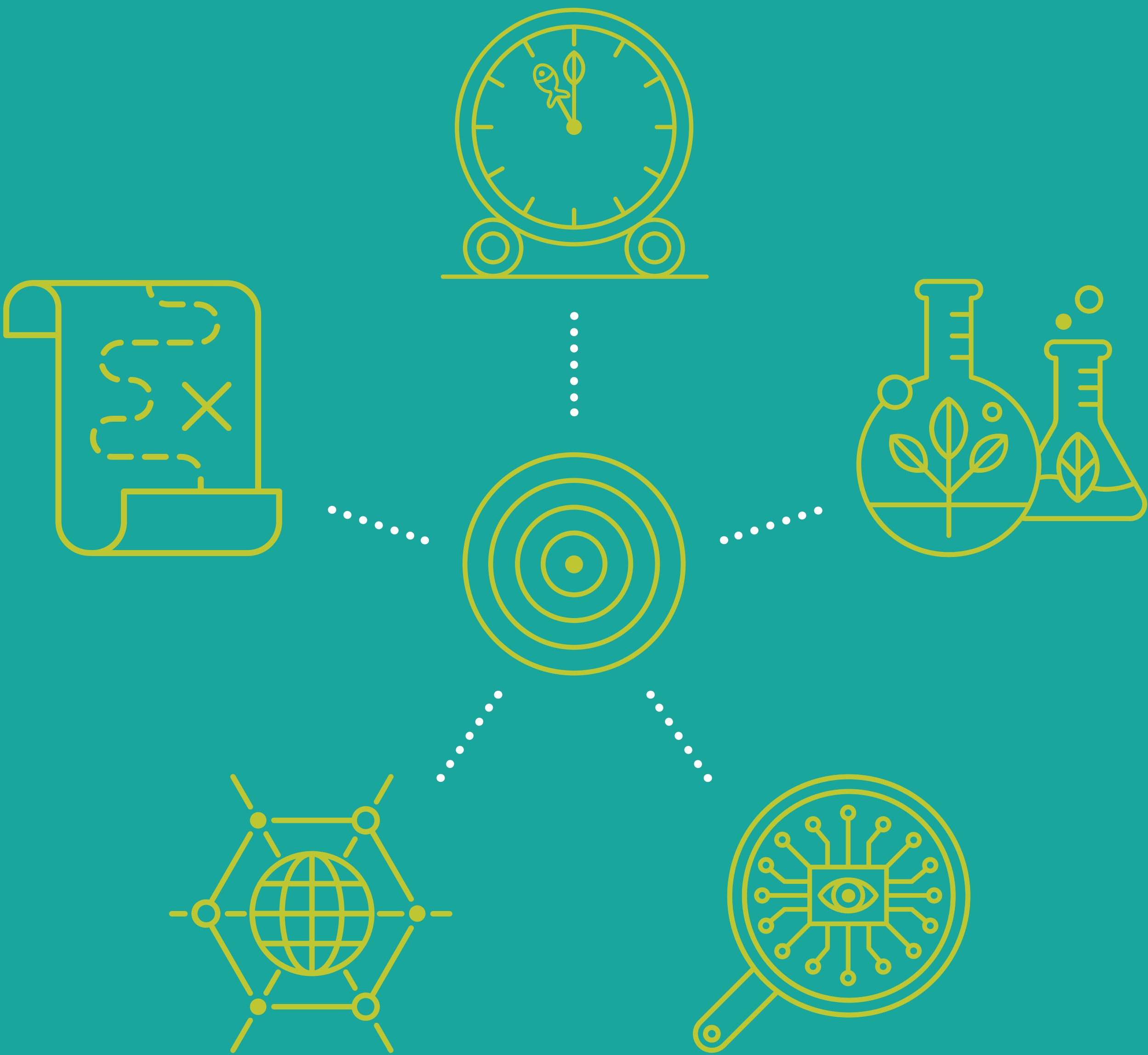
THE FUTURE OF ECOLOGICAL RESEARCH IN THE UK

A research agenda for the next 25 years



BRITISH ECOLOGICAL SOCIETY

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The views and recommendations presented in this report are not necessarily those of the organisations to which the authors belong and should therefore not be attributed to those organisations.

CONTENTS

1. INTRODUCTION

An ecological understanding of the world has never been more central and pivotal to the future of humanity and all life on Earth. It is a time of immense challenge but also of immense potential.

We have seen profound ecological changes in response to local and global pressures created by human activity. We need to understand the resilience of ecosystems, and support interventions that can maintain biodiversity and ecological function, while also recognising that some of these changes are irreversible and are creating new ecological systems.

We have collectively failed to reverse biodiversity loss and environmental degradation. This failure arises, at least in part, from still limited understanding of how ecological systems work. Perhaps more crucially, it results from a failure to embed ecological knowledge in public discourse, and in management and policy decision processes.

Delivering our national environmental targets and aspirations requires us, as a community of ecologists, to develop an agenda for generating and communicating the ecological understanding that society needs for a more ecologically vibrant and resilient environment in which nature and people thrive. We must commit to doing so in ways which are equitable and inclusive for people of all communities.

We need to:

- Build on decades of experience and insight across the ecological research community;
- Address previously neglected areas of ecology;
- Embrace new technological opportunities and frontiers of discovery, including novel ecosystems; and
- Build bridges to other areas of research, including the natural and social sciences, economics and the humanities.

This report identifies the broad priorities for ecological research in the UK for the coming decades.

Ecology is an indispensable discipline in predicting, identifying and responding to growing environmental risk, founded on fundamental advances in understanding. The priorities outlined below, based on a consultation of those involved in ecological research and practice, will shape strategic priorities for research enquiry, discussion and funding into the future.

WHAT IS ECOLOGY?

Ecologists study the interactions among living things and their environment. They provide new understanding of these critical systems as they are now and how they may change in the future.

Ecology provides new knowledge of the interdependence between people and nature that is vital for food production, maintaining clean air and water, and sustaining biodiversity in a changing climate.

ABOUT US

The British Ecological Society is the largest scientific society for ecologists in Europe with a membership of 7,000 in over 120 countries around the world. We support the ecology community at all stages of their careers through our journals, meetings, grants, and education and policy work. The first ecology society to be established anywhere in the world, we have been the champion of ecology for more than a century.

2. INTERDEPENDENCIES BETWEEN SCIENCE AND POLICY

The priorities for ecological research are driven by values, such as a moral imperative to improve the state of nature, a pragmatic and utilitarian desire to better people's living conditions and livelihoods, as well as a curiosity to understand the fundamental nature of the living world. All these motivations are necessary and valuable, and intimately connected.

It's important to emphasise that there are numerous points of interaction between ecological science and practice. In selecting priorities, we have reflected on how policy and practice can best be informed by ecological theory, and how it can inform ecological knowledge in turn. We have also considered how the outputs of fundamental science might be most appropriately packaged so that they can be readily accessed in creating solutions for societal challenges. There is a need to be aware of the point of balance on this issue and the views of different ecological and end-user constituencies.

The priority themes identified below seek to find this balance and embrace opportunities for both fundamental and applied ecological research.

BACKGROUND AND PROCESS

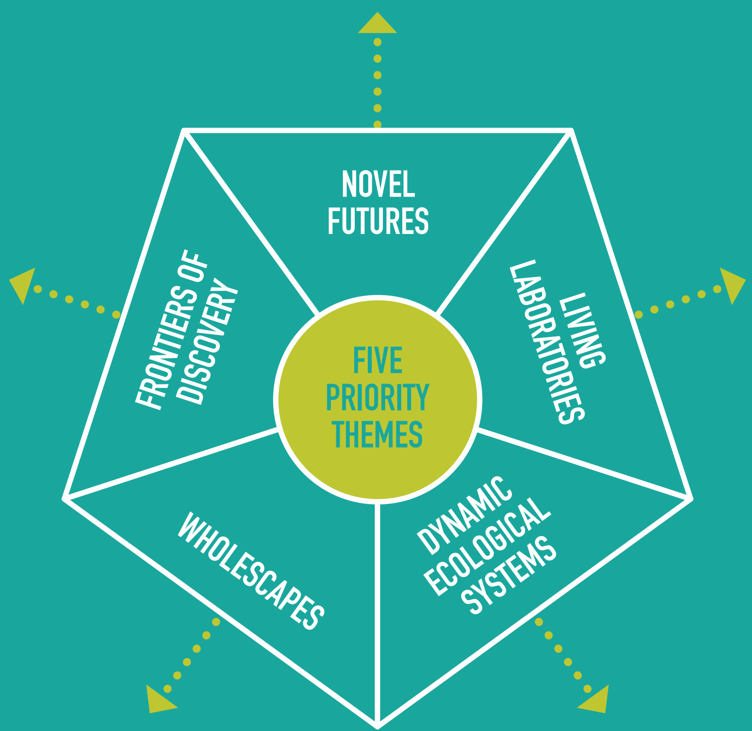
In 2022, the British Ecological Society began a consultation process to identify the priorities for pure and applied ecological research conducted in the UK over the coming decades. It aimed to help shape thinking, engage funders and set a research agenda for the UK.

The initiative involved:

1. A community-wide consultation that helped to understand the research landscape;
2. A two-day workshop with a group of academic researchers, practitioners, funders and government stakeholders from all four devolved nations;
3. A wider consultation at the BES Annual Meeting in Edinburgh in December 2022; and
4. Inputs from a Scientific Steering Committee.

The focus was on ecological research within the UK, though it is recognised that many of the outcomes apply equally to international ecological research. The UK plays an important role in international ecological research, but any such global perspective falls outside the remit of this report.

3. FIVE PRIORITY THEMES FOR ECOLOGICAL RESEARCH IN THE UK



THE RESPONSES OF ECOLOGICAL SYSTEMS TO A CHANGING PLANET

- Understanding and shaping ecological responses to climate change, other direct human pressures and non-native species
- Increasing the resilience of ecological systems
- Incorporating societal views of what the future should look like

THE EXPLORATION OF FUNDAMENTAL ECOLOGY

- Revealing poorly understood ecologies, such as the soil, forest canopy and deep oceans
- Using the rapid advance of technology to unlock new insights into ecosystems
- Relating this new knowledge to society's needs and the restoration of nature

RESTORATION PROJECTS AS A SOURCE OF RICH DATA

- Turning ecological restoration and stewardship projects into living laboratories for robust data and monitoring of conservation approaches
- Testing novel approaches and technologies
- Exploring new concepts such as rewilding, sustainable farming and green finance with policymakers, communities and businesses

BEYOND LANDSCAPES OR SEASCAPES, ECOLOGY AT THE LARGEST SCALES

- Understanding the connections and trade-offs acting across scales from the local to the global
- Mapping the links between ecological systems and supply chains, economic drivers and social values
- Gaining insight into the global spillovers from domestic ecological and land-use strategies

UNDERSTANDING THE COMPLEXITIES OF ECOLOGICAL DYNAMICS

- Advancing understanding of the emergent properties of ecological systems and dynamics
- Developing new analytical approaches and modelling
- Using artificial intelligence and simulations to generate insights on the impact of different stressors and changes in species and communities

3.1 NOVEL FUTURES

The ecology of planet Earth is changing rapidly. The ecological systems of today and tomorrow are already different from the ecosystems of the 20th century that were the focus of the developing science of ecology.

This change will continue. Atmospheric change alone ensures this, but this comes on top of other drivers. These include direct human pressures on habitat loss, degradation and fragmentation; "new native" species, some of which are invasive; amplified pathogen pressure; and novel pollutants such as microplastics, pharmaceuticals and long-lived compounds.

Opportunities offered through new technologies and ways of operating, as well as emerging challenges such as species migration and rising sea levels, will also lead to semi-natural and highly managed novel ecosystems in new locations.

These are novel futures and we don't sufficiently understand how ecological systems will respond. Nor how we facilitate, shape and generate positive ecological responses in the context of this rapidly changing and uncertain environment.

Moreover, there are possibilities to actively create and shape novel ecosystems in the context of climate change, non-native species and changed disturbance regimes. These require more focus on functional and ecosystem ecology and investigating approaches to nature recovery and management. They would need to be based on strong ecological foundations, ranging across approaches from regenerative agriculture to multitrophic rewilding.

One overriding concern is the resilience of ecological systems to climate change and other drivers. Ecological research needs to focus on analysing ways to increase ecosystem resilience and gain a new understanding of what resilience is in the face of contemporary climate change.

What types of resilience should be aimed for – for example, in ecological function, community composition or natural resources – and how can they be maintained under rapidly changing environmental conditions? Under what circumstances does resilience require the transformation of ecosystems, and what knowledge base can underscore active management initiatives?

There is a need for intensified engagement with social, economic and cultural research. It is crucial to engage with societal views of what the future should look like to meet concerns, challenges and needs. This includes understanding how to accommodate shifting values, for example towards novel and formerly non-native species and habitats, and the recovery of biodiversity and ecological functions.

3.2 LIVING LABORATORIES

The urgency of climate change and biodiversity loss requires a strong focus on ecological learning through implementation, experimentation and practice.

A broad range of ecological restoration and stewardship projects are being implemented by a range of actors, including government agencies, non-government organisations, private landowners, and private corporations seeking to meet carbon or biodiversity targets. These provide an opportunity. Researchers working closely with practitioners can develop some of the projects into "living laboratories" that maximise the potential for gaining robust scientific insight and dissemination of good practice.

These research-intensive landscapes and waterscapes, in some cases encompassing multiple habitats, would focus on understanding the implementation and effectiveness of ecological conservation, resilience, adaptation and recovery. They would implement well-designed ecological monitoring and experimentation frameworks aimed at deriving mechanistic, systems-level understanding.

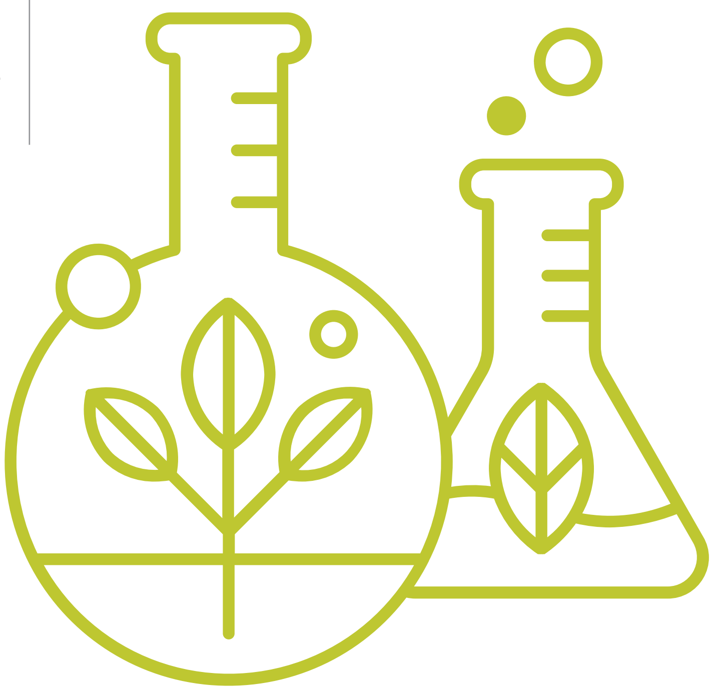
Living laboratories would provide a forum for:

- Exploring the potential of new techniques and technologies for monitoring spatial and temporal changes in ecological systems;
- Benchmarking and standardising metrics; and
- Testing and validating ecological theory and models.

Novel approaches and technologies could be tested and validated against rich ecological datasets. These technologies include remote sensing, distributed and connected sensor systems, lidar, eDNA, and bioacoustics, as well as new capacities to interpret large datasets using artificial intelligence approaches and emerging approaches for integrating and analysing data across social and natural sciences.

Living laboratories could also embrace social and cultural research to facilitate a holistic understanding of how ecological conservation and recovery can embrace multiple values and be most ecologically effective and socially acceptable. As such, they can be hubs for communication and wider engagement. They can be centres for national debate that are solutions-oriented, and places for collective learning on natural resource management and conservation across disciplines and alongside practitioners and land managers.

These sites would make more effective use of citizen science, for example by leveraging ecological information sourced through smartphone apps. The laboratories could also be spaces for exploring new concepts with communities, practitioners, industry and business. Examples might include rewilding, regenerative agriculture, sustainable farming, natural flood management, biodiversity credits, green finance, nature-positive markets and transitions to a circular economy.



3.3 DYNAMIC ECOLOGICAL SYSTEMS

In parallel with increased empirical understanding of how ecological systems respond to global and local change, we must advance theoretical understanding of the emergent properties of ecosystem dynamics and the maintenance or loss of resilience in ecological systems.

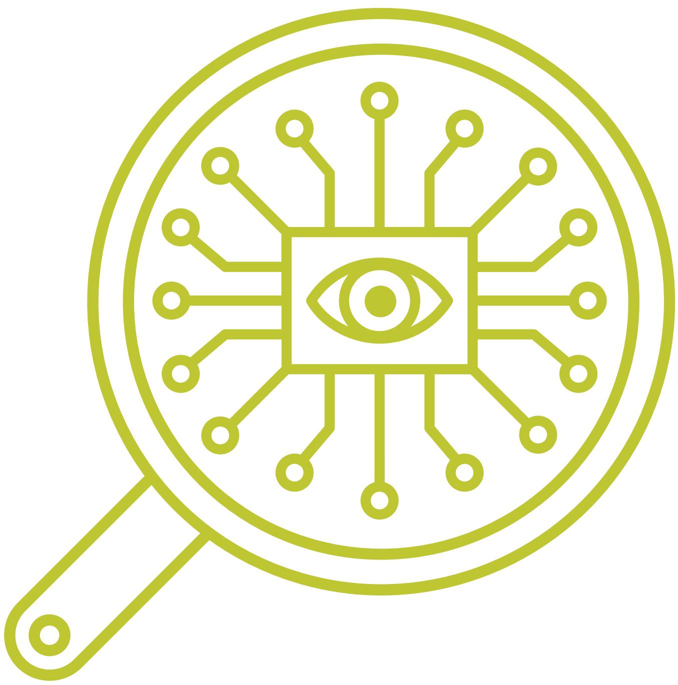
This includes understanding dynamics at short and long timescales, how shifts in ecosystem composition lead to emergent shifts in ecosystem functions, the cumulative impact of repeated stressors, criteria for ecosystem collapse and resilience, potential tipping points, ecological surprises and extinction and speciation dynamics.

New challenges mean there is a need for new approaches. This includes generating new understanding of the complex interdependencies of species across communities. The dynamics and stability of ecological networks, for example, remain beyond our predictive capacities. This makes it very difficult for us to anticipate and respond to emergent outcomes resulting from changes in community composition.

New analytical approaches have the potential to generate new insights when adapted for ecological purpose. Graph-theoretical approaches, by way of example, can facilitate the understanding of relationships across complex interconnected systems, and particularly how perturbations ramify through ecological systems.

Understanding dynamic ecosystems requires appropriate monitoring and experimentation to generate new knowledge which can further develop and validate improved theory and models. This includes improved models capturing ecosystem interactions with the wider Earth system, as these interactions can act as potential brakes or accelerators of climate change. Incorporating ecological dynamics, such as demography, competition and multitrophic interactions (e.g. predation, herbivory), into models is also important as these shape ecosystem properties and dynamics.

Understanding such dynamics and emergent properties can be helped by advances in technology and computation power (e.g. deep learning, computer vision). The availability of multiple types of both qualitative and quantitative data can enable a new level of "digital twin" simulations (advanced digital representations of the real-world system) and artificial intelligence approaches to data assimilation.



3.4 WHOLESCAPES

Ecological systems interweave with other systems and processes at multiple scales, from the local to the global. There is a need to understand the connections and trade-offs which act across these very different scales using the idea of "wholescapes".

More than landscapes or seascapes, a wholescape focus raises the level of attention to a larger scale. It moves from detailed understanding of processes in particular ecological systems (the focus of Living Laboratories above) to the ecological, economic and social connections across larger spatial scales.

At the regional scale, the concept of wholescapes recognises the connections across ecosystems and management types, in and across rural, urban, aquatic, coastal and marine ecosystems. For example, agricultural systems may rely on ecological subsidies, such as pollination and pest control, from adjacent semi-natural ecosystems, and yet also impact those ecosystems. Terrestrial, aquatic and coastal ecosystems are connected through processes such as nutrient cycling and pollution.

At a wider scale, a broader sense of wholescapes includes understanding the connections between specific ecological systems and wider supply chains, global economic drivers, and societal values. Such understanding ventures beyond a singular focus on ecology to understanding how ecological systems interact with social and economic systems. For example, it seeks to understand the global spillovers from domestic ecological and land-use strategies.

Robust and repeatable approaches for assessing our ecological footprint outside of the UK is also an area we need to prioritise, if we are to have an ethical approach to the management of wholescapes across the UK. We need to recognise the UK's impact on global systems and also how global connections, systems and trade drive change in the UK.

3.5 FRONTIERS OF DISCOVERY

Beyond applications of ecology to address the challenge of human-caused change, there is still a great need for basic exploration and discovery in ecological science. Much remains to be discovered about the nature and functions of life on Earth.

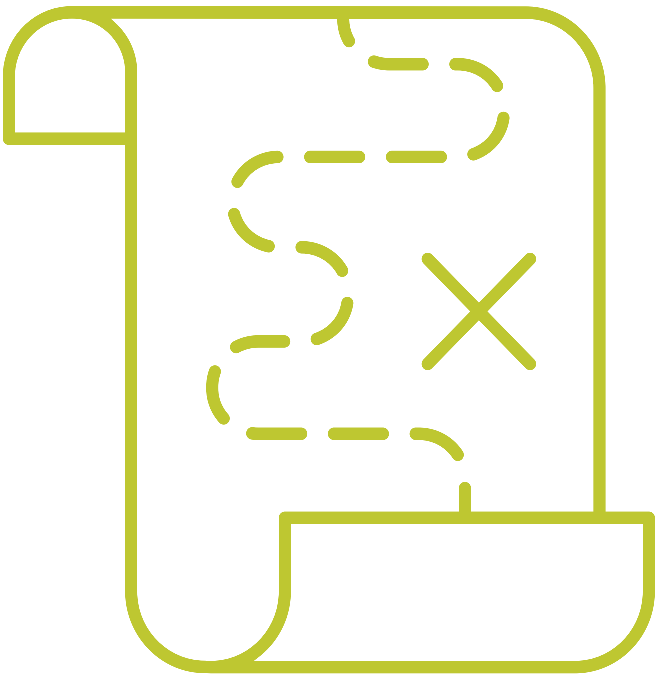
Such frontiers include poorly understood ecologies, such as those of sediment and soil, the forest canopy, the deep oceans and the deep subsurface biosphere. Other frontiers include the ecology of human health and wellbeing (such as human interactions with environmental microbiomes), the ecology of novel pathogens, and the impacts of, and interactions between, emerging pollutants such as nanoparticles and microplastics.

Technology is rapidly advancing our capacity to understand ecosystems, unlocking new insights into even familiar ecosystems. For example:

- Environmental DNA analysis and ecological and functional genomics can greatly advance understanding of the frequently cryptic components of ecological systems (e.g. soil fauna and microbial communities, or rare species);
- Bioacoustic monitoring facilitates high-frequency monitoring, or understanding of poorly monitored biomes such as soil and marine systems;
- Terrestrial laser scanning yields new insights into ecosystem structure and responses to change;
- Remote tracking and increasingly small individual tracking devices can reveal new understanding of species movements and spatial structure of ecological systems;
- Quantum environmental sensing allows for finely resolved monitoring of environmental systems; and
- Citizen science networks equipped with smart apps extend the volume of ecological observations.

Many of these technologies face the challenges of an abundance of data, and machine learning and other artificial intelligence approaches can advance extraction of, and make sense of, useful information at levels not previously attained.

A further challenge is how to link these new technologies to policy and practical needs. Can these new technologies lead to new metrics for monitoring and tracking ecosystem health, resilience and recovery? What does this new knowledge tell us about ecosystem integrity? What are the cumulative impacts of multiple stressors on ecosystem health (e.g. novel pollutants and pathogens, nanoparticles), particularly at microbial levels? How does understanding of the small scales (molecular and microbial levels) scale up and help us understand at ecosystem level?



4. SUMMARY

Ecology has been instrumental in identifying, highlighting and contributing solutions to some of the major environmental challenges of our time, while at the same time advancing understanding of the nature and functioning of the living world.

There are strong foundations to deliver a rich and fruitful research agenda, hastening both our understanding of present and emergent issues and the development of practical solutions capable of tackling the challenges of the 21st century and beyond. We will rise to the collective challenge of maintaining and restoring a flourishing biosphere that is the bedrock of our civilisation.

CALL TO ARMS

Ecological research has a key role to play in developing a more resilient, sustainable and equitable future in which nature and people thrive. To achieve this, we need to integrate fundamental and applied research and work across traditional disciplines, geographies and communities in these five priority areas.

The British Ecological Society is now looking for a wide range of partners, communities, decision makers and funders to join with us and realise this exciting new vision.

www.britishecologicalsociety.org/FutureEcology

APPENDIX

SCIENTIFIC STEERING COMMITTEE

Nine experts guided the work and set out the vision for the Future of Ecological Research in the UK. They have all made outstanding contributions to ecology in the UK and bring expertise across a wide range of areas.

CHAIR: YADVINDER MALHI

PRESIDENT OF THE BRITISH ECOLOGICAL SOCIETY

Yadvinder Malhi is Professor of Ecosystem Science at the Environmental Change Institute, University of Oxford and Director of the Leverhulme Centre for Nature Recovery. He explores the functioning of the biosphere and its interactions with global change, including climate change. Much of his work has focused on tropical ecosystems, but a recent focus has been on nature recovery and biodiversity restoration in the UK.

ROSIE HAILS

Professor Rosie Hails is Nature and Science Director at the National Trust, holding honorary chairs at Exeter and Cranfield universities. Her role is to develop the Trust's nature strategy, research portfolio and advise on science evidence relevant to Trust decision making. She leads teams focusing on nature conservation, trees and woods, wildlife management, land use, farming and public benefits delivered by nature.

JOSEPHINE PEMBERTON

Josephine Pemberton holds the Chair of Natural History at the University of Edinburgh. She is a molecular ecologist whose research lies at the interface of ecology and evolution. For many years she has been involved in running the long term, individual-based studies of red deer on the Isle of Rum and Soay sheep on St Kilda.

BRIDGET EMMETT

Bridget Emmett is Head of Soils and Land Use at the UK Centre for Ecology and Hydrology. She has over 30 years' experience in environmental research focusing on understanding the impacts of air pollution, climate change and land management for soils and ecosystems.

JANE MEMMOTT

Jane Memmott is a Professor of Ecology in the School of Biological Sciences, University of Bristol. She runs a research group that uses ecological networks as a tool for asking about the impact of environmental change. She works in a variety of research fields including pollination ecology, agro-ecology, invasion ecology, urban ecology and restoration ecology. Field sites range from English meadows to Hawaiian swamps and from Scottish islands to inner cities.

NATHALIE SEDDON

Nathalie Seddon is Professor of Biodiversity and Director of the Nature-based Solutions Initiative and Agile Initiative at the University of Oxford. Her previous research focused on understanding the origins and maintenance of biodiversity and its relationship with global change. Her work now explores the effectiveness of nature-based solutions to address societal challenges, both in the UK and globally.

JABOURY GHAZOUL

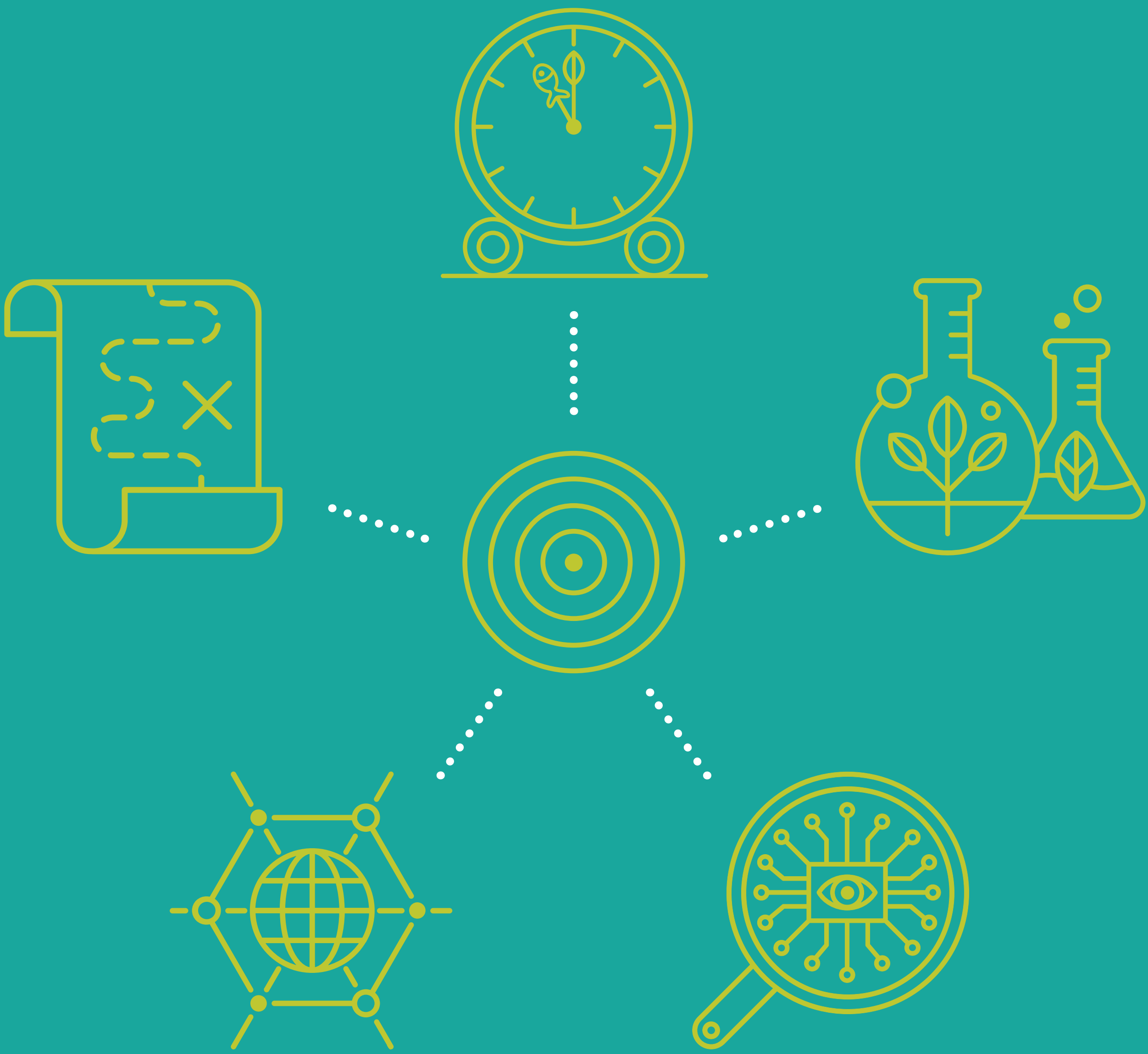
Jaboury Ghazoul is Professor of Ecosystem Management at ETH Zurich, a position he has held since 2005. He recently joined the board of NatureScot, where he is using his scientific knowledge to inform the implementation of nature conservation strategies in Scotland. Jaboury is a plant ecologist, with broader interests in forest and landscape ecology and management, working in both natural and human dominated landscapes.

STEVE ORMEROD

Steve Ormerod is Professor of Ecology at Cardiff University. He is interested in global change effects on freshwater ecosystems. He is currently Deputy Chair of Natural Resources Wales, a committee member of the UK Joint Nature Conservation Committee and Vice-President of the RSPB.

MARTIN SOLAN

Martin Solan is Professor of Marine Ecology at the University of Southampton. He is a marine benthic ecologist with broad interests in understanding biodiversity–environment interactions and the ecosystem consequences of altered diversity and environmental change. He champions strategic and applied interdisciplinary research in benthic habitats, from coastal to full ocean depth and across environmental gradients.



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