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Britain's Natural Capital

EDITORIAL

Natural capital – putting our most valuable asset at the heart of decision-making

Natural capital reframes our natural environment as a provider of valuable services to people. As a concept, it is sometimes regarded with suspicion, criticised for aligning the natural world to the values of the economic system, which many would argue has done more to damage than to protect nature. Some squirm uncomfortably at the suggestion that we might be 'asset managers' for the country's natural resources rather than protecting nature for its own sake.

But applying a natural capital approach works the other way: it demonstrates to the economic system that its interests depend on a flourishing environment. If we recognise the value of the benefits nature provides society – and, crucially, the consequences of their loss – we make it much more difficult to ignore them in decision-making. This in turn incentivises nature's protection and restoration, not just by those who already value it highly, but also by those who might otherwise regard it as secondary.

In Natural England and within Defra we apply natural capital approaches to inform management decisions at a local scale. We are also gathering evidence to assess the state of our natural capital at a national scale – and to intervene to protect it. The recent ban on sandeel fishing is a prime example.

This natural capital approach is both driving, and being enabled by, changes in the way we collect and commission scientific evidence. A whole-system approach is increasingly key to the way we understand and manage nature, involving consideration of entire ecosystems and natural processes. But natural capital encourages us to weigh up social and economic as well as environmental evidence, extending the 'whole system' to include our society and economy.

We are still only partway along this journey, though, and the next steps involve integration of this work into other sectors across government. As a country we need to take a natural capital approach not just to environmental sectors, such as climate adaptation and net zero, but also to food security, health and well-being, and resilient economic development.

A whole-system approach needs government buy-in. But as this issue shows, a significant amount of natural capital work happens outside government. We all need to work together on this because the consequences, good or bad, will affect us all. So as you read through this issue I hope you will pause and think about how a natural capital approach might be applied to your own work, and how it might help you to communicate and collaborate more widely, reaching the new allies we are going to need if we are to achieve nature recovery for a thriving society and economy.

Editorial: Dr Tim Hill is Natural England's Chief Scientist. He has held this role since 2014 and has been a member of Natural England's senior leadership team since March 2008, with previous roles including Director of Regulatory Services and Access, and Director of Evidence. He is particularly focused on ensuring that Natural England is strongly evidence- and evaluation-led in all the advice, decisions and actions taken to achieve nature's recovery. Tim has a first-class joint honours degree in marine biology and zoology and a PhD in marine ecology, and he has 30 years' experience of working for the UK government's statutory nature conservation bodies. He is a member of the Institute of Directors and the IES. He is married with three daughters and lives in North Yorkshire.

Cover design: Rob Barnes taught printmaking for over 40 years at Keswick Hall College, then The University of East Anglia in the School of Education. He continues to exhibit work in UK galleries and is based in the village of Langley, near Norwich.

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Why we need to help Nature get back in the black

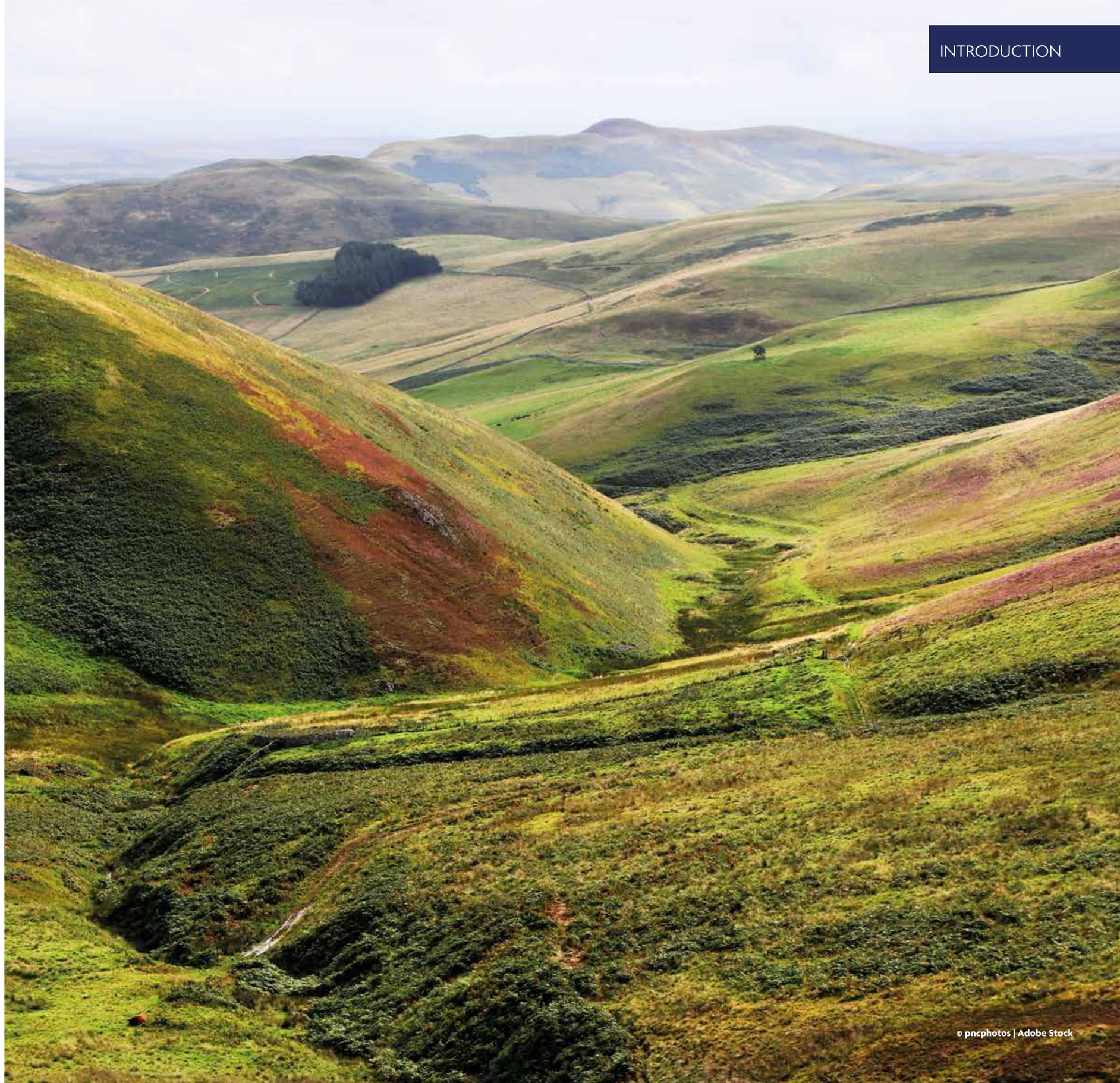
Tony Juniper takes stock of the state of our natural capital and what it will take for Nature to thrive again.

Natural capital is an idea that takes us right into the heart of Nature: what it is, why we rely on it so much, and how we can bring about its long-term recovery.

The current energy production and consumption model is complex, with inherently contradictory features. Proposed transitions will need to navigate the contextual factors underlying the different pathways to a sustainable energy future.

With Nature and climate change locked together in a deepening crisis, addressing these questions is one of the biggest challenges facing us nationally and globally. I am delighted that the IES has chosen to dedicate an issue of its *Environmental Scientist* journal to natural capital and privileged to be its guest editor.

INTRODUCTION



INTRODUCTION

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There are welcome signs that this challenge is starting to be recognised. The UK is playing an important leadership role in both adopting measures to halt the decline in Nature and encouraging other countries to play their part. We saw this in particular at the biodiversity COP15 in Montreal, Canada, where the UK helped to broker an international agreement in which almost 200 nations pledged to reverse biodiversity loss and protect 30 per cent of land and seas by 2030.

The Environment Act 2021 and Environmental Improvement Plan 2023 contain many of the mechanisms and targets to guide our efforts in relation to halting and reversing Nature's decline, demonstrating to the rest of the world that we are serious about leaving the environment in a better state than we found it.

Achieving these aims means doing things differently, however, particularly in the way we use our land and seas. Change is always difficult and, in this case, would be all but impossible without science to underpin new approaches and win over hearts and minds. We need to be able to present reliable evidence of the current situation and demonstrate a clear route to improvement. Crucially, though, and several authors in this issue make the point, that progress will be best made if the social and economic context that lies behind efforts for Nature recovery is properly understood.

Natural capital is essential in this regard. It allows scientists to set out with clarity and data what we all feel instinctively: that inextricable link between the health of Nature and the health of humanity. Natural capital identifies ecosystems and the services they provide us with – be they soils offering us food and clean water, or woodlands giving people places for fresh air and leisure, not to mention cooling our towns in summer. If these and other conclusions can be effectively communicated, and affected communities successfully engaged in the process of change, then progress can follow.

Establishing the full range of values we derive from Nature enables it to be put at the heart of discussions and decisions affecting its future – and the future of people who rely on it – in a visible, meaningful way. Expressing Nature in practical – including economic – terms has two crucial benefits: firstly, it makes it far harder for decision-makers to ignore it when the future is being shaped; and secondly, it provides reassurance that putting money into Nature is a sound investment.

Patricia Rice and Jane Lusardi sum this up well in their article about the work to evaluate natural capital as a way of supporting better decision-making. They say:

'Investment in the protection and recovery of nature is an investment in England's natural capital. As with any other capital asset, acting quickly to prevent and address the degradation of ecosystem assets makes economic sense. It secures and enhances the benefits that society and the economy depend on … meaning it will be cheaper and more effective in the long run.'

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Natural England's State of Natural Capital report (SONC), due to be published this summer, will become a key element of that support for decision-makers. It will bring together all the strands of available data on natural capital and present them in an accessible format. Of course, robust decisions require robust data to underpin them and the SONC will draw on the work of the Natural Capital and Ecosystem Assessment (NCEA) in England, set up to ensure that the baseline – and thus progress – can be measured.

Ruth Waters and Elizabeth Mitchell look at the NCEA in depth, showing how it is a test bed for new science techniques – especially in the marine environment – and how it is informing important policies such as the Environmental Land Management scheme. In one interesting example, they examine how ecological, economic and social science data are combined in a sustainable approach to cockle fishing in Morecambe Bay. This is but one reminder of the importance and potential for integrated approaches that go beyond the simple trade-offs of the past, when Nature and economy were seen as choices rather than as two sides of the same coin.

Many of the articles in this issue reveal the rich array of essential services provided by specific habitats. Tom Brook explores the world of saltmarshes, a dynamic but often overlooked place where sea meets land and which stores carbon faster than forests. The potential of seaweed to provide us with multiple benefits, including food and reduced impacts from storms and agricultural run-off, features in Leigh Eisler's article (along with some fragments of ancient poetry).

Moving inland, chalk streams are the most biodiverse river systems in the UK, as Charles Rangeley-Wilson notes, sustaining salmon and sea trout, starwort and water crowfoot. They are global hotspots for rare insect species, such as winterbourne stonefly and scarce brown sedge, yet many are imperilled by abstraction, pollution and damage to their natural physical structure.

Climate change is one of the biggest threats to our natural capital, and nowhere is this more visible than in those species whose ranges and behaviour are often changing, sometimes quite dramatically. Helen Roy points out that non-native invasive species are the product of human activity, and we are paying the price for this through increased disease risk – in the case of mosquitoes – and the loss of important biodiversity – in the case of Asian hornets and rats.

Field sports are another human behaviour that affects natural capital, sometimes positively and sometimes negatively. It is an issue that can arouse strong opinions, and so I am pleased that Andy Clements has been able to provide some dispassionate, rigorous scientific analysis of the relationship between shooting and natural capital.

The ways in which Nature supports the positive aspects of our lives – or indeed helps to mitigate the negative ones – come through very strongly in this issue. Nowhere is this truer than in Paul Wilkinson's account of the ambitious plan to turn a derelict shopping centre into Nottingham's 'mini Central Park'. The project was conceived very much in partnership with local people and will help to address inequalities in access to Nature and the health and well-being benefits that go with it.

The urban sphere is one in which natural capital can offer the most advantages to the most people. Alison Holt's article focuses on the open spaces owned by the City of London Corporation, which provide clean air, climate mitigation and noise reduction benefits for people living nearby, as well as places for recreation with associated health and well-being rewards. The corporation's portfolio is estimated to deliver £16 of natural capital benefits for every £1 invested – a huge return.

As Natural England's Chief Scientist, Tim Hill, argues in his editorial, being able to quantify the benefits of natural capital is a great way of incentivising people to protect and restore it. That is needed now more than ever as we attempt to prevent the continuing degradation of the web of life and help put it into recovery mode.

How might we go about restoring Nature and enhancing our natural capital? There are a number of approaches, one of which is the subject of Rob Stoneman's article: rewilding. He considers several successful projects across Europe that have benefited from river restoration and the reintroduction of species such as beaver and bison, which have all helped to shape Nature recovery at scale.

This is the level of ambition we will need if we are to ensure our natural capital thrives, along with the people and economy it sustains. I would like to thank all the authors for raising the profile of this important subject and I hope their writing will inspire you to support the recovery of the natural world. **ES**

Tony Juniper CBE is Chair of Natural England. Before taking up this role in April 2019 he was Executive Director for Advocacy and Campaigns at WWF-UK, a Fellow with the University of Cambridge Institute for Sustainability Leadership and President of The Wildlife Trusts. He was previously an independent sustainability and environment adviser, including as Special Advisor with The Prince of Wales's International Sustainability Unit.

Tony speaks and writes widely on conservation and sustainability themes. He is the author of numerous books, including the multi-award-winning bestseller *What Has Nature Ever Done for Us?* published in 2013. *The Ladybird Guide to Climate Change*, co-authored with His Royal Highness The Prince of Wales and Emily Shuckburgh, was published in January 2017. His latest book *Rainforest* was published in April 2018, and his next, *Shared Earth*, will be published in 2025.

Tony began his career as an ornithologist, working with Birdlife International. From 1990, he worked at Friends of the Earth, initially leading the campaign for tropical rainforests, and from 2003–8 was the organisation's Executive Director. From 2000–8 he was also Vice-Chair of Friends of the Earth International.

FEATURE

Reporting on the state of England's natural capital

Tricia Rice and **Jane Lusardi** reflect on the importance of establishing the right evidence frameworks now and for the future.

The economy and our society are intimately dependent on the health of the natural environment. Nature provides a wealth of benefits, such as clean air and water; it boosts health and well-being; captures and stores carbon; and has a vital role to play in helping society to adapt to climate change. Natural capital is an economic concept that views nature as an asset providing services and benefits to society (see **Box 1**). As with any other asset, nature needs to be in good working order to sustainably supply these benefits and services into the future.

BOX 1. KEY TERMS EXPLAINED

Natural capital. In a natural capital framework, nature is treated as an asset that provides benefits to people. These benefits are wide-ranging and essential for a thriving society and economy. Natural capital refers to the stock of nature that provides these essential benefits and includes living and non-living elements along with processes and functions.

Ecosystem assets. Ecosystems are made up of living (e.g. plants, animals, bacteria) and non-living (e.g. soil, climate, water) components interacting as a system. They are the stock of nature. The diversity of species within ecosystems enables these assets to be more productive, resilient and adaptable.

Ecosystem services. These are the goods and services provided by ecosystem assets that contribute to human well-being.

Benefits. The improvements in society's health, well-being and wealth that nature provides. When in good condition, the stock of assets provides multiple benefits to society and individuals. These benefits are essential and include things such as food, clean air and water, the reduction of flood risk, and our mental and physical health.

Biodiversity. The variety of life in all its forms and at all levels, including genes, species and ecosystems. Different species form communities that interact with the physical world to create ecosystems.

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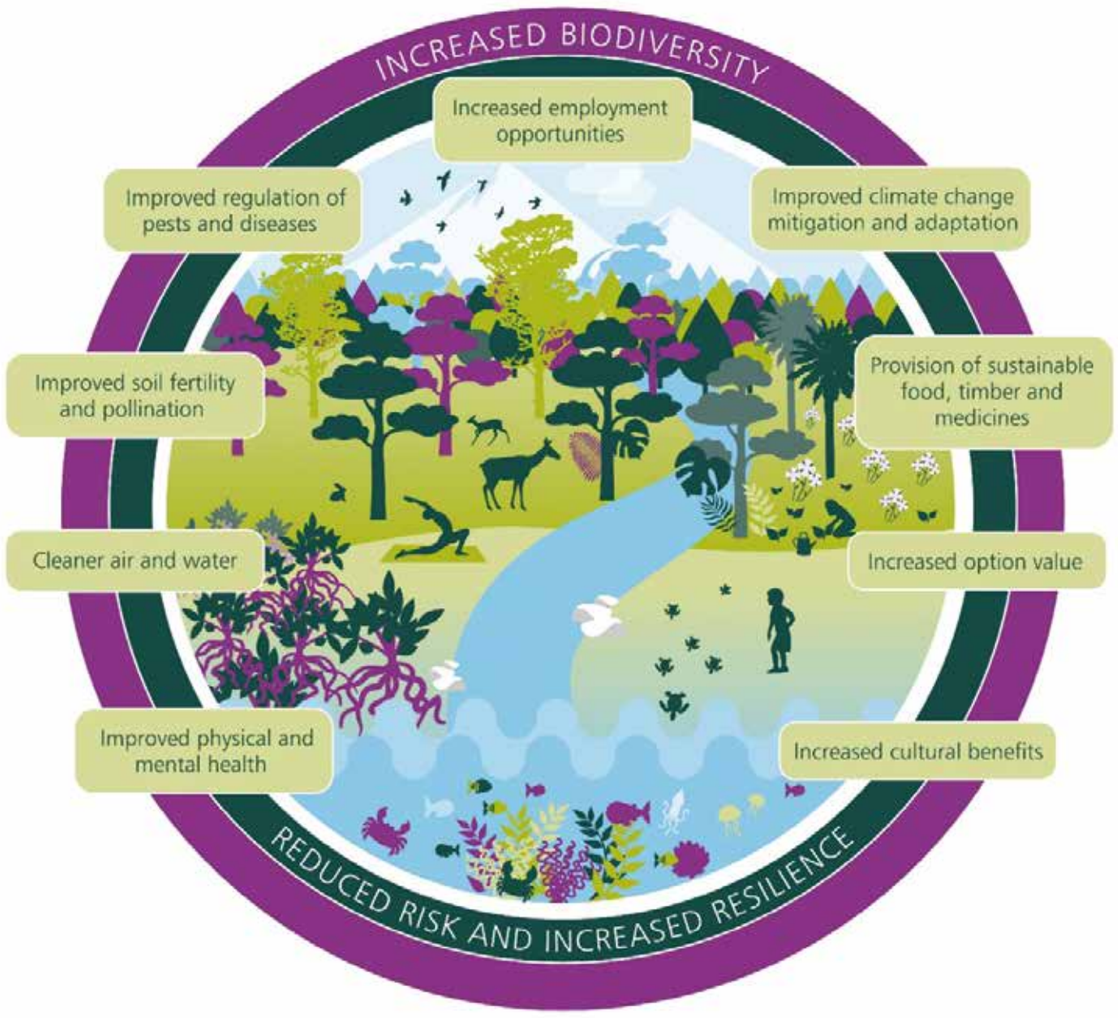
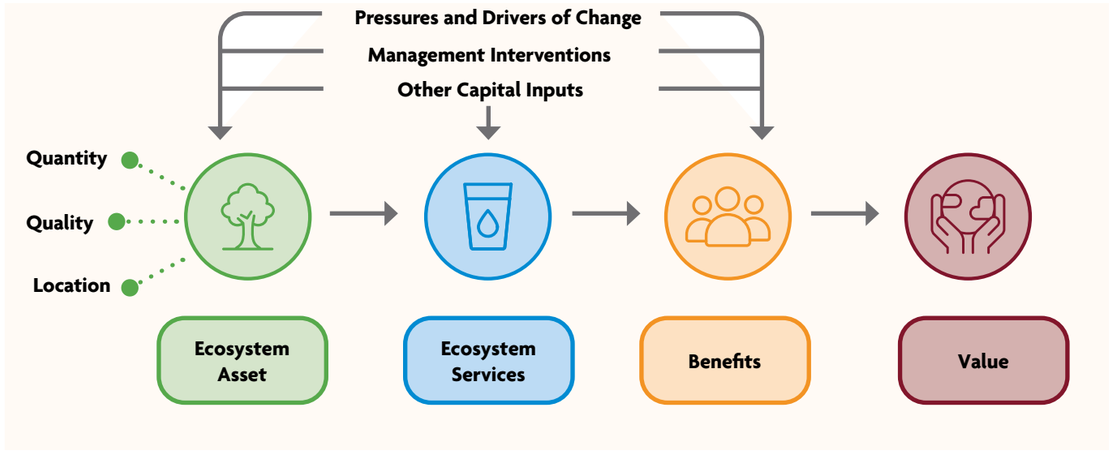


▲ **Figure 1. Increasing biodiversity reduces risks and increases resilience in the provision of benefits to people from ecosystems (Source: Dasgupta[4])**

These benefits are dependent upon the healthy functioning of ecosystems. However, evidence shows that ecosystems in England are impacted by drivers of change – past and present. We are in a triple nature, climate and pollution crisis.[1,2] The Biodiversity Intactness Index for England – summarising the change in ecological communities in response to human pressures – is at 41 per cent.[3] This shows England to be one of the most nature-depleted countries in the world. Therefore, it is essential and urgent to take account of the state of nature in decision-making across all areas of the economy and society that depend upon it.

The way in which nature underpins our society and economy is through living and non-living components interacting as an ecosystem. Ecosystems best deliver services and benefits when they are healthy and biodiverse, with a full complement of species (see **Figure 1**).[4] Loss of species reduces the resilience of ecosystems to carry out the functions underpinning these benefits. It also increases the chance of exceeding tipping points – when ecosystems move from being good-working systems to poorer, less productive ones. Once tipping points have been exceeded it is extremely difficult to recover them,



▲ **Figure 2. Natural England's Natural Capital Logic Chain based on Potschin and Haynes-Young's ecosystem services cascade.[7] (Source: Wigley *et al.*[8] © Natural England, 2019)**

and the consequences for society and the economy are considerable. It is unknown where many of these tipping points are, but many of our ecosystems are decreasing in area, degraded or declining.[5]

ESTABLISHING AN EVIDENCE FRAMEWORK

Natural England has developed a natural capital evidence framework that focuses on reporting how well ecosystems are functioning. It is the functioning of these whole systems that provides the benefits society relies on and is therefore fundamental to reporting on the state of natural capital.

Natural England's Natural Capital Indicators were designed to inform understanding of the state of natural capital.[6] A logic chain approach was used to link indicators of the state of ecosystem assets to the provision of ecosystem services and benefits to people (see **Figure 2**). This shows that the connection between how much (quantity), how good (quality) and where they are (location) underpins the ecosystem services, benefits and value people get from them.

This natural capital framework has enabled the systematic identification of robust ecosystem indicators, which underpin a sustainable flow of ecosystem services into the future. These indicators cover attributes of ecosystem quantity (extent), quality and location (see **Box 2**). Quality attributes are based on the natural processes that underpin the provision of ecosystem services and enable nature recovery.[9,10] Measuring changes in the asset indicators acts as an early-warning system of change to the flow of benefits from nature to people.

The indicators project sourced best-available data that could be used to measure the state of natural capital and highlight data gaps. These data gaps include specific quality and location indicators, as well as where data are not regularly updated or publicly accessible. Some of the existing data gaps are being filled by the Defra-led Natural Capital and Ecosystem Assessment programme, which will provide a step change in the availability and accessibility of national data for measuring the state of natural capital.

BOX 2. EXAMPLES OF KEY INDICATORS

Natural capital indicators for defining and measuring change in natural capital:[6]

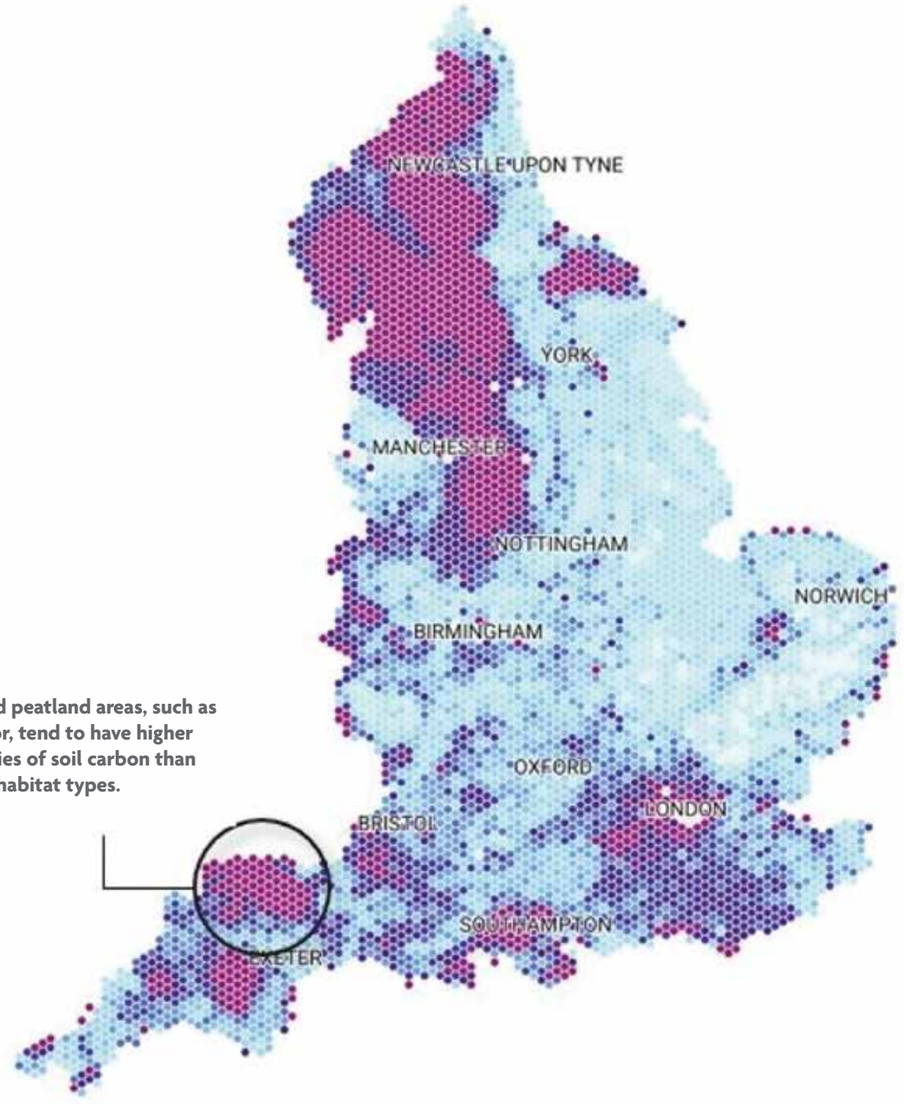
Extent of habitat.

For example, blanket bog, coastal and marine habitats, woodland, heath, semi-natural grassland, freshwaters, wetlands, and urban blue and green space.

Quality.

This includes the following:

- Hydrology and geomorphology: the naturalness of water levels, flows, flooding, extent of artificial drainage;
- Nutrient and chemical status: applies to water, soil and sediment, air;
- Soil and sediment: carbon, biota, peat depth, coastal sediment supply;
- Species composition: naturalness of biological assemblage; and
- Vegetation: cover, structure, roughness.



Upland peatland areas, such as Exmoor, tend to have higher densities of soil carbon than other habitat types.

▲ **Figure 3. An example natural capital atlas map. (Source: Wigley at al.[8] © Natural England, 2019.) Mean estimate of carbon density in topsoil (0–15 cm depth) – tonnes per hectare, mapped using data produced form Natural England and Centre for Ecology & Hydrology's Mapping Natural Capital project (2016). NB. This dataset is statistically extrapolated to a national level from Centre for Ecology & Hydrology's Countryside Survey data 2007.**

BRINGING EVIDENCE INTO DECISION-MAKING

Generating the evidence to measure and monitor the state of natural capital is one challenge. How to bring it into decision-making and act on it is another. To address this, Natural England has produced a series of natural capital atlases to provide a readily available source of spatial evidence, which are based on the natural capital indicators. Having tested this nationally and locally, a series of atlases at county and city region scale were produced (see **Figure 3**).[8,11] These make national data on the state of natural capital accessible to inform understanding of which benefits flow from which ecosystem assets across England.

Natural capital accounts are a way of organising information about natural capital to inform decision-making. They extend traditional accounts by putting an economic value on benefits that is not provided

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through the market. These accounts usually present a final balance sheet that reports on the costs and monetary values of assets. However, these values do not reflect whether ecosystems can continue to provide benefits into the future in terms of their quantity, quality and location (see **Figure 2**). To avoid the problem of partial accounts, which only report values in a final balance sheet, Natural England has developed a methodology that presents an 'extended balance sheet' showing the state of ecosystem assets, services, benefits, and their economic value next to each other.[12]

This approach can play an important role in communicating the benefits and state of assets in a place and can be helpful in informing strategic decision-making about natural capital assets.[13,14] But what if the decisions are not primarily about natural capital, yet the outcomes rely on the benefits natural capital provides? Making the state of nature central to decision-making in the departments and institutions that have an interest in the societal outcomes nature underpins is an ongoing problem for the environment sector. Bringing evidence on the state of ecosystems into this decision-making is harder still because the data are neither in one place nor are they comprehensible to wider decision-makers. This is the problem Natural England seeks to address.

THE STATE OF NATURAL CAPITAL REPORT

Natural England's forthcoming State of Natural Capital (SONC) report for England interprets the state of natural capital for decision-makers who are outside the environment sector. The report builds on the evidence framework developed through the previous indicators project in combination with the best-available data and, where there are gaps, expert opinion.

In a nutshell, the SONC report:

- Assesses the risk to England's natural capital by examining the previous and ongoing impact of key drivers of change on ecosystem assets and the benefits they provide. Where the risk is classed as very high and high, action is most urgent.
- Identifies the consequences of this risk on policy areas that are most dependent on the benefits the ecosystem assets provide. This covers six areas: economic resilience, water security, food security, net zero carbon emissions, climate adaptation, and health and well-being.
- Identifies priority actions that mitigate the risks in each of these six areas of delivery through reduction of pressures and nature recovery.
- Shows the state of ecosystem assets in terms of risk, summarises why they are at risk and identifies priority actions to tackle that risk in each ecosystem.
- Identifies specific ways decision-makers across policy can use the analysis in the report to reduce the risk to their areas of delivery by investing in nature recovery.

This SONC for England will be published later this year. It uses best-available data but is designed to use the data currently being collected by the Natural Capital and Ecosystem Assessment Programme in the future. The aim is to update the report every 5–6 years. Consistent and repeatable data are key to monitoring change and charting progress. Communicating that data and

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evidence to all areas of decision-making dependent on the state of the natural environment is also essential.

Investment in the protection and recovery of nature is an investment in England's natural capital. As with any other capital asset, acting quickly to prevent and address the degradation of ecosystem assets makes economic sense. It secures and enhances the benefits that society and the economy depend on, now and for the future, meaning it will be cheaper and more effective in the long run. The Dasgupta Review highlighted that the longer we allow ecosystems to deteriorate, the higher the economic cost of restoration will be.[4]

In England, and the UK more widely, there are various government policies, plans and targets that seek to recover nature. The UK has committed to protecting 30 per cent of land and sea by 2030, agreeing a new International Global Biodiversity Framework at the United Nations Nature Summit COP15 and the UK Environmental Improvement Plan, which sets out more details about the various mechanisms for nature recovery.[15] In England, the Environment Act 2021 has set targets to increase species abundance, reduce species extinction risk, and create 500,000 ha of wildlife-rich habitats outside of protected areas by 2042.

But there is a need to act quickly. This urgency applies to action for nature recovery and to reduce adverse drivers of change – many of which, including climate change, are rapidly increasing in severity. Pressures can push already highly impacted ecosystems towards tipping points they cannot recover from. Natural England's SONC report will show how risks to natural capital assets contribute considerable risk to other areas of delivery that are dependent on nature being in good working order. It will show that even where nature is not the primary focus, nature recovery has an essential role to play in delivering long-term outcomes for society and economy. ES

Dr Patricia Rice is a Principal Specialist in Natural Capital in the Chief Scientist Directorate of Natural England. She has worked in the specialist field of natural capital and the ecosystem approach since 2012 and is particularly interested in bringing the state of natural capital into decision-making.
✉ **patricia.rice@naturalengland.org.uk**

Jane Lusardi is a Principal Specialist in Natural Capital in Natural England's Chief Scientist Directorate. She has worked on natural capital science evidence and advice since 2009.
✉ **jane.lusardi@naturalengland.org.uk**

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CASE STUDY

Seaweed farming in Scotland

Leigh Eisler outlines some of the surprising environmental and climate benefits of cultivating seaweed.

There is nothing new about the use of seaweed in Scotland – either for food, feed or fertiliser. The earliest poem mentioning seaweed is attributed to Saint Columba while living on the Isle of Iona in 600AD, which reads:

'Let me do my daily work,
Gathering dulse, catching fish,
Giving to the poor.'[1]

For millennia, the people of Scotland, like the rest of the world, have utilised seaweed: gathering storm-cast seaweeds to spread on their lazy beds (a traditional, now unused method of farming on the coasts of Scotland and Ireland, seen as long furrows in the land today) or gathering Irish sea moss (*Chondrus crispus*) at low tides to make carrageen pudding. It is common to see sheep, goats and Highland cows eating washed-up oarweed (*Laminaria digitata*) or forest kelp (*Laminaria hyperborea*). Many small reefs and skerries (rocky islands) on the west coast are named in Gaelic according to the seaweed that grows on their rocky surface, as they were once a valuable resource to the rural coastal communities. Many seaweeds contain a high vitamin C content, scarce in the depths of winter along Scotland's coasts.

Within the last few centuries, kelps (referring to larger brown seaweed species) were burned in great piles for their ash content – first to create glass and soap, and later for extracting their iodine content. There was also a short-lived industry on the west coast of Scotland extracting alginate from harvested wild kelps.[2]

▲ **Figure 1. Aird Fada seaweed farm in Loch Scridain, off the coast of the Isle of Mull, Scotland. (© South West Mull and Iona Development)**

The act of deliberately cultivating and farming seaweed is new, however, to Scotland and to the UK more widely. The first seaweed farm was installed in Scottish waters in 2013 by the Scottish Association for Marine Sciences (SAMS).[3] By comparison, seaweed farming has been taking place in Southeast Asia for centuries – the result of a cultural reverence for eating seaweed, something that the UK and Europe has lost.

There are more than 600 identified species of seaweed in British waters, but fewer than 30 species are of commercial interest and even fewer are cultivated at scale.[4] The life cycles of the three groups that comprise seaweeds (red, green and brown) are complex, to say the least, providing a significant barrier to overcome. There are currently three native, brown seaweed species that are commercially cultivated in the UK:

- Winged kelp (*Alaria esculenta*), also known as dabberlocks and Atlantic wakame;
- Sugar kelp *(Saccharina latissima*), also called sea belt, or sweet kombu in Japanese cuisine; and
- Oarweed *(Laminaria digitata*), also referred to as tangle or kombu.

At Aird Fada, South West Mull and Iona Development (SWMID)'s farm on the Isle of Mull (see **Figure 1**), both winged and sugar kelps have grown successfully, and there is an abundance of wild seaweed species growing on the farm infrastructure, including oarweed.

KELP FORESTS

All three kelp species are found in kelp forests. In the wild, these forests create a dense habitat, providing shelter and a food source for all manner of species. These forests also act as buffers for coastal erosion: the morphology of the kelp fronds means they absorb energy in the water and reduce the impact of waves on the coast.[5] In the face of climate change, ocean acidification, rising waters and worsening weather, Britain's kelp forests can potentially reduce the severity of storm impacts.

However, we are losing kelp forests around the world to climate change. For example, winged kelp prefers cold water, and the boundaries of its habitats have already begun to recede northwards.[6] Warming waters also bring the threat of disease and increased predation upon kelp by molluscs such as the lacuna or banded chink shell (*Lacuna vincta*) and blue-rayed limpets (*Patella pellucida*).[7]

This threat is an issue for both wild and cultivated populations. Currently, there are no known diseases that afflict cultivated kelps in Britain, but warming waters could enable devasting infections.[8]

SEAWEED FARMING

All the cultivated kelps follow a similar seasonal growth pattern. For Aird Fada, kelps are initially grown at the SAMS seaweed nursery from spores to miniscule sporophytes, which embed themselves in twine. Come autumn, spools of sporophyte twine are deployed at the farm, wound around 100 m growing ropes that are suspended between headlines (parallel surface ropes used in aquaculture structures) at depths of 2–3 m. In the winter, they grow slowly as sporophytes, which settle on their growing-rope substrates.

Following midwinter, the growth rate increases proportionately to the day's length, with the sun's rays penetrating deeper into the water column. In early spring, there is an upsurge of nutrients – particularly nitrates and phosphates – that is buoyed up from the depths. The combination of cold March waters, nutrient surge and lengthening daylight creates the optimum growing conditions for kelp. The kelp absorbs the nutrients and sunlight and begins to grow rapidly – from around 40 cm in February to over 3 m long in May.

With nutrients and warming waters in April, come plankton and the onset of biofouling – the annual settling of a multitude of species on the seaweed surfaces in late spring, early summer. This is perfectly natural and expected but considerably limits yield. The biofouling species commonly observed at Aird Fada include epiphytic algae (other seaweeds that grow on top of kelps); bryozoans (colonial animals that form mats); hydroids (relatives of jellyfish, which grow in feather-shaped or branching colonies); sea squirts; and crustaceans (see **Figure 2**). These species all degrade the quality of the kelps: bryozoan mats deprive the fronds of large areas of photosynthesis, while other species begin to graze on the kelps, making the fronds brittle and prone to disintegrating. In natural kelp forests this is part of the annual cycle and a key component of the sprawling and complex food web; nevertheless, it is an issue to be avoided in seaweed farming because it reduces seaweed quality and, in turn, its end use.

As climate change warms the water, plankton blooms begin earlier each season in British waters, bringing on

▲ **Figure 2. Close-up of bryozoan fouling on a blade of sugar kelp. (© South West Mull and Iona Development)**

▲ **Figure 3. European shag resting on the structure of Aird Fada seaweed farm. (© South West Mull and Iona Development)**

biofouling sooner and limiting the harvesting window and, consequently, the maximum yield.[9] This early onset of biofouling will likely have a similar detrimental effect on wild seaweed populations – the growing window between winter and spring will shorten, reducing wild populations' ability to grow and synthesise the compounds that reduce or prevent biofouling.

Some species are more robust and stave off biofouling for longer than others. At Aird Fada observations show that winged kelp experiences considerable biofouling a month before sugar kelp; the exact reason for this is unclear, but there is speculation that the high iodine, alginate and mannitol content of sugar kelp deters fouling species, while the higher protein content of winged kelp makes it a more desirable food source.[10] Both species can become completely carpeted in biofouling before the height of summer, disintegrating to leave only stipes (the stalk-like part of seaweed that connects the fronds to the holdfast, which is a claw-like structure that grips the seaweed's substrate) and nothing sellable. In the wild, earlier biofouling will reduce the size that wild seaweeds will reach – increasing their susceptibility to predation. This results in a decreased population in winter, which would be less resistant to storms. Beyond the kelps, early biofouling will reduce habitat sizes for other species including commercial fish stocks.

ENVIRONMENTAL MOP

All seaweeds behave like a mop: they readily absorb nutrients and minerals from their environment. In areas where nutrient levels are abnormally high, unicellular algae and cyanobacteria, or species like sargassum, absorb nitrogen and phosphorous. They then reproduce rapidly, creating blankets on the sea surface that can deprive the surrounding area of oxygen and cause eutrophication, which kills other organisms. However, this characteristic has great potential to be harnessed for bioremediation through the careful selection of native species and ocean placement.

A significant issue facing humanity is a lack of synthetic fertilisers, particularly phosphorous.[11] Those fertilisers, along with other agricultural run-off, seep first into rivers and then into oceans, leading to toxic and problematic blooms. By locating seaweed farms near outlets of agricultural run-off, in conjunction with farming shellfish such as oysters and mussels, there is potential to recover valuable elements like nitrogen and phosphorous, as well as reduce run-off into our oceans. This helps to prevent eutrophication and the associated blooms, clears up harmful bacteria and clarifies the water while also re-oxygenating it. A noteworthy hindrance to this application is what can ultimately be produced from the seaweed and shellfish farms: as both would be utilised to absorb and filter harmful contaminants and microorganisms, neither would be suitable for food or animal feed. It can be argued that the shellfish should be allowed to remain in situ, scrubbing the ocean, while the best application for the seaweed would be as a fertiliser – creating a loop which, in part, would recycle run-off from farms.

ECOSYSTEM SERVICES

The primary goal of seaweed cultivation is to harvest it and create a product – either a food product, an additive for animal or fish feed, or a feedstock for biorefining or processing into a fertiliser. These applications require a seaweed that is either completely unfouled (especially for food or animal feed uses) or with minimal biofouling. Despite the limitation imposed by biofouling, seaweed farms can still provide a net positive ecosystem service to their environments.

The greatest volume of biodiversity witnessed on seaweed farms is during peak biofouling: the arrival of colonising species brings predators and grazers. At Aird Fada, when it is past optimal harvesting time, sand eels have been observed shoaling around the growing lines, which are followed by mackerel, seals and dolphins. Shags, eider ducks, terns, gulls and more have been seen resting on farm structures or flocking at the surface (see **Figure 3**). There is little doubt that seaweed farms provide an ecosystem service, boosting local biodiversity.[12]

However, there are limitations to this service. Unlike in wild settings, most of the seaweed will be harvested before it can provide a habitat for a complex ecosystem to spring from. There is also a potential risk of the (current) monoculture nature of cultivating kelps, and hard lessons have been learnt from such agricultural practices. Kelp monocultures can limit the biodiversity that can occur at seaweed farms – natural kelp forests are dense like the kelp grown on farms but the former are composed of multiple seaweed species.

An ongoing trial at Aird Fada involves deploying bare growing ropes to observe the settling rate of wild seaweed species, as well as the variety of seaweeds and other associated organisms. There is potential to engage with this wild settling to create an 'ocean hedgerow', which would provide a more natural habitat than the growing lines. These hedgerows could act as buffers at seaweed farms, while also providing a more permanent habitat. There is currently no commercial incentive to pursue ocean hedgerows, other than for the exploitation of wild, valuable species such as dulse (*Palmaria palmata).*

Given a seaweed farm's ability to provide ecosystem services by creating habitats and food sources, seaweed's capacity to absorb problematic nutrients and metals, as well as its photosynthesis process, which reoxygenates the water and reduces acidity, it is important to recognise these factors for being as valuable as the products seaweed can create. There is a new market emerging – the Natural Capital Marketplace – which could incentivise the inclusion of ocean hedgerows at seaweed farms, as well as the valuation of seaweed farming's ecosystem services.

SUSTAINABLE SEAWEED FARMING

To maximise the myriad benefits of seaweed farms, numerous aspects of the farm and the act of farming need to be undertaken carefully to ensure sustainability. These include:

- **Site selection**. Dense seaweed farms cause benthic (sea floor) shading, making it important to find a site where a farm will not impact the seabed. The distance between launch and landing locations should also be considered – the further the site, the more fuel required for visits and operations.
- **Material selection**. This is also crucial. It is difficult to use materials other than virgin plastic for seaweed farm infrastructure. Reusing materials where possible, finding multi-use alternatives and designing systems that reduce the amount of plastic deployed would be ideal.
- **Growing lines**. Their volume, configuration and density should be considered with respect to marine life entanglement. Loose lines, or lines close together come with a risk of larger marine organisms getting tangled. To date, there have been no reported incidents of marine life entanglement at seaweed farms.

Sustainable seaweed farming goes beyond the actual farming aspect. The considerable hurdles faced lie with efficient harvesting and landing, as well as with processing down the line.

AIRD FADA: A COMMUNITY VENTURE

In 2017, the idea of a community-owned seaweed farm was suggested to SWMID during a public consultation. There is a great need for industry diversification in Scotland's Highlands and Islands and it was recognised that seaweed farming was coming to coastal communities. The community decided to proceed with seaweed farming, to be run by SWMID with the following goals:

- Attract and retain people of working age to maintain a sustainable community;
- Increase job opportunities and year-round employment; and
- Enhance and protect the environment.

The community has been involved and consulted throughout the process – from the leasing application to licensing, commissioning and operating the seaweed farm. It was important to SWMID to involve the local creel fishing fleet – Loch Scridain is important to the local

CASE STUDY

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inshore fisheries, and it was imperative the seaweed farm did not impact their catch. The seaweed farm location was chosen by the fleet operators following suggestions provided by SAMS, and their knowledge of the loch for deployment of seeded lines and skills during harvesting have been invaluable.

The farm has been supported by several grant funds, including the European Maritime and Fisheries Fund, the Co-op Foundation's Carbon Innovation Fund and the Argyll and Bute Island Infrastructure Fund.

SEAWEED FARMING'S BRIGHT FUTURE

While there is great interest in seaweed applications, and the seaweed farm itself, the UK market is still in its infancy and struggling to compete with cheaper seaweed imported from Asia. Yet there is great potential in seaweed farming, despite what Virgil said: '*Nihil vilior alga*', meaning 'there is nothing more worthless than seaweed'.[13] Seaweeds have a wide range of applications and provide many benefits in the ocean, making them an invaluable resource in the face of climate change.

There are challenges facing the immediate future of seaweed farming, with many technological innovations needed to overcome bottlenecks in harvesting and processing. A cultural revolution also needs to occur in the west: there need to be innovations in seaweed cuisine to make it more palatable to non-seaweed enthusiasts. In British waters, seaweed farming has the potential to improve our coastal water conditions and regenerate commercial fish stocks. Mitigating human influence on the oceans will allow for wild kelp forests to flourish, and improved water quality will aid the regeneration of seagrass meadows. The cold Atlantic waters around the UK can support a strong seaweed industry, provided there is adequate funding and support for seaweed farmers. ES

Leigh Eisler is the Operations Manager for SWMID's Aird Fada seaweed farm. She holds a BSc (Hons) in Molecular Biology from the University of Dundee and is passionate about her environment on the Isle of Mull.

✉ **leisler@swmid.co.uk**

https://swmid.co.uk

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Rewilding our land and seas

Rob Stoneman reflects on what we have achieved and how much we still need to do to rebalance nature.

ANALYSIS

WHAT IS REWILDING?

Summer 2023, South Devon. All around is a typical landscape of rolling lowlands: bright-green fertilised pasture with the occasional field of maize or potato. At the edge of one field, a line of trees marks a watercourse. Like most British streams and rivers, this one had been channelised and was now barely discernible – a ditch acting as a receptor for the field drains that kept this once-floodplain land dry enough for pastoral or arable farming. In truth, any understanding of what that land had once been, written or passed down through the generations, has been lost. The scene is green and pleasant, but largely devoid of wildlife.

▲ **Beaver wetlands on a tributary of the River Otter, Devon. (© Rob Stoneman)**

The next field over is flooded with shallow water and covered with pink and purple wetland flowers. A green sandpiper angles across it; a heron rises lazily into the air; the little egrets walk out of view to hunt for frogs and fish; and all around damselflies and dragonflies patrol the scene in abundance. This transformation has come about in just 18 months, to the delight of nature lovers and to the acquiescence and acceptance of the landowner who switched the field from state-subsidised pasture to a state-subsidised agri-environment agreement for nature restoration.

The restoration works required no planning permission, no negotiations, no impact assessments; it cost nothing and was effected almost immediately. The ecological engineering that created such an impressive recovery of wildlife, re-naturalising the stream and reconnecting it to its floodplain for perhaps the first time in centuries, had nothing to do with human endeavour. Ecological balance was restored simply by allowing beavers to migrate up this small tributary of the River Otter – a wonderful example of rewilding.

But what is rewilding? The first mention is traced to a 1990 *Newsweek* article, and later clarified to define it as a 'scientific argument for restoring big wilderness based on the regulatory roles of large predators' and emerged from work in the USA focusing on the 3Cs of rewilding: cores, corridors and carnivores.[1,2] This definition resulted from a cascade of ecological impacts arising from the reintroduction of wolves to Yellowstone National Park, which altered the behaviour of elk – one of the big wild herbivores in the park. Elk, or wapiti (*Cervus canadensis*), favoured the open plain to the riverside for its 360-degree escape route – as opposed to the 180-degree route on the riverbank – allowing riverine vegetation to rebuild. In turn, more woody vegetation led to more beavers creating new wetlands and to more bison browsing the woody vegetation on the open plain, substantially increasing the diversity and abundance of wildlife in the park.[3]

In Europe, rewilders have taken a broader approach, perhaps reflecting that large wilderness areas such as those found across North America, Africa and Australasia do not really exist in Europe. A useful European definition of rewilding is a 'strategy [that] aims to restore self-sustaining and complex ecosystems, with interlinked ecological processes that promote and support one another while minimising or gradually reducing human interventions'.[4] This definition is based on three critical components of natural ecosystem dynamics – trophic complexity, stochastic disturbance and dispersal – on the basis that the 'restoration of these processes, and their interactions, can lead to increased self-sustainability of ecosystems and should be at the core of rewilding actions'.[4]

Rewilding can therefore be seen as those interventions that restore the random natural processes of wilder systems, that reconnect species to aid dispersal, and that restore species interactions through, for example, the reintroduction or reinforcement of lost species from the system. In turn, this sets up a continuum of rewilding in which interventions allow land and sea to revert to a more natural state.[5]

30 X 30

The UK Government was part of the 'high ambition' group at the 2022 United Nations Biodiversity Convention (COP15), which resulted in the Kunming–Montreal Global Biodiversity Framework Agreement. This group was successful in gaining agreement for two critical targets, often referred to as the 30 x 30 targets, that: (1) 30 per cent of ecologically degraded land and sea should be restored by 2030; and (2) 30 per cent of land and sea should be protected for their biodiversity.

Given that the UK's seas and land are nearly all degraded in some way, the two targets are roughly interchangeable, although the UK could aspire to a greater proportion of land and sea under restoration than 30 per cent. At times, the UK Government has noted that 28 per cent of land is protected for nature, but this includes National Parks and Areas of Outstanding Natural Beauty (AONB), which have no specific provisions to protect nature. Wildlife and Countryside Link considers that only 3.11 per cent of English land can be considered protected in a way that restores nature, encompassing those Sites of Special Scientific Interest (SSSI) that are in good condition.[6,7] Even with the strong provisions for restoration management mandated through the Countryside and Rights of Way Act 2000, designation has failed to stop nature degradation across much of the SSSI network.[8]

Given such a dire record, the 30 x 30 aspiration feels impossible to achieve, considering most land (71 per cent in the UK[9]) is given over to farming. With concerns raised over food security following Russia's invasion of Ukraine, there appears to be little room for nature's recovery in the UK.

However, as the Dimbleby Report noted, the least-productive 20 per cent of UK farmed land produces only 3 per cent of calories consumed in the UK.[10] This land could be released alongside renewed efforts to restore nature on SSSIs and within National Parks and National Landscapes (formerly AONBs). Marginal agriculture is significantly subsidised by the UK Government (now mandated through the Agriculture Act 2020 in England following the UK's departure from the EU). Likewise, the Welsh Government notes that:

'Less favoured area (LFA) cattle and sheep farming is completely reliant on income from subsidies (basic payments and agri-environment payments) and diversification, as farming is not profitable on LFA land (agricultural production generates an average net loss of £700 a year). For these farms, subsidies provide 88 per cent of average farm income'.[11]

A change in agricultural support towards nature's recovery rather than directly subsidising food production would appear to be a simple step towards achieving a 30 x 30 target and would have minimal impact on UK food production. Indeed, in many cases, low-intensity grazing would be part of a nature recovery system, allowing a continuation of food production but at a lower level.

One of the issues is the sheer complexity of making that switch. The agri-environment provisions in England offer hundreds of options within different schemes and over various time lengths. There is little support (advice) available to farmers outside paid agronomy services and grant-aided geographically and time-limited advice programmes, while the concept of whole-farm support has not been brought into new arrangements. Conservationists are advocating for a return to the original ambition of the agricultural transition plan, that the Government set out following the UK leaving the European Union, while recognising that farmers need support for that transition.[12,13]

Rewilding provides a solution through this morass. Interventions to restore natural processes can be straightforward and cost effective to put in place and can operate across the whole farm. UK examples show that rewilding can lead to a remarkable restoration of biological abundance and diversity. The most famous example is the Knepp Estate in Sussex, where arable farming was replaced by a wilder grazing regime deploying hardy cattle breeds, Exmoor ponies and Tamworth pigs (acting as proxies for auroch, tarpan and wild boar). Within a few years, Knepp held the largest populations of very rare bird and butterfly species in southern England, such as turtle dove, nightingale and purple emperors.[14]

REWILDING BENEFITS: DEVON'S BEAVERS

New beaver-created wetlands show a remarkable increase in species abundance and diversity. An enclosed beaver release in Devon transformed a small channel across a mainly pastoral field with minimal wildlife into a wet woodland mosaic over a few years.[15]

For example, bat species that started to use the site after beavers were released included Natterer's and barbastelle bats, with more intensive use by commoner bat species in relation to the surrounding land. This increase in bat diversity and abundance almost certainly relates to a higher invertebrate abundance following wetland expansion. Beetle diversity increased from eight species in the pre-beaver fields of 2011 to 26 species by 2015, after beavers had been introduced, progressing from indicators of seasonal stream generalists to more complex communities of beetles associated with natural heathland streams and seasonal flushes. This included finding a nationally scarce species – *Hydroporus longicornis* – that is usually associated with natural watershed mires. Similarly, bryophyte abundance increased from 43 to 55 species in just three years as the beaver wetlands expanded.[16]

This increase in habitat and species complexity has numerous other benefits. Flood peak attenuation benefits can be measured by comparing stormwater flow peaks of the channel entering the enclosure with that leaving it. Beaver habitat attenuated flows by 70 per cent. This pattern persisted even during prolonged wet periods, with flood attenuation regulated by increased flood storage and reduced flow through the beaver 'leaky' dams and beaver ponds. Reduced peak flows on mainstream tributaries are likely to have a significant impact on main river flood peaks and ultimately on downstream flooding.

The impact of the beaver-modified habitats could also be assessed in relation to water quality using a similar method. Above the beaver enclosure, water quality was poor with typically high agriculturally derived levels of nitrogen, phosphorous and carbon. All of these were substantially reduced as beaver dams and wetlands filtered out pollutants and allowed sedimentation in ponds.

WILD ENNERDALE

Wild Ennerdale is a partnership between the main landowners in the valley – Forestry England, National Trust and United Utilities – working alongside Natural England and others to create a single landscape scale vision and management approach. Previously, the valley had been characterised by Sitka spruce plantations and heavy sheep grazing. Under the Wild Ennerdale banner, the management approach has switched to allowing natural processes shape the landscape and its ecology. For example, sheep grazing has been substantially reduced and partly replaced by low numbers of bigger herbivores

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such as Galloway cattle that now mimic the lost aurochs (wild cattle) that once roamed this landscape. Rewilding interventions include river and wetland restoration, deer control and spruce tree removal.

Over two decades, this has seen the return of wildlife in abundance, reflecting a much more diverse landscape. The valley remains productive, supporting forestry, farming and tourism, with the Wild Ennerdale brand increasingly used to support tourism activities.

WILD KEN HILL

On the North Norfolk coast, a private landowner has redeveloped his farm into three distinct systems: an area that supports traditional nature conservation focused mainly on wetland birds; another that focuses on regenerative agriculture; and a third that is being rewilded. The rewilding approach was to manage the recovery of wildlife through the natural processes of extensive grazing using a mixed group of animals – Red Poll cattle, Exmoor ponies and Tamworth pigs – and using enclosed beavers to establish natural wetland systems. Monitoring has shown that the diversity of plants has doubled in just three years, demonstrating the effectiveness of the rewilding approach for ecosystems.[17] Moreover, this wonderful rewilding landscape now forms the backdrop for an expanding nature tourism venture.

HIGHLY PROTECTED MARINE AREAS

One of the easiest ways to intervene to re-establish natural processes is to remove those human pressures that work against natural processes – for example, removing a flood bank to reconnect a river with its flood plain in order to restore natural flood dynamics. At sea, these interventions are particularly effective because the other two axes of rewilding – trophic (food chain) interaction and dispersal ability – are still broadly in place. Highly protected marine areas are designed to ensure that all damaging activities – fishing, mining, digging, cabling and offshore development – are removed or banned from an area. Highly protected marine areas (HPMAs) are extremely effective across the globe and more so than partially protected marine areas.[18,19]

One of the more important co-benefits of HPMAs are the so-called spillover effects. Because HPMAs allow sea fauna and flora to develop and mature, these more mature adults breed more successfully, such that populations of marine species increase both inside and outside HPMAs.[20] This spillover effect has an important role in restoring fisheries.[21] For example, one study showed that the spillover effect compensated for the loss of fishing within the HPMA and added a further 10 per cent to catches.[22] Given that 15 per cent of animal protein eaten by humans comes from marine fishing and that 90 per cent of the world's fisheries are over-fished, the rapid deployment of HPMAs across the planet is an urgent priority.[23,24]


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CONCLUSIONS

Rewilding provides a cost-effective approach to substantially increasing nature's recovery in line with global commitments made through the Kunming–Montreal Global Biodiversity Framework. This is especially relevant in countries such as the UK where nature has been so depleted. In many parts of the UK, soils are too poor for economically rational agriculture. Here, rewilding provides a realistic way forward to achieve nature recovery aspirations *and* a just transition for farmers.

Rewilding can produce a range of highly significant co-benefits, as the examples above show. These include flood attenuation, carbon sequestration or reduced carbon emissions from land use, water quality improvements, fisheries development and tourism. These natural solutions to some of society's more intractable issues also provide the basis for a just transition for marginal soil farmers and fishers faced with reducing and changing public subsidy regimes. Rewilding provides a cost-effective key to unlocking new non-market public benefit subsidies, green finance revenues such as carbon or biodiversity credits, and nature and landscape tourism revenues. Importantly, rewilding does not have to preclude food production, as natural processes (such as wild grazing) can be emulated to produce high-quality, low-food-mile and culturally important food that can supplement continued bulk commodity food production on more productive soils elsewhere in the UK.

These are the multiple wins of rewilding. ES

Rob Stoneman started his nature conservation career with the Scottish Wildlife Trust, seeking to secure a better future for Scotland's lowland raised bogs. He then took on chief executive positions for various Wildlife Trusts – Sheffield, Hampshire & Isle of Wight, and Yorkshire – as well as working with Rewilding Europe. He is currently Director of Landscape Recovery for The Wildlife Trusts.

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FEATURE

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England's threatened chalk streams

Charles Rangeley-Wilson tells us why these distinctly English rivers are so special and how we can restore them to their former splendour.

It barely needs repeating that chalk streams are a special freshwater ecosystem, exclusive to England and our neighbouring corner of north-west Europe. There are a few chalk streams in France and Denmark, but most are found in England.

The World Wildlife Fund (WWF) highlighted this globally unique status in its 2009 campaign Rivers on the Edge, describing these streams as our rainforest and our responsibility.[1] That idea caught the public and political imagination and there was a strong drive to restore these precious streams to health. However, 15 years later and they are still very much rivers on the edge.


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WWF's 2009 campaign was not the first. Colonel G.K. Maurice wrote about the impacts of abstraction on the River Kennet in 1947 in a story he called *Passing of a River – an Obituary*.[2] The late Richard Slocock campaigned throughout the 1980s against over-abstraction from the River Piddle in Dorset. For many years river groups like the River Beane Restoration Association, the Ver Valley Society and the Darent River Preservation Society have campaigned on behalf of their beleaguered rivers.[3,4,5]

Spurred into action by all these campaigns, in 1993 the National Rivers Authority, forerunner of the Environment Agency, published a report into low flows caused by over-abstraction of English rivers.[6] Fifteen – almost one-third of the case studies – were on chalk streams. The scale of the problems were analysed and solutions proposed: providing compensation flows or turning down pumps in the summer. These were superficial measures and not enacted on all rivers, which means that in 2024, 11 of those 15 rivers still do not pass ecological tests for flow. Low flow caused by over-abstraction is only one manifestation of this struggle between nature and the demands of society. Chalk streams flow through a heavily urbanised, industrialised and farmed landscape. They are impacted by sewage effluent; by road run-off and agricultural diffuse pollution; by the drainage and ditching of their catchments; by invasive non-native species; and by intensive fishery management, to name a few of the headline pressures.

CHALK STREAMS ACROSS TIME

Chalk streams were formed by a serendipitous collision between geology, tectonic activity, erosion and climate. Chalk was laid down in prehistoric seas as the supercontinent of Pangea drifted apart. Sea levels were already much higher relative to the land than they are now. Tectonic activity drove them higher still, creating inland waterways across much of the continental landmass, including what eventually became Europe. In these sunlit, clear-watered seas swarmed billions of tiny planktonic, single-celled shellfish called coccolithophores, each protected by a dozen microscopic shell-like shields called coccoliths. These shields – individually invisible to the naked eye – rained down to the ocean floor over millions of years to form a deep, porridgy, calcareous ooze that hardened over time to become the softest, whitest limestone that we know as chalk.

The Earth cooled. Ice caps formed. Sea levels retreated, exposing the old sea floor as undulating uplands of chalk. The ice caps grew. Glacial bulldozers ebbed and flowed over the European landmass, wearing away the rocks until the only parts of that prehistoric sea floor that remained at the surface were the edges of a worn-down basin of chalk exposed in an arc that reaches across England from Bridport to Bridlington.

CHALK STREAM ECOSYSTEMS TODAY

Chalk streams rise where there are chalk outcrops, creating spring-fed streams that should be fridge-cool, alkaline, mineral-rich, clear as gin and almost inexhaustible: perfect conditions for an astonishing diversity of wildlife. Chalk streams are still, despite their ills, the most biodiverse of British river systems, bringing together upland and lowland ecologies. Think about it: chalk streams give us salmon that swim past the Houses of Parliament.

In addition to salmon, chalk streams are home to fish species as diverse as freshwater and sea trout, grayling, dace, brook-lamprey, pike, perch, chub, minnow and bullhead. Chalk streams are also vital habitat for our increasingly endangered native, white-clawed crayfish. They are global hotspots for rare insect species, like the winterbourne stonefly and scarce brown sedge, which have adapted to the distinctive winterbourne habitat (streams that tend only to flow in the winter months) of seasonal wetting and drying as the water table rises and falls along porous chalk valleys. They are habitat for the balletic mayfly (*Ephemera danica*) and other species of up-winged flies. Finally, chalk streams are home to water voles and otters; increasingly nowadays, they are also home to beavers.

Representative chalk stream plants include the English tree species that best tolerate wet conditions – the sculptors of our chalk streams: oak, alder and willow. Within streams are the iconic water-crowfoot (also known as ranunculus), whose constellations of white daisy-like flowers cover the water surface in spring. Then there are those tresses of starwort and mare's tail sashaying in the gentle flows. Along the banks are parades of yellow flag iris, like celebration-day bunting, purple loosestrife, water mint, water forget-me-not, marsh marigold, hemlock water-dropwort and many others.

RESTORING CHALK STREAMS

Key to understanding the evolution of chalk streams and to unlocking a future in which we make and keep room for these delightful rivers is recognising the degree to which the physical stream and the myriad species of animals and plants that occupy its habitats have evolved in symbiosis; how the stream has shaped the ecology and, in turn, how the ecology has shaped the stream – together forming the dynamic equilibrium that is a healthy ecosystem.

Generally, the way in which humanity has modified these streams has inhibited that dynamism and balance. A simple example would be the mills with which we staircased the steady slope of river gradients, turning fast-flowing water into ponds. We had built over 5,000 mills on our chalk streams by the time William the Conqueror invaded in 1066. Another example would be eutrophication caused by nutrient enrichment; too much fertiliser and the ecology skews sideways, algal blooms hoover up the oxygen from the water, suffocating the stream's ecological workforce: the plants, insects and fish. Today, through the combined impacts of over-abstraction, pollution and modifications, that natural process and dynamism of chalk streams is either shackled or has been erased.

Counting all those named on Ordnance Survey maps, there are about 275 chalk streams in England, ranging in size from rivers to rills. Of these, at least one-third are over-abstracted to the point where flow does not support a healthy ecology. Roughly a third have phosphorus concentrations – deriving mostly from human sewage and farm run-off – that prevent a healthy ecology, and significantly more have been so modified by dredging, weirs and canalisation that they cannot support a healthy ecology.

Generally, these are underestimations of the real scale of the problems chalk streams face. All chalk streams are adversely impacted by human activity. Most of those around London dry over unnatural lengths every summer and almost completely during periods of drought. In the town of Baldock, Hertfordshire, lie the remains of perhaps the most beleaguered chalk stream of all – so radically damaged that it cannot fail its ecological flow targets, because you cannot measure what is not there anymore . This is (or was) the River Ivel.

But if the Ivel is an extreme case, all chalk streams have been modified, dredged, ditched and canalised over past centuries and recent decades. *All* are abstracted, at least to a degree; some to a terrible degree. *All* are polluted; many by the cause célèbre of pollution in today's media, illegally released raw sewage, but many more with the ubiquitous, stealthy and perfectly legal discharges of scantily treated sewage from small works in rural headwaters. Then there is road run-off. The

diffuse pollution from farming. The invasive species, like the signal crayfish and Himalayan balsam. The list goes on…

STRATEGIES FOR RESTORING CHALK STREAMS

One thing is obvious, however: we must address all these ills together in the light of a thorough understanding of the relative impacts, costs and ease with which they can be addressed. The money we spend restoring flow and improving water treatment will yield much more impressive results if we restore the physical habitat of our streams too.

In recent years the catchment-based approach has developed a collaborative way of dealing with these intransigent problems through the creation of a national restoration strategy involving grassroots stakeholders, environmental non-governmental organisations, government agencies and industry.[7] The strategy is based on a so-called trinity of ecological health: natural flow, clean water and good physical habitat. It has identified a simple list of key actions under each heading: a flagship flow restoration project in the Chilterns, for example, to pioneer the concept of realigning abstraction on a regional scale; making chalk streams a high priority when it comes to addressing the impact of storm overflows; or ensuring that technical guidance in road management programmes takes account of chalk streams. It is hoped that bringing these disparate groups together will mark a step change in progress.

Focusing on the most essential things that are well within our grasp right now, we desperately need policies that address the 24/7 drip-feed of phosphorus-rich discharges from small sewage works to rural streams. Despite overall phosphorus discharges from sewage having dropped by 66 per cent between 1995 and 2020, few of these reductions have been made at small works in rural headwaters.[8] These have been ignored for far too long because of economic models that value investment relative to numbers of people, not the needs of nature. And yet these small sewage works have a significant, insidious impact.

We also need much better protection from farm run-off through simple measures like intelligent buffers that are based on site-specific risk. Currently our farming rules specify 1 m buffers along watercourses. But run-off

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FEATURE

can reach a river from miles away over road and ditch networks. Buffer strips should be 5–10 m deep and sited at the points of high risk, no matter where they might be. We should push for policies that intelligently realign abstraction pressure, but on a regional scale so that water tables can recover. To date we have reduced abstraction from chalk aquifers by about 100 megalitres relative to the dark days of the late 1980s, but we have made those reductions in a piecemeal fashion and in only a few places by enough to restore flows in a truly manifest way.[9,10] The River Piddle in Dorset is one of the few examples of a river where abstraction reduction and flow augmentation have had an obvious impact. Those realignment ideas exist; with collaborative will we can reduce abstraction in headwaters and move it to points further down valleys, where floodplain water tables are higher.

As much as possible we should physically restore and make space for chalk streams and manage their floodplains more intelligently, increasing their ability to capture and store carbon and to hold on to water. We should reconnect our chalk streams to their floodplains too by releasing them from their canalised straitjackets and by rebuilding meandering channels so that the streams can flow swiftly, flush sediment, and escape their channels in high flows.

The public's concern for chalk streams has never been greater. Politicians are now taking this seriously. Sections of the Government's Environmental Improvement Plan and Plan for Water are dedicated to chalk streams.[11,12] Chalk streams are also a high priority in the national framework for water resources, a pioneering plan to secure water resilience for people and nature over the next 50 years. And chalk streams are identified as high priority sites in the Storm Overflows Discharge Reduction Plan.[13]

Ofwat recognises that the cost of water must reflect its environmental value. Water companies have stopped quibbling about the impact of abstraction and started to engage with how to re-order things. Evidenced by recent projects from the likes of the Wessex Rivers Trust on the Upper Test at Andover and the Norfolk Rivers Trusts on the River Stiffkey, we are starting to evolve our concept of restoration from reach-based river gardening to works delivered at scale and focused on releasing a stream's natural processes.[14,15] We are starting to work together. There is hope for the future of our chalk streams. ES

Charles Rangeley-Wilson OBE is currently chair of the CaBA Chalk Streams Restoration Group. He is a vice-president of the Wild Trout Trust and an Angling Trust ambassador. He lives in Norfolk where he also designs and consults on chalk stream restoration projects.

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The importance of urban natural capital in Britain

Alison Holt walks us through some of Greater London's green spaces to demonstrate how they benefit our cities.

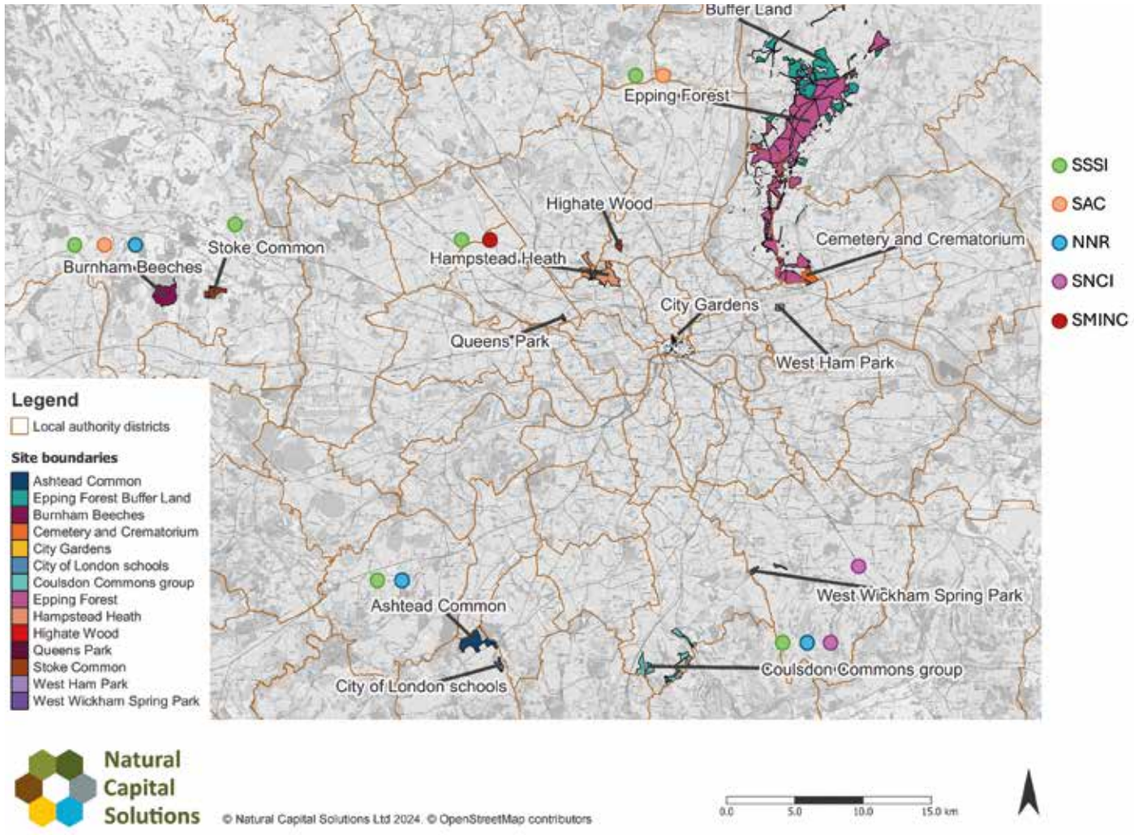
CASE STUDY

When we think about Britain's natural capital (the elements of nature that directly or indirectly produce value or benefits to people), it likely conjures up images of woodlands, meadow grasslands and upland moorlands that largely occur in rural areas. Indeed, these habitats are important for biodiversity and provide a wide range of ecosystem services that in turn deliver benefits to people. However, far fewer people live in these areas to benefit from or demand these services. It is in our densely populated urban centres that natural capital benefits are needed the most.

UNDERSTANDING URBAN NATURAL CAPITAL

The growth of cities has and continues to drive change in the patterns of natural capital and the delivery of ecosystem services.[1] Within urban areas themselves, the development of land is a major cause of natural capital loss.[2,3] This loss, due to the increase in sealed surfaces along with the concentrated activities and consumption of a high density of people, causes environmental issues such as water and air pollution, flooding and a lack of access to nature; it also drives climate change and high urban temperatures, all of which create further socio-economic challenges. The small patches of green and blue semi-natural habitats, managed parkland, gardens and allotments that remain in urban areas are vital for the provision of benefits where demand for them is highest. To design resilient and liveable urban environments, we need to consider the expansion and integration of natural capital in these areas, positioning green and blue infrastructure in places that will address inequalities around who will experience the disbenefits and who has access to the benefits.

In Britain we are making progress with a planning system that requires biodiversity net gain for developments and green space standards to ensure access to nature (England), promotes local living and 20-minute neighbourhoods (Scotland) and establishes spatial strategies (e.g. local nature recovery strategies in England) – all of which apply to urban areas. However, further enhancing and protecting urban natural capital assets and applying nature-based solutions and green and blue infrastructure are required to provide a wide range of ecosystem services. The first step towards this is to understand the baseline natural capital assets in urban areas and what benefits are currently being provided; this will help to identify where there is a need for nature-based solutions and where green infrastructure can be best placed to deliver benefits.



▲ **Figure 1. Location of the City of London Corporation-owned sites with their biodiversity conservation designations. (Source: Natural Capital Solutions[4])**

GREATER LONDON'S NATURAL CAPITAL

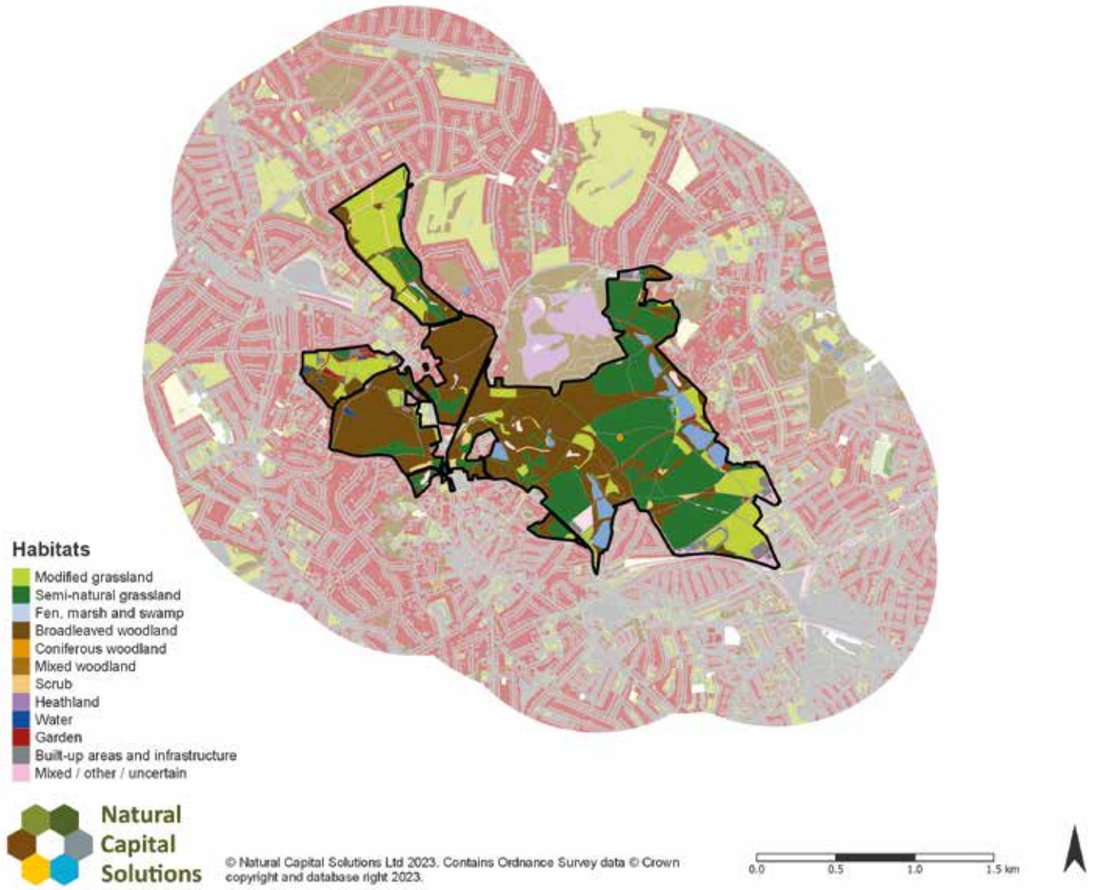
Natural Capital Solutions carried out one such study across the open spaces of central and Greater London that are owned by the City of London Corporation.[4] The Corporation was interested in understanding the level of provision and value of the public benefits that are supplied by the natural capital assets it owns and how these could be maintained and enhanced in future years. The Corporation's portfolio covers 4,460 ha and consists of a diverse array of sites from school grounds, churchyards and pocket parks, heaths, formal parkland and Victorian gardens (e.g. West Ham Park) through to expansive commons (e.g. Burnham Beeches) and large woodlands (e.g. Epping Forest). All are managed as publicly accessible spaces and as important areas for biodiversity in and around a densely populated city. Many of these sites have biodiversity conservation designations: Sites of Special Scientific Interest and National Nature Reserves at the national level; Metropolitan Importance for Nature Conservation and Sites of Nature Conservation Importance at the local level; and even two Special Areas of Conservation at the European level (see **Figure 1**).

The natural capital assets of the Corporation-owned sites were mapped and asset registers created. Approximately half of the land is covered with broad-leaved woodland – with many of the sites consisting of ancient woodland and veteran trees – while another 20 per cent is covered in semi-natural grasslands. Other habitats present are amenity grasslands, heathland, freshwater and scrub. Ten different ecosystem services (carbon sequestration, air quality, noise and local climate regulation, pollination, food production, timber and wood fuel production, water flow and quality regulation, and accessible nature) and one stock (carbon storage) were mapped.

Due to the dominance of woodland, but also to some extent to the mix of other semi-natural habitats at the larger sites, the provision of air quality, noise and climate regulation is relatively high. These services are particularly important in densely populated London, and the South East more generally, where there is a high demand for them, and they are an important component for achieving climate resilience and pollution reduction. Most significantly, these sites provide access to natural good-quality green spaces for recreation and health and well-being benefits. The density of people demanding these services is exceedingly high, particularly in central London. This makes these two services the most valuable of all those provided by these urban green spaces (recreation £180.6 million and health and well-being £78.2 million, annually). The woodlands, grasslands and heathlands are also important for taking up carbon dioxide, slowing the flow of water and filtering it, and for attracting pollinators.

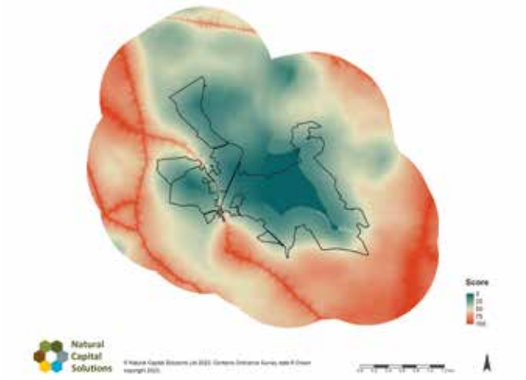
LONDON'S HAMPSTEAD HEATH

One of the sites in the Corporation's portfolio is Hampstead Heath. The site is dominated by broad-leaved woodland (40 per cent) and semi-natural grasslands (30 per cent), with amenity grassland covering 15 per cent of the area and freshwater lakes also being an important feature (see **Figure 2**). There is a mix of other habitats in small patches, such as heathland, scrub, coniferous woodland and gardens. The dominance of woodland and semi-natural grassland is ideal for carbon sequestration, but the woodland in the centre and to the west of the site is particularly important for taking up air pollutants (such as particulate matter – $PM_{2.5}$), for noise abatement, and for providing shade and reducing high temperatures in the summer (see **Figure 3 [a]**, **Figure 3 [b]**, and **Figure 3 [c]**). (Water also plays a role in reducing the urban heat island effect.)

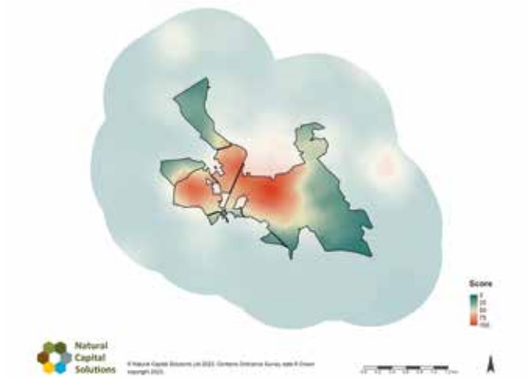


▲ **Figure 2. Baseline habitats at Hampstead Heath (using UK Habitat Classification broad habitats). Habitats at the site are dominated by broad-leaved woodlands (brown), semi-natural grasslands (dark green) and modified (amenity) grassland (bright green). The site is surrounded by densely populated urban areas. (Source: Natural Capital Solutions[4])**

▲ Figure 3. (a) Air pollution regulation



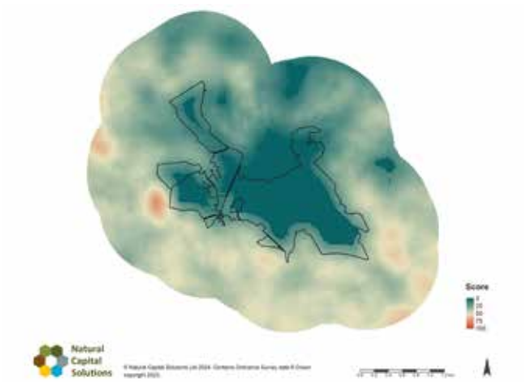
▲ Figure 3. (d) Demand for air pollution regulation



▲ Figure 3. (b) Noise regulation

▲ Figure 3. (e) Demand for noise regulation

▲ Figure 3. (c) Climate regulation capacity



▲ Figure 3. (f) Demand for climate regulation

▲ **Figure 3. The capacity of the habitats at Hampstead Heath to provide (a) air pollution, (b) noise and (c) climate regulation services, and the level of societal demand for those services based on population density, vulnerability (Index of Multiple Deprivation health scores), (d) proximity to busy roads, (e) sources of noise and (f) areas experiencing the urban heat island effect. Scores are on a 1 to 100 scale relative to values present within the study area. Red areas show a high provision or demand for this service, while blue areas show low provision or demand. (Source: Natural Capital Solutions[4])**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These are very locally relevant services: the site is surrounded by a dense urban fabric (see **Figure 2**), and therefore local demand for these services is high due to pollution and noise from main roads (particularly in the south-west) close to where people live (see **Figure 3 [d]** and **Figure 3 [e]**); demand is moderate to high particularly around the southern half of the site due to a high density of people vulnerable to high temperatures in the summer (see **Figure 3 [f]**). The site also provides access to good-quality green space to a significant number of people (see **Figure 4 [a]** and **Figure 4 [b]**). Good-quality green space in this model means not just amenity grasslands but diverse semi-natural habitats that provide colour, diversity and a range of wildlife, all of which increase well-being.[5]

The monetary valuation of the benefits supports the mapping. It shows recreational and health and well-being benefits delivered by the site to be very valuable (£34.7 million and £13.5 million annually, respectively) due to the large numbers of visits (8.1 million) to the site every year. Air pollution regulation and carbon sequestration also deliver significant benefits (£2.0 million and £280,000 annually).[4]

NATURAL CAPITAL ACCOUNTS

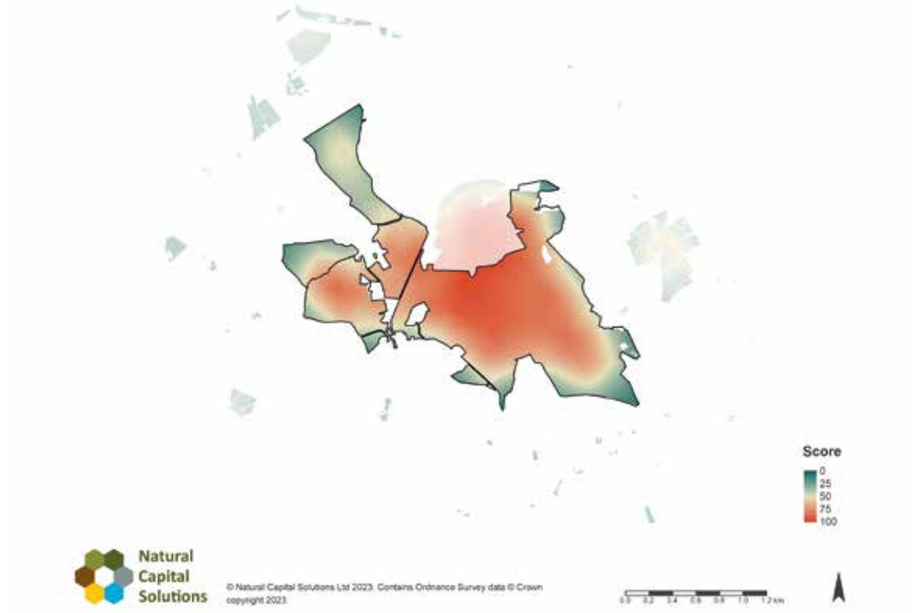
One of the significant uses of this study was to set up natural capital accounts for each site. This enables the Corporation to weigh up the value of the public benefits supplied by their urban green spaces against their maintenance costs. These costs can be high, approximately £19.6 million annually across all the Corporation's sites, and ongoing justification for the funds for managing these spaces is required together with a solid business case.

Many of the sites have a high benefit–cost ratio, meaning that they deliver a good return in terms of the value of the benefits being delivered by the assets for the amount invested. For example, for every £1 invested in managing Hampstead Heath there is an £8 return in natural capital benefits. Across the whole of the Corporation's portfolio, for every £1 invested there is a £16 return in natural capital benefits. We should always be careful not to expect the monetary valuation of benefits to be exact, and there are many caveats associated with both quantifying the ecosystem services and monetising the benefits; however, these estimates do provide a gauge of the overall magnitude of costs versus benefits and the relative value of the different benefits.

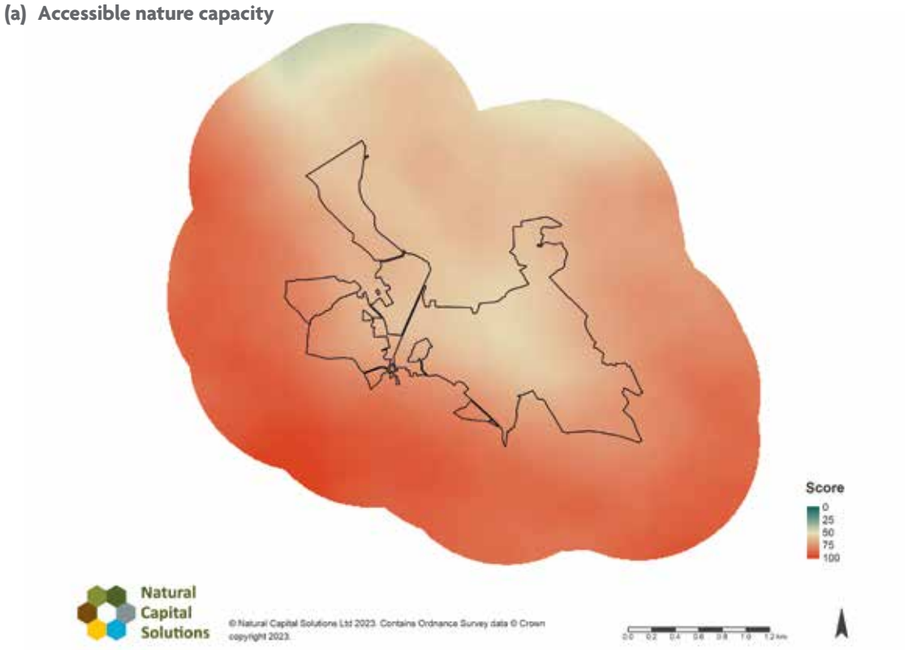
ONGOING NATURAL CAPITAL ASSET MANAGEMENT

This study also enabled consideration of how these assets could be managed to increase the benefits provided in the future. In the case of the Corporation's open spaces, the ongoing management for people and biodiversity would maintain, and in some cases increase, the provision of these ecosystem services. This could be achieved by, for example, restoration of semi-natural grasslands and heathlands and by small expansions of woodland.

Opportunities for large gains in the provision of benefits is not possible at these sites due to biodiversity priorities, the need for a mosaic of diverse habitats, and because,



▲ **Figure 4. (a) Accessible nature capacity**



▲ **Figure 4. (b) Accessible nature demand**

▲ **Figure 4. Accessible nature capacity (a) and demand (b) at Hampstead Heath. The capacity model shows the extent to which the habitats at the site are accessible and perceived to be natural. For example, the areas of high provision of this service (red) are both accessible and perceived to be natural. Habitats with relatively high perceived naturalness scores are woodland, heathlands and semi-natural grasslands. The demand model is based on population density, health scores, and distance to footpaths and access points into the site. Scores are on a 1 to 100 scale relative to values present within the study area. The white space in the capacity map shows built-up areas or areas with no public access. Red areas show high provision or demand for this service, while blue areas show low provision or demand. (Source: Natural Capital Solutions[4])**

as is the case with most densely urban areas, there is little space for significant expansion of semi-natural habitats. However, it is possible to consider where green infrastructure can be placed at these sites in relation to the services (e.g. air quality, noise, and local climate regulation) that are required to be provided locally, as opposed to carbon sequestration and food services that can be provided anywhere. The nearer such infrastructure can be placed to where demand is highest, the better. For example, trees or scrub and hedges could be planted at the edges of the site adjacent to where people live and near to sources of noise and air pollution.

Considering the quality of the benefits delivered is also key, particularly in relation to opportunities for recreation, health and well-being. Urban sites need to be managed for a variety of access needs, providing safe, easy and pleasurable movement through the natural spaces, a diversity of habitats in good condition for people and wildlife, seating for solitude, social areas, well-maintained footpaths, and recreation grounds, providing enjoyment for all generations.[6] We know from the Covid-19 pandemic lockdowns that these spaces are vital. But we need to ensure that they are accessible for all by focusing on social as well as green infrastructure – for example, schemes tailored to encourage people to go outdoors for therapeutic activities and promoting green prescribing in local medical centres.[7] There is, then, a chance that publicly owned spaces can help address the challenge of health inequalities.

The Corporation's study has demonstrated that urban natural capital can provide a wide range of ecosystem service benefits, which can be very valuable. It also showed that natural capital assessments can inform discussions and decisions about the opportunities available for enhancing benefits in the future, and where these can be placed to make the biggest positive difference to society. ES

Dr Alison Holt is a Director and co-founder of Natural Capital Solutions (NCS, https://naturalcapitalsolutions.co.uk/). She is an ecologist and interdisciplinary scientist specialising in natural capital assessment approaches. Prior to setting up NCS, Alison was an Independent Research and NERC Knowledge Exchange Fellow at the University of Sheffield. She was a member of Severn Trent Water's Expert Challenge Panel for the Price Review 2024 and is on the board of the South Yorkshire Local Nature Partnership.

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Shooting and conservation

Andy Clements reviews the evidence for impacts of shooting on our natural capital.

ANALYSIS

The impact on natural capital of shooting mammals and birds generates strong views, positive and negative, from widely different perspectives. Emotive issues aside, there is evidence of the impacts of shooting on the health and welfare of wildlife and on natural capital.

Legal shooting may take place for fun (as a sport or hobby), as the result of a business, for food or for environmental management purposes. Shooting affects conservation internationally – the widespread shooting of migrant birds across southern Europe and trophy hunting big game in Africa are two examples. When it comes to the UK, and England in particular, there are conservation implications from the illegal shooting of raptors, also known as birds of prey.

The environmental consequences of shooting wildlife are different for each taxa and regime. Rearing and releasing large numbers of non-native game birds in the lowlands results in a very different set of ecological impacts from those of wide-scale management of upland landscapes for shooting native red grouse. Wildfowling (the hunting of waterbirds) results in a small actual take of individual birds but can affect more of them through disturbance. The management of deer by shooting ought to be a mechanism for benefiting the condition of protected woodland areas, provided it is carried out systematically and at scale. However, shooting wildlife still relies on the use of lead shot, impacting both individual animals and the wider environment.

GROUSE, PEREGRINES AND HEN HARRIERS

Driven shooting of red grouse in the uplands of northern England requires the management of both the species and its habitats to maintain an artificially high population from which to take an annual harvest. Vegetation management through heather burning has significant impacts on priority habitats such as blanket bog, and there are potential benefits to other upland breeding birds.

The effects of rotational burning on upland peatlands has been the subject of intensive research for two decades, culminating in an evidence review by Natural England in 2013, which is currently being updated.[1] The original review and subsequent update each looked at around 250 studies, exploring the impacts on carbon cycling, habitat quality, fauna, and water quality and flows. The strength of the evidence in the original review that burning damages natural capital contributed to the Government amending legislation in 2021 to prohibit burning on peat over 40 cm deep in protected areas, except under licence. The review draft strengthens these original findings, supporting Natural England's position that burning on blanket bog is not compatible with the maintenance and restoration of its structure and function.

Managing grouse numbers by using medication to reduce losses to disease can also impact the environment; as the use of medicated grit has intensified, research demonstrates some ecotoxicity to invertebrates. Furthermore, management of high concentrations of red grouse also requires measures to control parasites. In addition, it is widely recognised that some in the shooting fraternity undertake the illegal persecution of many birds of prey, particularly peregrines and hen harriers. This has been well documented in the uplands of England and is recognised as the key impediment to limiting numbers of breeding pairs.

Since 2016, the Government has adopted a joint action plan with six management measures aimed at restoring the hen harrier population, including addressing illegal persecution.[2] A brood management trial is researching the effect of rearing some young harriers in captivity to reduce the impact on grouse chicks and exploring changes in the behaviour of illegal persecutors.[3] Although numbers of breeding pairs and productivity of harriers have increased, there is a high mortality of tagged birds compared to those living beyond grouse moors and no clear evidence that illegal practices have declined significantly. The evaluation of the trial has yet to be completed.

PHEASANT AND RED-LEGGED PARTRIDGE

Non-native reared and released game birds for shooting – which in the UK are pheasant and red-legged partridge – have significantly increased in numbers over the last few decades, with published estimates of 45–61 million birds being released annually. A growing body of research is investigating the ecological consequences of adding this level of non-native biomass to the environment. A report in 2020, jointly commissioned by Natural England and the British Association for Shooting and Conservation (BASC), took a rapid evidence assessment approach to look at these consequences.[4] The review considered direct effects, including nutrient enrichment, persistent changes in ground flora, atmospheric pollution and spreading of disease. Indirect effects included the planting of game crops, woodland creation, retention and management, legal predator control and provision of supplementary winter food.

The effects of these releases are ecologically complex. The report found 58 highly relevant research papers, mostly based on 'natural experiments' comparing sites with and without shooting. Definitive assessment of the net effect as being positive or negative was avoided. The direct effects of the reared and released birds tended to be negative, while the associated effects of game management tended to be positive. There is good evidence that game managers are better engaged in the land management of semi-natural and agricultural landscapes compared to other land managers, and that this can result in an increased diversity and abundance of wildlife. Legal predator control might be expected to benefit non-game wildlife due to reducing predation pressure from generalist predators; however, a study in 2019 showed that large-scale variation in avian predator populations is positively affected by game bird releases.[5]

Grouse with young , North Yorkshire | © Natural England/Paul Lacey

Pheasant | © Natural England/Paul Lacey

Erosion and enrichment of soils is demonstrated through case studies. In the Derbyshire Dales National Nature Reserve, soil erosion from high numbers of released birds caused licences to be withdrawn, and studies on Sites of Special Scientific Interest (SSSIs) suggest the precautionary principle should be applied. Disease risk is raised from the creation of unnaturally high densities and volumes of non-native species at a time of concern that poor environmental management increases the transmission of zoonotic diseases.

The management of livestock, other than game birds for shooting, is subject to strict biosecurity and husbandry standards; whereas, for game birds the shift from livestock to wild bird status on release substantively weakens these controls. A pool of naïve birds in the environment may act as a reservoir of disease. Conservation concern is reflected in the greater regulatory constraint on the release of large numbers of non-native game birds within and near protected areas, where individual licences must now be sought rather than relying on general licences.

The main findings of all these studies are that some practices can lead to damaging direct as well as associated effects on habitats and wildlife in England, which may be partially mitigated by closely adhering to best practice and, with respect to raptor persecution, not breaking the law.

NURTURED WILD GREY PARTRIDGE

This specialised and more exclusive practice of shooting native wild grey partridges has impacts on small areas of farmed landscape in southern England. Extra-wide field margins are maintained with seed mixes that benefit wildflowers and invertebrates, food is provided over the winter and predators are controlled. The effects can enhance the broad natural capital value of these areas, such as enabling farmland birds to overwinter more successfully, although pests and diseases may become problematic. There can be benefits to threatened species, such the stone curlew in East Anglia where predator control and habitat management enhance productivity and survival.

“Deer have an extensive and significant impact on natural capital through browsing and grazing in woodlands.”

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DEER

Deer are shot for sport and as part of conservation management. Deer have an extensive and significant impact on natural capital through browsing and grazing in woodlands and are the main cause of woodland SSSIs being in unfavourable condition in England.[6] The Government is developing a deer management strategy with the aim of lessening their impact on the environment.[7] However, there is currently a lack of coordinated management of deer populations at landscape scale and poor data sharing. National-level statistics on the status and trends of deer populations in England come from the British Trust for Ornithology’s (BTO) breeding bird survey recording common mammals. Over the 25-year period to 2022, both Reeve’s muntjac and fallow deer populations have increased by more than 250 per cent.[8]

More widely in the UK there is evidence from landscape restoration projects, such as Cairngorms Connect, that significant managed reductions in numbers of deer through coordinated shooting has strong beneficial effects on natural capital.[9] Indigenous Caledonian pine forest habitat is returning, along with its suite of rare and threatened species such as capercaillie.

WILDFOWLING

Conservation organisations recognise the sustainable harvesting of quarry wildfowl (bird species that can be shot during a particular season without a licence) through controlled wildfowling as a legitimate use of a wildlife resource. The most comprehensive and accessible dataset on wildfowl populations comes from the BTO’s wetland bird survey.[10] There is no evidence to date that shooting ducks, geese and some shorebirds is causing population-level effects. However, the issues of defining a sustainable harvest and disturbance require scrutiny.

A recent study by the University of Essex and the BASC has developed a new technique for calculating a sustainable harvest index for each species.[11] The study found evidence of potential overharvest for several species, but mostly for those experiencing the highest population growth trends. This suggests that waterbird hunting is not a primary driver of population trends and provides the basis for a framework for making informed decisions about harvests, and potentially for the introduction of a policy instrument.

Although best-practice wildfowling understands and respects the behaviour of large concentrations of waterbirds at favoured sites, there will still be widespread

Red-legged Partridge | © Natural England/Allan Drewitt

disturbance from the targeting of individual quarry. This impacts the habitat use pattern by significant numbers of waterfowl and can be mitigated, for example, by the creation of sanctuary areas such as those on Royal Society for the Protection of Birds' coastal reserves.

Woodcock provide an interesting case study of the interaction between shooting and conservation. The UK breeding population declined by 29 per cent from 2000–13, prompting the species to be added to the UK Birds of Conservation Concern's Red List and even a call from some shooters for the practice to stop.[12] The UK woodcock population swells in winter by the arrival of hundreds of thousands of birds from Europe. Woodcock is a quarry species from October to February, and some believe the shooting season should not start until December to avoid impacting British breeding birds. Research continues to establish why breeding woodcock are declining: climate change and habitat loss may be as important as any population-level effect from shooting.

LEAD FROM AMMUNITION

Lead poisoning is estimated to kill a million wildfowl a year in Europe and cause sublethal poisoning in at least another 3 million. This is a long-recognised problem with a considerable body of research focused on waterfowl, raptors and scavengers.[13] Recent studies have started to provide evidence that lead can negatively affect population trends and levels, and not only in quarry species. Given that alternative non-toxic ammunition exists and has been in use for decades, removing this source of mortality for wildlife would allow resources to be refocused around other population-level impacts on these vulnerable species.

CONCLUSIONS

Certain themes emerge from the evidence reviewed. The increasing intensity of management for red grouse in the uplands and the rapidly rising numbers of non-native game birds released in the lowlands are putting severe pressure on ecosystems that are already nature-depleted. Shooters' desire to secure large numbers of birds exacerbates the negative impacts, with waste resulting from meat not entering the food chain and the opportunity costs associated with land used to produce food for the birds in the first place. Extensification of game bird management and shooting in wilder contexts would be a positive move.

With respect to deer, the absence of a coordinated plan means that damage to important woodland habitats goes unchecked. Non-toxic lead ammunition alternatives exist, so there should be a willingness to end the damage caused to the environment and to species by the continued use of lead. Conservationists and shooters must work together to avoid the negative impacts and optimise the positive ones through best practice. Illegal activity should cease. Improving the evidence of impacts and filling knowledge gaps will enable shooting and conservation to continue to coexist and will contribute to minimising the impact on natural capital and to helping nature recover. **ES**

Dr Andy Clements OBE was Chief Executive of the BTO until 2020, served as a board member for Natural England until 2023 and as chair of the Natural England Science Advisory Committee, and currently chairs the UK Government's England Species Reintroductions Taskforce.

andyclements054@gmail.com

@_AndyClements

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FEATURE

Biological invasions: species on the move

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Helen E. Roy envisions a future where the threat of invasive alien species is reduced for the benefit of people and the environment globally.

Understanding the distribution of species is both fascinating and important for informing conservation action. Some species are retracting in range while others are expanding. Changes in species distribution are known to be driven by climate change and land and sea use change. Climate change can create opportunities for some species, while for others it leads to habitat changes – shifting from being suitable to becoming unfavourable.

One of the most dramatic ways in which species are moving is through the process of biological invasion, whereby a species is transported by human activity from its native range to a region within which it would not naturally occur. The involvement of human activity in moving a species – intentional or not – is the defining feature of non-native (also known as alien) species and distinguishes them from those that may have dispersed naturally, perhaps because of climate change.

THE THREAT OF INVASIVE ALIEN SPECIES

Introductions of non-native species are increasing at unprecedented rates globally. The recently published Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES) *Thematic Assessment on Invasive Alien Species and their Control* report estimated that there are 200 new species being introduced to new areas globally every year.[1] Some non-native species establish, spread and adversely affect biodiversity and ecosystems; this subset is termed invasive alien (non-native) species.

Invasive non-native species are costly to the environment and adversely affect people. It is estimated that such species cost over US$423 billion a year globally, which is

a considerable underestimate because many of the costs are hard to capture.[1] Invasive non-native species may also have adverse effects on our quality of life. Indeed, some may affect human health, such as non-native plants that produce copious amounts of allergenic pollen, or jellyfish that may have painful stings. Perhaps most notable are insects such as mosquitoes, which are vectors for introducing diseases to new regions of the world. It is perhaps unsurprising that one of the headline messages from the IPBES report is that invasive non-native species are 'contributing to the unparalleled degree of deterioration of the biosphere upon which humanity depends'.[1]

BIODIVERSITY LOSS DRIVER INTERACTIONS

The five major drivers of biodiversity loss – which include invasive species, climate change, and land and sea use change – are known to interact with one another. Some invasive alien species are only able to establish because the land has been degraded or the climate has changed in their favour. As an example, some invasive insects, such as ants, are benefitting from the warming climate in some regions and predictions indicate that more will do so in the future. More wildfires are a consequence of increased temperatures but also of an increase in fuel provided by flammable invasive plants. The IPBES report that 'climate change interacting with land- and sea-use change is predicted to profoundly shape and amplify the future threat from invasive alien species'.[1]

WE CAN MANAGE BIOLOGICAL INVASIONS

There are various approaches to controlling non-native species and managing biological invasions. Preventing their transport and introduction is the most effective way, achievable by implementing biosecurity measures. Everyone can make a difference. There are numerous campaigns – such as Check, Clean, Dry, and Be Plant Wise – that guide people in taking responsibility for reducing the threat of invasive non-native species.[2,3] In parallel, businesses can develop management plans to ensure their activities do not lead to their intentional or unintentional introduction.

Even after a species has become established within a new region there are options for its control. There are examples of successful eradications of invasive non-native species. For example, rats have been eradicated from many islands around the world. Rats pose a threat to human health and have also decimated some globally important seabird populations. Following their eradication, remaining seabird populations thrive, while there are also noticeable benefits for plant communities (see **Figure 1**).

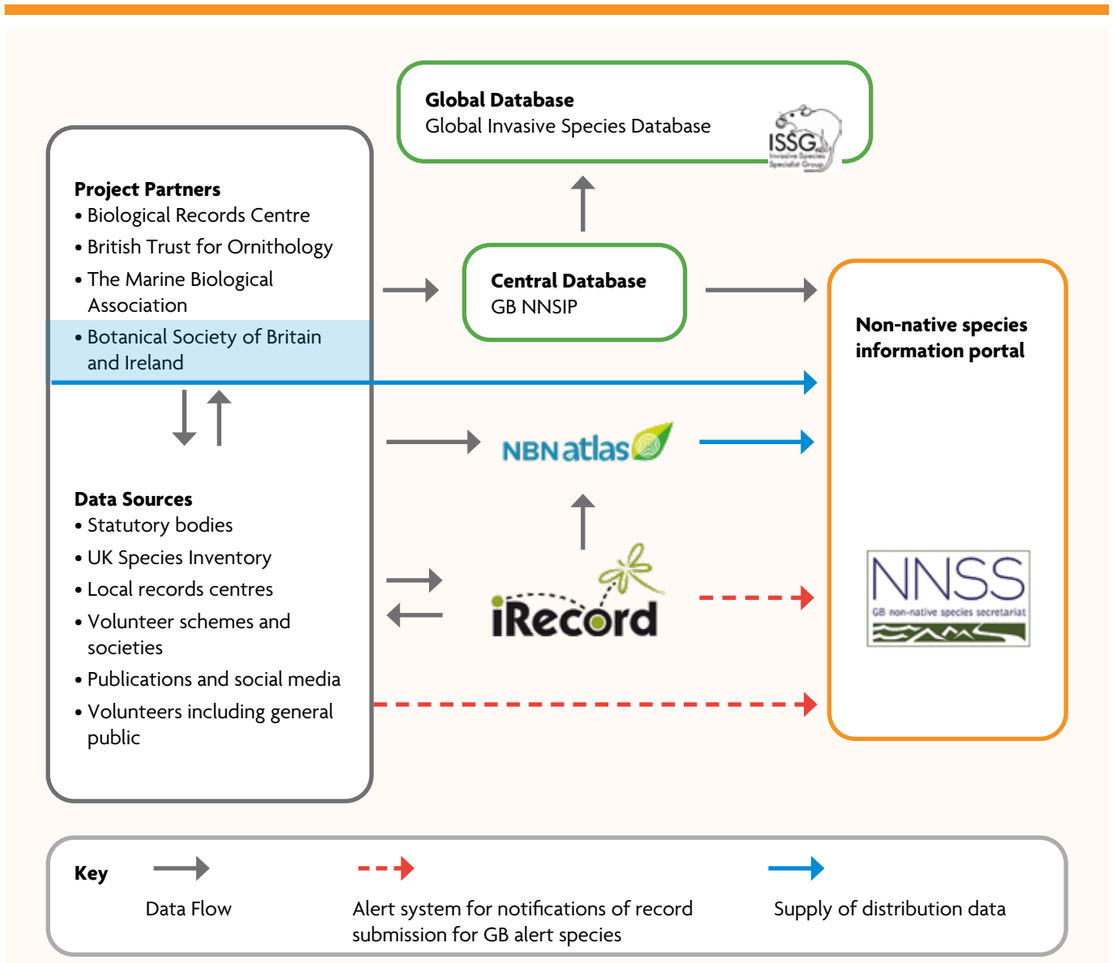
▲ **Figure 1. Thriving seabird populations on Anguilla.**

NON-NATIVE SPECIES IN BRITAIN

There are over 2,000 non-native species within Britain, with plants being the most numerous. The Defra-funded GB Non-native Species Information Portal compiles information on all non-native species while also providing an online alert system for people to report sightings of species of concern.[4] One such species is the Asian hornet (*Vespa velutina*). This was introduced to France several decades ago and spread rapidly. The Asian hornet is a predator of insects and poses a particular threat to pollinating insects. Worker hornets visit flowers and trees to collect nectar for carbohydrate, but they also gather high-protein food, such as honeybees (*Apis mellifera*), hoverflies and other insects, to feed to their larvae. Asian hornets produce large nests comprising thousands of workers; it is estimated that a single worker can take about 25–30 honeybees back to the nest each day, making them a major threat to beekeeping and wild pollinating insects.

In 2012, Defra funded a study to predict which invasive non-native species could arrive, establish and impact biodiversity and ecosystems within the next 10 years.[5] Unsurprisingly the arrival of the Asian hornet was considered a high risk. In 2016, the first record of one was received and rapid action ensured the nest was found and removed, leading to its eradication. All Asian hornet workers return to their nest at night and so night-time nest removal is an effective management approach. Every year since, there have been a few sightings; last year saw unprecedented numbers of reports, but the National Bee Unit has so far managed to eliminate them. In the coming year it will be important to sustain this response and people are requested to report any sightings of concern through the alert system. The bright yellow legs are characteristic of this insect.

Citizen science is proving an important component of managing biological invasions, increasing information availability while engaging people and raising



▲ **GB Non-native Species Information Portal for information compilation and sharing. (Source: UK Centre for Ecology & Hydrology)**

awareness of the major and growing threat of invasive non-native species. Indeed, collaborations among stakeholders and governments to ensure equitable access to knowledge is critical to underpinning effective action.

INVASIVE SPECIES IN OVERSEAS TERRITORIES

The 14 UK Overseas Territories (UKOTs) are home to many unique and, in some cases, endemic species. Concerningly, invasive non-native species pose a major threat to these globally important ecosystems. Furthermore, they are also a threat to food and water security. For example, myna birds (*Acridotheres tristis*) are found on a number of UKOTs and feed on fruit and crops. New Zealand flax (*Phormium tenax*) is adversely altering the flow of water within the cloud forest of St Helena. However, the ongoing initiatives to manage biological invasions on UKOTs are inspiring, including approaches to biosecurity (actions to minimise the risk of invasive non-native species such as inspections of cargo and cleaning of equipment), management and conservation, but there is a need to share information to support action and inform decision-making.

An ongoing Darwin Plus project is compiling inventories of non-native species for all UKOTs following a similar format to the GB Non-native Species Information Portal.[6] Collaborations with partners in UKOTs is increasing the information available and supporting initiatives to predict which invasive non-native species might be on the horizon, enabling communities to strengthen their biosecurity measures.

PROGRESS TOWARDS MEETING GLOBAL TARGETS

The Kunming–Montreal Global Biodiversity Framework agreement to halt and reverse biodiversity loss set a series of targets, of which Target 6 is ambitious. This target aims to tackle the impacts of invasive species and reduce their rate of introduction and establishment by at least 50 per cent by 2030.[7] Current predictions, based on a business-as-usual scenario, suggest that the number of non-native species will continue to increase at an unprecedented rate. Therefore, there is a need for immediate action to reduce the introduction and establishment of non-native species while simultaneously addressing climate change and land and sea use change.

Addressing the threat of biological invasions will strengthen the effectiveness of policies designed to respond to other drivers of biodiversity loss. Integrated approaches to managing environmental change, acknowledging the interactions between invasive alien species and other drivers, can support the alignment of policies leading to mutually beneficial outcomes.[1] Indeed, policy planning that reflects the interconnectedness of biodiversity loss drivers may have multiple benefits for people and nature and will certainly minimise the risk of any unintended consequences of our actions, whereby efforts to solve one problem may exacerbate the magnitude of others and may even have multiple benefits.

In conclusion, invasive non-native species are a major and growing threat, but there are effective solutions to addressing the problem. Raising awareness of the magnitude of the threat they pose is vital and ensuring the engagement of stakeholders in management strategies is critical to success. Providing adequate resourcing alongside cross-border and cross-sector collaborations will be important to achieve the much-needed ambitious progress towards meeting Target 6. Ultimately, managing biological invasions will have long-lasting benefits for people and nature. ES

Professor Helen E. Roy MBE, Honorary Fellow of the Royal Entomological Society, is an ecologist with the UK Centre for Ecology & Hydrology and the University of Exeter. Her research focuses on the effects of environmental change, particularly biological invasions, on biodiversity and ecosystems. Helen leads many collaborative national and international research projects on biological invasions, with a focus on enhancing information flow to inform understanding of the impacts of invasive alien species. Helen also enjoys science communication and public engagement with research, including citizen science, an approach that she has implemented in a number of contexts. She recently led a global assessment on invasive non-native species for the Intergovernmental Panel on Biodiversity and Ecosystem Services.

Acknowledgements
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CASE STUDY

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Great North Bog: a new approach to funding restoration

Paul Leadbitter, **Chris Woodley-Stewart**, **Rosie Snowden** and **Lyndon Marquis** review the state of play of the emerging blended finance model for restoring peat.

Peatlands are globally important ecosystems that play a significant role as both environmental and economic assets. Peat forms slowly, over thousands of years and under specific environmental conditions. The formation of peat begins with the accumulation of dead plant material, primarily mosses, grasses and shrubs, in waterlogged environments such as bogs, fens and swamps. These environments are characterised by high water tables, acidic conditions and low oxygen levels, which inhibit the complete decomposition of organic matter, leading to the layering of this vegetation as peat.

Despite covering only around 3 per cent of the Earth's land surface, peatlands store an estimated 30 per cent of the world's soil carbon and twice the carbon stored in all the world's forests, making them a crucial component in the fight against climate change.[1] It is estimated that damaged peatlands across the globe emit 5 per cent of the world's total carbon dioxide emissions.[2]

"Peatlands in the UK have immense ecological, cultural and economic significance."

THE UK'S PEATLANDS

Peatlands in the UK have immense ecological, cultural and economic significance, making their conservation and restoration crucial. Covering approximately 12 per cent of the UK's land area, these unique ecosystems play a multi-faceted role in supporting biodiversity, mitigating climate change and providing various other ecosystem services such as flood amelioration, drinking water supply, and recreational and economic opportunities.[3] A rich diversity of life thrives in peatlands, offering habitats for rare species like carnivorous plants, birds, mammals and insects. Peatlands also regulate water flow, reducing flood risk and maintaining water quality. Additionally, they provide cultural and economic benefits, supporting local livelihoods through a variety of activities such farming and tourism.

Damage to UK peatlands poses significant environmental and economic threats: drainage for agriculture, peat extraction for horticulture and overgrazing have led to their degradation. In the UK only about 20 per cent of peatlands remain in a near-natural state.[4] The loss of intact peatland ecosystems releases stored carbon dioxide, exacerbating climate change. Degraded peatlands also lose their ability to retain water, increasing flood risk and reducing water quality. Biodiversity also suffers, as habitat destruction impacts those rare species that depend on these ecosystems.

Restoring our peatlands has long been recognised as a no-regrets option given the benefits they provide to society. In the UK, peatland restoration has been taking place since the 1980s, though somewhat sporadically due to short funding cycles, the low profile of peat compared to other environmental issues, and the difficulty of retaining the momentum and capacity for the restoration process. Another factor has been the deep-seated belief that peatlands are wastelands that should be drained and improved for agriculture – a view that is still prevalent today across the globe.

Since the turn of the century, peatland restoration in the uplands of the UK has been gathering momentum, with partnerships such as Moors for the Future and the Yorkshire Peat Partnership and the North Pennines National Landscape team's Peatland Programme leading the way in developing landscape-scale collaborative projects of international importance.[5,6,7] Programmes like these were typically funded by a mix of grants from the National Lottery Heritage Fund, Biffa, the EU's LIFE and Interreg programmes, and matched with funds from the UK Government and water companies; this model has worked relatively well until now. With the development of natural capital markets (i.e. carbon credits) and the UK leaving the EU, there was a need to develop other financing models that would continue to fund landscape-scale peatland restoration. The need to collaborate to generate this funding at scale is in part the reason for developing the Great North Bog (GNB) coalition.

RESTORATION IN THE GREAT NORTH BOG

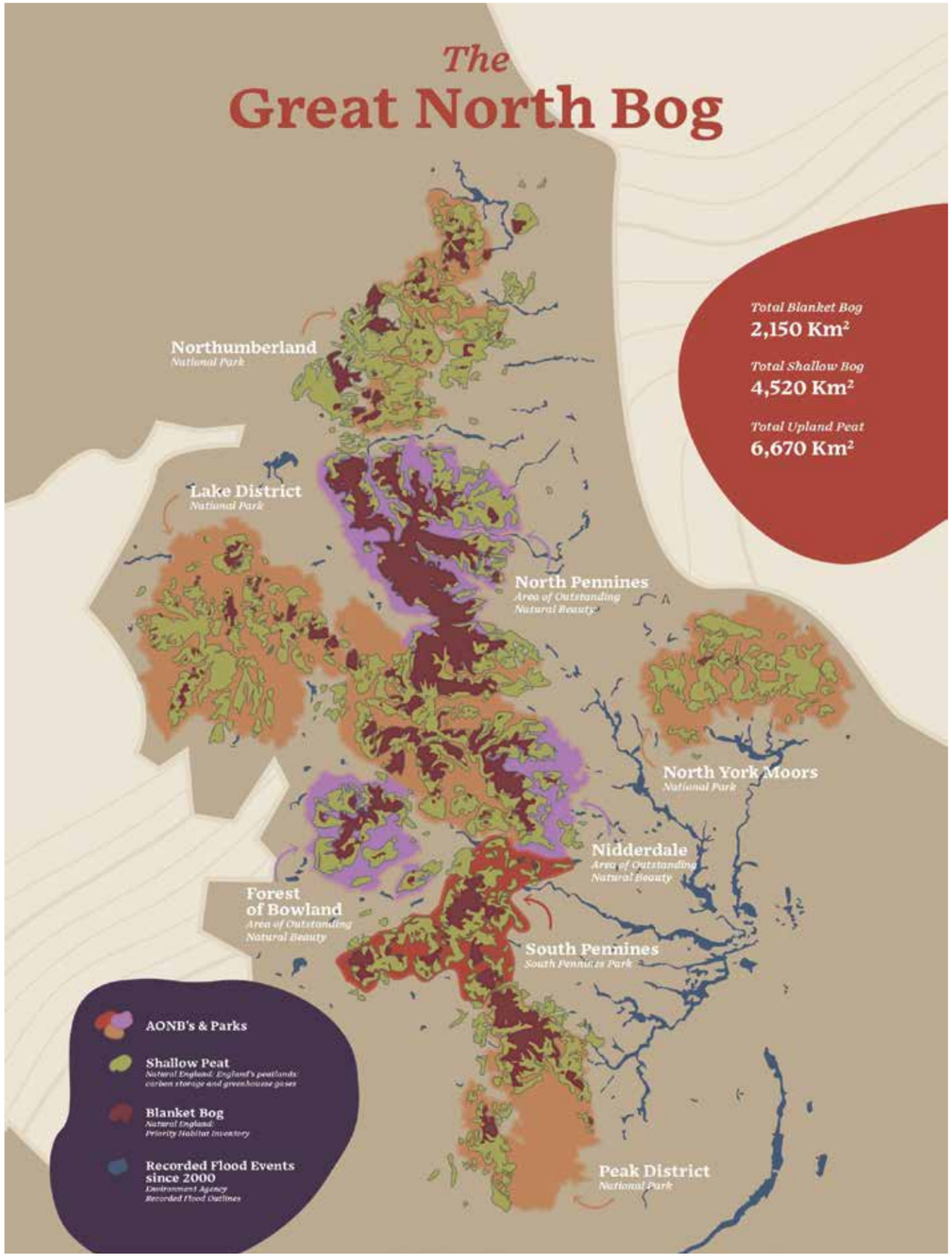
The GNB is an ambitious peatland restoration initiative developed by a coalition of North Pennines National Landscape, Yorkshire Peat Partnership, Moors for the Future Partnership, Cumbria Peat Partnership, Northumberland Peat Partnership and Lancashire Peat Partnership (see **Figure 1**).[8] It is a landscape-scale approach to upland blanket bog restoration and conservation across nearly 7,000 km² of peatland soils in and around the protected landscapes of northern England and represents the largest collaborative peatland conservation effort in Europe.

The UK has around 10–15 per cent of the world's blanket bog, which is a rare and internationally important peatland habitat.[10] Blanket bog is a type of peatland characterised by extensive, continuous coverage over large areas, often found in cooler, wetter regions such as uplands and high latitudes. It forms where rainfall exceeds evaporation, creating waterlogged conditions that slow the decomposition of organic matter, leading to the accumulation of peat. Blanket bogs typically develop on sloping terrain, where water flows down and collects, creating a thick layer of peat that can be several metres deep.

Approximately 92 per cent of England's blanket bog is in the GNB area.[11] The GNB stores over 400 million tonnes of carbon in its peaty soils and is the drinking water supply for over 15 million of people in northern England. However, it is also a largely degraded ecosystem due to past drainage, peat cutting, overgrazing and burning, and is currently emitting over 4 million tonnes of carbon dioxide equivalent gases into the atmosphere every year.

CAPITALISING ON PEATLAND CARBON

Of all the ecosystem goods and services that peatlands provide for society, those associated with carbon are the most readily monetised through natural capital initiatives such as the purchase of carbon credits.



▲ **Figure 1. Location of the Great North Bog across northern England. (Source: Great North Bog Partnership)[9]**

▲ Upland peat bog prior to restoration in the North Pennines National Landscape. (© North Pennines National Landscape)

BOX 1. PEATLAND RESTORATION TECHNIQUE

Peatland restoration takes on many forms depending on the type of bog, and techniques constantly evolve. The GNB peatland area is mainly in the uplands, and even within this region techniques vary due to differences related to microclimate, the genesis of the damage and ongoing pressures. GNB partners share the key restoration commonalities when restoring a blanket bog.

1. The first and most important technique is to restore the hydrology or slow the flow, which involves using leaky dams to slow the water flowing across the bog. This is key to success, as flowing water continually erodes bare peat, making the damage worse each year.
2. The next crucial step is to reprofile steep-sided gullies formed by the flowing water and to stabilise them to stop further erosion.
3. Once this has been done revegetating all bare peat areas is undertaken, using moss-rich brash and/or plug plants, which are typically sphagnum, cotton grasses and other specialised bog species.

While these three steps are quite simple unto themselves, the logistics and financing of restoring a large, often remote, damaged upland peat site is a relatively complex undertaking that requires specialist machinery, the proper permissions from stakeholders and agencies, and very careful planning. Over the past 20 years GNB partners have restored over 1,100 km^2 of blanket bog in England.

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▲ Upland peat bog in the North Pennines National Landscape three years after restoration. (© North Pennines National Landscape)

Damaged peatlands release carbon into the atmosphere; this carbon is quantifiable and can be monetised using the Peatland Code.[12] Launched in 2015, this is a voluntary certification standard for UK peatland restoration projects wishing to quantify and market the carbon benefits of this work. The Peatland Code is robust and provides assurances to voluntary carbon market buyers that the carbon credits being sold are real, quantifiable, additional and permanent.

A grant from the Esmée Fairbairn Foundation to support the six GNB partners enabled the setup of a governance structure and the development and adoption of a vision statement and strategy.[9] The GNB vision is for the peatlands of the northern English uplands to be intact and healthy fully functioning wetland ecosystems, providing benefits for nature, climate and people that are widely understood and appreciated. The GNB strategy sets out how partners will work together to:

1. Increase the pace and scale of restoration;
2. Raise awareness of the importance of peatlands and the benefits they provide;
3. Increase skills and capacity for staff and contractors;
4. Improve the evidence base for peatland restoration and conservation; and
5. Raise the necessary resources and further diversify income streams.[9]

One of the nature-financing priorities for the GNB coalition is to work collaboratively across northern England to test and develop peatland restoration-based carbon credits and to support the emerging peatland carbon credit market, as the upscaling of this market is still not functioning as it should for a variety of reasons (i.e. it is a nascent carbon market with low prices and concerns about liabilities should carbon projects fail).

While tapping into voluntary carbon market financing to support peatland restoration might seem a straightforward task, the realities of doing so on the ground and at scale are still problematic. The policy context to this is that the UK Government has set a goal to mobilise at least £500 million of private financing per year in England by 2027, rising to more than £1 billion per year by 2030, with much of that total expected to be related to carbon credits.[13] There is, therefore, a need to get the peatland restoration carbon credit – which can be seen as the low-hanging fruit of nature-based solutions – functioning properly.

TESTING THE MARKET

One of the current challenges with working at the interface between economy and ecology is the need to develop a trusted and ethically matched corporate partner who wants to buy the carbon, then developing that offer equitably with the landowner and associated


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stakeholders while simultaneously ensuring a gold-standard delivery for the peatland restoration work. In addressing these challenges, and developing the carbon market within the GNB area, there is also a need to avoid a 'race to the bottom', which could be a consequence of monetising nature benefits (i.e. getting the cheapest price for carbon credits and lowering restoration quality to increase profits). To overcome this, the GNB coalition approached the private sector to test the market for suitable corporate partners.

During 2023, GNB partners, working with a finance expert provided by Esmée Fairbairn Foundation, developed an expression of interest (EOI) document and process.[9] The intention was to go to the corporate sector and ask interested parties to bid to be GNB's finance partner with respect to purchasing carbon credits generated from GNB peatland restoration work. The GNB team received 15 EOIs from three groups of potential partners: investment funds, corporates and carbon trading platforms.

The follow-up EOI discussions have been an invaluable learning process. It has shown that, despite the concept of green financing having been around for many years, neither the corporate nor the conservation sector has yet finalised exactly how it should work. It has also highlighted that the conservation sector needs to be cautious and must have a strong voice in defining what good practice is with respect to nature-based solution markets. In part it relies on the conservation sector having clear values and sticking to them. The nature-first principle needs to be clearly articulated as blended financing begins to scale up over the next decade. The EOI process is almost complete, with expected corporate partners to be contracted to GNB coalition bodies in spring 2024.

Over the next four years the GNB aims to achieve the following:

1. Have enhanced restoration programmes in place across the north of England, led by regional delivery partners who have the resources to act.

2. Make peatland restoration a significant feature of the UK Government's Environmental Land Management scheme – one of several routes to public investment that are readily accessible as part of blended finance (i.e. from more than one source, such as a combination of government and private funding) to support the work.[14]

3. Have more businesses, land managers and landowners understand the potential to address their carbon emissions and deliver wider ecosystem services through support for peatland restoration given the growing corporate investment in the work.

4. Have more landowners and managers who are supportive of peatland restoration and establish clear business opportunities and incentives for them to do so.

5. Develop ecosystem services markets from the collaboration between GNB partners and businesses, with a greater understanding of their market value.

6. Have increased knowledge and capacity among partner staff, contractors and suppliers to support restoration work.

7. Establish an enhanced evidence base for the multiple benefits of peatland restoration and remove barriers to increasing this evidence base.

8. Have a supportive policy environment for peatland restoration to flourish.

9. Increase awareness among society of the value of peatland and the importance of its conservation and restoration for the goods and services it provides and of its value to nature recovery.

We are at a crossroads in terms of how we finance large-scale nature restoration and conservation across the world. Peatlands are vital ecosystems with a multitude of functions that make them vital to society and protecting them is a significant element in our fight against climate change. The GNB coalition is being proactive in developing and delivering a new blended finance model to support this across peatlands in northern England. ES

Paul Leadbitter is the Peatland Programme Manager at North Pennines National Landscape in northern England. In this role, which he has held for over 18 years, Paul leads a team of peatland specialists in the restoration of over 50,000 ha of degraded peatlands in England's largest blanket bog system.

Chris Woodley-Stewart is the Director of North Pennines National Landscape.

Rosie Snowden is the Peat Programme Manager of Yorkshire Peat Partnership.

Lyndon Marquis is the Peat Communications and Engagement Manager of Yorkshire Peat Partnership.

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FEATURE

The urgent need for natural capital data

Ruth Waters and **Elizabeth Mitchell** make the case for the natural capital approach.

Nature matters to all of us. It provides the resources for our economy, protects us from extreme weather, helps regulate our climate, improves our health, provides us with food and water, and offers beautiful places to rest and recuperate. Nature, however, is largely invisible in mainstream economics: we take for granted the benefits we get from it, expecting them to regenerate forever. We need to take account of nature in all our decisions for our own future, and that of the planet more widely. Natural capital data is the key to making this happen.

There is copious evidence that shows that biodiversity and nature are deteriorating across the world at unprecedented rates.[1] This is now affecting our own wealth. The recent United Nations (UN) Environment Programme's Inclusive Wealth Report shows that global inclusive wealth per capita has dropped by 5 per cent, which has been accompanied by a severe drop in natural capital of 50 per cent per person.[2] We have been accumulating produced and human capital at the expense of natural capital, and this simply is not sustainable. Demand is outstripping supply. This is no good way of managing our assets.[3] One of the great hopes of taking a natural capital approach is to make nature explicitly visible to all sectors of government, business and society, enabling us to take account of it in our decisions and to act accordingly.

EXISTING TOOLS AND APPROACHES

A plethora of tools, frameworks and approaches have been developed to make this process more straightforward. For example, we can use spatial modelling to explore options for planning and seeing the consequences of the choices we make. The Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) model maps and values ecosystem services and goods from nature, enabling decision-makers to assess quantified trade-offs associated with alternative management choices. It also helps to identify areas where investment in natural capital can enhance ecosystem service benefits for people (see **Table 1**).[4]

▼ **Table 1. A simplified table of ecosystem service examples.**

Ecosystems		
Provisioning services	**Regulating services**	**Cultural services**
Food	Water quality improvements	Recreation
Natural materials such as timber	Water flow control	Watching wildlife
Energy from biomass	Air quality regulation	Researching and studying nature
Water supply	Noise regulation	Heritage and beauty of nature
	Disease and pest control	Sacred or culturally significant places
	Climate regulation	
	Thriving biodiversity	

Based on the standardised CICES ecosystem services typology V5.1 [5]

These approaches can be participatory and local in nature, and can operate at different scales, from local to (in theory) global. Governments rely on accounts to inform their budgets and policies. The UN, in partnership with local, regional and international experts around the world, has developed standardised approaches to natural capital accounts. The System of Environmental-Economic Accounting: Ecosystem Accounting (SEEA EA) seeks to integrate economic and environmental data to provide a view of the interrelationships between the stocks of environmental assets and the benefits they bring to humanity.[6]

The UK has been proactive in developing and applying these methodologies. The Office for National Statistics (ONS) produces natural capital accounts for the UK; these show that in 2019 the stock of the aspects of UK natural capital that we can value is estimated to be £1.2 trillion.[7] The finance sector is also seeking to mainstream nature into its financial disclosures. The Taskforce for Nature-related Financial Disclosures has developed recommendations and guidance to encourage and enable businesses and financial institutions to assess, report and act on their nature dependencies, impacts, risks and opportunities.[8]

However, in all these approaches, there is a fundamental need for evidence and data to input into the tools, frameworks and appraisals.


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The Kunming–Montreal Global Biodiversity Framework, agreed as part of the Convention on Biological Diversity in 2022, has turbo-charged the need for high-quality, consistent nature-related data with ever-increasing demands from governments, businesses, financial institutions and civil society. The sort of data necessary for many of the decision-making frameworks is information on the state of natural capital – its quantity, quality, location and how it is changing – as well as ecosystem services values where possible and information on drivers of change. Ecosystem quality data have been identified as the priority gap to be addressed.[9]

TAKING A NATURAL CAPITAL APPROACH

The importance of natural capital has been recognised across the UK, although approaches vary around the world. In England, the Natural Capital Committee (NCC) ran from 2012–20 and was an independent advisory committee on protecting and improving natural capital. The NCC really got under the skin of the application of a natural capital approach, including changes to the Green Book issued by HM Treasury to appraise policies, programmes and projects, issuing guidance on accounting, and working with the ONS and Defra on the development of UK natural capital accounts. The NCC identified the urgent need for a natural capital baseline census, stating that 'understanding the state of natural capital assets is fundamental to measuring progress'.[10]

NATURAL CAPITAL AND ECOSYSTEM ASSESSMENT

To respond to this urgent need the Natural Capital and Ecosystem Assessment (NCEA) was set up in England. It is a significant investment designed to provide baseline natural capital evidence and to fill in gaps in our existing nature-related data, with the underlying goal of enabling sustainable engagement with nature. The NCEA has marine and terrestrial components, which largely take separate approaches, although both are run as partnership programmes by Defra.

The terrestrial programme collects comprehensive information on our ecosystems in terms of their quantity, quality and location across terrestrial and freshwater assets. On the marine side, there is a more targeted approach to integrating natural capital data into decision-making in specific locations and to ensuring that our monitoring methods are fit to support a natural capital approach. Both are in the final year of an initial

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three-year funding cycle and, while there is still much to do, data and evidence are emerging.

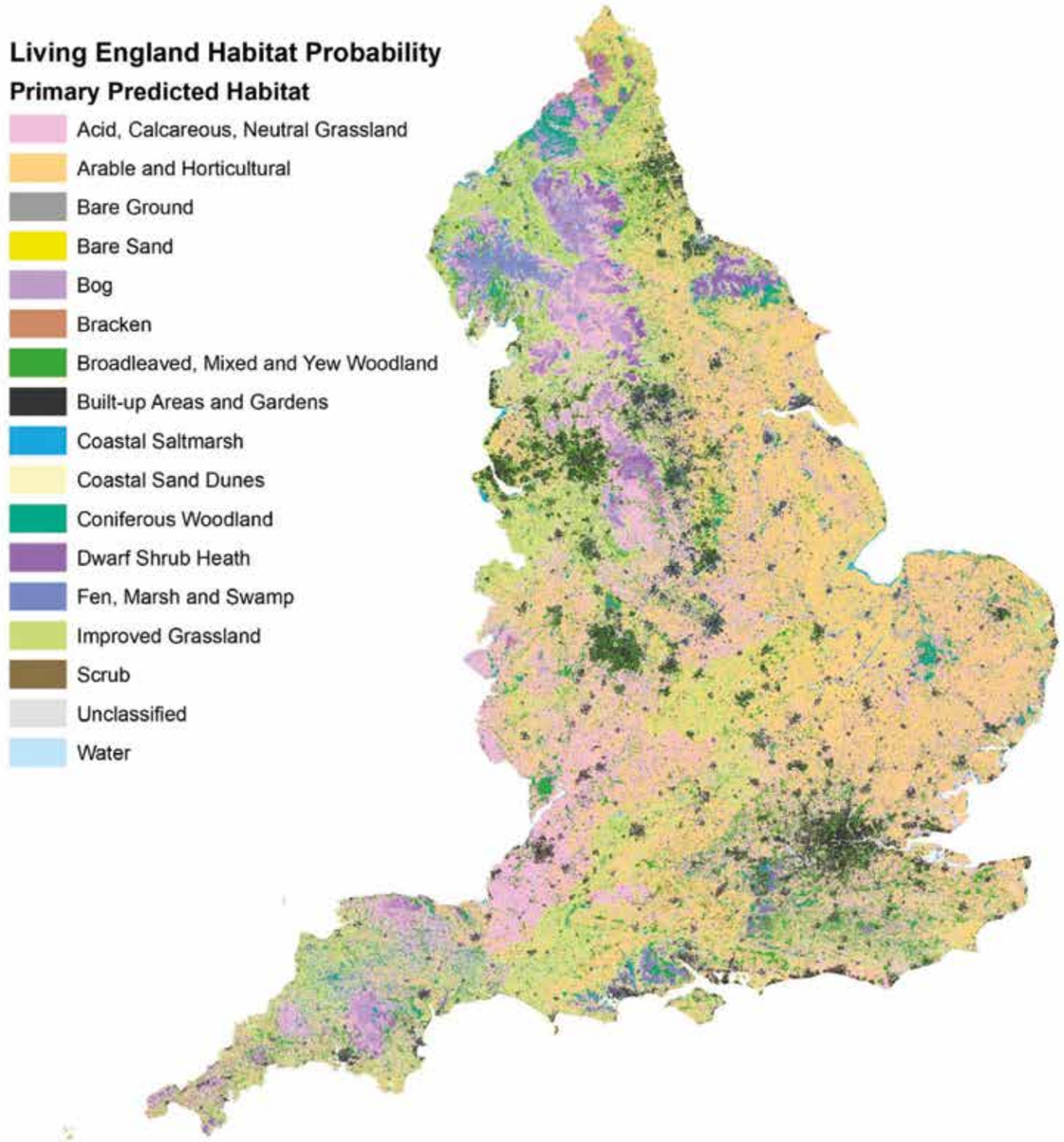
The NCEA is collecting data through Earth observation, field sampling and citizen science. It includes innovative techniques such as environmental DNA (eDNA), artificial intelligence and machine learning, and remote sensing, as well as field survey by ecologists. It is also looking at how to make the best use of data that are already available and how to better streamline data processes both within government and across the wider biological-recording sector. Wherever possible, outputs will be freely available online.

A few indicative projects from the terrestrial and marine NCEA (mNCEA) programmes include:

- **England Peat Map.** This is a modelled map of peaty soils across England, showing the extent, depth and surface features of peat and the types of vegetation it supports. The map will allow us to estimate how much peat we have and what condition it is in, potentially informing everything from national carbon calculations to climate regulation accounts and peatland conservation.[11]

- **England Ecosystem Survey.** This is the largest field survey in a generation. It collects data on soils, vegetation and landscape change across the country, using sampling across 3,000 plots on a five-year cycle. The data will be used to assess the quality of ecosystems and directly address key identified gaps in nature-related data. It will enable us to track the state of the nation's natural capital assets and inform the State of Natural Capital report.[12] It will also help support a host of policies and reporting priorities, such as the Environmental Land Management schemes.

- **Living England.** A habitat probability map for the whole of England, created using satellite imagery, field data records and other geospatial data in a machine learning framework (see **Figure 1**).[13,14]



▲ **Figure 1. Living England habitat probability map. (Source: Living England Phase 4 habitat probability map[13])**

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It shows the extent and distribution of broad habitats across England, providing a valuable insight into our natural capital assets and helping to inform land management decisions.

- The mNCEA is testing new techniques that will allow us to monitor our seas and coast as cost effectively as possible. For example, the programme is comparing six types of monitoring data (e.g. satellite, drone, topographic imagery) to see where remote sensing can be used instead of ground surveys in the intertidal zone.

- The mNCEA is also bringing together ecological with economic and social science data to allow more integrated decision-making. For example, at Morecambe Bay, a natural capital approach is being used to develop a cockle management plan that is fair to residents and the fishing community, as well as to birds and other biodiversity at the site.

New approaches like eDNA monitoring are being used across the programme, in some cases as trials (e.g. a comparison of eDNA versus acoustic data to monitor marine mammals) and in others to collect large-scale datasets (e.g. extra-urban ponds across the country). These are part of a wider effort across Defra to establish the place of eDNA alongside other novel and established approaches within the wider monitoring network.

The provision of data and evidence is potentially transformational for mainstream nature and natural capital decisions. It can make what was previously invisible visible, demonstrating the substantial risks we are carrying for the long-term prospects of our economy and society. With an ever-increasing demand for information across a much wider range of sectors and users, investment in natural capital data and the development of increasingly accurate and innovative approaches is a potential game-changer and one we cannot afford to ignore. ES

Ruth Waters is Director of Evidence at Natural England and leads the team working on the terrestrial NCEA. She is a strong advocate for natural capital and mainstreaming nature in decisions across society, the economy and government. Ruth was the lead scientist in the team supporting Professor Sir Partha Dasgupta on the independent review of the *Economics of Biodiversity*.

Elizabeth Mitchell leads on stakeholder engagement for the NCEA programme within Natural England.

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CASE STUDY

Putting the marsh back into Broad Marsh

Paul Wilkinson unwraps Nottingham's vision of creating a new green space to reconnect people and nature.

The phrase 'ecological and climate crisis' is now widely used. But the reality can be felt most keenly in our towns and cities, where many places that were once green and humming with wildlife are now grey concrete and steel, and where the sights and sounds of nature have been extinguished. The UK is in fact one of the most nature-depleted countries on the planet and is a place where, in the last hundred years, we have lost 97 per cent of our wildflower meadows, much of our woodland and wetland habitats, and where many of our once common wildlife species are in decline.[1]

CASE STUDY

Human beings are a part of nature, and we rely on it for our very existence. However, we are now a predominantly urban species, with cities being our main habitat.[2] Of concern is that, in many cases, the people living in our towns and cities are increasingly disconnected from the natural world and from the pressures that lead to its continued decline. This disconnect puts nature at risk, but it also has far-reaching impacts on our health and well-being.

The distribution of high-quality, wildlife-rich spaces in our cities is not equal, and it is often our poor and ethnic minority communities that have the least access to nature and who pay the highest price in terms of impacts on quality of life, health and well-being. This situation is described starkly in a recent report commissioned by Wildlife and Countryside Link, which concludes that millions of lives are shortened and worsened by distance from a healthy environment.[3] It is this loss – and lack – of nature across many towns and cities that means we must seize every opportunity to weave nature back into where it once was; to create the thriving, flourishing spaces that have a vital role to play in making our urban areas more liveable, resilient and fit for the future.

Opportunities to do this at scale do not come along very often. It is why the Nottinghamshire Wildlife Trust acted swiftly on a potential opportunity to turn the demise of a former shopping centre site in central Nottingham into something wilder.

THE OPPORTUNITY

In January 2019, Nottingham City Council declared a climate and ecological emergency and set an ambition to be the first carbon neutral city in the UK by 2028.[4] Around 18 months later, an opportunity to think differently and with a nature-first focus presented itself when the partly derelict Broadmarsh Shopping Centre, one of the biggest developments in Nottingham's city centre, was handed back to the City Council after the developer, Intu, fell into administration, making the future of the building uncertain.

Initially, the focus of public conversation and speculation was around redevelopment of the site for shopping, eating and entertainment. However, by now it was 2020, at the height of the Covid-19 restrictions, and it was clear that there was a significant increase in public awareness and appreciation of nature and the value of outdoor natural green spaces for their benefits to mental and physical well-being. There also appeared to be a fundamental recalibration of what people felt was important in their lives, with open and green spaces becoming increasingly highly valued.[5]

Against this backdrop, the Nottinghamshire Wildlife Trust, a locally based nature conservation charity that has been championing urban wildlife for over 30 years, worked closely with landscape architects and urban designers Influence, to launch an ambitious Broadmarsh Reimagined campaign. Its aim was to encourage the City Council to take the once-in-a-generation opportunity to reshape the fabric of the city to match its green ambitions.[6]

Broadmarsh Reimagined proposed that 100 per cent of the derelict and demolished site should be transformed into a natural urban oasis, which could become Nottingham's living, breathing heartbeat – a mini Central Park. Here, people could connect with nature and escape the stresses of urban life without leaving the city, as well as being a flagship demonstration of the City Council's wider green ambitions. Nottingham has green spaces to be proud of, not least the Arboretum city park and the magnificent Wollaton Park, but the heart of the city is unmistakably grey, not green. As new developments have replaced old, fragments of remaining green space have disappeared and opportunities to recreate vital new green areas have been lost.

As well as emphasising the nature and well-being benefits, the Broadmarsh Reimagined campaign also highlighted the opportunity of such a bold green vision for setting the city apart and on course for a greener economic recovery. It could also boost tourism and stimulate inward investment as part of a wider vision and transformation of the city as a visitor destination, built around the enhancement and promotion of its natural and cultural heritage. The scheme could generate jobs and growth within the immediate Broadmarsh vicinity as well as across the city by creating a more attractive space for people to visit. Furthermore, it could offer natural solutions to climate change such as contributing to urban cooling and flood alleviation through management of run-off through the new marsh.

Other cities around the world such as Denmark's Copenhagen, Germany's Freiburg, and the USA's


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Portland, which share Nottingham's ambitions to cut carbon emissions, have also set themselves apart by putting nature and accessible green space at the heart of urban planning to create vibrant, liveable and resilient cities.[7,8,9]

RESPONDING TO DEMAND FOR MORE NATURE

To guide decisions around the future of Broadmarsh, the City Council initiated a Big Conversation to invite residents' views. Held over the autumn of 2020 through a dedicated website and app as well as in person at a pop-up shop on Lister Gate, the Big Conversation attracted over 3,000 individual responses and 11,000 comments from residents, businesses and business groups, charities, campaign groups, schools, colleges and national architects.

The Nottinghamshire Wildlife Trusts' Broadmarsh Reimagined campaign ran in parallel with the City Council's Big Conversation and attracted local, regional, national and international interest and, importantly, support from around 15,000 people, including many city residents. The combination of these public responses led to shifting the dial significantly from a potential focus on built development towards a more nature-centred approach.[10]

In response to the Big Conversation, the City Council created an Independent Advisory Group to develop proposals that reflected the public's views and aspirations. At the same time, the decision was made to revert to the original name of Broad Marsh. This group, with design input and inspiration from Hetherwick Studio, embraced the nature-first concept and the potential for the Broad Marsh redevelopment to connect to wider ecological, societal and economic opportunities. A focal point was identified: the Green Heart.

DESIGNING THE GREEN HEART

Having publicly endorsed the concepts developed by the Independent Advisory Group, the City Council established a project team of landscape architects and designers, ecologists, engineers and construction specialists to develop detailed designs and plans for the Green Heart. Early on in this process the team developed key design principles linked to the vision for the Green Heart: public realm criteria, site analysis and constraints, and spatial arrangement and uses. Central to these design principles was the idea of 'Nottingham-ness' and of creating a place as an integral part of the city.

To inform the design, ecological surveys were conducted across areas adjoining the Green Heart to better understand the range of habitats and species already present in the vicinity so that connections could be made via the planting scheme and design features. Understanding the surrounding ecology was critical to ensuring that the Green Heart sits within and connects to the wider landscape as part of a nature recovery network through the city.

Essential to ensuring the Nottingham-ness of the Green Heart was consideration of the surrounding topography, history of the site and connections to other parts of the county. From a topography perspective, the Green Heart is framed by and connected to the Nottingham cliffs and caves, which provide a dramatic backdrop and influence the area's substrate, drainage and light. The design of the Green Heart, therefore, took inspiration from this to create a dry rock garden, which would be more sparsely planted with drought-resistant plants. Historically, the city of Nottingham was connected northwards to the extensive, iconic Sherwood Forest, which extended over half the length of Nottinghamshire County. To make this connection, a network of tree planting was built into the centre of the design, as an echo of the forest that was once on site.

However, by far the biggest challenge in rewilding this part of the city centre was the reintroduction of a large new vegetation-fringed wetland in the southern area of the Green Heart. As the Broad Marsh name suggests, this area was once an extensive wetland, part of floodplain of the River Lean, and so putting the marsh back into Broad Marsh became a major focus involving hydrologists, engineers, ecologists and design specialists. The new marsh will create an attractive public realm and will play an important role in climate change mitigation and adaptation, habitat creation and place-making. It will bring significant benefits to nature by attracting a range of species of birds, amphibians and invertebrates that would have previously struggled to find a home to naturally colonise the area.

If delivered to its full extent and to a high ecological quality, the Green Heart and its radiating network of nature-friendly arteries and capillaries will add almost 10,000 m^2 of new natural green space in the city and provide important links to other green and blue spaces across the area – from Nottingham Castle and Nottingham Canal to the green infrastructure planned to be created across the 36-acre Island Quarter regeneration site and beyond. Therefore, the Green Heart and nature regeneration opportunities across the Broad Marsh area could contribute significantly to wider recovery: nature recovery; economic recovery, by differentiating Nottingham from similar-sized cities; and social recovery, by boosting public well-being and addressing the fact that the most disadvantaged city residents have the least access to natural green space.

While final designs have been completed and construction of the Green Heart is underway, there is still a long way to go to ensure the vision for the Green Heart and the wider Broadmarsh area is realised. Nottinghamshire Wildlife Trust takes great pride in the role it has played to inspire and shape an ambitious vision for nature for a wilder Nottingham and hopes to inspire other local government authorities across the UK and beyond to weave nature into the fabric of their towns and cities. ES

Paul Wilkinson, MCIEEM, is the CEO of Nottinghamshire Wildlife Trust. He previously worked in The Wildlife Trusts as national policy lead on issues such as farming, planning, climate and landscape-scale nature conservation. Paul was also Regional Policy Director for The Wildlife Trusts in the East of England and has worked in local government on county-level policy issues.

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FEATURE

(Re)turning the tide: changing perceptions on the value of saltmarshes

Tom Brook discusses the advantages of harnessing these unique habitats for the benefit of our environment and society.

Saltmarshes stand as frontline defenders of our coasts, uniquely equipped to combat the forces of nature. An intricate maze of creeks and channels criss-crossing a rich mosaic of plant life with an extraordinary adaptation to saline environments buffers our coasts from storms and erosion and fosters a distinctive biodiversity. The dynamic interface between land and sea is vividly echoed by the thriving animal and plant life within – as much of a home to birds like egrets, dunlin and spoonbills as they are to European eel, flounder and other fish. What is more, these resilient ecosystems act as efficient carbon sinks, playing a pivotal role in the global fight against climate change.[1] Recognising saltmarshes for these benefits means their preservation is not merely an environmental choice but a strategic investment in sustaining Britain's coasts.

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Yet few habitats have been as maligned as saltmarshes. Throughout our industrial history these marsh marvels have been viewed as unproductive wastelands, with as much as 85 per cent of their original extent drained for agricultural use or filled in for urban development.[2] Driven by the notion that saltmarshes were of little value, their conversion was seen as necessary for economic progress and to make the land more valuable. Indeed, despite their prevalence across the UK, misconceptions about their significance are still strong today.

Despite this, a transformative and positive shift is underway, garnering increasing support from policy-makers, academics and non-governmental organisations making a concerted effort to improve the evidence base to support increased investment in saltmarsh conservation.[3] This change is, in part, attributed to the adoption of the natural capital approach, which demonstrates the immense value of these ecosystems – particularly their ability to capture and store blue carbon (i.e. carbon sequestered within coastal and marine environments). Saltmarshes, once overlooked and underestimated, are now recognised as a valuable ecosystem with a pivotal role to play in sustaining the well-being of people and the environment and in achieving our net zero ambitions.

WHAT MAKES A SALTMARSH?

Existing on the fringe of land and sea, saltmarshes are coastal wetlands subjected to the rise and fall of the tide. They are characterised by salt-tolerant vegetation, forming a gradient of habitats from high marsh, in reach of only the highest spring tides, to low marsh that is regularly inundated by saltwater. These coastal ecosystems provide crucial habitat for a wide array of flora and fauna, supporting biodiversity and serving as nurseries for many marine species. Birds, fish and invertebrates rely on saltmarshes for breeding, feeding and refuge, making them essential components of coastal ecosystems.

Saltmarshes also offer substantial value in terms of carbon sequestration and storage. The organic matter in saltmarsh soils captures and retains atmospheric carbon dioxide through constant succession of plant life and filters particulate matter washed in from the tides – capturing carbon on two fronts. This function is particularly significant in the context of blue carbon, which has gained increasing attention over recent years as the rate of blue carbon sequestration is estimated to be significantly higher than that of forests (see **Figure 1**).[4]

Perhaps most notably, saltmarshes help to safeguard our coastlines and contribute to our well-being. Coastal protection is one such example, with saltmarshes acting as natural buffers against storm surges and erosion. Their ability to reduce the impact of waves helps protect coastal infrastructure and, therefore, communities. Additionally, saltmarshes contribute to water quality improvements by filtering pollutants and nutrients from run-off, such

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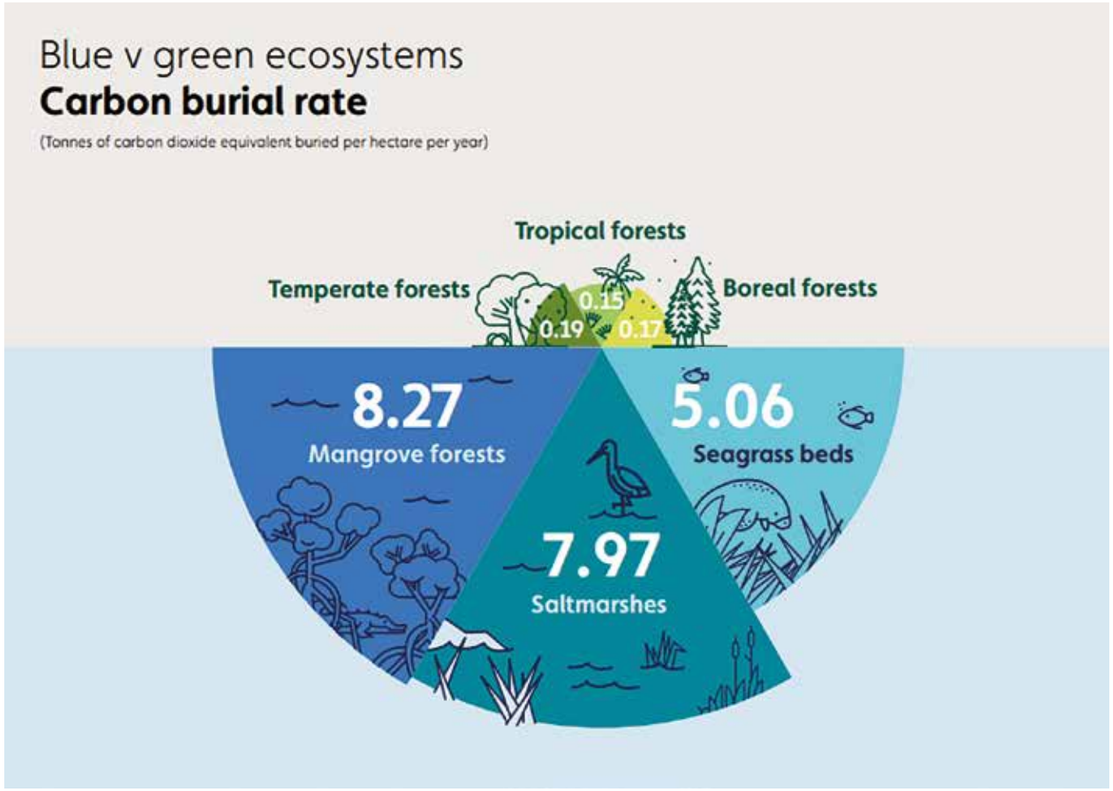

▲ **Figure 1. Carbon sequestration abilities of blue and green ecosystems. (Source: Wildfowl & Wetlands Trust[4]). Data from McLeod et al. 2011.[5]**

as excess nitrogen and phosphorous, enhancing the overall health of marine environments. Recognising and valuing the natural capital of saltmarshes is essential for informed and sustainable management practices that balance conservation efforts with human needs.

NATURAL CAPITAL TO SCALE UP RESTORATION

While efforts to estimate the natural capital of saltmarshes have advanced significantly, achieving a precise valuation remains challenging due to the complex interactions within these ecosystems and the multitude of services they provide. Some regulating services, such as flood mitigation, have been well documented and are valued at £62 million in England and £9 million in Wales, with almost £2 billion worth of assets benefitting directly from flood alleviation provided by saltmarshes.[6]

For others, however, uncertainties persist. This is particularly true in assigning monetary values to non-market goods and services like biodiversity conservation and recreational benefits. Despite these challenges, ongoing research and interdisciplinary collaborations continue to refine our understanding of saltmarsh natural capital, facilitating better-informed decision-making, management strategies, and initiatives dedicated to protecting and restoring these habitats.

One such initiative in England is the Restoring Meadow, Marsh and Reef (ReMeMaRe) (pronounced 're-memory') programme, which aims to reverse their decline.[7] For saltmarshes, this initiative plans to build on several examples of successful saltmarsh restoration through managed realignment – a process which sets back coastal defences to return tidal movement in designated areas, thus restoring saltmarshes and mudflats. While there are clear benefits in doing so, several challenges remain in scaling up efforts, including prohibitively high costs and competing demands for land use, as well as limited funding and justification for private landowners to engage in these initiatives.

Other restoration techniques include regulated tidal exchange, where tidal flow is carefully managed to mimic natural processes to encourage the establishment and growth of saltmarsh vegetation. By strategically allowing water to flow through engineered structures such as sluices, tide-gates or pipes, restoration practitioners can


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create conditions conducive to saltmarsh colonisation and expansion. Additionally, the beneficial use of dredged sediments offers another route to increasing saltmarsh restoration efforts. Dredged sediments, often obtained from navigation channel or harbour maintenance activities, can be deposited onto degraded saltmarsh areas, providing essential substrate for vegetation establishment and helping to increase marsh elevation in the face of sea level rise. However, less than 1 per cent of dredged sediments are used in this way.[8]

Enter the UK Saltmarsh Code – a natural capital financing mechanism that will operate similarly to the woodland and peatland codes, establishing a voluntary standard through which companies can support saltmarsh projects with verified climate mitigation benefits.[2,9] The code is being developed by a leading group of academics and is set to pave the way for significant investment in restoring the UK's saltmarshes by providing an income stream for restoration projects and supporting the achievement of national net zero goals. With the potential to incorporate payment for ecosystem services in other forms, such as nutrient run-off mitigation, the Saltmarsh Code could attract a diverse range of investors and kick-start the development of blue carbon markets in support of conservation efforts in other habitats like seagrass meadows and kelp forests.

BRINGING BLUE TO THE BOARDROOM

Coastal and marine ecosystems such as saltmarshes are critical to our natural capital and climate resilience. The carbon sequestration potential of these ecosystems has drawn increased attention from investors and has been well documented in blue carbon habitats outside the UK, such as mangroves.[10] This could help to channel private capital towards restoration and conservation projects – supporting the UK in meeting its national obligations and limiting the effects of climate change – and provide substantial benefits to coastal communities and biodiversity.

With operationalisation of the Saltmarsh Code expected in the coming months, the UK has a unique opportunity to create a scalable blue carbon market, opening the door to the inclusion of coasts and seas in our net zero ambitions. There remain, however, several challenges in scaling up saltmarsh restoration, such as competition for land use. While natural capital approaches – like the Saltmarsh Code – may increase how these habitats are valued by some sectors, work is still needed to transform perceptions across society. There remains a considerable risk that saltmarsh restoration, and particularly managed realignment, if not communicated properly, could affect a community's sense of place and feeling of security against coastal flooding. Saltmarsh restoration must, therefore, take a truly multi-disciplinary approach to combine stakeholder engagement and science to inform policy integration. ES

Tom Brook is a blue carbon specialist at WWF-UK, working with teams in the UK and internationally to translate the latest scientific knowledge into policy. Tom's role is to develop and implement best practice within coastal restoration and conservation projects, increasing the transparency, credibility and bankability of these ecosystems. He has over five years' experience of managing blue carbon research and has conducted assessments across a range of habitats including saltmarsh and seagrass, as well as wild and farmed seaweeds.
tbrook@wwf.org.uk

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Tel +44 (0)20 3862 7484
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