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Research and analysis

Defra group research and innovation interests

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Introduction

The Department for Environment, Food, and Rural Affairs (Defra) has, as its name suggests, a broad range of responsibilities. It runs programmes to deliver much of the research and monitoring needed for policy development, both nationally and internationally.

[Credit: Royal Botanic Gardens, Kew]

Working with a wide range of centres of scientific expertise, including Public Sector Research Establishments, universities, industry, and national and international organisations, Defra sets policies to ensure a healthy and sustainable environment and to achieve production of food at high standard for consumption at home and for trade.

Defra's policies are evidence-based and rely on research to ensure they are effective and take account of up-to-date understanding. This document describes the broad areas where Defra needs further research and innovation to inform its programmes and policies.

This research will help Defra realise the goals set out in important government strategies, respond to the climate crisis and make progress following the exit from the EU. It will also inform legislative commitments of the devolved administrations, such as those of the Environment (Wales) Act 2016.

These research and innovation interests are presented in this document at a high-level, giving an overview of the breadth of Defra's enquiry. They are expected to be areas of interest for at least some years. In many cases they represent long-running fields of research endeavour and span more than one discipline. These research needs have been influenced by the substantial perturbation of the coronavirus (COVID-19) outbreak. This document includes early consideration of the new and altered research needs that will arise.

Identifying the departmental research and innovation needs will ensure Defra's evidence activities inform, and are driven by, policy and operational needs. Enabling greater strategic oversight of the evidence activities.

Research to address these areas of interest is delivered by a range of organisations and people. Some of the research is undertaken in the Public Sector Research Establishments (PSREs) in the Defra group which have extensive specialist research expertise. But Defra also works with a broad range of universities, research institutes, industries and industry bodies, charities and volunteer organisations, and with other government departments. Defra benefits from the global excellence of UK environmental science and research.

Research that contributes to Defra's policy making and programmes is funded through a variety of routes. Some is funded and commissioned by Defra directly and targets specific short-term evidence needs in the department. Some is more extensive research funding by UK Research and Innovation (UKRI). This includes novel and innovative research to inform Defra's strategic research interests. Relevant UKRI research is delivered in a variety of programmes, including those in the Strategic Priorities Fund.

This document does not present a view of the structure or processes by which research is commissioned and used in Defra, nor of the breadth of research undertaken in the PSREs in the Defra Group. But the document structure includes a section which discusses research interests in each of the five "Outcome Systems" that Defra uses internally. This section is preceded by sections that consider research needs in areas that cut across Defra's portfolio, such as climate and land-use, and a section about important research tools and approaches.

Defra Group System is structured around five outcome systems listed below:

- natural environment and rural
- floods and water
- food farming and biosecurity
- marine and fisheries
- environmental quality

The department actively seeks connections with relevant external research. Defra experts attend conferences and take part in research programmes; Defra runs more than 20 specialist advisory bodies to consult leading external experts; Defra runs a number of intern, studentship and secondment programmes; and Defra commissions research teams to address particular problems. We are always seeking new approaches to learn about research in the areas outlined in this

document. That research is fundamental to the evidence-based policy making that the department prides itself on.

The eight Public Sector Research Establishments in the Defra Group. Seven of these are Defra arm's length bodies. Fera is a Joint Venture between Defra and Capita PLC.

- Animal and Plant Health Agency (APHA)
- Centre of Environment, Fisheries, and Aquaculture Science (Cefas)
- Environment Agency (EA)
- Fera Science Limited (Fera)
- Forest Research (FR)
- Joint Nature Conservation Committee (JNCC)
- Natural England (NE)
- Royal Botanical Gardens Kew (RBG Kew)

Other scientific arm's length bodies in the Defra group are:

- Marine Management Organisation (MMO)
- Veterinary Medicines Directorate (VMD)

Cross-cutting research and innovation questions

Several key themes cut across Defra's domain. These often involve consideration of the complex and multifaceted interaction between the environment and human activity, and the application of multiple disciplines.

Climate change and Net Zero

Adaptation and resilience: Defra is the lead government department for climate adaptation, responsible for the assessment of appropriate action to protect and enhance natural and human systems in a changing climate. Also, for increasing resilience and mitigating against risk. Such assessment is used in many areas, including for the statutory requirement of the Climate Change Act to produce a 5-yearly, "Climate Change Risk Assessment (CCRA) and National Adaptation Programme (NAP)".

Although Defra has overarching responsibility for producing the CCRA and is responsible for managing several climate risks (such as impact on the natural environment), a number of climate risks (such as the impact on transport, health, business) are the responsibility of other government departments (for example Department for Transport (DfT), Department for Health (DfH), Department for Business, Energy and Industrial Strategy (BEIS), Ministry of Housing, Communities and Local Government (MHCLG).

Areas of interest in adaptation:

- how can we develop and exploit new methodologies to ensure cost-effective monitoring of climate change and adaptation actions and impact on climate risk? How do we measure resilience to test the success and cost effectiveness of actions, and incorporate resilience indicators into decision making?
- what are appropriate adaptation actions to climate change across government, now and as change progresses, and when is it reasonable to implement these? How can we better understand the risks and opportunities around the policy drivers for adaptation (and mitigation)? How do we avoid maladaptation and ensure resilience to a range of possible futures?
- how can we assess the impact of the National Adaptation Programme and Adaptation Reporting Power on improving resilience?
- what criteria should we use to determine acceptable sectoral climate resilience scenarios across government departments, and when building preparedness externally?
- how can we address barriers to action on adaptation, including behavioural change, and how can government policy best encourage these changes?
- climate projections (for example UK Climate Projections 18) indicate increased climate variability and extreme events (storms, heat waves, drought) in the future. How will these changes impact natural and human systems? How can we protect against damage caused by such increased variability?
- how will natural habitats and systems respond to accelerating rate of change, including woodlands, soils, freshwater ecosystems, and marine systems? What will be the implications of these responses on managing the risks and impacts of climate change, and what inevitable changes will we have to accept in our ecosystems?
- how do we better consider and adapt to the effects of climate change at regional and local levels, to develop a better understanding of conflicting demands?
- how do climate risks interact with socio-economic factors and vulnerabilities? Where do inequalities lie, and how can access to adaptive benefits be maximised for the most socially vulnerable/disadvantaged in society?
- how can society and government act to protect and enhance nature, thereby sustaining the ecosystem services (including mitigation and adaptation to climate change) it provides, under a changing climate?
- how will changing freshwater budgets impact river flow, water availability, the risk of flooding, and natural systems?
- what is the impact of rising sea level on coastal systems, natural, and human? Can natural systems help to mitigate against coastal incursion and degradation?
- how can we build resilience of biodiversity and society to climate change through ecosystem restoration, better land management, and land use?
- how will crop, livestock, and woodland resilience alter in the future, impacting optimal agricultural and forestry practices for the UK? What practices and policies can we develop to drive adaptation?
- how is climate change affecting the emergence and transmission of infectious diseases, and how can we become more resilient to these outbreaks?

- how will the changing climate affect the persistence and movement of chemical contaminants in the environment?
- how will agriculture affect the resilience to climate change of surrounding habitats and communities- for example water availability, flooding, land use change, chemical harm on ecosystem functions related to climate resilience?
- what will be the ecological, economic, and social impacts of sea level rise? How effective are our current responses?

Achieving Net Zero: To limit future warming requires rapid reduction of greenhouse gas (GHG) emissions and achieving net zero by 2050, as required by UK legislation. Climate mitigation is led in government by the Department of Business, Energy and Industrial Strategy (BEIS). But Defra is responsible for efforts to reduce GHG emissions from four sectors: agriculture, waste and wastewater, land-use, and fluorinated gases (F-gases). Defra also has responsibility to promote forestry, which acts as a carbon sink. Together, the four Defra sectors represent 15% of the total net UK GHGs, with agriculture being the biggest contributor (about 10% of UK emissions).

Defra has research interests in reduction of emissions, the removal of GHG from the atmosphere, and in understanding the impacts of mitigation activities on other environmental outcomes:

- which practises can most effectively reduce emissions of GHG (including CH4 and N2O) from agriculture, waste, and wastewater, land-use, and F-gases in the UK and internationally?
- how can the UK protect and increase its standing stock of organic carbon: trees, peat, soil, and salt marshes? How can these habitats most efficiently be distributed spatially given limited land and other needs (for example urban space, food production, recreation)? How can increases in carbon stocks be achieved while maximising co-benefits such as biodiversity, clean water, and nutrient balance?
- what is the GHG emissions reductions potential from different land-based interventions per unit area per year, how will natural carbon sources and sinks evolve in the future, and what are their timeframes for delivery from implementation? For example, what levels of emissions reductions can be achieved by actions within the new Environmental Land Management Scheme's outcomes framework, and from forestry, and over what time frames are these delivered?
- how can the UK develop measurement of carbon fluxes from different habitats and farming systems which are in different conditions and using different management approaches? This is especially relevant for peatland and coastal habitats
- how can we predict the potential impacts of a changing climate on actions and strategies to mitigate climate change (for example how will future climate change impact the delivery of carbon sequestration by different habitats)? What tools are available to allow for effective planning of climate change mitigation strategies that are resilient to a changing climate?

- how can we develop pathways towards net zero that are socially, economically, and environmentally sustainable? What is the range of viable solutions, and what are the associated co-benefits and trade-offs? This includes developing spatially explicit models and tools to inform decisions at the landscape level, including prioritisation of conflicting land use demands
- what is the role of the consumer in delivering net zero and how can changes be achieved equitably? What are the potential market responses to such changes and how do we avoid unintended consequences?
- what are the real-world barriers that prevent land-users (for example farmers) taking up low/negative carbon measures, and how can these be overcome? How can we improve the estimation and validation of take up for these practices?
- how can the UK optimise sustainable growth of biomass for use in power generation (bioenergy) and, with appropriate storage, for removal of atmospheric CO2? How can the negative environmental consequences from biomass production and use (on soil quality, water quality, air quality, and biodiversity) be minimised? What's the full life cycle analysis for different feedstock? What's the scalability of different feedstocks within sustainable limits?
- how can a more strategic approach to land use be developed through aligning climate change objectives (adaptation and mitigation) with objectives for biodiversity and ecosystem services? How can the environmental co-benefits of mitigation actions be identified and quantified?
- what are the competing pressures, trade-offs, and synergies of different land-uses in relation to climate change in a post COVID-19 world?
- can other land-based approaches to greenhouse gas removal, such as enhanced weathering and biochar, help achieve net zero without negative environmental impacts?
- how should mitigation of other greenhouse gases and pollutants be compared to and combined with CO2 mitigation (i.e., what is the balance of action and what are the appropriate metrics to compare them), and what do these mean for the timing of the requirement for net zero emissions?
- what are the impacts of greenhouse gas removals and negative emission technologies on climate and the environment? What are the trade-offs of negative emissions techniques and other interventions?
- what are the positive and negative environmental impacts of increasing renewable energy production (wind, solar, geothermal, and so on) and other actions taken to decarbonise the economy?

Land use

In the densely populated UK, competition for land between urban, rural, food, energy, recreation, environmental outcomes, industry and other uses is a fundamental issue. Our interaction with the natural environmental is often through our use of land.

We need to assess, in a changing society and climate, how best to sustainably use available land area as well as the full suite of natural environment considerations in that use:

- how can we balance different interests at local and national levels, to provide the resources we need, reduce degradation of natural capital and improve the state of the environment?
- what is the best way to model trade-offs and synergies across multiple environmental, social, and economic goals resulting from land use and land management?
- as well as modelling and understanding major land use change (for example from agriculture to forestry), how can we understand the effects of more subtle changes in land management across wide areas (for example changing tillage practice)?
- how to optimize the deployment of different nature-based solutions to realise their various benefits and avoid negative outcomes (for example some tree planting on peatland)?
- what are the broader environmental consequences of changes to the housing and planning system, and what is needed to support a lower-carbon future?

- what are the likely changes to our agricultural sector following COVID-19 and how can the agricultural system transition be best guided towards a sustainable trajectory while ensuring food security?
- how can we optimise the food system to support future food production and consumption sustainably whilst reducing environmental impacts?
- what is the most effective means to support community regeneration through use of parks and public spaces?
- what is needed to enhance or create natural areas to provide nature-based solutions?
- how can we understand better land/sea interactions?

Nature-based solutions

How can we effectively protect, manage and restore natural and modified ecosystems to help address societal challenges? Whilst also providing biodiversity benefits and human wellbeing – from abundant wildlife to green jobs to clean water?

Societal challenges include mitigating and adapting to climate change. These could be addressed by supporting ecosystem functions that deliver services such as carbon sequestration, coastal resilience, and natural flood management:

- how can we most effectively implement nature-based solutions, such as tree planting and peatland restoration, to address climate change, support progress to net zero carbon emission, reduce biodiversity loss and prevent poverty?
- how do we maximise the various benefits of nature-based solutions, and address any trade-offs and associated risks, through our plans for nature recovery, afforestation, peatland restoration, natural flood management, and improved water quality?
- how can we effectively use nature on our land to help provide the services we need (carbon uptake, flood defence, resilience through biodiversity, clean air and water, recreation for public health and so on) and balance the provision of these services?
- how can local planning for nature-based solutions be best reconciled with regional and national strategies? What are the most effective ways to combine place-based participatory approaches with evidence and analysis of the likely effectiveness of nature-based solutions?

Natural resources and trade

The wide range of products harvested from nature and produced by agri-food and forestry industries represent a significant proportion of UK GDP. Ensuring that these products are produced and traded sustainably to the financial and broader benefit of the UK, without damage to the environment, involves a range of critical research questions:

- what is the UK's long-term requirement for natural resources from global markets? Which resources are exposed to production/supply risks owing to geopolitical, macro-economic, pandemic, or environment factors and what are the likely impacts of change to the UK economy?
- what are the trade-offs between primary resource extraction versus reclamation of resources from waste streams in the context of resource security? How circular can the UK economy become?
- how do we minimize the risk of plant and animal disease import to the UK as traded products change, and as the UK goes through a period of significant change in its international trading arrangements post-EU and post COVID-19?

Interactions between animal, human, and environmental health: "One Health"

Human and animal health are closely entwined, often via the environment in which they interact. The COVID-19 pandemic has provided a forceful demonstration of this interaction. Human and animal health is also strongly influenced by the "health" of the environment. These interactions, considered as a system, define the research field, "One Health":

- what is the burden of antimicrobial resistance (AMR) in the environment and within food systems, and to what extent is this facilitating the development and transmission of AMR between animal and human populations?
- how can we design and embed robust, cross-cutting indicators of, and improve our understanding of, human, animal, plant, and environmental health in systems under pressure from climate change?
- how will the prevalence and incidence of animal and plant pathogens in domesticated organisms and wildlife adjust to climate change? How can we better integrate cross-sector surveillance and response to ensure the risk of large-scale epidemics or pandemics in humans (such as COVID-19), animals, and plants are minimised?
- how can we improve the management of our ecosystems, including biodiversity loss, chemical pollution, environmental degradation, and the introduction of alien species, to reduce the risk of infectious zoonotic, animal, and plant diseases?
- how does exposure to biodiverse environments link to human microbiome diversity and shape health outcomes?
- what is needed to further understand the value of plants and the wider environment to society, and how is this relationship eroded by pests and disease?
- how can a One Health approach promote a cultural change to curb the expansion of illegal wildlife trafficking and implement solutions that will ultimately benefit humans and the planet, galvanising the role of protected species conservation and biodiversity on disease prevention and mitigation?
- how can we model existing data from human, animal, plant, and environmental health indicators to better understand the interconnection and potential impacts of climate change?

- how do we deploy emerging technologies to move from post-disease/outbreak surveillance to pre-emergence surveillance and mitigation of risks?

Tools and approaches

The research areas identified in this document rely on a wide range of research tools and approaches, spanning disciplines across the sciences and social sciences. This section is not an exhaustive list of the tools and approaches of interest to Defra. It identifies some areas of particular relevance and change, which will be important in addressing the challenges faced by Defra and represented throughout this document.

Behavioural and social science

Societies demand resource from the environment and shape that environment. The social science of human-nature interactions is of fundamental importance to Defra:

- how can we encourage or incentivise behavioural change among businesses, communities, and individuals to achieve positive outcomes for the environment? What models of societal change might be used to underpin these behaviour change initiatives?
- how has the COVID-19 pandemic influenced how people engage with and value environmental systems (including nature, wildlife, and farming and food supply)? What opportunities does this present to lock-in positive behaviour change and secure environmental objectives in the longer term?
- how can we make the most of participatory/ co-design approaches with different groups in society, including digital engagement, to generate new ideas, learn from existing practice, and build consensus for the future of policy?
- what makes communities resilient to natural hazards and other crises? What can we learn from the coronavirus pandemic about the loss of resilience and protecting vulnerable communities to inform future response to crises? What are the important social dimensions for achieving environmental and infrastructure resilience?
- which techniques are best for estimating the effects of interacting risks? How do we ensure that communication of risk is relevant and effective? What lessons can we take from the response to the coronavirus pandemic about the communication of risk and of the need for behavioural change?
- how can local governance best be coordinated with national?
- what principles should be used to delegate responsibilities to local communities, and how can these areas be empowered to deliver?
- how can we balance devolved responsibilities with the need to avoid a weakening of national guidelines/ standards?
- how can we encourage the development and dissemination of innovations in the agri-environment sector? What are the right conditions for success?
- how will different groups of society, particularly in rural communities, be affected by changes associated with the move towards Net Zero and the goals of the 25

Year Environment Plan? How can positive effects be adopted more widely and negative impacts be mitigated?

- what do we know about the public acceptability of necessary restrictions such as counter disease measures? What lessons are applicable from public acceptability of the coronavirus restrictions to the animal and plant health domain?

Systems and futures

Defra's areas of responsibility cover a wide range of interacting natural and human systems. Changes that affect one outcome are often likely to have knock-on implications for others. Policy in areas such as land management, biodiversity conservation, pollution prevention, food security, fisheries, and waste management, need to be designed in the absence of perfect knowledge of how human and natural processes interact. It can be particularly difficult to attribute cause and effect in such complex systems where evidence is often partial and fragmented.

Consideration of the issues that Defra deals with as parts of systems, i.e. in terms of relationships between the parts can help us to unpick complex or seemingly chaotic situations, and better deliver robust positive outcomes for society. To facilitate more effective decision making, a range of approaches and specialties need to be applied to the above challenges. Research is required in the following areas:

- systems analysis that considers human-environmental systems as a complex set of interactions, and the novel use of systems thinking to consider the feedbacks and consequences of action in this system
- development of systems approaches that can be used to inform policymaking. This includes approaches to provide insights into complex systems, identify points of intervention, account for multiple perspectives, and frame policy decisions
- development of models to support decision making on complex and wicked problems (for example on land use, environmental trade-offs, food systems)
- how can we best develop an inclusive societal vision for a just transition towards sustainability? At what spatial scale should such visions be developed and how to reconcile across scales? How can we best manage the polycentric governance to implement these visions?
- how can we assess and mitigate systemic risks involving environmental factors? What are the best approaches for monitoring that tracks system dynamics based on key 'watchpoints' to trigger mitigation actions?
- horizon scanning and futures: Challenges to the UK can be varied and diverse, ranging from manmade deliberate actions by foreign states to naturally occurring events such as flooding, soil erosion and so on. Assessment of current and future challenges will need to be combined with the above-mentioned risk management approaches

Environmental monitoring and data science

Geospatial data: Effective use of modern data architecture and analysis to make full use of data collected in the Defra Group and other relevant sources (for example from satellites, climate observations/models, and from other government departments).

- data science: Application of techniques, including AI and block chain, to unlock opportunities for improved and more efficient environmental monitoring, regulatory compliance, and land management
- consistent and long-term environmental monitoring: Time-series increase in value for ecology and policy making as they grow in length. Decades of data are required to answer emerging questions around, for example, climate change impacts on biodiversity and the efficacy of management measures
- molecular biology: The ongoing evolution in the costs, speed, and ease of DNA measurements will allow entirely new approaches to complement traditional biodiversity monitoring and increase understanding of ecosystems, biodiversity, diseases, and other aspects of the environment
- advanced electronics: How will sensors, omics, geographical information systems, internet of things, be used to support regulation and enforcement needs across the agri-envrionmental and food sectors?
- risk management: Novel approaches to assessment and analysis of risk and resilience

Defra group's outcome systems

Natural environment and rural

Measuring change

Measuring change enables us better target action to secure a healthy environment and support our rural communities and economies. It also helps us to evaluate the effectiveness of those actions. As well as meeting legislative and policy commitments to report on the state of our environment, both domestically and internationally:

- what is the status of our natural environment, is it being effectively monitored to note change in the UK and globally? We require robust, reliable data and information that can be used to assess status and trends in the natural environment (genetic and species diversity and trends, invasive species, habitats extent, condition and character, as well as soils and ecosystem services and functions)
- how to measure ecological connectivity and design coherent ecological networks through nature restoration?
- how can we develop and exploit new methodologies to ensure cost-effective monitoring (for example remote sensing and environmental DNA)?
- global drivers of declines in nature are well documented but we need to understand how drivers interact in the UK and globally, as well as the global

impacts of UK activities. We also need to understand how our actions to address declines (such as policy responses, intervention and environmental management) impact drivers

- what are the emerging drivers of change and what might future change look like? New thinking, analysis, and data can improve our understanding, and our ability to anticipate how economic, social, and environmental drivers might change in the future. How these affect the trajectory of environmental outcomes and the future state of rural communities and businesses?

Ensuring an informed response

To achieve resilience to climate change, halt biodiversity loss, sustainably manage land and support rural communities and economies, we need informed and targeted policy development, interventions, and enforcement. These must engage appropriate actors (individuals, communities, businesses, and government) and be at the right scale and place. We also need to evaluate the impacts of our interventions:

- analysis of social and economic interactions with the environment and natural resources. What are the links and trade-offs between biodiversity, climate, sustainable management of forestry, soils and peatland restoration, economic development, food, health, wellbeing, and global poverty?
- how can we encourage or incentivise behavioural change to achieve positive outcomes for the environment, and how can we enable appropriate informed adaptive management with communities?
- how can different mixes of ‘responses’ – such as regulations, taxes (for example polluter pays), subsidies (for example public money for public goods), and spatial planning – impact the delivery of environmental, economic, and social outcomes at different spatial scales?
- what actions would most effectively and efficiently improve the status of the natural environment and secure economic, social, and health benefits domestically and globally?
- how can rural communities and businesses contribute to and benefit from the attainment of national economic, social, and environmental objectives?
- what approaches will best empower rural communities to develop social, economic, and environmental interventions appropriate to their own local circumstances?
- how do we ensure a sustainable economic recovery post COVID-19 with environmental outcomes built in; and what is the potential for rural communities and businesses to contribute?

Taking a natural capital approach

Adopting a natural capital approach improves understanding of economic, social, cultural, and environmental values. Helping to encourage behaviours and practices that support stewardship and sustainability:

- what is the value of different elements of the natural environment in economic terms and more generally? How can we best capture and integrate intangible values into decision-making?
- how does investment in the environment bring benefits to society, including through health, wellbeing, and natural capital? Who are the beneficiaries and how do we quantify and communicate those benefits – and costs?
- how do we incorporate the full spectrum of natural capital and the value of the benefits it provides into policy development, analysis, and appraisal? What are the tools we need to make use of robust economic values easier for everyone – across government and beyond?
- we also need to look internationally: How does our domestic approach compare internationally? How does implementation differ between developing and developed countries?

Floods and water

Floods and coastal erosion

Climate change is increasing the threat of flooding. We have already committed to reducing the risk of harm from flooding through improving resilience, expanding the use of natural flood management, and putting in place more sustainable drainage systems. To achieve this outcome we need a strong evidence base which can help us optimise our approaches to achieve resilience and maximise the use of natural methods where they work:

- how can we better understand future flood and coastal erosion risk? Including assessing the impact of climate change, and wider social, political, or economic factors
- how do we better prepare for the scale and frequency of future incidents? Including assessing our collective capacity and integrating incident management
- how can we optimise the management of flood and coastal erosion infrastructure?
- what are possible governance and finance options for flood and coastal erosion risk management?
- what is the potential of new technology and innovation to change and improve flood planning and infrastructure?
- how do we increase societal resilience to flood and coastal erosion risk?
- how can we ensure appropriate availability and uptake of insurance to achieve better outcomes?

Water

Clean and plentiful water underpins human activity and supports natural ecosystems. A robust evidence base is required to develop policy to ensure there is a plentiful supply of water in the long term and to significantly enhance the quality of water available to all forms of life:

- how do we better understand the impact of the past, the pressures on the present, and the changes of the future when understanding water and the environment?
- what are the actions that will have the biggest impact on restoring freshwater habitats as far as possible to more naturally functioning ecosystems?
- how do we better understand the impacts of climate change on water, habitats, and species?
- what types of governance may improve resilience of the water system?
- which interventions can be used to incentivise improvements in water quality in the environment?
- how can we manage the land to provide benefits to society and minimise harm to the aquatic ecosystem?
- how can we promote efficiency and investment in the water sector and incentivise environmentally responsible behaviour from all branches of society?
- how do we effectively monitor and assess the impact of emerging threats on water quality and ecology (for example plastics, antimicrobial resistance, neonicotinoid pesticides, nanoparticles, pharmaceuticals, invasive species, and chemicals) to inform risk-based decision making?
- how do we improve our modelling of water resource availability for people and the environment?
- how can we monitor prevalence of COVID-19 and similar viruses through our water systems to act as an early warning system and inform public health decisions?

Remediation and emergencies

Defra is responsible for providing advice, guidance and access to capability to remediate areas from chemical, biological, radiological, nuclear (CBRN) and major hazmat incidents. The evidence we gather ensures that we can do this using the latest, most efficient technique:

- identify, prioritise, and investigate scientific and technical challenges for remediation from a chemical, biological, radiological, nuclear (CBRN) or HAZMAT event

Food farming and biosecurity

We want UK science in the areas of animal and plant health, food, and farming to be internationally respected, impactful, and of a collaborative interdisciplinary nature.

Sustainable food and farming

We need research to develop a world-leading resilient food and farming system which enables the sector to grow and be more productive sustainably. Research and innovation will help champion trade of British food, produced to the highest environmental and animal welfare standards, in global markets. It will also maintain food safety, providing consumers with healthy, sustainable and affordable food choices:

- how can we reliably measure and improve the welfare outcomes for livestock on farm, during transport and at slaughter?
- how do we respond effectively to challenges including a rapidly growing population, changing consumption trends, finite land use, resource constraints, changing climate, globalised markets, and black swan events such as COVID-19 all of which impact on food and farming system security and supply chain resilience?
- how do we future proof farming and food chains to global shocks? What is the potential for wild relatives, landraces, and orphan varieties to increase diversity and enhance resilience?
- how do we reduce the impacts of production on the environment through more sustainable food production, processing, and manufacture? And how do we

influence consumer choice towards healthy and sustainable dietary choices?

- what are the changes that will affect the quality and availability of agricultural land and how will these affect UK's food and farming systems?
- how should policies be designed and schemes implemented to help the food and farming sector preserve and enhance the natural environment, while meeting other priorities such as the commitment to net zero emissions of greenhouse gases?
- how can innovation boost productivity to transform and future proof the food and farming system in ways that are sustainable and resilient; including the use of agritech, robotics, and automation to drive change and enable food and farming sectors to compete globally?
- how can we best supply healthy safe sustainable affordable food that commands consumer confidence and meets the needs of all consumers (including vulnerable groups)?
- what capability and capacity in the food and farming industry is needed to deliver future rural community policy needs?
- what data and evidence are needed to inform policy and delivery and what are the best sources to meet these needs? How can we improve broad access to this data and enhance knowledge exchange across the agri-food industry?

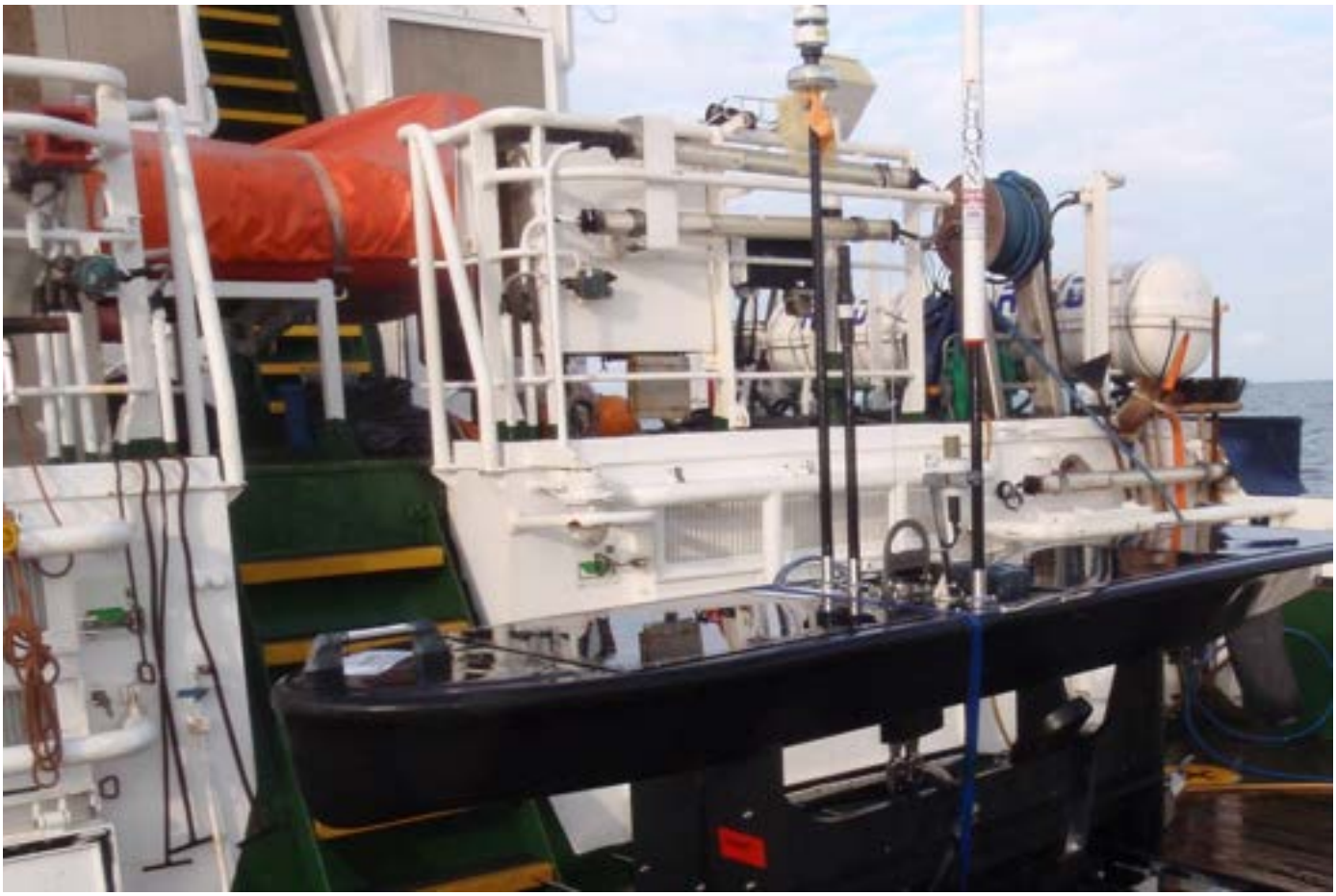
Biosecurity: protecting animals and plants from health risks

We want to protect the nation from the effects of animal and plant diseases and pests, to enable sustainable production, trade, and a vibrant natural environment. Our focus is on building resilience to prevent, detect, adapt, and enable risk-based control:

- how can we develop and apply science, technology, and evidence to inform and deliver a risk-based approach to animal and plant biosecurity?
- how can we enable better biosecurity standards and behaviours to control and minimise the impact of disease and pests? how can we build systems that are resilient to introductions of pests and diseases and that can support adaptation and recovery? How can we breed animals and plants which are resistant to key diseases?
- how do we protect pollinators and maximise beneficial insects?
- endemic animal diseases undermine agricultural productivity, negatively impacting animal welfare, farmers' livelihoods, public health, and threaten trade. Increased research into improved methods of detection and control of bovine TB and other such endemic diseases remains a priority for Defra
- how can we better understand and prevent the development of antimicrobial and anthelmintic resistance? How can we develop better diagnostic tests to encourage more judicious use of antimicrobials and anthelmintics?
- how can we use digital innovation and precision farming techniques to measure animal health and welfare outcomes for livestock, and to provide early warning of livestock disease and health threats?

- the risk of an unknown pandemic human disease (“disease x) has been at the top of the National Risk Register for some time and been realised this year in the shape of COVID-19. Two thirds of new human infectious diseases originate in animals. How can we better understand and prepare for future threats? How can we better join up animal and human health research, capability, and digital backbone across government to facilitate agile responses?
- we need to better understand the true value of plants and trees to society and deliver ongoing research to understand and prevent the introduction and spread of threats to UK plants – natural and crops. This include key threats such as Xylella, emerald ash borer, and other risks highlighted on the UK Plant Health Risk Register.
- we need to better understand the impacts of invasive non-native species on our natural ecosystems, including as vectors of disease

Marine and fisheries



Clean and safe seas

We need to protect the marine environment from pollution and improve measures to reduce impacts by better process, methods, novel technology, and communication to support marine policy. Research is required to:

- understand the risks from contaminants of emerging concern, micro and macro marine plastic litter, emergencies (for example oil spills), and man-made underwater noise

- determine the socio-economic costs of plastic litter on marine wildlife, ecosystems, and maritime industries. The costs incurred from changing to other materials, including the potential benefits to be made from new industries including small medium-size enterprise.
- understand the full benefits of offshore renewables. To identify and mitigate their environmental impacts by establishing socio-economic evidence to provide information to influence marine policy and development decisions

Healthy and biologically diverse seas

Our knowledge of the function and resilience of marine ecosystem services needs strengthening. Research questions include:

- what are the social, economic, and cultural impacts of marine policy, management, and interventions on stakeholders and coastal communities?
- how effective are marine protected areas and how can we monitor and evaluate the ecological, social, economic, and cultural costs and benefits of these areas?
- using climate-smart management, how do we best protect marine biodiversity that might change as a result of climate change?
- what are the interventions needed to reverse climate change or at least hold it steady to begin to mitigate the multiple stresses it causes?

Productive seas and freshwater and migratory fish

The UK's ambition is for sustainable growth and to manage the impact of COVID-19 on the wider marine economy. Research is required to:

- improve fish stock assessments over a greater range of species and improve management of freshwater, migratory, and marine fisheries, and protected species
- assess socio-economic information to support and incentivise a change to secure the long-term sustainability of seafood exploitation whilst reducing the environmental impact of exploitation
- develop innovative technologies and foster industry and business engagement to support sustainable fisheries and aquaculture, offshore energy production, maritime transport, carbon sequestration, and recreation
- integrate fisheries monitoring in a systems approach to manage and maintain sustainable productivity. Integrate marine planning systems to protect habitats and species, and reduce the industry's costs to enable economic development

Ocean and coastal processes

Effective measures for adaptation and mitigation to climate change risks are needed to be developed by research to:

- further our understanding of how climate change is affecting the health of the ocean as a result of acidification and warming seas

- assess how marine protected areas can act as nature-based solutions to the effects of climate change by sequestering carbon

Environmental quality

Air quality, noise and soundscape

We need research to articulate the health and environmental costs and benefits of complex policy interventions that influence air and soundscape quality. This includes the environmental impacts and human health related ones. Research is required to:

- better understand of ecosystem responses to air quality impacts and of restoration trajectories / rates of recovery of impacted systems in response to policy interventions
- understand differential toxicity of particulate components, the importance of non-exhaust sources, relevance of pollutant mixtures, and the biological mechanisms for effects from different sound sources
- develop methods to assess personal exposure to air pollution and noise at a range of spatial scales and quantify health impacts and costs
- improve our understanding of how behavioural change can help meet air quality and noise/soundscape policy ambitions and improve the evaluation and dissemination of effective policy interventions
- improve quantification of air pollution and noise impacts on ecosystems
- develop new and improved monitoring and modelling approaches, incorporating systems-based considerations which better reflect real world changes
- develop innovative and improved abatement technologies for air pollutant emissions and noise generation across all sectors and sources

Resources and waste

Defra seeks to increase the circularity of our economy through greater resource efficiency, waste prevention, and maximising recycling. Research is required on:

- how do we encourage the design of longer lasting and easily repairable consumer items?
- increasing understanding of the macro-economic benefits of resource efficiency. Developing metrics and measurement techniques to identify key areas for intervention to achieve these benefits and to monitor progress
- improving the use and design of extended producer responsibility schemes in the UK that could yield significant benefits
- what is needed to bring the UK to a best-in-world performance on recycling, particularly in difficult areas such as urban recycling? How can we improve secondary material markets to drive further recycling increases?

Chemicals, pesticides and hazardous waste

We need to understand the risks associated with the chemicals we use as well as their impacts on the environment, and the role of government and others to prevent harm, in line with the goals of the 25 Year Environment Plan (https://www.gov.uk/government/publications/25-year-environment-plan):

- what are the population-level impacts of sublethal pesticide and other chemical exposure in the environment?
- how can we improve horizon scanning capability for emerging global chemical risks to the environment?
- what are the biggest chemical, pesticide, and hazardous waste-related risks to the environment and human health, both in the UK and globally? What are the costs of inaction? How are these risks most effectively monitored and managed, and what is the role of government?
- how can innovation in chemical production, use, and disposal across the supply chain minimise chemical-related risks, benefiting the circular economy and reducing pollution?
- what is the relationship between chemicals and environmental and human stressors, such as climate change and biodiversity loss? What will the impact be on ecosystem services, both now and in the future?

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