservation?

by Mike Morecroft

Recent research coordinated by Natural England suggests that larger and less fragmentated areas of habitat make species populations more resilient to a changing climate.

Some impacts of climate change are inevitable; in some cases we will have to accept that species are occurring in different places or that habitats have changed, and adjust our conservation objectives accordingly. However there is growing evidence that the way we use and manage the land can affect the vulnerability of species to climate change. It is therefore important to increase species' resilience to climate change and help them survive in at least some parts of their current range.

Ecological theory suggests that restoring natural habitats, increasing the number and size of conservation areas and increasing the connectivity of habitats within the landscape should make species less vulnerable to climate change. There are a number of reasons for this including larger populations being less likely to become extinct in years with particularly adverse weather conditions, and – as mentioned in the previous article – the potential for species to survive locally in refugia where they are buffered against change.

A few years ago we reviewed these theoretical studies[6] but found little empirical evidence. It would have taken a long time and a lot of resources to investigate this experimentally, so we looked for an alternative approach. Fortunately, we can draw upon some of the excellent environmental datasets that we already have to look at how the impacts of climate change and extreme weather events affect species in different landscapes. In particular, bird and butterfly populations are very well monitored in the UK and these data in combination with the land cover maps that Natural England holds provide a good opportunity to explore how features in the landscape might influence the resilience of populations.

A number of scientific papers and reports have recently been published from this work, much of it done in collaboration with the Centre for Ecology and Hydrology (CEH) and the British Trust for Ornithology, who we have commissioned to carry out analyses of the data[7].

In particular, we have examined how landscape-scale characteristics, such as area of semi-natural vegetation and the extent of fragmentation, modify the effects of extreme weather events. This is important as climate change is expected to bring more extreme weather, such as droughts and flooding. Extreme weather events also provide good insight into more general relationships between species populations and their environment which can be studied over a few years, rather than the decades over which more gradual changes can occur.

Hot dry summers are perhaps the most serious climatic threat to many species in England. Many butterfly species thrive under hot, dry conditions, but a significant minority, such as the speckled wood and ringlet suffer adverse impacts often because of the impacts on food plants.

We worked with CEH to identify species that are more sensitive to drought, using long-term annual monitoring data from the Butterfly Monitoring Scheme. The analyses identified the decline in populations following a drought and the subsequent recovery phase together with the factors that moderated or exacerbated impacts[8]. A paper published last year in partnership between Natural England and CEH[9], went further to model how droughts, such as the one in 1995, might become more common and how it might affect the butterflies. The paper used two different climate change scenarios, one based on low greenhouse gas emissions, the other on much higher emissions. An increasing incidence of drought caused by climate change led to butterfly populations not being able to fully recover from one drought before the next one occurred, leading to a decline and ultimately extinction. However, modelling based on the historical responses of butterfly populations to drought show that this pattern could be moderated where habitat occurred in larger blocks rather than fragmented across the landscape. This meant that under the lower emission climate change scenario the species survived, although less fragmented habitat was not sufficient to offset the effects of the higher emissions scenario.

The ringlet (above) and the specked wood (left): two butterfly species that are negatively affected by hot, dry conditions

Larger blocks of habitats can be better for species in a number of ways. They support larger populations of species which mean that it is less likely species will become extinct during an extreme event, compared to a small population. Very fragmented habitats are also often poorer quality as proportionately more of the area is on the edge of patches and subject to disturbance, pollution deposition and in the case of woodlands, higher levels of light and more water loss.

Extremely cold winters are likely to become less frequent with climate change, but historically they have had a significant adverse impact on bird populations. They also serve as a useful model to study the effect of landscape-scale habitat characteristics on populations during cold winters. Another paper from our work in this area[10] showed that populations of some woodland bird species were more resilient to cold winters where there was less fragmentation of the wider landscape and patches of woodland were larger (Figure 6).

Blue tit

Great spotted woodpecker

Figure 6: Habitat fragmentation influences how populations of woodland birds are affected by extreme winter weather events. Research by Newson and others, including Natural England staff, found that populations of woodland generalist species, such as blue tits, declined more in fragmented landscapes; while populations of woodland specialists such as great spotted woodpeckers recovered faster from a population reduction if within a large woodland patch.

The findings of studies like these are now being incorporated into the Climate Change Adaptation Manual (see article in the Sharing our Evidence section), as well as influencing our strategic thinking, for example on where to prioritise habitat creation.

Studying the ecology and conservation needs of black bream

by Randolph Velterop

Conservation of black bream in the Kingmere Marine Conservation Zone provides a case study of the challenges of conserving species in the marine environment. Research into this poorly-understood fish has revealed fascinating insights into its behaviour and ecology, and highlighted how critical life history events such as spawning need to be better understood and considered in conservation and fisheries management.

The black bream is arguably one of the UK's most fascinating and charismatic fish species. It is highly valued for both its sporting and eating qualities and so is targeted by both commercial and recreational anglers. It has limited formal EU/UK fisheries management protection and until recently detailed knowledge about its ecology and behaviour was scarce.

Black bream on nest

The **Kingmere Marine Conservation Zone** (MCZ) off the Sussex coast was proposed by the Sussex Inshore Fisheries and Conservation Authority (IFCA) in order to protect the most important black bream nesting site in the English Channel, Kingmere Rocks. Natural England works closely with the IFCA to advise on appropriate management.

The potential impacts of recreational angling

Kingmere is the UK's premier location for black bream fishing. On average 60 fishing vessels per day can be observed during the peak nesting period (April to June)[11]. The IFCA tentatively estimated an average of 16,500 fish (~6 tonnes) may be caught annually by recreational angling from within the MCZ boundary during the nesting period, but the exact level of exploitation is unknown and needs to be studied further[11].

Recreational angling has in the past often been considered a relatively benign activity, but increasingly, evidence from both England and across the world that its impacts might be much more serious than previously thought and need to be given greater attention[12, 13, 14]. Best estimates suggest that recreational angling accounts for 25% of the catch of black bream across sites in the English Channel[14, 21].

A black bream caught by a recreational angler

The impacts of angling can be magnified when it targets spawning aggregations, as this has a greater effect on the reproductive output of the population[15]. Fisheries management of spawning aggregations is further complicated by the fact that as populations decline from overfishing, adults continue to aggregate for spawning, thereby

maintaining anglers' catch rates and masking population decline until close to collapse. Monitoring of catch rates alone can mean such population declines go undetected.

In the absence of formal management, catch and release (C&R) angling is increasingly being promoted as a conservation tool to minimise angling impacts on target populations. However, the desired conservation benefits of C&R rely on the assumption that a high proportion of released fish will survive, and impacts on physiological and behavioural performance will not compromise the reproductive potential of individual fish[16].

Gathering new evidence

At Kingmere, Natural England is therefore faced with the challenge of developing management advice for an activity with unclear but potentially serious effects, for a species with poorly-understood ecology, nesting behaviour and sensitivity to angling. We have been working closely with partners, including the IFCA, Bournemouth University, the aggregates industry and wildlife photographer Matt Doggett, to build the evidence base required for implementing effective management.

This research has drawn on the small amount of published work[17, 18] and new data collected in the field, including video footage of nesting. As a result, a clearer picture is starting to emerge, which has implications for the management of activities such as recreational angling within sites designated to protect this species.

Ecology and behaviour

Black bream lead complicated sex lives; born female, later changing sex to male. Like birds these fish aggregate, build nests and have specific habitat preferences, a trait that makes them an easy target for exploitation but also an ideal candidate for spatial protection through measures such as marine protected areas.

Nest distribution, abundance and site fidelity

Every spring the bream return to known inshore nesting sites in large numbers. Tagging studies undertaken by the Sussex IFCA since 2013 are starting to suggest that, much like salmon, bream return to the same nesting sites. The males, (30-40cm), use their tails to excavate an estimated 70kg of gravel to make 1-2m diameter gravel 'nests' which they use to attract females[19]. Several thousand eggs are attached to the bare rock in the centre of the nests (Figures 7 and 8).

Figure 7: Excavated black bream nest.

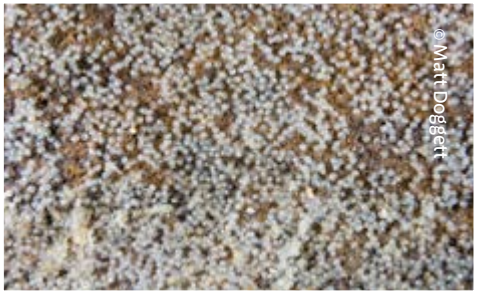


Figure 8: Black bream eggs on nest.

The nests are so pronounced that their extent and abundance can be clearly mapped using remote acoustic survey techniques (Figure 9).

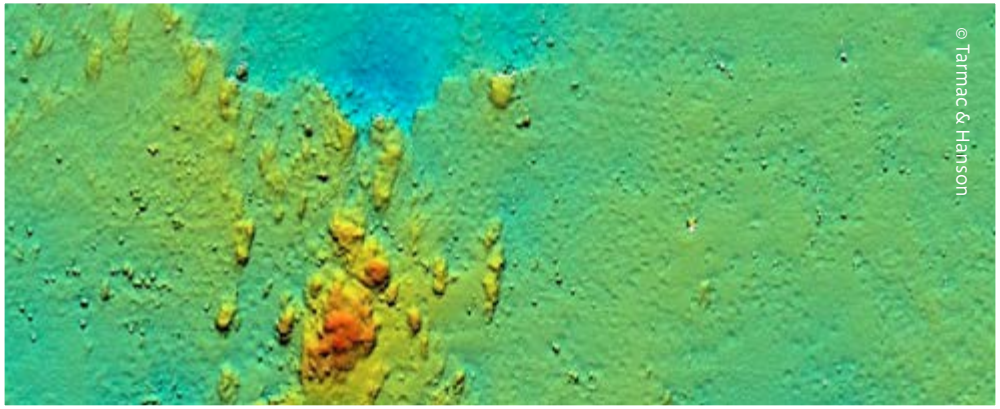


Figure 9: Bathymetry data showing black bream nests as pitted craters on the sea floor.

Male nest guarding behaviour and vulnerability to disturbance

During the nesting period each nest has a guarding male tending to the nest, cleaning the eggs and ferociously fighting off predators including wrasse, crustaceans and other black bream (Figure 10).

Until recently this behaviour had not been witnessed. Video footage recently collected (see Figure 10) provides the best evidence of black bream nest guarding behaviour to date and shows the trials and tribulations of black bream reproduction.

Figure 10: A male black bream guarding its nest and eggs from marauding goldsinny wrasse; see also attached link to Matt Doggett's **black bream project video**

While this footage is yet to be quantitatively analysed, it is clear how the removal of guarding males by disturbance or C&R angling may lead to the subsequent loss of reproductive output from predation. Studies on species with similar reproductive traits to black bream have shown conclusive links between stress caused by C&R angling during nesting and failed reproduction[20]. C&R fishing results in nest abandonment, reduced guarding effectiveness and reduced reproductive output. Similar impacts are therefore also likely to be applicable to black bream.

Direct evidence of effects of recreational fishing

In 2015 Natural England and Bournemouth University undertook a study to assess the physiological and behavioural impairment response of black bream to C&R angling during the nesting period. This now published work observed a range of impairment responses, providing evidence that angling is likely to reduce health, survival and reproductive performance of fish after they are released. Of the bream caught by anglers and sampled, 17% were deep hooked and considered at high risk of post-release mortality. Reflex impairment was observed in 32% of the catch suggesting an elevated risk of the reduced performance and survival of released fish. The dominance of males (89%) in the total catch indicates how angling is likely to leave many nests unguarded and vulnerable to predation. Indeed, dissected stomachs of a proportion of males (15%) contained freshly predated bream eggs, highlighting a likely cause of brood loss at vacant nests, irrespective of whether the captured male was then released and able to navigate back to its nest and continue guarding[21].

Conclusion

The evidence collated to date for black bream and surrogate species suggests that even C&R angling may not be compatible with the conservation objectives of marine protected areas designated to protect nesting populations of black bream.

This highlights the challenges to providing conservation advice and putting in place effective management in the marine environment. Lack of data is a significant and persistent issue, and being unable to visually illustrate the impacts of an activity poses significant challenges to stakeholder buy-in and support. As a result, management in the marine environment is often a compromise.

Better quantitative evidence will help explain why marine protected areas and their features are important and require protection. However, visual images and video footage showing marine animals and their behaviour can have a real impact on people's understanding of the marine world and help create better environmental outcomes. Marine conservation is to a large extent about education, something that scientists need to get better at embracing.

Travelling on the wild side:
green transport corridors research has wide-reaching impacts

by Clare Warburton and Nick White

Natural England's research on green transport corridors has been significant in influencing the transport sector's approach to managing the natural environment.

The launch in October 2015 of the National Infrastructure Commission, under the leadership of Lord Adonis, was a clear sign that infrastructure is at the top of the political and economic agenda, with transport being a key focus of the Commission.

Green transport corridors is an innovative research project that is helping to change the way vegetation alongside roads and railways, the 'soft estate', is managed for wildlife and wider ecosystem services, as well as improving the resilience of road and rail infrastructure to climate change.

It was inspired by the **Natural Environment White Paper**[22] (NEWP 32) which identified that transport agencies and key delivery partners could 'contribute to the creation of coherent and resilient ecological networks'. The research produced two reports:

- NECR 169 Review of literature: how transport's soft estate has enhanced green infrastructure, ecosystem services, and transport resilience in the EU. This **literature review**[23] brings together peer reviewed and grey literature exploring the role of green infrastructure on the transport soft estate.
- NECR 168 Transport green corridors: options appraisal and opportunity mapping. This research develops an **opportunity mapping**[24] methodology for linear assets informed by adjacent land use, and pilots the approach in two Nature Improvement Areas. Opportunity mapping is used to identify the areas on the transport network with the greatest potential to enhance ecosystem services, deliver ecological connectivity and increase transport resilience to climate change.

The road and rail network can have adverse impacts on some species, and this has sometimes prevented us from recognising that road and rail verges can be important for wildlife. The research found that these linear assets can provide vital wildlife corridors connecting habitats in towns, cities and countryside and helping deliver the **Lawton vision**[25] of a 'better, bigger and more joined-up' landscape. It also found that such linear features can provide a significant range of beneficial ecosystem services, such as pollination, biomass, climate regulation, enhanced landscape quality and sense of place.

Enhancing for pollinators and reducing risk from tree and leaf fall

An example of this innovative approach is creating a greater structural diversity on the soft estate through thinning and coppicing to create glades and reintroducing species-rich grassland management to:

- promote plant and pollinator species diversity.
- increase transport's resilience to climate change by reducing safety/operational risks from leaf and tree fall in locations where this is a high risk.
- provide a sustainable source of biomass for local communities.

Collaborative approach

The collaborative nature of the project has been a key feature in its success. It is being delivered through a partnership between Natural England, Network Rail, Highways England, the Nature Improvement Area Partnerships in Humberhead Levels and Morecambe Bay Limestones and Wetlands, and the local Wildlife Trusts.

Wider impacts of our evidence

The research has helped Natural England to steer change by:

- enabling us to provide timely advice to strategic transport bodies such as Highways England and Network Rail on how they manage 40,000ha of rail estate and 30,000ha of strategic road estate, as well as for local highways who are responsible for the bigger soft estate adjacent to the local authority road network, at a time of significant change for these organisations.
- helping to ensure that Nature Improvement Areas are considered within Highways England's £300m environment funds.
- opening up discussions with industry regulator the Office of Rail and Road on the multifunctional ecosystem services that could be delivered by the soft estate and the benefits that soft estate management could deliver for industry, in terms of increasing the resilience of our strategic transport networks.
- providing a springboard for sector-led embedding of green infrastructure into the management of linear assets through the establishment of the Linear Infrastructure Network, chaired by Transport for London, so that we now have a country-wide and coherent network of stakeholders using the report's evidence.

Hairy-footed flower bee

- recognising the role that road and rail corridors can play in delivering the National Pollinator Strategy[26].
- opening up opportunities for Natural England to speak at national and international conferences hosted by the Bat Conservation Trust, Kew Royal Botanic Gardens, Westminster Energy, Environment and Transport Forum and the European Combine Project.

The literature review and opportunity mapping reports have been downloaded over 1,500 times since publication in December 2014.

Using our research in the Humberhead Levels and Morecambe Bay Limestones and Wetlands Nature Improvement Areas (NIAs)

On the back of the initial £20,000 research contract, Natural England and the Wildlife Trusts committed to co-funding two project officers to trial new management approaches on the road and rail soft estate in the Humberhead Levels and Morecambe Bay over 3 years until 2017.

Using the opportunity mapping work completed in the first phase, the project officers are working with Highways England, Network Rail, local wildlife partners and landowners to develop new approaches at six trial locations. The trials will support: better habitat connectivity; management and buffering of protected sites; grassland enhancement to deliver the National Pollinator Strategy; sustainable drainage; scrub and woodland management; and harvesting of biomass for bioenergy. The projects will enhance habitats for a number of priority species, with a specific focus in the Humberhead Levels on the willow tit.

The lessons learnt from the pilots will be used to inform operational good practice for Highways England and Network Rail and the approach is already being picked up in other Nature Improvement Areas.

Future research and opportunities

One of the specific opportunities identified through the initial research was the potential for the soft estate to function as a commercial asset that could start to pay for its own maintenance. The estate produces large quantities of biomass, much of which has previously been considered low quality and inaccessible and has consequently remained unutilised. New technologies and a more buoyant wood fuel and bioenergy feedstock market means there is now much greater potential for the use of this biomass. For example, wood, grass and bracken on the soft estate can be harvested to bring a market return, and, if done in a sustainable way, bring greater benefits for wildlife.

We are now starting to look at how these opportunities could be realised.

Roadside biomass harvesting in Brittany, France

Filling the evidence gaps

The research identified evidence gaps on how to effect change from grey engineered to green ecosystems-based solutions. It also identified the need for a greater understanding of the role of crossing points to reduce severance impacts and specifically identified the potential for green bridges to play a greater role in connectivity. Further work is required to better understand the contexts in which these features are most effective.

Green bridges review

We moved to fill this evidence gap by commissioning **Green Bridges - A literature review**[27] which considered evidence from 56 green bridges across the world to broaden our knowledge of how effective they are in addressing landscape, access and ecological fragmentation caused by the road and rail network.

The review has been downloaded 1,600 times since publication in July 2015. It found that not only do the bridges help to prevent important wildlife habitat from becoming fragmented by aiding species movement, they are also used by wildlife as a home in their own right, particularly where they closely resemble surrounding habitats and contain features such as ponds and nest boxes. In addition, green bridges, also known as landscape bridges and wildlife overpasses, can provide crossing points for people, benefit pollinators and, if designed sensitively, can mitigate some of the effects of transport infrastructure on the local landscape.

A21 Scotney Bridge following construction (2005)

The information contained in the review will help developers and planners involved in major transport infrastructure projects, such as High Speed 2, to factor new green bridges into their construction plans or consider the greening of existing bridges. We have already taken forward specific recommendations, such as working with partners to develop a **Green Bridges Guide**[28] which was published by the Landscape Institute in December 2015.

A Partner View: Sheena Crombie, Senior Ecological Advisor, Highways England

"Highways England recognises that roads may prevent effective movement around the wider countryside for some species, and contribute to habitat fragmentation. Over the years it has investigated the possibility of providing green bridges at key localities but has found two significant problems when considering their construction. Firstly a lack of knowledge on how the structures work and function, and secondly the high cost for what were unproven benefits. The Green Bridges Guide will help to give a better understanding of both these issues, providing clear guidance on the design of green bridges to designers and planners working to improve and enhance the environmental performance of the Strategic Road Network. The publication will add to the knowledge base for civil engineers and the ecological community."

Cultural 'heat maps' show what people value about their local landscapes

by Andy Wharton

Public support for landscape change and nature conservation increases when perceptions and cultural values are recognised, acknowledged and integrated into the planning and design at the outset. This research explores new ways to capture and understand what people value about their local landscapes and how this information can be used and integrated into decision-making about landscape change.

We know that people experience and gain a wide range of benefits through their interaction with the natural environment. Some benefits are very tangible, for example, a particular landscape feature or view, others may be more experiential, influenced by cultural factors, perceptions and familiarity to specific places and characteristics. These are sometimes described as cultural or landscape services. While we can spatially map landscape features, ecological processes and habitats, it is more challenging to capture and map what people value and experience in their local landscapes.

Digital evidence on what people value

In 2015 we commissioned two research studies to help find effective ways of capturing and mapping public perceptions and cultural values in the context of proposed landscape change. The studies used social research methods as well as new technology to test ways of capturing and mapping information digitally.

In parallel, Natural England is collaborating with the South Devon Area of Outstanding Natural Beauty and Plymouth University to develop a research-based landscape App to collect baseline information about landscape features valued by people. A prototype version of the App will be field tested during 2016.

The **first study**[29], undertaken by The Research Box in collaboration with Cambridge University's Centre for Landscape and People, looked at how people perceived changes in the landscape as a result of greater ecological connectivity. It examined the case for integrating features with experiential and cultural value within the landscape into the design of ecological networks. It included a small-scale pilot that tested different methods and scales of capturing people's perceptions, and what they currently value in Bedfordshire's Greensand Ridge Nature Improvement Area. The research found that members of the local community could easily identify individual cultural services (such as inspiration, beauty, tranquillity and the presence of wildlife), as well as indicate the highs and lows of cultural service delivery at different geographic scales. Importantly, the public were able to locate these services on paper maps.

A follow-up study, due to be published in 2016, was undertaken for Natural England by Research Box and ADAS UK in three landscape focus areas within Morecambe Bay in Lancashire – the Duddon Valley, Arnside and Silverdale Area of Outstanding Natural Beauty and an area between Lancaster, Morecambe and Heysham. In each focus area a workshop was held with members of the public. Participants were invited to use a Participatory GIS tool (PGIS) or a simple smartphone survey App to capture their experiences of the landscape.

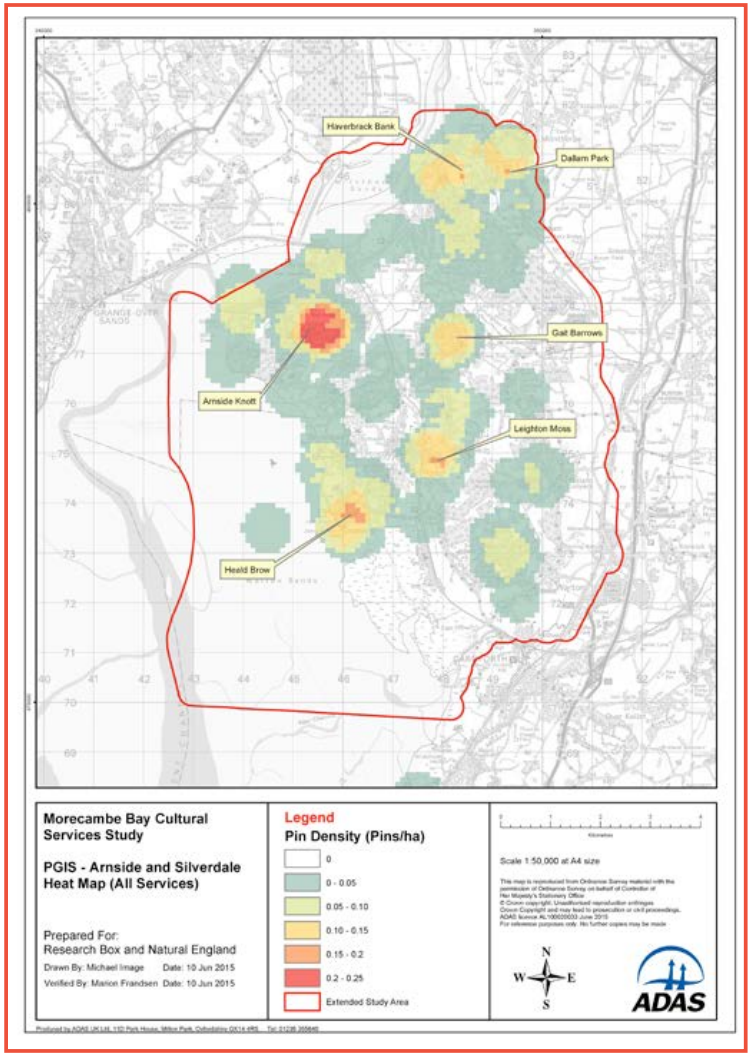
The PGIS tool operates as an interactive website. People are able to place digital pins where they experience cultural services and to say whether they are identifying a specific point of interest or a general area. The website also provides the ability to record notes and upload photographs that users may have taken of the point of interest.

The Morecambe Bay area study has demonstrated the potential benefits of mapping cultural values using the PGIS tool.

While the study, as a pilot, had a small sample of pin data from users (385 pins eligible for statistical and spatial analysis), it demonstrated how the data could be analysed alongside a range of land cover and environmental data sets – showing the relationship between what people valued, landscape and ecological features, areas designated for conservation value and the wider landscape. The outputs can be presented, for example, as visual heat maps indicating areas of shared cultural value.

Further potential for PGIS and smartphone Apps

The studies concluded that there is further potential for technology such as PGIS and smartphone Apps to give a location to what is sometimes considered more qualitative data for GIS spatial analysis. However, the studies have also made clear the value of complementing this sort of citizen science with face-to-face participatory workshops, which bring deeper and richer information about what people value. This gives us a stronger evidence base to make more informed decisions about landscape change.



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A new narrative for freshwater and wetland ecosystems

by Chris Mainstone

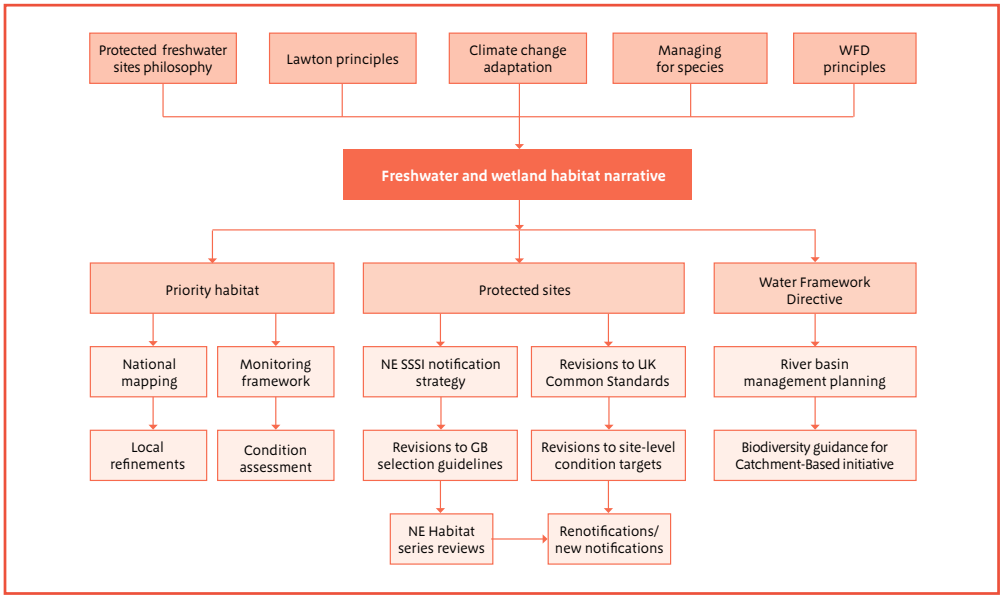
At times there are some serious challenges when policies to protect and restore biodiversity meet other statutory requirements. One of these challenges is integration with strategies for protecting and restoring water and the water environment, governed by the Water Framework Directive (WFD).

As a culmination of several years' work, Natural England's freshwater and wetland specialists have produced a narrative that seeks to provide a common language for biodiversity and water aspirations, underpinning all policy and technical discussions on the conservation of freshwater and wetland ecosystems. The **research report** [30] draws on a wide range of evidence to highlight the conservation importance of naturally functioning freshwater and wetland habitat mosaics, shaped by natural environmental processes and operating at a range of spatial scales.

This natural ecosystem function lies at the heart of both biodiversity objectives for freshwater and wetland systems (through implementation of protected site legislation and England's wider biodiversity strategy) and water objectives (through achieving ecological status objectives under the WFD).

The research report emphasises the critical importance of natural ecosystem function to characteristic species assemblages of freshwater and wetland habitats, including priority species, and promotes an approach to species conservation based on the restoration of natural processes. Evidence-based messages are provided for how local decision-making can best accommodate natural ecosystem function at a range of spatial scales from individual sites to catchments/landscapes.

The narrative now forms the evidence foundation for various major workstrands on freshwater ecosystems as shown in the schematic below:



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It is also a central piece of evidence in Natural England's water strategy and has informed Natural England's conservation strategy. It is being heavily drawn on by stakeholders in the development of new biodiversity delivery guidance for the WFD Catchment-Based (CaBa) initiative. More broadly, it has the capacity to inform UK and European level debates about the place of biodiversity objectives in water management.