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Also

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**Editorial**

Winter is here and many of us will be adding flu jabs and cold remedies to our Christmas lists to keep us healthy until spring arrives. For our trees though the changing seasons bring no respite, as a surge of pests and diseases threatens to change the face of our woodlands and hedgerows for ever.

In this issue of *Planet Earth*, Tom Marshall talks to researchers taking a variety of approaches to understanding these problems and finding ways to protect or restore the unique character of the British countryside.

These range from detailed examination of the pests themselves, to gene sequencing of the affected trees, and include a study of public reaction to tree-health issues and how we might all be able to help.

The rest of the edition has a distinctly aquatic feel. We hear from a programme working to provide safe water for people in African cities, and how researchers are collaborating with Dŵr Cymru Welsh Water to find better ways of cleaning up drinking water closer to home.

In our podcast Q&A we hear about a hands-on approach to finding out how marine creatures react to noise from offshore construction. Meanwhile a major research programme is investigating how animal behaviour changes once tide and wave energy devices are in place.

Josie Robinson explores the feasibility of using the Southern Ocean to absorb carbon while Bethan Davies looks even farther south to present new insights into Antarctica’s frozen history.

Finally, Africa Gómez gives us an update on the tadpole shrimp — a creature often dubbed a living fossil but which, it turns out, is far from a relic from the age of the dinosaurs.

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**Corals could be cured with probiotics**

Some coral diseases could be cured with a dose of good bacteria.

New research, in *Proceedings of the Royal Society B*, looked at the microbes responsible for White Band Disease (WBD), which can erode vast stretches of coral and leave many reef species with nowhere to feed.

It’s a long-standing problem and now scientists have used antibiotics to identify the microbes responsible. They tested four antibiotics on diseased coral and found that two successfully treated WBD. Through a process of elimination they then worked out which microbes were causing the disease.

‘The disease-causing microbes were present in both the diseased coral and the antibiotic treatments which didn’t work, but not in the two antibiotics which cured it,’ explains Dr Michael Sweet of the University of Derby, lead researcher on the project.

The results demonstrated that WBD, at least in this case, was caused by three different bacteria and a microbe called a ciliate. The work highlights the importance of ciliates in coral disease.

‘The initial bacterial infection hinders the coral immune system, then the ciliates come in and eat the tissue,’ explains Sweet. ‘It’s like when you have a cold and you become more vulnerable to other diseases.’

The researchers don’t advocate using antibiotics in the oceans as this could lead to antibiotic-resistant microbes in the future. Instead they think dosing corals with a probiotic could help.

Corals produce mucus similar to the micro-flora in the human stomach which, if disturbed, can make you more susceptible to disease; probiotics are thought to restore these micro-flora. If we could dose diseased coral with a community of good bacteria, the coral might be able to fight off the pathogen on its own.
For the first time scientists have used measurements of third-hand smoke to understand the cancer risk tobacco compounds pose.

The study, published in Environment International, shows that for children under six the level of potentially cancer-causing chemicals exceeded the acceptable exposure limit guidelines set by the US Environmental Protection Agency in three quarters of smokers’ homes and two thirds of smoke-free ones.

‘If you go into a room and can smell the smoke even though someone hasn’t smoked there for a while, that’s third-hand smoke. It’s in the materials, walls and the dust and can stay there for months,’ says Dr Jacqueline Hamilton of York’s Wolfson Atmospheric Chemistry Laboratories, the paper’s lead researcher.

The researchers collected dust samples from the vacuum cleaners of 48 private homes and then did toxicological analysis of their composition.

‘We found nicotine in every single house dust sample, regardless of whether it came from the home of a smoker or a non-smoker,’ Hamilton says.

Hamilton suspects that in smoke-free homes this comes from tobacco compounds getting onto clothes and skin during the day or from external pollution.

‘The highest levels were for people who lived in flats and apartments, so if other people in the building are smoking that can transfer through the vents into people’s homes,’ she explains.

Abandoned rubbish dumps routinely leach chemicals into rivers throughout the UK, say scientists.

At Port Meadow alone, on the outskirts of Oxford, they estimate 27.5 tonnes of ammonium a year find their way from landfill into the Thames. They add that it could be happening all over the UK.

In water, ammonium breaks down into nitrogen. This can trigger excessive plant growth and decay, damaging water quality and starving fish and other inhabitants of the oxygen they need to survive. Most worrying are blue-green algal blooms, which produce toxins that can kill animals and make people seriously ill.

‘We’ve been getting rid of waste for an awful long time,’ explains Dr Daren Gooddy, of NERC’s British Geological Survey. ‘Since Victorian times, we’ve been putting it into landfill and ad-hoc waste dumps on the edge of our towns and cities, often on the fringes of floodplains. There are 11 landfill sites at Port Meadow alone. If you scale that up for the whole of the UK, then you’re probably talking about thousands of them.’

To disentangle the different sources of the chemical, and get an estimate of the total amount moving through the floodplain, the team took regular groundwater samples over three years. They used isotopic analysis – a kind of chemical fingerprinting technique – to work out how much of the ammonium present was from household waste. In the Thames at Port Meadow, this could increase concentrations by up to 40 per cent.

Today’s landfills are lined with a thick layer of clay to limit the risk of chemicals leaking out into the environment. But around the UK there are many un-lined historic landfills leaching nitrogen into rivers.

The research is published in Science of the Total Environment.
**Penguins need protection**

An international scientific team has called for new measures to protect penguins around the world.

Writing in *Conservation Biology*, they say habitat loss, pollution and fishing are the main threats.

Their report concludes that we urgently need to establish Marine Protected Areas (MPAs), where wildlife is protected from damage and disturbance. But they acknowledge that this won’t always be possible, particularly where habitats lie in international waters.

‘Penguins and humans often compete for the same food, and some of our other actions also impinge upon penguins,’ says Dr Phil Trathan of NERC’s British Antarctic Survey, who led the study. ‘Whilst it is possible to design and implement large-scale marine conservation reserves, it is not always practical or politically feasible.’

Many penguin populations have declined greatly over the past two decades. Eleven species are now classified as ‘threatened’ by the International Union for the Conservation of Nature (IUCN), two as ‘near threatened’ and five as ‘of least concern’.

Forty-nine scientists from around the world examined all 18 species, looking at the main ways people are interfering with their populations, including habitat damage, marine pollution, fishing, climate change and toxic algal poisoning.

They say unless we deal with threats to penguin habitats on land and at sea, they will struggle to cope with the extra pressures of climate change.

The 2002 United Nations World Summit on Sustainable Development set a target for governments to protect 20 to 30 per cent of habitats in MPAs. But Trathan notes that most existing ones are too small to give penguins enough protection.

Creating large marine reserves often requires international cooperation – particularly hard in areas where marine resources are already under pressure.

Alternatives include more rigorous zoning of shipping lanes, fisheries and oil rigs, and using better fishing methods so fewer penguins get caught in nets. Catch limits on some fish species might also help to relieve some of the pressure on their food sources.

**Man-made drainage could raise flooding risk**

Urban drains could increase flood risk by sending water into rivers too quickly, say scientists.

A paper in the *Journal of Hydrology* says storm drainage systems can result in higher peak flows that rise and recede more quickly. It suggests that storm drains may sometimes do more to increase the risk of flooding than changes in the land surface.

The authors hope their research will help guide future planning decisions, particularly where city meets countryside. ‘When we’re thinking about urban developments, we need to start thinking about the land use in terms of its hydrological impacts,’ says James Miller, of NERC’s Centre for Ecology & Hydrology, who led the study.

‘It’s not just the changes at the surface that matter – what goes on beneath with drainage and the retention of water is just as important. New urban development tends to be really dense, and requires a lot of engineering. Allowing for some space and design would be really beneficial in some places, but the planning issues are very entangled.’

The team measured rainfall, runoff and evaporation in two adjacent river catchments in Swindon, UK, over 2011 and 2012. One was heavily urbanised, while the other was relatively new fringe development on previously rural land – what scientists call ‘peri-urban’.

The peri-urban catchment contained two distinct drainage systems – one with a mixture of natural and man-made drainage, the other dominated by a storm drainage system. Analysis showed that storm drains influenced the speed at which water reached the river more than either impermeable land cover or the type of development.

The team also used historical maps to simulate the hydrological effects of urban development from the 1960s to the 2010s. They found that, after the introduction of a large-scale storm drainage system to the peri-urban area in 2010, floods lasted half as long on average, but peak river flows increased by over 400 per cent compared with the 1960s.
A UK-led international team has done the first experiment recreating what would happen if CO₂ started leaking after being stored deep under the sea floor. Their findings support the idea that this could be a viable way to cut our impact on the climate.

They piped the gas 11 metres below the seabed in Ardmucknish Bay, near Oban in Scotland, releasing it into the sediments there over 37 days. They then used chemical and acoustic sensors to track how it emerged, while also measuring its effects on the ecosystem. Monitoring carried on for a year, to give a sense of how well the environment recovered from any changes the CO₂ had caused.

The scientists found that small leaks do little damage to the plants and animals around them, and that the effects fade quickly once the CO₂ stops flowing. A lot of the gas didn’t even emerge at all – about 85 per cent seems to have been trapped in the sediments. It’s an encouraging message for supporters of carbon capture and storage (CCS) – the idea of taking CO₂ emissions and storing them in depleted oil or gas reservoirs or saline aquifers before they can affect the climate.

‘Our results suggest that if you had a small leak – the kind you’d expect from something like an abandoned oil-well bore going into the reservoir – the effects would be pretty limited in space and time,’ says Dr Jerry Blackford of Plymouth Marine Laboratory (PML), who led the study, published in Nature Climate Change. ‘There are some changes to sediment and water chemistry and nearby ecosystems, but they are confined to the immediate area of the leak and don’t last for long once it stops.’

CCS is considered one of the most realistic proposals for fighting climate change while letting us keep using fossil fuels until we develop low-carbon energy sources. But there are concerns the gas could leak, perhaps damaging seabed ecosystems nearby. This is the first study to pipe CO₂ directly into the seabed; previous ones have only released the gas into the water above, so don’t reveal how gas bubbles through sediment before escaping.

These findings don’t just establish that small leaks do little short-term harm; they also show it’s feasible to set up a monitoring system that would let us be sure they weren’t happening.

Both chemical changes to the water and effects on nearby living things were limited, and soon reversed once the CO₂ stopped – environmental chemistry was back to normal within 17 days. There were differences in the genes active in the site’s microbial community while the gas was flowing, but little sign of long-term harm.

‘There’s a huge variety of microbes in these sediments, but at any particular time not all of them are active,’ Blackford explains. ‘The changes we detected probably came from a new set of bacteria becoming active because the CO₂ created conditions that suited them; the original bacteria hadn’t gone away and reappeared once conditions returned to normal.’

Bigger organisms were also relatively unscathed. Some even seemed to enjoy the new conditions, and those that didn’t could move away. It’s possible longer-term exposure would prove more harmful. Blackford is now planning a follow-up experiment that will last for longer, giving scientists a better idea of the effects of a more persistent CO₂ leak.

The team included scientists from PML, the British Geological Survey, the National Oceanography Centre, the Scottish Association for Marine Science and Edinburgh, Heriot-Watt and Southampton universities, alongside Japanese colleagues. Diving work was done by the NERC Facility for Scientific Diving.

The results are now helping plan and design large-scale CCS pilot projects in the UK, enabling the companies involved to devise monitoring strategies. Blackford is also part of a project aimed at developing autonomous underwater vehicles with the right sensors to monitor for CCS leaks.
Sewage treatment contributes to antibiotic resistance

Wastewater treatment plants could unwittingly be helping spread antibiotic resistance.

New research suggests that processing human, farm and industrial waste in one place might be helping bacteria become resistant to even the strongest antibiotics.

Bringing many different types of bacteria together in sewage plants could let them swap genes that confer resistance. So antibiotic-resistant bacteria may be evolving much faster than they would in isolation.

The study, published in the Journal of Antimicrobial Chemotherapy, shows there are reservoirs of highly resistant gut bacteria in the environment, threatening the health of people and animals. It suggests we need new ways to process waste without helping breed drug-resistant bacteria.

‘The way sewage plants mix up different types of waste means they’re hotspots, helping bacteria share genes that mean they can deactivate or disarm antibiotics that would normally kill them,’ says Professor Elizabeth Wellington of the University of Warwick, who led the study.

Earlier research suggested that farming and waste-processing methods contribute to reservoirs of resistant bacteria in the environment. But until now few studies had looked at the role of wastewater effluent.

‘A greater volume of antibiotics is used in farming than in anything else. Huge amounts are used globally, mainly for treating infections in food animals but also to promote growth,’ Wellington says.

With colleagues from the universities of Warwick and Birmingham and the Health Protection Agency, she decided to look for these bacteria near wastewater treatment plants. They analysed sediment samples taken both upstream and downstream of a sewage works, looking for bacteria with resistance to a class of clinically-important drugs called third-generation cephalosporins (3GC).

These are broad-spectrum antibiotics used to treat a range of problems, including meningitis, septicemia and so-called hospital-acquired infections. Worryingly, the scientists found that 3GC-resistant E. coli were seven times more common downstream from the sewage plant than upstream.

‘Our findings suggest that resistance is spreading, because of a gene called blaCTX-M-15. This gene is carried on a mobile genetic element called a plasmid. Bacteria collect these genes to allow them to adapt to their environment,’ says Wellington.

‘This is a big deal, because this is the most common bacterial antibiotic resistance gene causing failures in treatment of infections, and it’s the first time anyone has seen this gene in UK rivers. The problem is we use river water to irrigate crops, people swim or canoe in rivers, and both wildlife and food animals come into contact with river water.’

‘These bacteria also spread during flooding. And with more flooding and heavy rain, this could get worse.’

‘Primarily what we’ve shown is that there are increased numbers of clinically-important antibiotic resistant bacteria in sediment downstream of a large waste water treatment plant, which is significant given the types of resistance genes we’ve identified,’ adds co-author Dr William Gaze of the University of Exeter. ‘There is some evidence that selection may have taken place in the plant or in the river, based on genetic analyses of the resistance genes.’
GM flies could save fruit crops

Genetic engineering could save fruit crops ravaged by the Mediterranean fruit fly, according to scientists who changed the genes of some male flies so they only produce sons.

The flies do serious harm to global agriculture. We currently control them with a combination of insecticides, traps, biological control and the Sterile Insect Technique (SIT) – treating males with radiation to make them sterile before releasing them into the wild. This is the commonest method, and probably the most environmentally friendly. But SIT males don’t usually mate so well in the wild because irradiation weakens as well as sterilising them.

A Proceedings of the Royal Society B paper reports that GM flies from Oxitec Ltd. are healthier than SIT flies, so females find them as attractive as wild males.

‘SIT is a great idea as it’s completely species specific and it massively reduces the amount of insecticide used, but because females prefer healthier males you need to try and introduce more sterile males than will be in the wild,’ explains Dr Philip Leftwich of the University of East Anglia, the project’s lead researcher. ‘The idea with genetically engineering the flies is that you get much healthier flies which haven’t been damaged by irradiation. If the males are healthier and more attractive you don’t need to release as many – it brings down costs.’

The team worked with large greenhouses filled with lemon trees at the University of Crete, comparing GM flies with wild and SIT populations. ‘The genetically engineered males aren’t sterile, just incapable of producing daughters, so when we release them into the population and they find females, they use up their eggs whereas in SIT females can simply remate with a wild male. The sons carry the gene too so they help with the process. Eventually you get a sex bias in the population and it collapses,’ Leftwich explains.

The team now hope to get approval for open-field studies.

NERC researcher wins Science of Risk prize

London-based insurance giant Lloyds has awarded its Science of Risk prize to Dr Juliet Biggs of the University of Bristol for a paper in Nature Communications that could ultimately lead to an effective early-warning system for volcanoes – even remote and inaccessible ones. She looked at 500 volcanoes worldwide, monitoring which were deforming to establish statistical evidence linking this to their potential to erupt. NERC supported the work through its COMET centre and STREVA programme; the European Research Council and NASA also provided funding.

Environmental satellite science centre funding renewed

NERC has agreed to fund the National Centre for Earth Observation (NCEO) for five more years. The £23m contract with the University of Leicester will ensure continued support for NCEO’s important work using satellite instruments to shed light on some of the most pressing environmental science challenges facing us, including climate change, pollution, deforestation and detecting wildfires. NCEO is a partnership of nearly 100 scientists around the UK; it was set up in 2008 to make sure environmental science gets the greatest possible benefit from satellite data.

NERC scientists lead UN ocean acidification report

A major new international report has shown unequivocally that ocean acidification (OA) will have serious consequences for marine life, and in turn for people. We’ve known for a long time that CO2 emissions will lower the ocean’s pH, but exactly how this will affect marine life hasn’t been clear. Published by the Secretariat of the Convention on Biological Diversity, the report concludes that not only is OA under way, it will have a major impact on living things. The economic risks alone are huge – damage to coral reefs alone, which millions of people rely on for food, could be worth nearly a trillion dollars a year to societies worldwide. The UN report draws on science produced by the £12m UK Ocean Acidification Research Programme, co-funded by NERC, Defra and DECC.

in brief . . .

Genetic engineering could save fruit crops ravaged by the Mediterranean fruit fly, according to scientists who changed the genes of some male flies so they only produce sons.

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Litter now everywhere in the ocean

Litter is now found in even the remotest part of the oceans. That’s the depressing conclusion of scientists trying to understand how much rubbish lies beneath Europe’s seas.

Using 588 video clips collected by unmanned submarines for geological mapping and marine biology studies, the team found few areas untouched by human waste.

“We didn’t focus on specific footage; it came from lots of different studies but we viewed it all. And the biggest surprise was that we found litter everywhere – everywhere we had footage from had been polluted,” says Christopher Pham, a PhD student at the University of Azores in Portugal and lead author of the study, published in PLOS ONE.

“The majority of what we found was plastic, specifically softer plastics like carrier bags, although we did find other things like pieces of buckets,” he continues. “We found batteries, part of a plane, pieces of oil drum, shoes, chairs, plastic bottles, clothes, but mostly plastic.”

Scientists have probed the extent of marine litter before, but this is the largest survey so far. It included 32 sites, taking in some of the deepest and most remote locations around Europe, including the Charlie-Gibbs Fracture Zone between the Azores and Iceland.

At almost three miles deep, this is one of the deepest cracks in the Atlantic Ocean, and one of the most remote. And yet rubbish had collected even there.

“The highest levels of litter were in the submarine canyons, while on the seamounts and around coasts there was less rubbish overall, but what we found was mostly fishing gear,” explains Pham.

The researchers say items like plastic bags, which are only used for an hour or two at the most, are the biggest culprit. If the problem isn’t addressed soon, it could cause huge and permanent damage to marine life.

Ship noise endangers eels

Noise made by passing ships stops eels from using their survival instincts, according to scientists investigating the effects of sonic pollution on fish.

The study, published in Global Change Biology, found only 38 per cent of the eels that were exposed to ship noise responded to a predator attack, compared to 80 per cent in normal conditions. Even those that did react were 25 per cent slower than normal.

“Over the past 20 years eel populations have declined by 90 per cent due to climate change,” says Dr Steve Simpson of the University of Exeter, who led on the study. “The eels are spawned in the Sargasso Sea, and then spend 18 months finding their way back to Europe. To do this they have to cross busy shipping lanes and acute acoustic events, like the noise of a passing ship, which may be adding to the problems they have to overcome.”

The team tested the eel’s response to two types of predators – ambush and pursuit. Eels being subjected to noise were half as likely to respond when the predator attacked, and those being chased were caught twice as quickly as their undistracted peers.

“Acoustic disturbance clearly has a serious impact on these endangered animals with direct consequences on their life-or-death behavioural responses,” says Simpson. “We don’t know if the noise is just distracting them or if they’re stressed by it, but either way they’re failing to respond to a potential predator.”

“We know shipping isn’t going to stop, but we can do things like move a shipping lane so it doesn’t interact with the migrations paths of animals,” Simpson suggests.
Butterflies use royal disguise to infiltrate ant nests

Certain butterfly larvae have learnt to mimic queen ants so that the workers will take care of them.

A study in PLOS ONE compared the noises made by two types of butterfly larvae: one preys on the ants, while the other moves cuckoo-like into the nest to be looked after by the workers.

Ants’ well-defended colonies are a tempting shelter for other species. But the ants have evolved complex chemical and acoustic signals to distinguish between residents and intruders. Both butterfly species have developed their own signals to trick the ants into thinking they belong – but it turns out they use different tactics once they’ve gained access.

People can’t hear the signals, so the researchers put the larvae on a microphone in a tiny recording chamber. ‘We found that once the ‘cuckoo’ caterpillars had been adopted their signals tended to imitate a queen – the highest status in the colony,’ says Dr Luca Casacci of the University of Turin, who led the team of scientists.

Conversely, the predatory larvae sounded more like the queen before they were adopted, but once in their noises weren’t such a precise match. ‘They are usually trying to feed on the ant larvae so they don’t need to interact with the workers in the same way the cuckoo species does,’ explains Casacci.

The ants produce sound using an organ on their abdomens made up of a plectrum and a series of ridges similar to a guitar. But the researchers still aren’t sure how the caterpillars mimic the ants so closely.

Parasite hampers honeybee homing

Honeybees carrying a common parasite have much less chance of making it back from foraging trips, say scientists.

35 per cent of bees infected with Nosema ceranae never made it home. Among healthy foragers, the figure was less than ten per cent.

‘This is obviously bad news for bees infected with the parasite,’ says Dr Stephan Wolf, of Rothamsted Research, who led the study, which appears in PLOS ONE. ‘But in some ways it’s surprising that so many infected bees did so well.’

“We’re talking about heavily infested animals, but we couldn’t find any difference in their flight patterns – they didn’t seem to get lost or confused. It seems some of them were just too exhausted to make it back to the nest.’

Managed honeybees pollinate important commercial crops throughout the world, but they have declined in recent years. A 2014 study suggested many European countries now face honeybee shortfalls. The problem is particularly acute in Britain, where there are only enough honeybees to pollinate a quarter of crops. Alongside the unintended consequences of pesticides, diseases and parasites have shouldered most of the blame.

The team attached tiny radar transponders to the backs of a mixture of clean and infected bees. Just 16mm long and weighing less than an average pollen load, each one transmitted a distinct signal, letting scientists track every bee’s position in real time.

The bees were released some distance from their colony, challenging them both to get their bearings and to make it back to the hive. Many infected bees seemed to tire, taking longer stops before settling on the ground and disappearing from the radar.

The only available treatment for Nosema, a fungicide called fumagillin, is banned in the EU over environmental safety concerns. And researchers disagree over its effectiveness. Work continues on developing safe and efficient alternatives.

Meandering air flows cause extreme weather

Large meanders in the flow of air around the planet are a major cause of prolonged extreme weather in the northern hemisphere.

The so-called planetary waves weave throughout the northern hemisphere’s lower atmosphere, marking the boundary between cold Arctic air to the north and the warm tropics to the south.

A study published in Nature Climate Change says that larger planetary waves can cause droughts in Europe, central Asia and the central belt of North America.

But their effects are not the same everywhere. On the east coast of Canada and the US, the chances of cold snaps increase, while western Asia is more likely to be exposed to prolonged wet spells.

‘The impacts of large and slow-moving atmospheric waves are different in different places,’ says study leader Dr James Screen, a NERC fellow at the University of Exeter.

‘Many people will have heard weather forecasters talking about the influence of the jet stream on our weather,’ says Screen. ‘These planetary waves are slightly different. They occur lower down in the atmosphere and are associated with low and high-pressure weather systems.’

The waves can suck colder air from the north, or tropical air from the south, into unusual territory, triggering changes in weather patterns that affect large swathes of the northern hemisphere.

Screen warns that the group has not tried to predict future changes. As the world warms up, he says, the effects of planetary waves may be overwhelmed by rising temperatures.

PLANET EARTH Winter 2014
Arctic bugs can survive in frozen ground as cold as -27°C, scientists have revealed. It’s the first time higher-order invertebrates like spiders, flies and beetles have been found coping with such cold. The previous record was a little below -10°C.

The study in *Journal of Thermal Biology* suggests they may stand up better to climate change than we’d feared – an important finding because they play an important role in Arctic ecosystems. ‘There has been this prevailing view, almost a dogma, that invertebrates survive winter better under snow cover,’ says Professor Pete Convey, of NERC’s British Antarctic Survey, who led the research. ‘But this has never really been put to the test in real-world conditions. Our results suggest that in the communities we’ve studied it makes no difference at all.’

The research happened on Svalbard, a Norwegian archipelago in the Arctic Ocean where the sun’s never seen for three months a year. Temperatures plummet as low as -30°C.

The scientists cut samples of tundra soil, placing them in groups where they’d get different amounts of snow. One received no snow all winter, one got shallow snow and another got deep snow. The last stayed in the lab at a constant 7°C. Half of each set was retrieved, thawed and the invertebrates extracted in late November, and the other half was retrieved the next March.

Soil temperatures in the exposed samples closely mirrored those in the surrounding atmosphere, rapidly fluctuating, and at one point dipping to -27°C – much colder than the snow-covered samples. But when the samples were gently thawed out in the lab, the bugs recovered remarkably well from their inactive winter state, regardless of the temperatures they’d faced.

Convey hopes this work will challenge assumptions about bugs’ resilience to climate change, and focus attention on winter ecology in polar environments.

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**Cool Farm Tool gets cooler**

The Cool Farm Tool (CFT), a web app that tells farmers their environmental impact and how to reduce it, has gone from strength to strength lately. It’s attracted new corporate supporters and gained abilities that move it far beyond its initial purpose of tracking farmers’ carbon emissions.

Originally the CFT was an Excel spreadsheet; earlier this year it relaunched as a web app allowing farmers and the companies they supply to use it far more readily. Companies like US food giant Kellogg’s have come on board, joining organisations including Heineken, Marks & Spencer, NERC, PepsiCo, Tesco, Unilever and Yara.

The tool is finding new uses. For instance, M&S worked with WWF to understand the impact of new management practices, like more targeted use of fertilisers and pesticides, on Indian cotton farms’ emissions. The trial showed these cut greenhouse gas emissions by around a third — a finding that would have been much harder to reach without the CFT.

Originally the brainchild of Dr Jon Hillier, a mathematician and NERC Knowledge Exchange Fellow at the University of Aberdeen, and Christof Walter, then of Unilever, with support from the Sustainable Food Lab, it’s now drawing on the work of others to move beyond carbon emissions alone. For example, researchers at Reading University have worked to extend it to tell farmers about their impact on local water supplies. And a Cambridge team including another NERC KE Fellow, Lynn Dicks, conducted a pilot project on how pesticides affect vital insect pollinators.

This is leading to the development of a prototype biodiversity impact module for the CFT, supported by NERC’s Biodiversity & Ecosystem Service Sustainability programme, in collaboration with consultancies CLM and Anthesis.

The tool has already been used on more than 10,000 farms worldwide, forming an essential component of supply-chain analysis for several members of the Cool Farm Alliance — the not-for-profit UK company behind the CFT.

The food companies behind the CFT support it because it helps them work with the farmers who grow their products to reduce their environmental impact. Farmers are enthusiastic because it’s a usable, consistent tool that helps them meet the environmental demands being put on them by clarifying where they are at present and what they could do to improve.

For more information, see www.coolfarmtool.org
Hungarian red mud spill did little long-term damage

The effects of the 2010 red mud spill that threatened to poison swathes of the Hungarian countryside have turned out to be far less harmful than originally feared.

The disaster happened when heavy rain caused a dam to collapse at a containment facility in Ajka, releasing around a million cubic metres of toxic sludge.

The mud, a byproduct of refining aluminium from bauxite ore, was dangerously alkaline, extremely salty and contained potentially toxic metals like chromium and vanadium. And this was the first time it had been released in such quantities. We didn’t know exactly what it would do, but some feared severe long-term effects on people and wildlife.

But research in *Environmental Science: Processes & Impacts* shows that there’s now little trace of the red mud in the rivers downstream of the spill.

‘It’s a good news story,’ says Dr Will Mayes of the University of Hull, the paper’s senior author. ‘Our results show that the combined effect of the structure of the sediment and the Hungarian government’s remediation efforts have mostly dealt with the spill’s after-effects – we found the geochemical signal from the red mud has almost completely disappeared.’

The Hungarian government acted quickly, spending around €127 million on measures including removing mud from rivers and floodplains and treating it to reduce its alkalinity. The mud’s fine-grained nature also meant that in many areas any that didn’t get cleaned up was quickly washed downstream and into the Danube, where it was diluted to the point of harmlessness.

Mayes received urgency funding from NERC in the spill’s immediate aftermath; his team travelled to the scene and worked with Hungarian geoscientists to test sediments in the rivers downstream. At the time they found numerous alarming pollution hotspots where toxins from the mud seemed to be building up. For their recent study they returned to retest the sediments at the same places. Even at the worst former pollution hotspots, there was little trace of the red mud.

Mayes says the knowledge gained in the wake of the spill will help governments deal better with similar events in future.

Invading ladybirds prefer cities to woodland

Invasive harlequin ladybirds prefer sunny cities, say NERC-funded scientists investigating where the alien insects may turn up next.

The research, published in *Journal of Biogeography*, shows how habitat destruction and climate factors are affecting the harlequin’s spread.

‘Our new study indicates that environmental factors, particularly habitat, have made some areas of Britain such as cities more vulnerable to rapid invasion of the harlequin ladybird than other areas. This was true even when recording intensity and proximity to initial invasion sites were taken into account,’ says Dr Bethan Purse of NERC’s Centre for Ecology & Hydrology (CEH).

The results also show that harlequins have struggled to spread into coniferous woodland. Many British ladybird species are largely confined to these forests and it seems these are more resistant to harlequin invasion than others.

‘Coniferous woodland could potentially provide a refuge for some native ladybirds which would otherwise be threatened by the harlequin,’ explains co-author Dr Helen Roy of CEH.

The scientists used models to predict where the insects may turn up next. This kind of modelling is used to study how diseases expand, but it’s the first time scientists have used it to explore the spread of an invasive alien species using data from a citizen-science study.

‘It’s really important to understand all the factors that interact with a species as it spreads, like climate and landscape, particularly when we’re thinking about alien species,’ says Roy. ‘We could apply what we’ve found to other alien species to make predictions of how they might spread, and what factors they prefer.’

The data used in the study was collected between 2003 and 2011 as part of the UK Ladybird Survey – a citizen-science project which asks people to send in pictures and descriptions of their sightings of harlequin ladybirds.
The idea of scientists manipulating nature to avoid climate change evokes images of Dr Evil toying with volcanoes. Yet the concept – known as geoengineering – is a very real one. It’s controversial, but it may be a necessary last resort if we don’t lower our CO₂ emissions.

If we reach a fatal tipping point with climate change – a serious possibility – we would look to scientists for help, like in the film The Day After Tomorrow. So although geoengineering is far from ideal – it’d be better not to emit the CO₂ in the first place – scientists are a well-prepared bunch, and we research every option. Proposed geoengineering methods range from orbiting space mirrors to simply pumping CO₂ into the ground. The one I focus on is ocean iron fertilisation (OIF) which aims to make the oceans absorb more CO₂, removing it from the atmosphere before it can affect the climate.

You might remember from school biology that plants take up CO₂ during photosynthesis so they can grow. In the oceans this job is done by tiny plants, known as phytoplankton or algae – like the green sludge that grows in lakes. When the phytoplankton die, they slowly sink down into the depths. Most of the dead plant matter decomposes as it sinks, releasing the carbon that was absorbed during photosynthesis into the water; from there it ultimately escapes back into the atmosphere. But if the phytoplankton sink deep enough before being broken down, the sheer volume of the ocean could keep the carbon confined to the deep dense water – perhaps for centuries.

This happens naturally across the world’s oceans, enabling the sea to sponge up a third of human CO₂ emissions and reducing our impact on the climate. It doesn’t happen in the Southern Ocean, though. The water here contains lots of nutrients, but it lacks...
iron, which phytoplankton need to grow. So an oceanographer got the idea of fertilising the Southern Ocean with the missing nutrient iron to allow algae to grow there as well, soaking up more CO₂ into the ocean.

Just add iron?
That’s the theory, but would it actually work? In field studies when scientists have gone to the Southern Ocean and thrown iron into the sea, they did indeed cause algal blooms. We’ve also looked at places around islands in the Southern Ocean where iron fertilisation happens naturally as iron is released from the mud; there, we do see more carbon sinking to the deep.

Now if the first stage of OIF is trapping CO₂ in plant form and the second is transporting the carbon to the deep ocean when the phytoplankton die, then what’s the third and final stage? This is where I come in. The third stage is long-term carbon sequestration in the deep ocean. To sequester something means to keep it out of reach in a safe place; the goal is to keep CO₂ out of the atmosphere by trapping it deep under water for a long time, at least a century.

I assume that steps one and two have been successful, and we’ve managed to get a lot of carbon into the deep ocean – actually quite a big assumption and a hot research topic in itself. So what happens next? By using a computer model which replicates the ocean’s circulation, we can predict what might happen to the carbon over 100 years. To do this I put markers, representing the carbon, across the Southern Ocean at a depth of 1,000m within the ocean circulation model. The markers have no weight so neither sink nor float; instead they ride the ocean currents, just like CO₂ molecules would. I tracked the markers within the simulated ocean for 100 years to see where they’d end up and, crucially, if the carbon would stay away from the atmosphere – the whole purpose of OIF.

Having analysed 25,000 markers, I can tell you that a lot of them (66 per cent) did find a way out of the deep ocean and back into contact with the atmosphere, taking on average 38 years. We expected some of the carbon would leak out over 100 years, but two thirds is quite a lot. Not only that, but it escaped very quickly!

With over half the carbon escaping back into the atmosphere, you may be beginning to wonder what the point is, but remember this is only one experiment and only a computer simulation of the ocean. The real ocean is such a complex system that recreating its behaviour in a computer model is immensely difficult, a bit of a black art of oceanography. We can never fully rely on simulations – although the level of accuracy in ours is impressive – but we can use them to provide us with potential scenarios, whose likelihood we can then check with further research.

So how did this Houdini carbon manage to escape in our experiment? The key factor is the ocean circulation. The Southern Ocean is like the M25: it connects all major oceans – not just horizontally, but also vertically. Here, deep water rises up to the surface on a massive scale. This is due to the trade winds, which push water near the surface away from Antarctica so that water from the deep rises to fill the gap. In our experiment this was the carbon’s main escape route from the deep ocean.

The bottom line is that location is crucial. We were half right to think the Southern Ocean is a good place for OIF; it has an abundance of all essential nutrients except iron. Yet our research suggests that although there are some areas that are suitable for geoengineering, ultimately it’s a bad location because of its highly dynamic circulation. Even carbon that did stay in deep water for the full century was spread all over the world by the circulation, making it almost impossible to monitor the sequestered carbon – this would be essential in a carbon credit market where someone would be paying to have carbon locked up on their behalf to offset the pollution they were causing.

All this suggests OIF alone is probably not the miracle cure for all our climate-change problems. But it may have a role to play alongside other geoengineering methods. There are places in the world’s oceans that do seem to be suitable for OIF; so the research must continue. Of course, the best course of action is to cut our carbon emissions, and leave geoengineering to movie directors.
Ancient mainstays of our woodlands, hedgerows and parklands are at risk from a surge of pests and diseases – but a new research programme is bringing experts together from many fields to find solutions.

*C* _halara fraxinea_ – the fungus behind ash dieback – was first spotted in the UK in early 2012 in a consignment of trees from the Netherlands. It had already spread widely, and it’s now almost certainly present throughout much of Britain.

It’s already devastated European ash populations across the Continent since arriving in the early 1990s. Some trees can resist it, but most can’t. Ash accounts for around 13 per cent of UK broadleaf cover, so dieback could change the landscape as profoundly as Dutch elm disease did a generation ago. Right now there’s no defence and no cure.

A major research programme is helping us understand and control this woodland catastrophe, and perhaps even prevent the next one; in an increasingly globalised world, the flow of new pests and diseases is only likely to increase. Tom Marshall spoke to some of the scientists working under the Tree Health and Plant Biosecurity Initiative.
GENOMICS FOR MORE RESISTANT TREES

The European ash may be in trouble but Dr Richard Buggs at Queen Mary, University of London thinks the solution could already be in the ash family’s genes. Some close relations aren’t bothered by the ash dieback fungus at all – for example in Manchuria it’s been around for a long time but doesn’t seem to harm living trees.

Buggs has already sequenced the European ash genome (see www.ashgenome.org) and now he’s doing the same for 35 different ash species from all over the world. His research group will analyse the results to identify which genes confer disease resistance. We may be able to transfer those genes into the European ash, with regular breeding techniques or even using genetic modification (GM) technology.

Social scientists are investigating what people think of the different options, and which they’d be prepared to accept. ‘We don’t want to spend many years creating a wonderful new genetically modified disease-resistant ash tree, only to find the public isn’t willing for us to plant it,’ Buggs says.

He’d like to make sure the ultimate result is resistant not just to *Chalara*, but also to the emerald ash borer – an even deadlier threat that’s moving across Eurasia and could reach the UK in the next decade or two. It would be tragic if scientists could deal with the danger dieback poses to our ashes just in time for a new pest to arrive and finish them off.

POPULATION BIOLOGY TO CONTROL DISEASE

*Chalara* is spreading fast – but what will its long-term effects be? Will it fizzle out, reduce the ash to a minor hedgerow shrub, or even drive it to extinction? It all depends on how the fungus and its host’s defences evolve.

Professor James Brown of the John Innes Centre is focusing on the fungus’s pathogenicity – its capacity to harm its host. Some *Chalara* strains are deadlier than others, but does this extra investment in pathogenicity weaken the fungus in other areas, like reproducing or surviving cold winters? If there’s a high cost to being deadly, there’s a good chance the ash population will make a long-term recovery as tree defences evolve.

Brown also wants to understand the fungus population’s genetic structure, to see how natural selection acts on that population – the more genetic variation it contains, the faster it can evolve to beat ash trees’ defences.

‘Understanding variation in the fungus’s pathogenicity will tell us about the long-term prospects for the ash population developing resistance,’ says Brown. If the fitness cost turns out to be very high, we might be able to rely on natural selection alone – though in practice we may want to speed up the process. Brown’s project could show how to breed more resistant ashes or manage woodlands to encourage the spread of disease-resistant genes.

It may also help contain the disease in the shorter term. The group is examining a related but harmless fungus that arrived in the 19th century and is now widespread in UK ashes. If the two fungi are close enough to share genes and diseases, viruses that infect the naturalised fungus could be transferred to the newcomer to slow its spread.
THE ECONOMICS OF ASH DIEBACK

Planting woodland is a long-term gamble; it’s not like sowing a field of wheat, where the risks are short-lived and if the crop fails you may be able to recoup your losses next year. The chances of eventual profit have to be weighed against many risks – from a drop in the price of wood to disease destroying the plantation.

Dr Adam Kleczkowski of the University of Stirling is leading a team of mathematicians, forest ecologists and economists to understand how disease affects foresters’ decision-making, and how ash dieback is changing this. For example, will they stop planting ash – or could they plant more, hoping for a crop before the disease reaches them? We don’t know, and we need to if we’re to grasp the disease’s long-term effects.

‘More diseases will appear, and to deal with them we have to stop reacting afterwards and start preparing before problems occur,’ Kleczkowski notes. ‘We have to be more proactive in finding solutions.’ And with around half of UK forests in private hands, we need economic solutions as well as political ones.

Kleczkowski plans to identify the forces affecting the spread of tree pathogens including ash dieback, and use these to improve models of economic decision-making so they account for the presence of disease. This should illuminate the behaviour of foresters and woodland managers faced with trade-offs between disease risk and other factors.

All this will deepen our understanding of dieback’s economic dimensions, and of how it affects already-complex decision-making. Some of its costs are easy to measure – lost carbon credits, destroyed timber crops. Others, like reduced enjoyment of woodlands, are subtler; the scientists will carry out experiments asking people to choose between different outcomes to get a clearer idea of how much they value these intangible benefits.

At the project’s end, Kleczkowski aims to have a list of potential anti-disease policies, ranked by cost-effectiveness. This will include things we already do and potential ideas for the future; it will help policymakers plan the war on plant pathogens for the long term.

BIOLOGICAL PEST CONTROL

Professor Tariq Butt of Swansea University specialises in biological insect control – killing pests using other organisms. He’s an expert on Metarhizium anisopliae, a fungus that’s raised killing insects to a fine art. Unlike chemical pesticides, it’s lethal to the intended victim but harmless to other insects and the wider environment.

This could be critical to our trees’ future, because damaging invasive insects are already loose in our woodlands, and others are likely to follow.

The initial focus is the pine processionary moth, now found across much of Europe although not, for the moment, in the UK. Its caterpillars stunt tree growth, potentially devastating timber profits.

They’re also covered in stinging hairs that can detach and blow on the wind, causing swelling and extreme pain and making it risky just to walk in the woods. They can even cause blindness if they get in a victim’s eyes; two of Butt’s collaborators in Turkey have already been hospitalised after a fieldwork accident.

The researchers are working on lures to get moths into Metarhizium traps. One idea is attracting males with female pheromones; another is using tree signalling chemicals to make females think they’ve found the perfect spot to lay their eggs.

Similar techniques should work on many pests, like vine weevils and the Asian longhorn beetle. Butt is working with forestry companies and other organisations including the Food and Environment Research Agency (Fera) and the Forestry Commission.

‘We take trees for granted, but if major species start disappearing from the landscape it will have a huge psychological impact on us all,’ says Butt. ‘Even if we eventually find solutions that lets them return, a landscape full of saplings just won’t be the same.’

Using the Genie system to detect ash dieback in the field.

Citrus longhorn beetle.
The way a tree looks and grows depends on genes – its genotype – and the local environment. As natural selection acts, some genotypes do better than others. Yet if the environment changes – for example, if the climate gets warmer or we move seeds from one place to another – then once-successful genotypes can become stressed and susceptible to disease.

Individuals within a species vary in their ability to cope with these complex environmental pressures. This variation could point to solutions, if we know enough about how trees relate to their whole ecosystem – including pests and diseases.

For instance, assessing the tree’s microbiome – the tiny organisms living on and in its leaves, which may act like a human’s beneficial gut bacteria – will reveal if and how it affects disease risk.

Cavers will also consider how Scots pine is grown and managed, working with landowners, foresters and others to increase awareness of tree-health issues, and find ways to apply science to tree management. ‘We want to produce guidelines on how to use natural variation to minimise the impact of disease on many tree species,’ he adds. ‘By looking at many health issues together, we think we can come up with helpful guidance for conservationists, foresters and the general public.’

**Better Biosecurity Through Technology**

An interdisciplinary group led by Dr Rick Mumford of the Food and Environment Research Agency (Fera) is building technologies to help stop pests and pathogens at the border, or at least detect them before they spread too far.

Insects and fungal spores can get to the UK naturally, but many arrive in plant shipments, so monitoring imports is essential. Two technologies will help inspectors at ports: an electronic ‘nose’ that can detect volatile chemicals emitted by many infected plants; and cameras that pick up subtle disease-induced changes by looking beyond the spectrum of visible light. Both can detect many problems long before they are visible to the naked eye.

Other projects aim to give early warning of pests and diseases in the wild to improve our chances of stopping them getting a foothold. ‘Monitoring imports is vital, but it’s a thin blue line around the country,’ Mumford notes. ‘If a new disease gets through it can be several years before we find out, and in that time it can spread a long way. We need better surveillance technology.’

His group aims to create systems that capture fungal spores and test for the DNA of known pathogens; detectors to pick up the genetic material of waterborne diseases like sudden oak death; and smart insect traps that catch invasive species with customised lures and then transmit images to base for identification. The researchers are working with citizen-science experts at the Centre for Ecology & Hydrology to create risk maps to guide trap placement, drawing on the expertise of amateur entomologists.

Many of these technologies have already been developed in areas like homeland security, where they’re used to detect explosives, drugs and other illegal items. Others are widely-used scientific instruments. The challenge is turning them from research tools into portable devices that are easy for plant inspectors, foresters and others to use in the field.

**What Do We Really Think of Tree Health?**

The arrival of ash dieback has triggered heated debate in the media and beyond, and many of us now know enough about tree health to report sightings and take steps to avoid spreading disease.

But there’s still a lot we don’t know about public understanding of tree-health risks – and about the social, cultural and economic factors that shape it. Dr Clive Potter at Imperial College London is exploring how people encounter tree pests and diseases in different contexts, and assessing the role the media and other communication channels play in informing people of the risks they pose.

They’ll study public reaction to, and involvement with, three recent outbreaks in the UK – ash dieback, sudden oak death and the oak processionary moth. Their findings will help build public trust in initiatives like Defra’s Plant Health Risk Register, which assesses threats to UK flora. They’ll also help policymakers and risk managers find better ways to communicate with the public, making the issues relevant and help people understand how they can make a difference.

The Tree Health and Plant Biosecurity Initiative is funded by the Biotechnology and Biological Sciences Research Council, Defra, the Economic and Social Research Council, the Forestry Commission, NERC and the Scottish government. They are investing £7m in projects lasting up to three years to address threats to UK tree health, under the auspices of the Living With Environmental Change partnership.
The term ‘living fossil’ was coined by Darwin and has since been applied to various species that appear not to have changed for millions of years. But when Africa Gómez and colleagues took a closer look at tadpole shrimps they concluded we should ditch the term for good.

From the age of the dinosaurs?

Challenging the idea of living fossils

In *On the Origin of Species*, Darwin used the term ‘living fossil’ informally, to convey how little lungfish and platypus had changed over millions of years. The label stuck, and is now commonly used to refer to species such as the coelacanth, the horseshoe crab and the ginkgo tree. Tadpole shrimps gained this epithet because ancient fossils of these small, pond-dwelling crustaceans appear almost indistinguishable from living species. Indeed, for over a century, tadpole shrimps (or more precisely the two genera *Triops* and *Lepidurus* which make up the order Notostraca) were regarded as a group that had diversified remarkably little since their origin over 300 million years ago – what we refer to as ‘morphological conservatism’.

Tadpole shrimps can be up to 10cm long when fully grown and have a broad oval carapace or shell at their front end and a long slender abdomen, giving them a tadpole-like shape. They live in temporary stands of water and their eggs can survive for a long time in dry sediment. In fact you may have encountered *Triops* ‘kits’ in shops – packets of eggs and food from which you can hatch your own small *Triops* as pets. The fact that these are often marketed as ‘from the age of the dinosaurs’ or ‘prehistoric sea monsters’ suggests the living fossil tag is firmly lodged in popular imagination.

But ‘living fossil’ has been taken to mean that evolution has stopped altogether. This was not what Darwin meant but in any case, is it true? Tadpole shrimps may be morphologically conservative but a closer look reveals there’s a lot more to them, in particular the different ways they reproduce. Many populations are dioecious – they have equal frequencies of males and females – but others have mostly hermaphrodites and only a small proportion of males. This rare mechanism, known as androdioecy, is found in only a handful of animals. The hermaphrodites in androdioecious populations have sperm-producing lobes in their ovaries and they can both self-fertilise and mate with males.

Building on earlier work (see *Planet Earth Winter 2008, www.planetearth.nerc.ac.uk/features/story.aspx?id=212* we set out to investigate the evolution of sexual systems in tadpole shrimps. In particular, we wanted to know when and how many times hermaphroditism had evolved, and whether it had favoured colonisation – after all, it would only take a single self-fertilising hermaphrodite to establish a new population. In order to do this, we had to establish an evolutionary tree for tadpole shrimps.

The first step was to spend months in the lab, hatching recalcitrant eggs from mud samples from around the world. Once we had enough individuals from each species we recorded the sex ratio and reproductive mode for each and sequenced a sample of nuclear and mitochondrial genes. Given the morphological conservatism of the group, we couldn’t use tadpole shrimp fossils to date episodes of diversification. So we reviewed the literature on other branchiopod crustaceans – the taxonomic group that includes *Triops*, water fleas and fairy shrimps – to find key dated fossils of related species. Then we calibrated the ages of the molecular clocks and used them to calibrate the fossil record. The result was a well-supported evolutionary tree that spanned the last 300 million years.

They too evolve like any other organism – it’s just that their external form has survived the test of time.
We used molecular clock methods and our gene sequences to produce a dated evolutionary tree of tadpole shrimps. Once we had the evolutionary tree, we could use established computer programs to map the reproductive modes onto it to investigate how they had evolved. We found that five different evolutionary branches – or lineages – had hermaphroditic reproduction, and that they had most likely evolved independently.

We had seen in previous work that northern Europe was recolonised after the ice ages by hermaphroditic or androdioecious lineages of the European tadpole shrimp Triops cancriformis. This time we confirmed the correlation between hermaphroditism and latitude for the whole group: we found that species that live closer to the poles, and hence are likely to have colonised the area more recently after the ice ages, were more likely to be hermaphroditic. This supports the hypothesis that hermaphroditism confers an evolutionary advantage – because it only requires one individual it’s a sureer way of colonising newly available environments. So the way tadpole shrimps reproduce has evolved over time to meet environmental challenges.

Previous work had also revealed the presence of ‘cryptic species’ of Triops species that look very similar but are genetically divergent and can’t interbreed. Our results revealed at least 38 species but there are probably many more waiting to be found in remote areas of the world. This abundance of cryptic species makes it very hard to assign tadpole shrimp fossils to a particular lineage – they just look so similar.

As a result the fossil record doesn’t reveal very much about patterns of evolution and diversification within the group and it’s this that misleads researchers to conclude that tadpole shrimps have changed little over their long evolutionary history. Our results showed that tadpole shrimps have in fact undergone several periods of radiation and extinction. Living tadpole shrimp species are much younger than the remarkably similar fossil ones and have had at least two episodes of evolutionary radiations. For example, 250-million-year-old fossils have been assigned to the living European species Triops cancriformis whereas our results indicate this species evolved less than 25 million years ago.

A multidisciplinary approach, using DNA sequences, fossils and natural history data from modern species, can give us a very detailed understanding of the evolution of different groups, and is critical to studies of enigmatic creatures like these. Tadpole shrimps haven’t stopped evolving at all: their reproduction and physiology have evolved and they have experienced bouts of radiation, at least one of them quite recently. Our results agree with molecular and morphological studies of other so-called living fossils, which show they too evolve like any other organism – it’s just that their external form has survived the test of time. In short, evolution is not just skin-deep, or in this case carapace-deep, and we think the term ‘living fossil’ should be abandoned for good.

Africa Gómez is a lecturer in evolutionary biology at the University of Hull. The team comprised: Thomas Mathers, now at the Genome Analysis Centre in Norwich; Rob Hammond, University of Leicester; Bernd Hänfling, University of Hull; and Ronald Jenner, Natural History Museum, London.

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Across much of Africa, cities are growing quickly. Current projections estimate that by 2050, 60 per cent of the population will be living in urban areas – half of them in slums. Many of these people have little access to services such as clean water and sanitation, and the UN has identified fixing this as a major priority.

The lack of piped drinking water forces many slum-dwellers to use shallow wells that are at high risk of contamination from poor environmental hygiene and inadequate sanitation; this is likely to increase as cities expand. This means drinking water is often contaminated by disease-causing micro-organisms from pit latrines and insanitary surfaces, with serious implications both for public health and livelihoods.

Diarrhoeal disease, for example, is a major cause of childhood deaths, and cholera can spread rapidly in these conditions. The combination of urban population growth, political instability in some parts of Africa and the ongoing lack of investment in the continent’s water and sanitation sector mean this issue needs to be urgently addressed.

Kabwe, in Zambia, is a bustling transport hub on the main highway between Lusaka, the capital, and the second city Ndola. The inhabitants depend heavily on groundwater for their water supply. In slum areas the use of shallow wells is very common, and on average only one in ten people have adequate sanitation.

Since Kabwe’s mining industry collapsed in the late 1970s, the proportion of houses supplied with clean piped water has fallen. Older residents remember when most households in the town were supplied with both raw and treated water; they knew not to use the tap in the garden for drinking as it was unsafe. Fast forward 40 years and the infrastructure can’t support the rising demand. In slums like Makululu, residents have turned to shallow, unprotected hand-dug wells, to supplement household water use. This is a
One of our number, Dan, co-ordinated a team of Zambian and UK scientists to carry out a groundwater quality survey across Kabwe in 2013–14. This revealed that shallow household supplies (less than 10m underground) were highly contaminated throughout the year with faecal bacteria and nitrate, as well as elevated concentrations of the commonly-used insect repellent DEET.

There was significantly more contamination in the wet season compared to the dry season, and in poorer areas compared to richer ones. Deeper groundwater sources (more than 50m below ground) were generally free from faecal bacteria, but some in poorer areas showed elevated nitrate, another contaminant from pit latrines. Shallow wells therefore pose an ongoing risk to users and even deep sources need to be protected in the longterm.

As part of the work Dan is leading, the team tested a field sensor designed to measure a protein called tryptophan, an indicator of waste-water contamination, particularly with faecal matter – the most serious problem for people who drink water from shallow wells.

The study’s findings are exciting; it seems the sensor will be a really useful tool with a wide application for rapidly mapping groundwater contamination by faecal bacteria. It needs no reagents and is easy for health workers to use in the field. It can detect both the presence of faecal contamination in groundwater and how much of it there is within minutes, compared to a day or more for other methods. This can be crucial when helping households manage their water supply, particularly during an outbreak of water-borne disease. The test could be invaluable in the early stages of assessing risks in water supplies, or in monitoring the effects of attempts to improve groundwater quality through planned interventions.

**Safe for human consumption?**

Kisumu is Kenya’s third largest city and grew up around the Lake Victoria railhead of the historic railway that once linked the port of Mombasa to Uganda. In colonial times, the city was planned with a centre consisting of administrative buildings and European residential areas, with housing for Africans around the periphery.

As the city has expanded since independence, the provision of public services has struggled to keep pace with population growth in the former outlying African neighbourhoods. This means residents find their own means of meeting their need for water and sanitation, using shallow hand-dug wells to supplement the gaps in piped water supply coverage, and pit latrines for sanitation. As with Kabwe, the presence of pit latrines near shallow wells in Kisumu has a high risk of contaminating groundwater with human waste.

In Kisumu between 1999 and 2004, a group of Kenyan and British researchers led by Steve carried out a water quality survey of hand-dug wells in some of these outlying neighbourhoods. The team tested for microbiological and chemical contaminants, mapped out pit latrines and wells, and recorded hazards around the wells, such as nearby pit latrines.

Earlier this year, Jim co-ordinated a follow-up survey by the same team to see what had changed over the past decade. As well as recording hazards and testing wells, the team also interviewed well owners and those using the groundwater.

The survey showed that the groundwater from the wells is still heavily contaminated with faecal bacteria. The number of hazards around the wells had increased in the decade since the first survey, as Kisumu’s population expanded. Interviews with well owners and groundwater consumers suggest that they are generally aware of these risks and try to cook with and drink piped water rather than well water.

In a more detailed study of two neighbourhoods, the survey also suggested that residents were using over 300m³ of groundwater a day. For those struggling to make ends meet, groundwater remains an affordable way of supplementing the costly piped water supplies, despite its high levels of microbial contamination.

There has been a long-running debate about the relative importance of water quality and water quantity. Some argue that cleaning water up is the way forward for public health. Others say delivering enough water to meet people’s needs – no matter what its quality – will bring greater benefits.

Perhaps the way forward for Sub-Saharan Africa’s growing slums is to recognise that groundwater is an affordable option that the urban poor are unlikely to stop using any time soon. We should focus on practical ways of reducing the risks they face from contamination – this involves a range of measures including siting wells and boreholes a safe distance from potential sources of contamination such as pit latrines and sewers, and using better construction techniques, such as adequately lining well shafts and sealing wellheads with a concrete apron to reduce contamination. It’s also essential to maintain and protect head works – the equipment at ground level, including the well cover and the device used to lift water.

Other measures that could help include simple and more hygienic methods of collecting the water, such as using a hand pump or rope winch rather than a rope and bucket which can pick up contamination from the ground. And all this must be supported by effective communication of the risks to households. It’s a big challenge as most of Africa has very limited water-quality data with which to inform policy and practice, but new tools like the tryptophan field sensor, being trialled in these projects, may enable better targeted water quality monitoring.

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A new history of Antarctic ice

There's still a huge amount we don’t know about the history of the southern polar ice sheet. Bethan Davies was part of an international team that brought together the latest findings to reveal a complex and dynamic Antarctica.

How sensitive is the Antarctic Ice Sheet to climate change? How does it react to a warmer atmosphere and ocean, and how can we estimate how much ice it is losing now? To answer these questions, we need to know how it has retreated and thinned since the last ice age.

The Scientific Committee for Antarctic Research (SCAR) commissioned an international team of 78 scientists from 14 countries to compile the most complete review of the history of the ice sheet to date. The team includes scientists from many backgrounds, including marine geologists, those studying changes recorded in lake muds, ice-sheet modellers, terrestrial glacial geologists and glaciologists.

The review looked at the ice sheet’s extent and thickness at the Last Glacial Maximum — the peak of the last ice age, 25,000 years ago — and then every 5,000 years until the present. The challenge we faced was to take information from many sources and many different international teams, and turn it into a unified history of the Antarctic ice cap over the last few tens of thousands of years.

The Earth is still rebounding after the weight of the ice sheets was removed at the end of the last ice age, and measurements of the modern sheet’s height above sea level or changes in mass have to take this into account. This in turn means we need detailed knowledge of past ice volumes. And rates and magnitudes of ice-sheet change during periods of past rapid climate change — such as the last transition between the last ice age and the present interglacial period — and over the last few thousand years put current ice-sheet change into context, and help us understand thresholds and tipping points beyond which even more rapid changes may occur.

The changing ice cap

You might imagine the relationship between ice and temperature is simple — when the climate gets colder the ice increases, and when it warms the ice melts. But our results show the ice sheet is dynamic, with various areas gaining and losing ice at different times.

Around much of the continent, the glaciers reached their peak about 20,000 years ago, when large areas of the ice sheet reached the edge of the continental shelf. Yet in parts of the colder, drier East Antarctic Ice Sheet the story was very different, with the ice sheet remaining relatively stable for the last 25,000 years. In fact, the ice surface in its interior was up to 100m lower than the present day, because the cold, dry air meant there was less snowfall.

In several cases, our work highlighted apparent contradictions that will need more work to understand. For example, the Weddell Sea was a particular area of contention, with apparent discrepancies between the evidence from land and sea. Part of the problem is that this region is remote, even by Antarctic standards, so data are sparse and the extensive sea ice makes investigation from ships difficult.
The limited marine data we do have from the Weddell Sea region suggest that at its maximum, the ice sheet extended to near the outer edge of the continental shelf, implying it was thicker than the present one. In contrast, geological evidence from mountain ranges inshore suggests that there was very little change in the ice sheet's elevation between the Last Glacial Maximum and today. This limited change in thickness indicates that the ice in the Weddell Sea embayment was thin and floating, rather than grounded in the deep troughs on the continental shelf. This leaves scientists with two alternative scenarios to test and investigate over coming years.

Again and again, we learned that things are more complicated than we'd thought. For example, a key finding is that the ice-sheet's retreat from its maximum extent was asynchronous; that is, it did not respond to a warming climate in a uniform way. In the west around the Antarctic Peninsula, Bellingshausen Sea and sub-Antarctic islands, the recession was well under way by 18,000 years ago. But at that time most of the East Antarctic Ice Sheet was still grounded near its greatest extent, and the grounding line – the transition between floating ice and ice that rests on the sea floor – in the Ross Sea barely moved at all. By 10,000 years ago, the Antarctic Peninsula Ice Sheet, ice in the Amundsen Sea, and glaciers on the sub-Antarctic islands had largely receded to the inner continental shelf. By 5,000 years ago, their configurations were similar to the present. Conversely, ice-sheet recession in East Antarctica didn’t really get under way until 12,000 to 6,000 years ago, when the oceans were warming significantly. At a more local scale, individual ice streams shrank back at different times, often depending on the landscape they flowed through.

Some of our discoveries have implications far beyond Antarctica. One was that the ice sheet contributed less than 10m to global sea levels as it melted – less than earlier studies estimated – and probably contributed relatively little to the rapid rise of around 20m in global sea levels around 14,500 years ago. Some scientists have thought Antarctica was the source for this massive increase, but our research suggests that other ice sheets probably played a bigger role.

The review reveals a complex Antarctic Ice Sheet that responded sensitively to changes in air and ocean temperature in different ways at different times. Patterns of ice recession varied strongly from place to place, controlled in part by the landscape and ocean water depths. Ice-sheet modellers will now use the project’s results to test their computer models on historical data; if the models can successfully simulate what we know happened in the past – known as hindcasting – then we can be more confident in their projections of the future. This will in turn help us understand how the Antarctic ice will respond to a changing environment.

It is clear from the project that the glacial history of large areas of Antarctica remains little-studied and poorly understood, and in some areas we still can’t decide between competing hypotheses. It’s a complicated story that highlights the complexities involved in reconstructing ancient ice sheets. Major reviews like this identify the state of the art and clarify future research directions. They give the scientific community access to a wide range of data sources; data that often would not have been available otherwise. Other specialists can then use these data; for example, computer modellers need accurate geological information against which to test their models.

By understanding how, how quickly and how much the ice sheet responded to oceanic and atmospheric changes in the past, we will be better able to judge how it will react to similar changes in the future, and will be able to provide better projections of future sea-level rise.

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Nobody wants peat in their tapwater, and in some situations it can even threaten people’s health. Getting rid of it is costly for water companies, and a warming climate will increase the problem. The more they know about these changes, the better they’ll be able to cope. Tom Marshall found out how NERC-supported science is helping operators stay ahead of the game.

As water runs off upland landscapes into reservoirs, it washes organic matter out of the soil. This dissolved organic carbon (DOC) is a major headache for water companies; it gives tapwater a peaty tinge and sometimes creates strange smells and tastes. Usually this isn’t dangerous, but few customers appreciate drinking brown water.

More seriously, DOC can cause microbes to breed in water supplies after they’ve been treated, carry pollutants like metals or pesticides or even react with the chlorine that’s used as a disinfectant to form by-products like trihalomethanes (THM), which are suspected of being carcinogenic. All this means water companies have to pay a lot of money to remove carbon from their water before it can be sent to consumers, particularly when that water has flowed over peaty soil on its way to the reservoir.

The problem is only likely to increase. Average DOC levels in water running off upland catchments in north-west Europe and North America have been rising for decades. Climate change will make this trend worse, bringing more extreme weather that will wash more carbon out of the soil over short periods. Treatment facilities need to get better at dealing with sudden spikes of carbon, or we risk corresponding spikes of pollutants in our drinking water.

Professor Christopher Freeman and his team at Bangor University have been working with Dŵr Cymru Welsh Water to understand the role of different water-treatment methods in removing DOC and other precursors of THM. They worked alongside the company’s researchers to spend a year monitoring the output of a particular treatment works whose water contains a
lot of DOC, because it comes from a reservoir that’s fed by a large upland catchment of peatland, grassland and conifer forest.

Among other things, their study revealed that the way DOC was being removed at the treatment works makes the whole process more vulnerable to spikes of the chemical precursors of THM as the climate changes. The company has to maintain disinfection by-products at extremely low levels, both to comply with the law and to avoid endangering its customers’ health, and Freeman’s work shows a changing climate will put it at more risk of breaching these limits. The research also revealed seasonal patterns in THM risks – it turns out they are greater in spring and summer.

The scientists sampled the water throughout the treatment process, providing the first in-depth insight into the complex chemical interactions that take place as the carbon is removed. Dŵr Cymru Welsh Water says Freeman’s work, published in Science of the Total Environment, has been vital in helping it create a long-term plan to deal with the problem, forming an important element of its asset-management strategy.

‘Knowledge that DOC levels are on an increasing trend allows us to plan strategically for the future,’ says Peter Perry, the firm’s operations director. ‘Removal of DOC is the major treatment cost involved in producing potable water across the industry.’

He explains that the insight into the trends in DOC and its effects that Freeman’s research provided has let the company identify treatment works that are at risk of breaching limits on disinfection by-products, and to make better-informed decisions about what to do about the problem. Possible responses range from investing in better DOC treatment equipment, switching from chlorination to alternative disinfection techniques, or diluting with water from another source. If none of these are cost-effective, abandoning especially problematic works and piping water from elsewhere may even be necessary.

According to Perry, the research has been invaluable in helping the company understand the risks it faces. ‘Their findings are continuously helping to improve our knowledge and understanding of the complex interactions within our drinking water catchments, and provide a valuable insight into how they affect our ability to produce drinking water,’ he explains.

‘NERC funding got us involved in a whole series of studies that have been of huge interest to us as environmental scientists,’ Freeman says. ‘But there’s something incredibly rewarding about seeing your work prove of value to an end user like Dŵr Cymru Welsh Water, and to realise it is helping their customers.’

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The research was funded by the EU, by Dŵr Cymru Welsh Water and by NERC.
During 2014 and 2015, the first arrays of tidal turbines are expected to be installed in UK waters, and plans for the first commercial arrays of wave energy devices are well advanced.

The UK is rich in marine renewable energy sources. We have excellent tidal energy potential with a number of regions of strong tidal currents and others with large tidal ranges. Much of our surrounding ocean, especially the west coast, is exposed to the full force of Atlantic waves. This resource wealth has stimulated innovation, with dozens of designs for marine energy devices coming out of UK universities and small businesses.

Now large multinational companies are investing in or buying devices that have been successful in ocean tests and prototypes are giving way to the first commercial installations, backed by established marine industry and energy companies.

It's a fast-moving sector and the UK academic community and industry are working hard to tackle the challenges it presents. Where are the greatest concentrations of energy and how much is harvestable? What forces should the devices be designed to survive and how can we minimise the costs and risks of operating in such extreme environments? What effects will energy-harvesting devices, individually and cumulatively, have on the environment?

I lead a project called FLOWBEC – FLOW and Benthic ECology 4D – which is studying how currents, waves and turbulence at tide and wave energy sites influence the behaviour of marine wildlife, and how the presence and operation of energy devices could affect that behaviour – whether they might deter wildlife, for example, or perhaps attract certain species by replicating the foraging conditions they prefer.

The environmental challenge

Before we can understand what effects energy devices might have, we need to understand the undisturbed environment. This means studying conditions at the sites and the behaviour of the wildlife that is present there.

The standard way of measuring waves and currents, with wave buoys and sonar current meters, is problematic in some of the more extreme conditions as there’s a high risk of equipment being damaged or lost. Tidal sites present a further challenge as the effects of headlands, tidal channels and shoals mean measurements at a few points may not give an accurate picture of conditions across the whole site.

One answer is to use remote-sensing techniques, using radar, cameras and satellites to map the ocean from vantage points on shore, the air or from space.

FLOWBEC uses two types of radar to map tidal currents and waves at study sites – a ship’s radar at the European Marine Energy Centre in Orkney, and a longer range High Frequency (HF) Doppler radar that covers the Wave Hub site in Cornwall. The quality of the results often depends on local conditions at the time.
but having the equipment out of the water means it’s much easier to operate and maintain, and can give you almost immediate access to the data rather than having to wait for an instrument to be recovered from the sea.

We use many techniques to study the animals themselves, some remote and some very much hands-on. Observations from the shore or a boat are complemented by underwater measurements using sonar to track wildlife such as seals, diving birds and fish, and shore-based radar to track birds in flight. Radar can also pick up larger marine species like whales when they are at the surface although they can be difficult to distinguish from the background ‘sea clutter’.

Other related projects, such as RESPONSE and QBEX, also tag and track individual animals. Larger tags can transmit data via satellite, radio or phone networks, but we usually have to rely on the smaller ones, from birds and fish, being returned by a member of the public once it’s been separated from its host or the animal has been captured.

Tagging is proving invaluable for observing animal behaviour over longer periods. We’re already seeing that individual animals of the same species tagged at the same location may behave in very different ways, so it’s really important that we gather information on sufficient numbers for all the species affected to make sure we capture these natural variations in behaviour.

Concurrent observations of wildlife above the surface (radar, visual) and below the surface (sonar) made by the FLOWBEC team show the advantages of this approach when combined with environmental information such as tidal currents, turbulence and sea surface roughness derived from radars or computer simulations. We are starting to understand the way different species of marine wildlife use their perception of the physical environment to decide where and when to forage for food and what conditions they prefer to avoid – factors which vary depending on species.

Our research programme, and others like it, are also highlighting how much we still have to learn about marine wildlife, as there is often relatively little information available about the presence and behaviour of marine animals either individually or collectively at potential development sites.

The UK’s renewable energy resources are undeniably important, and worth harvesting provided the benefits outweigh the costs. The environmental effects may be hard to measure but if we are going to move to low-carbon electricity in a responsible way we need to be sure we are not solving one environmental problem by creating a new one.

The good news is the need to understand and mitigate the environmental effects of marine renewable energy is driving innovation in tools and methods that will support industry and the environment.

The Atlas of UK Marine Renewable Energy Resources uses tide and wave models and a variety of observations, such as tide-gauge and wave-buoy measurements, to produce detailed regional descriptions of potential marine energy resources in UK waters. The atlas guides policy and planning decisions and some of the most promising UK sites have been leased to developers for testing and commercial energy extraction.

Energy is harvested by an array of turbines designed to generate electricity through the action of waves or currents.

The large areas, extreme conditions and relative inaccessibility of many potential sites mean we may need to find new ways to make the best use of the energy they generate; electricity cables to shore may not always be practical or affordable, and once the power is brought to the shore the electricity grid may not be suitable for exporting the generated power. Ways around this include using the energy on-site or at least locally to make high-energy-cost products, fuels such as hydrogen, or to produce fresh water by desalinating sea water.

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FLOWBEC: http://noc.ac.uk/project/flowbec

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Renewable energy is an important part of the UK’s energy mix and we need to know more about its effects on marine animals. Steve Simpson and Rick Bruintjes explain how they’re using a home-made pile-driver to investigate.

**Richard Hollingham:** We’re at a former shipyard at Blythe, just north of Newcastle. Steve, what is this experiment?

**Steve Simpson:** This is probably the biggest fish tank you have ever seen. It’s 80m long, 20m wide, 3m deep with cod, plaice and crabs all getting on with their day-to-day business. We’re looking at the impact of pile-driving noise on these animals. Pile-driving is used for building offshore, for example for wind farms, and there is a lot of uncertainty about how that might affect marine animals. So we’ve built an experimental piling rig, a small pile-driver driven by that tractor over there, which bangs on a 3m-long steel pipe set into the sediment at the bottom of this dry dock.

**Richard Hollingham:** What are all the ropes and wires slung across the dock here?

**Rick Bruintjes:** These are underwater microphones called hydrophones that pick up the noise of the pile driving. All the fish we put in have a little tag that pings at very high frequency and the hydrophones can detect this too, so they tell us where the fish are with an accuracy of approximately 20cm. Some fish also have heart-rate monitors and accelerometers that measure their tail beat.

**Richard Hollingham:** Why isn’t the tractor running at the moment?

**Steve Simpson:** We’re doing two hours on, two hours off for two solid days. After that we’ll look at the movements of the fish and the information about their behaviour and physiological condition from the other monitors, and compare these for the periods of piling and the periods in between.
Our research is different from previous studies that have played recordings of pile driving using underwater speakers. In reality a lot of the energy is transferred directly into the sediment and with our piling rig we can look not only at the acoustics in the water but also at how that sound is propagated through the sediment. For the plaice and crabs that are on the seabed that’s much more important than what is happening higher up in the water.

Richard Hollingham: Rick, what’s the benefit of doing this on such a large scale?

Rick Bruintjes: The main question, which is a very simple but nobody has really answered, is do fish avoid noise? Using such a large aquarium we should actually be able to tell if the fish swim away from the noise, or are attracted by it or do anything else – they might freeze because of it or double their swimming speed. And we need to understand whether these effects are bad for the fish.

Richard Hollingham: There are several shipping containers here too, full of your equipment. Let’s head in here to see the other part of the experiment.

Fiona here is an undergraduate working on the project. Fiona – on the bench you’ve got a basket from a deep-fat fryer with a plastic tub inside; what on Earth is this?

Fiona: We’re going to put a crab or a mussel in each container; fill it with water and measure the oxygen content. Then we’ll lower it into the dock, and measure the oxygen content of the water inside again after periods of quiet and periods of pile driving to compare how much oxygen the crab or the mussel has used. If they’ve used more oxygen during the piling phase it means their metabolic rate has got higher, which could indicate stress. I know it looks crazy but I think it will work – I’m hoping it will work!

Richard Hollingham: Back outside, looking at this tank again: if you imagine it as a fish tank it is vast but compared to the sorts of projects that are going on offshore, all the way round the British coast, it’s still quite small. Can you get enough from this?

Steve Simpson: I think we get two things from this. The scale means we can look at animals moving naturally, and much more accurately replicate the acoustic conditions in the sea and the seabed. But we’re also trialling technology that we could take offshore. And that’s really our longer-term ambition: to see whether the pinger systems could be used at a larger scale, to see how the heart-rate monitors and accelerometers might work in a sea-pen or even with totally free-living animals.

Richard Hollingham: Rick, this is increasingly relevant as we’re seeing more and more offshore, particularly wind, generation, in the UK but also around Europe and the rest of the world.

Rick Bruintjes: That’s right. The UK is definitely at the frontier of offshore wind energy. As we speak there are large areas where piles are being driven into the seabed for wind farms, which is a very good thing. But wind turbines can be up to 200m high, so the piles they use are on average 5 to 10m in diameter. You need a very big hammer to drive these into the seabed and it makes a lot of noise. Just how important that noise is, well, that is still to be found out.

Richard Hollingham: Steve, how important is this research given the state of the industry and the number of turbines being built?

Steve Simpson: I think the UK stands to be a global lead on offshore renewable energy. We are certainly a small island surrounded by energy-rich waters, whether it is tidal and wave or wind. But at the moment we’re still not certain what effect the noise might have on certain species of animal and this means the industry is held up sometimes. We hope to generate evidence that will reduce that uncertainty so offshore renewable energy can fulfil its potential as part of our future energy budget.

And I guess the nice thing about noise as a pollutant is that we could stop it tomorrow; we can control noise in a way we can’t control temperature, ocean acidification, chemical pollutants, micro-plastics. So you could choose simply not to make noise during a spawning season or to redirect a shipping lane if you’ve got a sensitive biological event. By providing the evidence that could help that decision-making we may soon be able to accelerate the development of renewable energy which is important if we’re ever to meet our 2020 and 2050 obligations for carbon dioxide emissions.

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This feature is adapted from the Planet Earth Podcast, 2 September 2014. It was recorded at the Offshore Renewable Energy Catapult https://ore.catapult.org.uk/home

The full podcast is available at http://planetearth.nerc.ac.uk/multimedia/story.aspx?id=1757

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Dr Rick Bruintjes is a NERC-funded marine renewable energy intern studying the impact of noise on fish behaviour in co-operation with the University of Bristol, University of Exeter and consultancy HR Wallingford.