Amphibians under threat

Also inside:
- A dose of nature
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- Flood-risk management
- DNA sequencing
About us

NERC – the Natural Environment Research Council – is the UK’s leading funder of environmental science. We invest public money in cutting-edge research, science infrastructure, postgraduate training and innovation.

Our scientists study the physical, chemical and biological processes on which our planet and life itself depends – from pole to pole, from the deep Earth and oceans to the atmosphere and space. We work in partnership with other UK and international researchers, policymakers and business to tackle the big environmental challenges we face – how to use our limited resources sustainably, how to build resilience to environmental hazards and how to manage environmental change.

NERC is a non-departmental public body. Much of our funding comes from the Department for Business, Innovation and Skills but we work independently of government. Our projects range from curiosity-driven research to long-term, multi-million-pound strategic programmes, coordinated by universities and our own research centres:

British Antarctic Survey  
British Geological Survey  
Centre for Ecology & Hydrology  
National Oceanography Centre  
National Centre for Atmospheric Science  
National Centre for Earth Observation

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For the latest environmental science news, features, blogs and the fortnightly Planet Earth Podcast, visit our website Planet Earth Online at www.planetearth.nerc.ac.uk.

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Editorial

We all know a walk in the woods or by the sea makes us feel better. But scientists and doctors are only just starting to realise just how much of an impact regular exposure to nature can have on our mental and physical health.

NERC knowledge exchange fellow Dan Bloomfield is particularly well-qualified to explore this area – a trained ecologist, he’s also a practising psychotherapist. In this issue you can read him describe his project, A Dose of Nature, looking at whether instead of prescribing drugs, doctors could treat health issues from circulatory problems and substance abuse to depression with a course of walks in the countryside.

To make this happen, Bloomfield has had to build relationships with many groups of people to share knowledge and understand different stakeholders’ goals and concerns. He’s now working with six GP surgeries and their communities to test the idea.

There are still challenges to deal with, but the concept could bring enormous benefits – helping people overcome mental and physical conditions that blight their lives, easing pressure on doctors and perhaps even helping build support and funding for nature conservation.

Elsewhere in the issue, Trent Garner outlines how we’re starting to understand the array of deadly diseases threatening the world’s frogs, toads, newts and salamanders, and Stephen Brusatte and Sarah Shelley tell us what one unassuming fossil reveals about the rise of the mammals.

Continuing last issue’s retrospective theme, Mark Robinson of the Centre for Ecology & Hydrology sketches out how hydrology has developed into a discipline in its own right over the last 50 years – a story that runs in parallel to NERC’s own existence, and that wouldn’t have happened without NERC’s support in its early years.

Finally, Ed Hawkins explains why we shouldn’t let variations from year to year distract us from the long-term downward trend in Arctic sea ice. It’s a topical subject, given recent reports of a recovery in the area covered by ice over the last year or two. Ed points out that this is exactly what we’d expect to happen – natural processes rarely move in a straight line, and these fluctuations will continue even as we move towards an ice-free Arctic. The situation’s like a ball bouncing down some stairs. If you only watch for a moment during one of the bounces, you might decide the ball’s escaped the pull of gravity and will soon be hovering near the ceiling. Paying attention for a little longer would show otherwise.

£1.7m to train 3,000 citizen scientists

A new project will teach thousands of people to monitor and protect sea life around the UK’s coastline.

Capturing our Coast will be the biggest exercise in UK marine citizen science ever undertaken. Organisers hope it will shed light on how our seas are responding to global climate change.

Volunteers will get training in how to collect high-quality data around key species that scientists use as indicators of the health of whole ecosystems. The results will also help inform future policies and conservation efforts.

The initiative is a partnership between numerous research organisations, and will draw on NERC-supported scientific expertise. Funded by the Heritage Lottery Fund, it’s led by Newcastle University’s Dove Marine Laboratory and also involves the universities of Bangor, Hull and Portsmouth. Also taking part are bodies including the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), the Coastal Partnerships Network, the Earthwatch Institute, the Marine Biological Association, the Marine Conservation Society, the Natural History Museum, Northumberland Wildlife Trust and the Scottish Association for Marine Science (SAMS).

‘We are living in a time of rapid climatic change that has not been seen in millions of years. This is an opportunity to document changes in the natural world that may reflect that,’ says Professor Mike Burrows of SAMS. ‘We are not looking for people to become experts overnight but if a lot of people can gather evidence on little changes, we can fit that into a bigger picture. As scientists, we can’t be everywhere but people can tell us what’s going on in their backyard and we can collectively gather the evidence.’

The project is open to volunteers from September 2015. If you’re interested in nature and want to take part, email bigseasurvey@ncl.ac.uk
Tackle farm emissions to fight air pollution, say UN experts

Cutting methane and ammonia emissions from agriculture could be the most cost-effective way to deal with threats to global food production and human health, according to a UN scientist meeting.

The experts, who included scientists from the Centre for Ecology & Hydrology (CEH), met in Milan for discussions in support of the UNECE Convention on Long-Range Transboundary Air Pollution.

Methane and ammonia emissions are major contributors to particulate matter in the atmosphere, which causes health problems and has been implicated in millions of premature deaths. Methane is also a powerful greenhouse gas and breaks down into ozone in the atmosphere, which damages vegetation and causes an estimated $20 billion worth of crop losses every year.

It's a particular problem in Asia, where ozone levels sometimes exceed 150 parts per billion, more than ten times natural levels. Simple and inexpensive measures at a few per cent of Europe's biggest industrial farms would cut ammonia emissions in 2030 by some 27 per cent from 2005 levels. These could include things like covering manure stores, or injecting manure into the soil rather than spreading it.

Professor Mark Sutton of CEH argues that such measures could benefit agriculture as well as the environment and our health. 'Keeping nitrogen in the farm system can help farmers save on their fertiliser bills, while reducing air pollution, water pollution and greenhouse-gas emissions,' he says. ‘It can make a major contribution to improving nitrogen efficiency across the world economy.’ He adds that one of the simplest ways for ordinary people to cut their contribution to the problem is to eat less meat.

Vortex technology
a new way to clean up water

Research by a team including NERC-supported scientists could improve life for millions of people in developing countries by letting them sterilise waste water cheaply using simple technology built from components including plumbing parts, a drill and a model boat propeller.

The technique uses a continuous vortex in a pipe to bring pathogens into contact with something that kills them – at the moment, copper powder embedded in seaweed extract. The scientists, working alongside researchers from Protein Technologies Ltd, sent prototypes of the so-called vortex bioreactor to places including South and North America, South Africa and India to test its performance in the field. It worked better than they’d hoped, and the team now hope to launch it so it can be used around the world to kill harmful microbes in people’s water.

‘We see total destruction of bugs like E.Coli after only a few minutes, and we haven’t even optimised the system yet – we’ve been focused on proving it could work first,’ says Dr Mike Allen, a microbial biochemist at Plymouth Marine Laboratory, who led the project.

‘What started out as a technology to help convert microalgae in biofuels spun off, quite literally, in the direction of global waste water sanitation,’ he adds. The scientists think the technology could revolutionise water treatment in the developing world. It’s simple, easy to maintain, can be powered by hand, bike or motor and will work at any scale, from a single toilet block to a city. It’s a cheap, low-tech but high-performance alternative to UV water sterilisation, and its creators are hoping it will attract attention from NGOs and government agencies; they plan to make it freely available for humanitarian applications.

The results of trials at a water treatment plant in Pune, India, appear in a paper in Nature Scientific Reports; they show the treatment quickly rendered all E.Coli and related bacteria inactive in the plant’s effluent. The project received funding from the Bill and Melinda Gates Foundation.

DOI:10.1038/srep09461
Scientists look to the Persian Gulf for insight into corals’ future

NERC-funded research in the world’s hottest sea, the Persian Gulf, is helping scientists understand how coral reefs will adapt to climate change.

Reefs are some of the richest habitats on Earth, and provide many benefits to people including food and income from tourism. But they are under severe threat from environmental change – in particular, from warming waters. If we’re to halt coral reefs’ decline, we need a detailed understanding of how they are responding to these problems.

Specialist partnerships between corals and symbiotic algae dominate reefs in the southern Arabian Gulf.
A study in Nature Scientific Reports details the scientists’ discovery of Symbiodinium thermophilum, a new species of heat-tolerant symbiotic algae in corals in the Persian Gulf. The stony structures we think of as coral are the result of a mutually-beneficial relationship between animal hosts and unicellular algae that make energy from sunlight for them. These algae are often sensitive to temperature change, and for many an increase of just 1°C can spell disaster. Understanding how the newly-discovered algae can stand living in warmer waters, and how far that tolerance goes, will help reveal how corals more generally will cope with a changing environment.

Another paper in the International Society for Microbial Ecology Journal builds on that discovery by outlining where the new species lives – known to scientists as its biogeography. It also shows that it’s not just adapted to warm waters, but also to the very salty conditions of the Gulf; this will probably limit its ability to spread worldwide.

“Our results have important implications for coral reef management as they show the strong dependence of coral stress tolerance to local environmental conditions,” comments Professor Jörg Wiedenmann, head of the University of Southampton’s Coral Reef Laboratory and leader of the study. He adds that this suggests so-called assisted migration – moving species to new places where they can thrive and help the new ecosystem become more resilient to environmental change – isn’t a promising conservation strategy for corals.

The scientists’ work also contributed to the creation of the Mideast Coral Reef Society (www.mideastcrs.org), which aims to improve communication between academics, government agencies, NGOs and the private sector.

DOI:10.1038/srep08562; 10.1038/ismej.2015.80

**£2m to explore low-carbon futures**

NERC is investing up to £2m in research on how possible UK energy futures would affect resources like groundwater and natural habitats, as well as ‘ecosystem services’ – the benefits nature gives us, from clean water to enjoyment of the wild. For example, a future with more wind farms could affect people’s enjoyment of natural landscapes.

The scientists will also estimate the economic value of the ecosystem services associated with each future pathway, helping policymakers bring energy and environmental factors together when making decisions.

The scenarios examined include the kind of steps the UK will need to meet its policy goals of maintaining energy security, keeping energy affordable and cutting greenhouse-gas emissions by 80 per cent by 2050.

**Working together to tackle dangerous microbes**

The new Environmental Microbiology & Human Health programme will address important ways people can be exposed to microbes that put their health at risk. It’s NERC’s first collaboration with the Defence Science and Technology Laboratory (Dstl) and the Food Standards Agency (FSA).

The focus is on studying harmful microbes in different habitats to understand the potential risks to people. It will generate new methods, knowledge and data that will inform public health policies and help manage disease outbreaks. The programme will investigate aquatic systems like rivers, recreational waters, beaches and shellfisheries as well as airborne microbes in cities, farms, industrial sites and waste-management facilities.

**Voyage of Discovery to London**

As part of NERC’s programme of events to celebrate its 50th anniversary, the UK’s state-of-the-art research ship RRS Discovery will be making a rare visit to London from 7 to 11 October. She’s set to leave her base in Southampton, travel up the Thames and moor alongside HMS Belfast near Tower Bridge.

During her stay she’ll host a wide variety of science exhibitions, stakeholder receptions and other activities designed to show off the breadth and quality of UK environmental science.
Experts at the British Geological Survey have taken another step into the world of Minecraft by creating 3D representations of the geology of important sites across the UK. You can now use the wildly successful computer game to explore the rocks beneath north London, the soils ancient glaciers deposited in York and the faults beneath the slopes of Ingleborough.

All this is represented in coloured glass blocks, so players can see through different geological units and get a better sense of how the landscape’s different layers fit together. BGS’s first step in this area was to create a 2D model of the whole UK landscape in Minecraft.
If you’re a Minecraft player and fancy exploring the ground beneath our feet, you can download the files for free at www.bgs.ac.uk/discoveringGeology/geologyOfBritain/minecraft
Observing the Atlantic
A decade of surprises

Scientists have been monitoring how water circulates through the North Atlantic for more than a decade now, through NERC’s Rapid Climate Change programme (RAPID) and its successors. A new review in Science sets out the highlights of what they’ve found out.

A major UK-US collaboration, RAPID created a huge array of monitoring equipment stretching from Morocco to Florida to monitor changes in the Atlantic Meridional Overturning Circulation (AMOC); observations started in 2004.

AMOC plays a central part in regulating the global climate – it’s a vital mechanism by which heat moves around the world, with warm water from the tropics flowing north and being replaced by colder water from around the Arctic.

Apart from anything else, it’s the reason the UK is so mild compared to other places at similar latitudes. If it were to decline abruptly due to climate change, as some researchers have suggested is possible, the effects on northern Europe’s climate would be profound. So it’s important to understand how AMOC will interact with global environmental change.

We still don’t have all the answers, but we know a lot more about the circulation and its natural variations now than we did, thanks to the RAPID array.

It turns out, for example, that the circulation naturally varies a lot more than we’d thought. More dramatically, it dipped by 30 per cent in 2009-10, perhaps causing significant changes in the weather such as that year’s severe winter – researchers are still investigating.

Over the whole period of observations, AMOC has declined, each year losing about half a million cubic metres per second – a drop in flow that’s around ten times as fast as climate models predicted. Whether this is a long-term trend due to climate change or is part of natural variability remains to be seen. There’s no doubt that a decade of observations has transformed scientists’ view of how the oceans and climate interact.

The North Atlantic and Arctic Oceans are critical components of the ocean-climate system. Warm tropical waters flow northwards, releasing heat to the North Atlantic region, and eventually flow into the Arctic Ocean. Cold waters sink in the northern North Atlantic and flow southwards forming the Atlantic Heat Conveyor.

In the next issue of Planet Earth we’ll have a detailed account of RAPID’s first decade from Professor Meric Srokosz of NERC’s National Oceanography Centre, coordinator of the RAPID Climate Change science programme and the Science paper’s co-author.

DOI:10.1126/science.1255575
What did the River Severn ever do for us?

The Severn Estuary and Bristol Channel aren’t just one of the UK’s greatest natural wonders. They are also a precious economic asset that’s supported human society in countless ways throughout the history of settlement in these islands – and continues to do so today.

That’s the message of a recent study into the social and economic benefits the estuary’s natural habitats give us. These ‘ecosystem services’ range from shipping and fisheries to carbon storage, flood-risk control and insights into our past from the region’s archaeological sites.

The project was funded by the NERC Marine Renewable Energy Knowledge Exchange Programme and carried out by Plymouth Marine Laboratory and the RSPB. It set out to identify the key ecosystems in the Severn Estuary and Bristol Channel that provide essential benefits to local communities and the nation as a whole.

It then mapped these ecosystem services and assessed how much they benefit society. Again, in some cases this was easy and in others less so – putting an economic value on a fishery or port is relatively straightforward, but estimating the worth in slowing climate change of salt marshes’ and mudflats’ capacity to absorb carbon is more difficult. Likewise estuaries’ role in preventing flood damage isn’t as obvious as the way they enable shipping, but the flood defences they save us having to build would be extremely costly.

In the past, the benefits that are easier to value have tended to get priority, and the results haven’t always been good. The researchers hope their work will help guide sustainable development that balances all the different benefits the estuary provides, including its potentially important tidal energy resources. To read the final report, ‘Ecosystem service mapping in the Severn Estuary and inner Bristol Channel’, or a non-technical summary of the findings, visit http://bit.ly/IHYADFE.

Key
1. Intertidal coarse sediment.
2. Intertidal boulders.
3. Offshore subtidal gravel, intertidal sand.
4. Intertidal rock, intertidal biogenic reefs, intertidal mud, subtidal sand, subtidal mud, blue mussel beds.
5. Salt marsh, subtidal rock, biogenic reefs, tidal swept algal communities, subtidal macrophyte communities.

Valuing nature – what do we really think?

A new report sheds light on how the public feels about efforts to value natural environments and the many benefits they give us, known as ‘ecosystem services’.

It’s informed by the results of a major public dialogue project run by the University of Exeter’s Centre for Rural Policy in partnership with NERC, the Department for Environment, Food & Rural Affairs and Sciencewise. Researchers held nine one-day events in Birmingham, Exeter and Glasgow, culminating in a day and a half in London with participants from each city and representatives of national and local governments, academics, NGOs and others.

The report seeks to explain why the natural environment matters to people, as well as exploring how current approaches to environmental policy and decision-making resonate with public concerns and priorities.

Many of the findings are about what you’d expect – people value natural environments for many reasons; they don’t just provide livelihoods and prosperity, but also encourage exercise and give us a chance to improve relationships with family and friends, connect with the past and even find inner peace.

Those who took part generally support the need to make an economic case for the environment, but they emphasise that we shouldn’t think of nature as a bottomless pit of resources but rather as something that helps us to function and that therefore needs to be cherished and protected.

The report also suggests local communities should be more involved with decisions on natural environments, and that people want decision-makers to prioritise long-term considerations rather than short-term financial gain.
DATA AS ART is a groundbreaking science/art project being developed at NERC’s British Antarctic Survey (BAS). It uses visualisations of real science data from the poles to create stunning, thought-provoking artworks that also relate to important and exciting science stories. These images are just a small selection of what the project’s produced.

BAS is now exploring where these artworks will be displayed. The first exhibition will be on board RRS Discovery when she’s in London as part of the events to mark NERC’s 50th anniversary (see p5).

For more information, contact Pete Bucktrout, the project’s creator at BAS, on pbu@bas.ac.uk, or visit www.bas.ac.uk/project/data-as-art
News

Lichen?
There’s an app for that

CEH scientists have developed a new mobile app that lets citizen scientists determine which lichen species are present in an area, and from this tell how much nitrogen pollution it receives.

Some lichens are sensitive to nitrogen pollution; others aren’t. By identifying what’s growing on tree trunks and branches, app users can get an accurate estimate of how polluted the area is.

Excess nitrogen, often coming from farmers using fertilisers, is harmful to many ecosystems but particularly dangerous to slow-growing groups like lichens and mosses.

Using the app will help scientists get a sense of how these vulnerable families are doing across the UK, and by extension which areas are suffering most from nitrogen pollution. It includes an identification guide, a simple recording system and an automatic way to determine pollution levels.

The app is based on a field guide produced in collaboration with the Joint Nature Conservation Committee, the Natural History Museum, the Northern Ireland Environment Agency, Scottish Natural Heritage, the Scottish Environmental Protection Agency, Sniffer and the University of Nottingham. The guide is published by the Field Studies Council. The software works on both iOS and Android devices, and is available for free at www.apis.ac.uk/lichen-app

Report predicts winners and losers from climate change

Wasps, bees and southern species like the Dartford warbler and the emperor dragonfly are likely to benefit from climate change in England, according to a new study – but other species such as curlews and cuckoos, as well as damp-loving mosses and liverworts, are in danger.

The report assesses the risks and opportunities of climate change for English plants and animals. It’s published by Natural England in partnership with the British Trust for Ornithology, NERC’s Centre for Ecology & Hydrology (CEH), the RSPB and the University of York.

Its authors looked at potential shifts in the distribution of more than 3,000 species due to climate change, making this the largest and most comprehensive assessment yet. If average global temperatures were to rise 2°C by 2080, more than a quarter of these species would be at medium to high risk of disappearing from a substantial portion of the area of the country’s that’s currently suitable for them.

Just over half the species could potentially move into new areas, but this may be easier said than done; many aren’t particularly mobile, and may face barriers in the landscape that make it hard for them to reach theoretically favourable new habitats.

Many of the species at risk are already of conservation concern, and often live in upland habitats and hence prefer cooler conditions. They include twites, golden plovers and mountain crowberries. Others expected to suffer include seabirds like kittiwakes and some lowland species including lapwings, rare spring sedge, orange ladybirds and triangle hammock spiders.

In contrast, populations of birds including avocets and little egrets are predicted to increase, as are moths including the large wainscot and white line dart moths.

Read the full report at http://publications.naturalengland.org.uk/publication/4674414199177216.

£8.5m to answer big climate questions

NERC is making a major investment in three new projects to improve our understanding of climate change and its effects.

They target some of the major subjects in this area that scientists still don’t understand well, and will help society understand and cope with the challenges of a changing climate.

A team led by Dr Richard Sanders of NERC’s National Oceanography Centre will get £3.1m to investigate the ocean’s twilight zone – between 100m and 1,000m below the surface – and its role in transporting carbon from the atmosphere to the deep.

Dr Guy Woodward at Imperial College London heads a group that receives £3m to use cutting-edge genetic techniques to shed light on the resilience of whole ecosystems to climate change – from big, familiar animals to the tiny microbes on which ocean life ultimately depends.

Finally, the team of Professor Martyn Tranter of the University of Bristol has been awarded just over £2.4m to find out why the Greenland ice sheet is melting more quickly than expected. In particular they’ll investigate whether warming is triggering the growth of microbes, making the ice surface darker and so causing it to absorb more of the sun’s heat. If this turns out to be true, it will have serious consequences for the ice sheet’s future, and also for other things including how quickly sea levels will rise over the next few decades.
An international team including experts from NERC’s British Antarctic Survey (BAS) have found new evidence that large volcanic eruptions were responsible for many extremely cold summers recorded over recent millennia.

Their study, published in *Nature*, shows that 15 of the 16 coldest summers between 500BC and 1,000AD followed major eruptions, with four of the chilliest happening just after the biggest volcanic events on record. Throughout history these episodes have triggered crop failures and famine, perhaps causing disease outbreaks and even bringing down whole societies.

‘Using new records we are able to show that large volcanic eruptions in the tropics and high latitudes were the dominant drivers of climate variability, responsible for numerous and widespread summer cooling extremes over the past 2,500 years,’ says Dr Michael Sigl of the Paul Scherrer Institute in Switzerland, the paper’s lead author.

It’s well known that eruptions cause variations in the climate, firing sulphate particles into the upper atmosphere where they reflect some of the sun’s light back into space before it can warm the Earth. But these effects have been hard to quantify and compare because of inconsistencies in data from different sources. In particular there were problems squaring evidence from tree rings with that from ice cores.

The scientists looked at more than 20 ice cores from Greenland and Antarctica. They used cutting-edge dating techniques to produce a new and more accurate reconstruction of changes in atmospheric temperature in the wake of nearly 300 volcanic eruptions stretching back to Roman times. They also worked with historians to uncover ancient records from China, Babylon and Europe describing unusual atmospheric conditions that suggest the after-effects of a major eruption.

‘What makes this study special is the accuracy of the dating techniques brought to bear on the ice-core record,’ says co-author Dr Robert Mulvaney of BAS. ‘Now we have much more certainty in attributing recorded climate responses to specific volcanic activity recorded in the ice.’

The scientists say the results will help build better climate models, and that the methods they’ve developed can now be used to reconstruct the climatic impact of volcanoes all the way back to the last Ice Age. Lead institution on the paper was the Desert Research Institute; most of the funding came from the US National Science Foundation’s Polar Programme.

DOI:10.1038/nature1456

NERC’s National Oceanography Centre in Southampton has completed its £3m Marine Autonomous and Robotic Systems (MARS) Innovation Centre.

Partly funded through the UK government’s Eight Great Technologies initiative, the centre aims to help scientists work alongside the private sector to share NOC’s world-leading expertise in marine robots, driving innovation and spurring economic growth.

The paint’s only just dry, but the centre already has several businesses lined up to occupy it. Camberley-based Planet Ocean is the first to sign up; after submitting a successful joint funding bid with NOC to Innovate UK, it’s about to start a project to launch and recover multiple underwater vehicles from an unmanned surface craft.

‘This really is just the beginning,’ says Kevin Forshaw, NOC’s associate director for innovation and enterprise. ‘We have already seen the effect working with NOC can have on small marine technology businesses, so we’re confident we have an offering that works. The centre provides the Solent region with a true hub for marine technology development and we believe it will attract business from all over the world, bringing jobs and a new growth industry to the region.’
What do you get when you cross ecology with psychotherapy? Quite possibly you end up with profound benefits for people’s wellbeing – and for the health of the NHS. Dan Bloomfield explains why for many chronically ill or isolated people help could lie just beyond their front door.

A dose of nature

For nearly two years I’ve been running a project in Cornwall that brings together two quite different sectors: health and the natural environment. I’ve always been fascinated by how the two relate to each other. I started by studying ecology, first because nature fascinated me and then, I began to realise, because it made me happy. I noticed that being outdoors was the key to my physical health as well as my mental wellbeing. Nature pleased me, calmed me, gave me a sense of perspective. Somehow, it also made me walk a bit further, or climb a bit higher.

A few years ago I also began to train as a psychotherapist. The success of psychotherapy depends on the effectiveness of the relationship between the therapist and patient and the context of that relationship has an enormous bearing upon the outcome. Instead of sitting indoors I began to take clients outside for a walk and we both noticed the difference. It made me wonder; if going out in nature was beneficial to health and wellbeing, could we eventually reach a point where a doctor, rather than prescribing antidepressants or even statins, might offer a dose of nature instead?

That question led me to a Natural Environment Research Council fellowship in the field of knowledge exchange. This essentially means bringing together different groups of people outside academia to find out how and where research could be better applied, to maximise social and economic benefit. On the one hand, academics have a lot of knowledge about health, wellbeing and the natural environment, and also a lot of questions. On the other, environmental organisations are keen for people to value our natural assets more, and to bring the things that nature does for us — clean our water, circulate our carbon, control our pests and, perhaps, underpin our health — to everyone’s attention. And on the third hand (one I often wish I could grow), the health system is very keen to reduce costs, to find alternative ways of caring for people, to reduce the impact of future epidemics of obesity and depression, and to involve the voluntary and community sector more. If we brought these agendas together, could we make nature prescription a reality?

Right from the start there was an enormous amount to learn and to share. The health system, with its acronyms and concepts like commissioning of services...
and care pathways, has its own language of which many of us – myself included – understand only a smattering. I got a rapid education in NHS restructuring and the like, but as my fellowship progressed I was delighted and relieved to discover many GPs, nurses and managers who ‘got’ the concept and wanted to take part.

The idea of using the outdoors for health is hardly new. It’s what comes naturally to many of us, after all; to go outside when we need to clear our head or stretch our legs. It’s part of the broader prevention and public health agenda, to reduce the risk of problems arising in the future. Initiatives like Project Wild Thing are doing a huge amount to reconnect children with play and adventure in natural outdoor places. But what about people who are already suffering from chronic conditions, or multiple health problems? What about people who are isolated, or have circulatory health problems combined with substance abuse, or depression, or who are obese?

Once the GPs, the environmental charities and trusts, and the academics began to talk to each other some things became clear very quickly. The actual diagnosis was less important than whether the doctor felt getting out in nature was something the patient might readily be encouraged to do. Transport can be a problem for some, but one that can be solved nonetheless. And there needs to be someone – a facilitator or leader – to receive the doctor’s referrals and guide patients to put it into practice, otherwise it could amount to no more than easily-ignored advice.

So it was a question of bringing together the right people, something the fellowship was designed to do. Once we’d done that, patient referrals began.

We now have six Dose of Nature projects, each a partnership between local GP surgeries and the communities in which they sit.

There are huge challenges to all of this. Everyone is time poor, especially in primary care, and everyone is under budgetary constraints. Because of the need for facilitation, a course of nature-based activities is not free, and we are researching how the costs compare to other standard treatments, and whether the NHS prescription fee can follow such a referral.

But these are also problems that nature prescription can help solve, by reducing the number of people needing to see their doctor and eventually, we hope, by providing a new source of income for nature conservation. The project has created a lot of interest around the country, and the aim now is to spread what we have learnt out to all parts of the English NHS so it can be repeated elsewhere.

We are also instigating some further research, hopefully funded from the health side of things, that will look in more detail at what kinds of specific ‘dose’ for patients with different conditions we need to commission. We need to model the economics of this in such a way that eventually the costs are borne by the health system, perhaps via the prescription charge. And we also need to understand in finer detail what the advantages are to the natural environment of specifically using it in this way.

Eventually, I hope, we’ll get to a point where a doctor will commonly order a dose of nature, and we’ll have a Natural Health Service to work alongside the NHS. It’s been a great journey so far, and one that I hope is just beginning.
Amphibians under threat

Frogs, toads, newts and salamanders look like hardy creatures and anyone observing a pond full of frogspawn could be forgiven for thinking their future was secure. But several emerging diseases are attacking the world’s amphibians, sometimes with devastating results. Trent Garner explains how we’re starting to understand the extent of the threat.

There’s no denying that the places we do fieldwork are stunning. Monte Limbara, the French Pyrenees, the Picos de Europa, the Serra de Tramuntana, the Drakensberg, all are high-elevation sites of exceptional beauty and striking biodiversity. Unfortunately, the need for these expeditions takes the edge off the views. I’ve yet to experience a mountain-top vista that compensates for finding hundreds of amphibian corpses in and around mountain ponds and streams. It doesn’t help that in many cases these corpses are the lion’s share of their generation – juvenile amphibians that should be vigorously pursuing the food they need to survive the upcoming hibernation period. Instead, many of the live ones aren’t even capable of righting themselves when placed on their back.

For more than a decade, I have been part of an international team investigating the emergence of a lethal infectious disease, chytridiomycosis, in amphibians across Europe. What started in 2004 as a collaboration between the Zoological Society of London, Imperial College and the Museo Nacional de Ciencias Naturales of Madrid, has grown to a collective of researchers based at more than 20 institutions or NGOs across Europe, working with other research teams in North America, Africa, Australia and Asia. Our goal is to understand under what conditions emerging diseases threaten European amphibian biodiversity. The cause of chytridiomycosis, infection with a chytridiomycete fungus, was initially described in 1998, affecting Latin American and Australian amphibians in the wild and captivity; the previous year; amphibian mass mortality from chytridiomycosis was first seen in Europe. Our studies have shown that Batrachochytrium dendrobatidis, the first chytridiomycete species known to cause the disease, is killing amphibians in at least seven EU countries, causing population decline and local extinction in some cases. Peñalara Natural Park, in the mountains near Madrid, is ground zero for European chytridiomycosis. Here, common midwife toads (Alytes obstetricans) have disappeared from an area where previously thousands of tadpoles could be counted at a single breeding site. Tyrrenhenian painted frogs (Discoglossus sardus) are all but absent from places on Sardinia where infection with B. dendrobatidis is recorded.

But are these local conservation issues reflected across Europe? We don’t yet know for certain, but our general impression is that European amphibians...
Common midwife toads have disappeared from an area where previously thousands of tadpoles could be counted at a single breeding site.

are not comprehensively threatened by chytridiomycosis: we have not seen the rapid spread of infection and death that has struck Central American amphibians.

There are several reasons why this may be. First, *B. dendrobatidis* is composed of many and varied genetic lineages and only one of these, a highly virulent form, is consistently associated with amphibian mass mortality and population decline. Second, while some environmental conditions can favour the spread of the disease, others limit the likelihood, strength and severity of infection. Third, the process of infection can be limited through the food chain, as microscopic predators like rotifers feed on infectious *B. dendrobatidis* spores. Finally, some of Europe’s native amphibians are naturally resistant to infection, possibly through the antimicrobial qualities of their skin or the antifungal microbes that live on them.

Based on a first look at our European survey and experimental data, we believe that only midwife toads, painted frogs and fire-bellied toads (*Alytes, Discoglossus* and *Bombina*) are highly susceptible to lethal infection with *B. dendrobatidis*. These results should be treated with caution, however, because we couldn’t include all European species in our analysis and in some circumstances even species resistant to infection in the lab may fall prey to lethal chytridiomycosis in the wild. And exposure to pathogens can cause mortality even in resistant populations, because the energy invested in resisting infection is diverted away from other tasks resulting in weaker animals that don’t survive; this calls into question the value of field observations for fully understanding the risks of infection. Throw in the inevitability of changing European climates, and it’s clear we need to keep assessing *B. dendrobatidis* and keep working to develop mitigation strategies.

Our story doesn’t end there, however. A new species — *B. salamandrivorans* — is emerging on continental Europe, this one a salamander and newt specialist that rapidly kills almost every European tailed amphibian we have tested. Right now it’s affecting fire salamanders (*Salamandra salamandra*) at three locations and it’s spreading, devastating populations in a matter of weeks; it may have caused the near-extinction of fire salamanders across the Netherlands. *Batrachochytrium salamandrivorans* and *B. dendrobatidis* are both found in the amphibian pet trade, which is largely unregulated and has no disease-control standards.

But an even greater threat may be emerging on the Continent. Ranaviruses have long been recognised as a danger to amphibians, reptiles and fish, and now a new strain has devastated amphibians across Iberia and at high-elevation sites in France. Newts, salamanders, toads and frogs are all susceptible at all stages of life. Even worse, there have been reports of the virus affecting terrestrial reptiles with similarly lethal effects. There is strong reason to believe we are seeing the emergence of a disease that can devastate both amphibians and reptiles.

Although both of these diseases are notifiable to the OIE, the World Organisation for Animal Health, there are no clear strategies for mitigating their impacts on biodiversity. We are currently trialling several strategies – including treating animals with antifungals, or altering amphibian skin microbiomes to enhance their antifungal capacity — with varying levels of success; some look promising for controlling chytridiomycosis, but tackling a virus that threatens terrestrial reptiles and aquatic amphibians will require an extensive, joined-up and international effort. We are working with the Global Ranavirus Consortium and other stakeholders in the hope that we can develop an effective strategy before this important part of Europe’s biodiversity is diminished for ever.
The rise of the mammals

An asteroid strike put an end to the dinosaurs 66 million years ago, making way for mammals to thrive – that much we know. But how exactly did our ancestors go about their march to dominance? Stephen Brusatte and Sarah Shelley introduce an unassuming fossil that holds some of the answers.

Edward Drinker Cope named more than 1,000 species and published nearly 1,500 papers during his long career in vertebrate palaeontology. He worked on everything, from fish and frogs to sea-living reptiles and dinosaurs. But in 1881 he announced a discovery that stood above the rest. In the characteristic understatement of a 19th-century gentleman scientist, Cope boasted that the new fossil would be remembered as ‘an important event in the history of palaeontological science’.

He wasn’t referring to a charismatic dinosaur of colossal size or an early branch of the human family tree. Instead, he was talking about an unassuming little mammal called Periptychus, just about the size of a dog, found in the dusty badlands of the American Southwest.

Cope’s excitement was prophetic. Periptychus may look like nothing more than a cute pet, but it and a growing number of other mammal fossils are now helping us better understand one of the pivotal moments of Earth history. At the end of the Cretaceous, about 66 million years ago, a 10-kilometre-wide asteroid slammed into what is now Mexico. It rudely interrupted a world in which dinosaurs were dominant, and had been for more than 100 million years. The asteroid hit with the force of several million nuclear bombs, unleashing a torrent of tsunamis and wildfires and sending dust into the stratosphere, blocking out the sun and poisoning the atmosphere. Ecosystems were devastated and many plants and animals went extinct. When things eventually settled down and the Earth recovered, dinosaurs were nowhere to be found and mammals were everywhere.

This is one of the classic stories in Earth science, repeated to every first-year geology student. The asteroid knocked out the dinosaurs making way for mammals, which had been living in the shadows for tens of millions of years, to prosper; eventually leading to primates and, later, to us. But surprisingly we still know little about when and how mammals started their march to dominance. Why did some mammals survive the extinction but not dinosaurs? How quickly did mammals diversify after the asteroid? When did the major groups of living mammals like rodents, elephants and primates originate?

Periptychus and its kin seem to hold the key. These so-called ‘archaic’ mammals thrived during the first few million years after the dinosaurs died out, during a time called the Paleocene (66-56 million years ago). They were the very mammals that took the reins from Tyrannosaurus and Triceratops, establishing a new world in which mammals invaded nearly every conceivable environment across the globe and ascended to the top of the ecological hierarchy.

When rapid environmental change occurs, animals and ecosystems that have been successful for millions of years can suddenly disappear.

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the food chain in many ecosystems. But surprisingly, after the initial fossil discoveries by Cope and other 19th- and early-20th-century palaeontologists, research on these archaic Paleocene species nearly died out itself. As dinosaurs and fossil hominids grabbed the headlines and research funds, Periptychus and other Paleocene mammals became an afterthought.

But now a new generation of scientists is returning to these Paleocene fossils because of their obvious importance in understanding a major interval of environmental change. We have been working in New Mexico (USA), one of the best places in the world to find both the latest Cretaceous dinosaurs and the Paleocene mammals that replaced them. We are doing fieldwork with our colleague Thomas Williamson, who for more than two decades has been scouring the San Juan Basin area of northwestern New Mexico in the hunt for new fossils. Our joint work in the Paleocene-aged Nacimiento Formation is aimed at finding new Paleocene mammals, tracking the diversity of mammals across this interval, and better understanding the environments they lived in.

Working in New Mexico harkens back to the early days of palaeontology, when explorers would fan out to remote corners of the globe in search of the unknown. Fieldwork in the San Juan Basin probably hasn’t changed much since Cope’s day. Although New Mexico is within the borders of one of the most economically developed countries in the world, a lot of unexplored territory and many undiscovered fossils remain. Most of the state is vast, empty desert: it is a third larger than the UK in land area, but has only 3 per cent of the population. When we’re out prospecting in the barren, candy-striped hills it isn’t uncommon to go entire days without seeing other people.

Our field expeditions over the past five years have produced many new fossils and an emerging picture of what happened to mammals before, during, and after the end-Cretaceous mass extinction. We’ve discovered spectacular new specimens of big plant-eating mammals like Pantolambda and Ectoconus (a close cousin of Periptychus), fast-running species like Tetraclenodon, weird burrowers like Wortmania, and bizarre rodent-like mammals called multituberculates. Our team has also used radiometric dating to place these fossils in time, analysed sediments and isotopes to reconstruct the environments they lived in, and used diversity analysis to look at broad evolutionary trends during this dynamic period of mammal evolution.

There’s still plenty to do but an evolutionary picture is coming into focus. Mammals did not pass through the mass extinction unscathed; the close relatives of modern marsupials were decimated but the hitherto unspectacular placentals (mammals that give live birth to well-developed young) weathered the storm and radiated in the aftermath. This radiation was rapid: within a few hundred thousand years at most there were complex ecosystems with mammals of many sizes, up to about cow size, filling many niches, eating different types of food, and living in the ground, on the land and in the trees.

So it looks like the end-Cretaceous extinction was a knife-edge moment in evolution. Right up until the asteroid impact dinosaurs prospered, then the environment rapidly changed and very quickly entirely new animals – placental mammals – moved in and took over. There is surely a lesson here: when rapid environmental change occurs, animals and ecosystems that have been successful for millions of years can suddenly disappear and the world changes in an instant. When this happened at the end of the Cretaceous it set in motion a chain of events which led, eventually, to humans. If it happens again, who knows where that unpredictable chain could lead.

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One warm year and we’re told an Arctic without sea ice is just around the corner; the next cold one and it’s claimed the ice is recovering. Ed Hawkins explains why Arctic melting will continue to be erratic for the foreseeable future – but says the overall trend is only heading one way.

Arctic sea ice melts each summer, reaching its minimum extent sometime in September, before refreezing through the winter. Over the past 35 years, the area of sea covered by ice in September, known as sea-ice extent, has fallen by about 35 per cent overall, and this decline is projected to continue as global temperatures increase. As a result, commercial Arctic shipping has increased, taking advantage of shorter journey times from Europe to Asia, while possibilities for oil, gas and mineral extraction are being explored and Arctic tourism is growing. Decisions about such activities need to assess both risks and opportunities. To do this, we have to consider both the overall long-term decline in sea ice and, importantly, the natural fluctuations that cause the sea ice to vary from year to year.

In 2007 and 2012 the summer ice extent was dramatically lower than in previous years, causing some prominent forecasts and media speculation that we would soon see Arctic summers which were ‘ice-free’ (meaning there would be less than a million square kilometres of sea ice).

Most climate scientists were more cautious. The weather in 2007 and 2012 had been warmer than usual and the weather was particularly favourable for melting sea ice. Although we have detected a human influence on Arctic sea ice, there was no evidence that
Satellite observations of September Arctic sea ice extent.

Role of trend and variability in Arctic September sea ice extent changes

these particular weather patterns would happen every year.

In contrast, 2013 and 2014 had more sea ice than 2012, leading to contrasting speculation that a recovery was under way. But is this true?

The graph shows that Arctic sea ice extent – the black line – has fallen over the long term, with the dashed line representing the linear trend. But there have also been shorter periods of rapid melt, no change, and apparent increases in extent during this decline – represented by coloured trend lines for some deliberately-chosen eight-year periods.

Erratic changes are what we expect to see. Short periods are not a guide to long-term trends.

The most recent eight-year period, starting from the extreme low of 2007, shows an upward trend. This does not mean Arctic sea ice is recovering. As with global temperature, these erratic changes are what we expect to see. Short periods should not be used as a guide to long-term trends.

How long before the ice is gone?
Imagine a ball bouncing down a bumpy hill. Gravity will ensure that the ball will slow down. If you only watch the ball for a short time, you might conclude it was moving against gravity. A longer-term view would show this was just a bounce.

There is no reason to think that sea ice, or any other aspect of the climate, will change smoothly over time. The climate system simply does not work that way.

Previous studies have suggested that natural climate variations (or ‘bounces’) play a key role in how sea ice evolves, and suggested that some of the rapid melt in the early 2000s was a temporary acceleration.

New research by a team of Canadian and American scientists and me, published in Nature Climate Change, suggests that the recent apparent pause in melt rate is a temporary ‘bounce’ in the opposite direction, and that this is exactly what you might expect.

We analysed the state-of-the-art climate models that are used to make projections of future climate. These simulations show a long-term decline of sea ice, but also exhibit shorter periods of both little change and faster change in Arctic sea ice, just like those seen in the satellite observations. What we have seen recently in the Arctic is well within the range of these simulated expectations. We also found that a decade or more with little apparent change in sea ice would not be a surprise – this often happens in the climate simulations, even in a warmer future.

The causes of these fluctuations in melt rate are still being explored. One suggestion is that slow variations in Atlantic Ocean temperatures are involved. More observations of the Arctic Ocean, atmosphere and sea ice would help answer this question. Satellite measurements of ice thickness, such as from CryoSat, are also transforming our understanding of how sea ice varies from year to year.

We expect the long-term decline in Arctic sea ice to continue as global temperatures rise. There will also be further bounces, both up and down. An often-asked question is ‘when will the Arctic be ice-free?’ – or equivalently, when will the ball reach the bottom of the hill? The Intergovernmental Panel on Climate Change (IPCC) concluded it was likely that the Arctic would be reliably ice-free in September before 2050, assuming high future greenhouse-gas emissions (where ‘reliably ice-free’ means five consecutive years with less than a million square kilometres of sea ice).

Individual years will be ice-free sometime earlier – in the 2020s, 2030s or 2040s – depending on both future greenhouse-gas emissions and the natural erratic fluctuations.

Even when it reaches the bottom of the hill the ball will continue to bounce. Similarly, not every future year will be ice-free in summer. But if global temperatures continue to increase, the bounces will get smaller and the ice-free periods will get longer and spread from early autumn into summer and later autumn.

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Scientists agree: flood damages will increase dramatically across Europe over the coming decades. And as extreme rainfall events happen again and again, some places will be hit harder than others. So why is it that some areas are becoming more prone to flooding, and others not? Louise Slater explains why collecting data on river flows is so important in our efforts to find out.

**CHANGING CHANNELS**

We generally assume that floods happen when big storms produce more water than the rivers can hold. Yet in reality, rainfall is only part of the story. The actual capacity of rivers to contain flood flows can also change over time, for better or for worse.

A river channel’s capacity is essentially the amount of water that can move through it in any given period of time, and depends on its width and depth, and on how rough or smooth the bed is. If a river gradually fills in with sediment, debris, or vegetation, it will become shallower, narrower and rougher. This reduces how much water can flow through it, and how quickly. So as a river channel’s capacity decreases, the land will be inundated more frequently, even if there is no increase in rainfall.

These changes in rivers’ capacity can happen naturally, as storms alter the volumes of sediment that are flushed through streams. But they also increasingly occur because of human activity. Most rivers have been ‘fixed’ and modified by river engineering at some point in their course. River channelisation, for example, usually involves straightening or deepening channels to make them more navigable, to claim land for agriculture, or to control flooding. But it also has less desirable consequences. Channelisation can destroy wetlands and the diverse wildlife they support, or steepen the river’s slope so water flows faster, eroding the channel in places and increasing floods further downstream.

Farming practices and urbanisation also contribute to changes in flooding. When the land is deforested, compacted (for example by cattle and heavy machinery) or made impermeable through the construction of roads and built-up areas, the rainfall cannot soak into the soil, so it runs off directly into rivers. This process makes rivers much more ‘flashy’ – more prone to sudden increases in flow after heavy rain, and so more susceptible to flooding. The runoff may also carry soil into river channels, where it accumulates over time and reduces their capacity to contain flood flows.

![The ADCP remote-controlled (ARC) boat](image-url)
Researchers have long suspected that changes in river form affect flooding, but had never really studied this ‘geomorphic’ effect because they could not get hold of the data they needed to do so.

In reality, we have been measuring rivers for about a century at stream gauging stations around the world, to estimate and predict river flows. These measurements are known as hydrometric data. But it is only in the last decade or so, with the arrival of the Open Data movement, that hydrometric archives have become publicly accessible in many countries, including the UK.

**Open data for flood-risk management**

Now that the data can be freely accessed, we can estimate how changing channel capacity affects the risk of flooding in hundreds of rivers. To do this, we measure just how much streamflow the channels can contain at different points in time, and see how those changes modify the probability of rivers overflowing, independently from the influence of climate or people.

So how much difference do these changes in channel capacity actually make to flood risk? The data show that even very small changes in the capacity of the river channels, of about 10 per cent, can increase or decrease flooding by one to two days a year on average. These small changes are much more common than we think, and can occur gradually over several years, or abruptly after a single storm.

In the Midlands, for example, the capacity of river channels appears to be decreasing progressively over time, due to weeds and reeds growing within the channels. The vegetation traps silt, so the channel capacity slowly decreases. If the amount of water flowing in the stream stays the same, then floods will inevitably become more frequent and severe. Elsewhere in the country, where rivers are less prone to being clogged by weeds and sediment, we see the opposite effect: the channels are progressively eroding, and flood hazard is falling.

The effects vary greatly from river to river. For instance, channels with sand and silt banks may change their shape more often than those with stable banks, just as rivers in relatively undisturbed environments may adjust more easily to changes in flow than those in heavily-managed river basins.

Measuring these changes is vital if we wish to improve flood management systems and accurately estimate flood hazard for the insurance industry. Only by assessing the main causes of changing flood hazard – especially channel morphology, land use and climate – will we truly understand how the magnitude and frequency of floods is set to change over time.

As a society, we need to realise just how important it is to collect hydrometric data in many places. The UK’s population is projected to reach 70 million in just over a decade, and more than five million people already live and work in properties that are at some risk of flooding. We must recognise the true value of our data archives, if we wish to monitor the evolution of our rivers and natural resources successfully.

In the UK we are lucky enough to have some of the best stream-gauging equipment in the world. We have some of the most advanced technology, including remote-controlled boats with acoustic Doppler current profilers (ADCPs) that can map the depth and flow speed of our rivers in some of the most difficult locations. These boats are powerful, fast and easily manoeuvrable, letting us obtain new data on changing river flows and forms in a way that was never possible before.

Our hope is that the river measurements made with these new technologies will become fully available to the public, with complete information on when and where each measurement was made. Then over time, the full ‘patchwork’ of data will give us a fantastic overview of how rivers across the country are evolving in space and time. In turn, we will be able to target problem areas where unstable river channels are increasing floods or undermining structures such as bridges, roads, walls and buildings.

Recording changes in river capacity and streamflow is important on so many different levels. As well as improving our ability to predict floods, these measurements also provide information that will help protect some of our most valuable resources – namely the aquatic health, water quality and navigability of our rivers around the UK.

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Scientists have tended to assume that microbes are so small and move so easily from place to place that they are randomly spread about the planet, rather than distributed according to the kind of ecological rules that govern bigger organisms. By using DNA sequencing, Simon Creer and colleagues have revealed that’s not so – these tiny creatures aren’t so different to the larger life-forms we see every day.

We live in a period sometimes called the Anthropocene, and we are changing the environment faster and more profoundly than ever before. Scientists are increasingly focusing on the relationships between biodiversity and ecosystem function, since we rely on ecosystems for all of the benefits they provide. These ‘ecosystem services’ include food from the marine, terrestrial and freshwater environments.

Microbes play a fundamental role at the base of all food chains, supporting biogeochemical and nutrient recycling. If living things didn’t decompose after they die, the ocean floor would be littered with detritus, your compost heap would no longer work and freshwater ecosystems would be clogged with organic matter. Luckily for us, an army of microbial species of incredible diversity and mind-boggling complexity perform such jobs, helping energy flow through cycles of life and death. Bacteria and fungi are among the key groups that break down organic matter, with microscopic animals and microbes known as protists forming the next link up in the food chain. Yet microbes are so diverse, and the number of taxonomists who can actually identify them is so small, that even specifying the different organisms present in an environment is a major bottleneck. Before we can even start thinking about investigating how biodiversity affects the whole ecosystem’s functioning, we need to know what lives there.
My interest in this was first ignited when I met a group of experts on nematode worms – at the International Seabed Authority in Kingston, Jamaica, 2005. We were there to discuss new ways of identifying microscopic communities in the world’s oceans, and the meeting coincided with the publication of the first ‘next-generation sequencing’ genome paper in *Nature*.

We’ve long known that it is possible to use small variable stretches of genomic DNA that are shared by many species like ‘barcodes’ to identify particular species. But this was inefficient for large numbers of individuals, because there are so many of them and sequencing one creature at a time is costly and time consuming. In the bar afterwards Professor Kelley Thomas, a biologist from the University of New Hampshire, pointed out that we could harness the power of the new generation of DNA sequencers to sequence all the barcodes from a whole community simultaneously rather than looking at one individual at a time. The rest, as they say, is history.

Over the past decade, these techniques have transformed how we assess microbial biodiversity. They are now not just routinely used on microbes, they have also been used on larger animals, plants, fungi and even whole food webs.

Part of my interest in the field lay in a desire to understand the distribution patterns of microscopic eukaryotes (organisms whose cells have complex internal structure) and how these patterns arose. Until we know this, it is hard to say how they will respond to climate and environmental change.

In particular, it has been predicted that species below a certain size weren’t confined to particular geographical ranges. If this was true, studying microscopic communities in the context of climate change would become less relevant – organisms found all over the globe are less likely to be harmed by changes in temperature than ones that depend on particular local conditions.

### Underestimating diversity

It also became clear to me that previous researchers often lumped hugely diverse groups of living things together under subheadings like ‘macroinvertebrates’, or ‘meiofaunal organisms’ in ecological studies. Meiobionta are small animals up to about half a millimetre long. Most belong to three families – nematodes, flatworms and arthropods.

Sixty per cent of animal groups include meiofauna that live in the sand or mud of the seabed, and there are an awful lot of them. Nematodes alone can be present in abundances up to a hundred million individuals per square metre.

Nevertheless, because we were lumping different communities together or only focusing on specific animal groups within them, we couldn’t understand how different groups of creatures respond to different ecological and environmental processes. By using DNA sequencing to discover all the groups and species that are present in a particular place instead of trying to identify individuals under the microscope, we can now track the distribution of different groups and species in both space and time. This is something that’s never been possible before, and is particularly cool!

Sequencing shows that marine microscopic animals are impressively diverse, with definable ecological distributions but also recognisable ecological preferences. This dispels the theory that these sorts of smaller creatures are distributed widely and lack biogeographical boundaries.

This in turn suggests that hidden microscopic communities are likely to be affected by environmental change, just as we see happening above the ground. Academics worry about how climate change may trigger local extinctions and biological invasions, with serious ecological consequences – how will this play out in microscopic communities?

Many assume that the microscopic world is so diverse, that it can withstand changes in composition. What we’ve learned through sequencing lets us study ecological change at relevant spatial scales. After all, it will be important to understand how resilient microscopic communities are to climate change, because these guys form the trophic links between true microbes and larger creatures in the ocean floor – about 70 per cent of the Earth’s surface!

We have also found that certain groups, such as free-living predatory flatworms, are much more diverse than we’d thought. This suggests the way we’ve traditionally assessed marine benthic biodiversity largely ignores some of the key creatures higher up in food chains. In recent work with the UK Environment Agency in the Thames and Mersey estuaries (and in independent studies from Australia), we have also shown that different groups of microscopic life respond differently to environmental stresses, and that each estuary has its own distinctive microscopic community.

This is important for monitoring ecosystems’ health. Not only are genetic approaches faster and cheaper than traditional methods, but they tell us more about the variety of life of microscopic communities and their ecological preferences. Microscopic animals are much more diverse than the bigger organisms that environmental agencies usually use to measure ecosystem health, so they should tell us much more about the status of whole ecosystems.

Further exciting developments in the field of molecular biodiversity assessment focus on the fact that many creatures leave traces of DNA in their environment. Many studies now show that directly sequencing all the DNA in filtered water taken from ponds, lakes, rivers, oceans (and even leeches!) can yield valuable insights into what lives in these habitats.

Combined with ever-developing sequencing technologies, we now hope to use environmentally derived DNA to link biodiversity to ecosystem processes and so understand the effects of change at the ecosystem scale. The next time you are by a river or lake, just think about how much eDNA may be flowing by – derived from the complex community of living things that live, eat, poo, moult and die in the water. It’s quite amazing!

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Half a century of HYDROLOGY

Water is a vital part of all our lives, and one of the building blocks of environmental science. So it’s hard to believe it has only been studied as an academic field in its own right relatively recently. Mark Robinson surveys the young discipline’s first few decades, and explains how NERC helped kick-start its development.

Hydrology – the study of how water moves through the landscape – is vital to human civilisations as well as to natural ecosystems. Yet it has only emerged as a distinct scientific discipline in the UK over the last 50 years or so. It’s no coincidence that this emergence coincides with NERC’s own lifetime.

The newly-formed research council was quick to recognise hydrology as one of the fundamental environmental sciences. Within two years of its foundation in 1965, NERC had set up the Institute of Hydrology (IH), bringing together a multidisciplinary team of scientists and engineers at Wallingford, and from the early 1970s NERC started to fund postgraduate courses in hydrology at several universities. Before that, people from many disciplines – including engineers, meteorologists and geographers – did what we’d now term hydrology, but hardly anyone called themselves a ‘hydrologist’.

The critical role of water might seem obvious, but early progress in hydrology’s development and expansion as a science was by no means easy. There were many struggles with vested interests and interdisciplinary and interdepartmental disputes before hydrology was really established as a subject in its own right.

Within the UK, hydrology had to struggle to gain recognition and to compete for funds against long-established research organisations and disciplines. The critical mass of scientists at Wallingford gave them a voice. And being part of a research council made them independent of vested interests such as engineers, landowners and conservationists who might wish to tilt the young science and resulting advice in particular directions.

Initially the rigid post-war science structures, with separate organisations for water chemistry, ecology and other research fields, meant that these were off-limits to early hydrologists. But the early IH had more than enough challenges to tackle, and carried out many pioneering studies. The transformation of a small research unit into the Institute of Hydrology with significant funding, an interdisciplinary remit and an agenda of both applied and basic scientific research had a decisive influence on hydrology’s identity, both nationally and internationally.

One notable early example of IH’s work is the Floods Study Report, published in 1975. The UK engineering profession adopted this as the standard reference work for designing river defences and structures such as bridges to cope with flooding, until it was superseded by the Flood Estimation Handbook in 2000. IH researchers also led some groundbreaking catchment studies and hydrological investigations that inspired generations of geographers and environmental scientists.

These included very detailed studies of the processes by which water moves through catchments, and the factors controlling its ‘loss’ to the atmosphere by evaporation from different vegetation covers. Such information is fundamental for developing mathematical models that underpin better water resource management, to provide more and cleaner water; and for developing approaches for assessing the likely effects of land use and climate change.

Of catchments and conifers

One early example of the dual monitoring and process-study approach was the long-term research at the Plynlimon experimental catchments. In the 1960s there were concerns that the huge conifer plantations created by the Forestry Commission across the UK’s uplands could threaten our water reserves. In response, IH researchers started a long-term monitoring programme at Plynlimon near Aberystwyth, chosen because it offered two almost identical river catchments next to each other – with the exception that one was used for grazing sheep and the other was covered in conifer plantation. This allowed researchers to compare how water moved through each catchment and understand the changes the conifers caused.

Their results have shown that large-scale commercial forestry can severely affect water resources because the forest canopy interrupts rainwater before it reaches the ground, so that compared to grassland up to twice as much water is lost back to the atmosphere through evaporation before it can
Servicing and downloading data from one of the automatic weather stations at Plynlimon.

reach streams and reservoirs. Alongside knowledge of the adverse effects of conifer forests on water quality (including acidification of streams), these findings helped change UK forestry practices radically. Woodland managers no longer create conifer plantations in hydrologically-sensitive areas, and when old plantations are felled they are replaced with more environmentally sensitive mixed forests.

Similarly, pioneering measurements at Thetford in East Anglia made a unique contribution to understanding the physical processes behind evaporation, and the experience gained later helped scientists make the first direct measurements of evaporation from tropical rainforest in Amazonia in the early 1980s. The observations there and afterwards at other sites across the world have informed generations of climate-change models.

Along the way hydrologists made major advances in developing new instrument sensors, including an automatic weather station for remote locations, a soil moisture probe for easy repeated measurements that did not require taking soil samples, and instrumentation to measure evaporation directly.

From the late 1980s IH scientists began to research water quality as well as quantity. Studies of acid oxide deposition from industry and cars gave us a better understanding of processes like acidification that were causing damage to upland landscapes, and newly-developed modelling techniques provided guidance on how to address these problems.

In 1994, IH merged with other bodies including the Institutes of Terrestrial and of Terrestrial Ecology to form the Centre for Ecology & Hydrology (CEH). This means hydrologists can now work more closely with other environmental scientists. This includes closer cooperation with meteorologists to study climate change and explore options for mitigating and adapting to it. Similarly, hydrologists and ecologists now work together on projects ranging from finding out the best ways to restore damaged wetlands to determining how endocrine-disrupting chemicals are affecting fish near sewage works. Multidisciplinary teams in universities are likewise taking a more holistic approach to tackling environmental problems.

Today, population growth and climate change are putting unprecedented pressure on water supplies, and hydrologists’ expertise will be vital in managing these problems. The challenges for today’s young hydrologists are as relevant as they have ever been, and the need for innovative research and well-trained technicians has never been greater: Hydrology has truly come of age!

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Footprints can tell us a surprising amount about the lives of the animals that made them. Richard Hollingham finds out how.

Richard Hollingham: I’ve come to the beautiful Isle of Purbeck on Britain’s Jurassic Coast to an area of exposed dinosaur tracks. They are being studied and mapped by a team from the University of Manchester – we’ll talk to them in a moment. But first I’m joined by local geologist Paul Ensom. Paul, we’re surrounded by fields, but this is a shallow dish of exposed rock and within it are these depressions. What are we looking at?

Paul Ensom: We’re standing on a surface of Purbeck limestone. It was exposed in the late 1990s by a local quarryman – it caused quite a sensation. A team came down for the National Trust, which owns the site. They surveyed it and came to certain conclusions about what had made the marks. Dinosaur tracks are not always straightforward.

RH: Each one of these is about, what, four times the size of a human foot, maybe even more. They are circular – there’s no obvious footprint.

PE: No. One thing we’ve discovered here is that sometimes the animals were walking at a higher level and their tracks were being transmitted down onto lower levels of limestone. So one dinosaur could produce several levels of track all in one go. A sort of wonderful replication system, which of course was quite good from the quarryman’s point of view – they got more for their buck.

RH: Well let me introduce the team from the University of Manchester: Phil Manning, Victoria Egerton and Bill Sellers. Phil, what kind of animal was walking across this landscape?
Phil Manning: You’re looking at the tracks of enormous long-tailed, long-necked, barrel-bodied quadrupeds, the sauropod dinosaurs. These trackways are a fantastic insight – not only into where the animals were walking; the geometry of the tracks can even tell us about how they walked. So if you want to walk with dinosaurs this is the perfect place to study them.

RH: We’ve got a field of cows behind us, a grazing field of cows. Is this the dinosaur equivalent?

Bill Sellers: It’s very hard to work out exactly what the animals would have been doing when they made these tracks. It’s difficult to spot any sort of pattern and it looks like it might just be a herd of trampling dinosaurs, but we’re hoping that when we’ve done the mapping properly we’ll be able to identify some specific trackways, because it’s much more interesting in terms of working out what the animals might have been doing if we can identify an individual and follow its path.

RH: Victoria, this has been exposed since the late 1990s but you are now mapping it in detail.

Victoria Egerton: Yes, so what we’re trying to do now is create a 3D digital reconstruction, so we can measure how big these footprints really are, how deep they go in and the depressions that they make so that we can understand more about what the sediment underneath was doing at the time that these animals made their footfalls.

RH: So, Phil, talk me through how the scanning works. You’ve got here a tripod, a surveyor’s tripod really, but on the top is a box which looks like two shoeboxes stuck together with a computer screen on one side, and in the centre a camera – something like that. What’s it doing?

PM: It’s firing out a laser beam which then reflects back from a surface. We know the speed of light, so the detector picks up that reflection and calculates how far away whatever it bounced off is. It does 50,000 of these points a second. The really cool thing is it has a high dynamic range camera built in as well, so after it has taken the laser scan of the surface it then takes photographs which you can overlay, giving you a perfect colour 3D representation of your landscape, your skeleton or your person holding a microphone doing a recording in the middle of a field. It’s the ultimate 3D capture device.

RH: And what does this tell you that simply getting down on your hands and knees with a tape measure wouldn’t?

BS: It’s really hard to get 3D data from just a tape measure, and the 3D data is what we need to try and reconstruct what these animals were like.

RH: So creatures 140 million years ago left these marks. You’re building up a picture of what they were like. How has that picture changed thanks to this technology?

PM: The fossil record is an incredible mosaic of information, with lots and lots of pieces missing. Whenever we find something as beautiful as this we can piece together a few more of the tesseractae, as it were, to make better deductions about how these animals might have functioned, how they might have walked, and more importantly where they lived – dinosaur bones can be transported miles from the point of death.

RH: So what was this area like?

BS: This was a lagoon, so you get both land-dwelling animals and marine ones. This animal was moving along the shoreline and presumably there were food sources nearby that it was taking advantage of.

VE: One of the nice things about footprints is that they are evidence of behaviour, something we don’t really get in the fossil record. This tells us about living, breathing animals that walked across this landscape – it’s incredible to have that record.

RH: Paul, you’ve been coming to this site for almost 20 years now, since it was discovered.

PE: Yes. The interesting thing about the site is that having been discovered and described, it was actually buried to protect the surface and it’s only because Dorset County Council, the Jurassic Coast team, are in discussions with the National Trust on whether this can now be opened up to the public that it’s now been recleared and is being reassessed. The new survey, new technologies being used, new ideas about dinosaurs and new thoughts on the nature of these tracks all make this a very important bit of research.

PM: It can also help inspire future generations of scientists. We’re really pleased to be working with the Jurassic Coast team on a fantastic project – the Jurassic Classroom. They’re bringing primary school teachers here to see what we’re doing. Kids all over the UK will be able to learn about our research and how it can help us understand more about dinosaurs, but more importantly about how they can become involved with looking at this kind of data and get much closer to literally walking with dinosaurs.

This Q&A is adapted from the Planet Earth Podcast, 3 March 2015. The full podcast and transcript are on Planet Earth online: www.planetearth.nerc.ac.uk/multimedia/story.aspx?id=1796