Ideas 2016

Ideas submitted as potential strategic programme areas

Title	Summary
Reducing the uncertainty in projections of sea level extremes	Coastal flooding results from sea level extremes. The frequency of these events is *very likely* to increase during the 21st century, in many regions by a factor of at least ten. Sea level is projected to rise by 0.28 to 0.98 m in the global mean by 2100, with substantial regional variation (IPCC WG1 AR5, 2013). Coastal flooding events are mostly triggered by storm surges, during which extremely high local sea level is produced by low atmospheric pressure and high winds, whose occurrence will also change with climate. Coastal systems and low-lying areas will increasingly experience adverse impacts such as submergence, coastal flooding, and coastal erosion (IPCC WG2 AR5, 2014), with serious implications for societies, infrastructure and ecosystems. Consequently, regional sea level change and its impacts are the subject of one of the "Grand Challenges" of the World Climate Research Programme, which aims to promote high-priority research. The risks from sea level rise and coastal flooding are identified as needing more action by the UK Climate Change Risk Assessment Evidence 2017. Therefore we propose a SPA that focuses on reducing the large uncertainties in climate projections of sea level extremes for the 21st century, through enhanced process modelling frameworks and improved synthesis of observations. The SPA would cover (a) global mean sea level rise, due mainly to the expansion of the ocean as it warms, and to loss of mass from ice-sheets and glaciers, (b) the geographical pattern of sea level rise due to ocean regional density and circulation change, land movements, changes in tidal range and changes in the Earth's gravity field in response to changes in land ice, and (c) changes in the severity and occurrence of storms (mid-latitude and tropical cyclones). The major intended outcomes from the SPA would be an assessment of the *very likely* (90% CI) range of future change in global and regional sea level and the probability of extreme events (going beyond the IPCC AR4 assessment of the 67% CI) and quantified risk assessments for two regions: (1) the UK/ the north-western European shelf; (2) an overseas region with a risk of storm surges from tropical cyclones (e.g. South East Asia).
Understanding subsurface microbial ecology: current services, future risks	We are increasingly dependent on, and at risk from, microbial activities in the subsurface. The microbial population of our aquifers combined with the unsaturated zone is an essential protection for our existing groundwater resources. The microbially mediated attenuation of contaminants is a key factor in mitigating the potential impacts of contaminants from both diffuse and point sources. Conversely, microbially mediated contaminant release such as Arsenic and heavy metals may threaten these resources. However, most of our understanding of subsurface microbiology comes from the investigation of site-specific pollution incidents and their active treatment. Some estimates place the (deep) subsurface biomass of Earth as up to one third of the total planetary biomass. Microbial souring of offshore oil and gas production wells has long been an issue of concern for the oil and gas industry. Microbially induced corrosion may threaten deep radwaste facilities. As we seek to exploit new energy reserves in deep shales and other oil and gas formations onshore we will introduce microbial life to new horizons, in addition to any indigenous microorganisms that may be present.). We need a much improved understanding of the microbial ecology of the subsurface. This needs to focus on the investigation of ambient (baseline)

	conditions distant from known point problems. There remain fundamental questions around the presence and activities of organisms in the subsurface, what energy sources they are using, how organisms and pathogens move into (from surface), out of and within the subsurface, what effects and impacts might arise from changes on the land surface or anthropogenic activity in the subsurface ?
Understanding the interaction between 'core' Planetary Boundaries and predicting and mitigating future impacts	There is an urgent need for society to rethink how we decouple growth from impacts and to ensure that we live within the Earth's limits. The Planetary Boundaries (PBs) concept provides a framework for describing the Earth's limits and for estimating absolute sustainability. However, there are both scientific and technical challenges that need to be overcome to operationalise the PB framework: setting boundaries at different spatial scales; establishing global data sets and models to build understanding of the interaction between boundaries and; projecting earth system responses to human activities and pressures in order to mitigate future impacts. We propose to focus on two PBs, and their interactions, namely climate change and biosphere integrity identified by Steffen et al. (2015) as the two "core boundaries" in the framework, because each of them "has the potential on its own to drive the Earth System into a new state should they be substantially and persistently transgressed". Whilst the scientific and technical challenges are different for these PBs, the interactions between them are potentially significant. As such, it is important that work to address them is not undertaken in isolation and builds on UK science strengths, fostering collaborations between scientific disciplines. Operationalisation of the PB concept will also require engagement with the business community in order to develop decision-making tools which can be used in product procurement, innovation and strategic contexts.
Soils in the circular economy	This idea is about understanding and securing the future of UK soils for agriculture and wildlife. It arises from our relatively poor knowledge of the state of soils, the increasing pressures from society's use of soil, and the critical long-term risks to ecosystem services from damage to our soil resources. Environmental, economic, social and cultural factors interact to determine the quality and sustainability of soils, a multi-disciplinary approach is therefore required to make progress in this crucial area. We believe it is timely to make a step change in our understanding of the condition of soils (integrated across physical characteristics, chemistry and biology); the short and long-term pressures and risks to soil (including farming practices, spreading waste to land, climate change); the consequences for ecosystem services; and the efficacy of land and soil management options. The programme would place particular emphasis on chemical inputs and impacts which are inadequately understood. This requires advances in our approaches to measuring soil quality, and modelling of future pressures and impacts on soil resources. Improving the measures and assessment of soil quality could enable the financial value of soils being developed by the Natural Capital Committee to be used to successfully shape future soil and land use policy. A responsible research approach and socio-economic analysis would help to direct the programme and explore the feasibility of responses to achieve sustainability.
Integrating and understanding processes	The conversion of atmospheric nitrogen (N_2) to biologically reactive forms of N (N_r) is essential to support plant growth and global food production. However, the increased use of N fertilisers, low fertiliser use efficiency and

underpinning the biogeochemistry of the nitrogen cycle (N-CASCADE)	fossil fuel combustion has doubled the global fixation of nitrogen, contributing to global warming, threatening biodiversity and damaging human health as N_r cascades through the atmosphere, soils and waters, before eventually returning to atmospheric N_2 (Steffen *et al.* 2015). If unchecked, projected global growth of N_r inputs during the 21st century to support increasing food and energy production will lead to accelerated environmental degradation. Biosphere-atmosphere fluxes of N_r are very sensitive to changes in climate, eroding benefits of planned control measures (Fowler *et al.* 2015). This SPA will deliver a step change in our capabilities to measure and model N cycling processes at a range of scales through the application of emerging technologies that will provide critical new knowledge of key mechanisms and processes required to quantify N_r flows, pools and budgets (inc. atmospheric inputs, biological N fixation, volatilization, losses in water, accumulation and ultimately denitrification). This will lead to new intervention strategies that help to join up policies for food and energy security and mitigation of climate change, air pollution and water pollution.
Subsurface heat as a potential major future energy resource	The UK faces binding targets for renewable energy generation by 2020 (electricity 30%, heat 12% and transport 10%). Europe has outlined even more stringent scenarios; up to 75% by 2050. These challenging targets require a total rethink of our energy supply towards sustainable sources. Natural subsurface heat offers a potentially huge resource of renewable, geothermal energy (be that for direct heat usage or electricity generation), and its application is global. Fundamental to the successful exploitation of subsurface heat is a thorough knowledge of the thermal resource (thermal input/output, volume of hot rock, rock properties), and fluid flow properties that facilitate heat transfer from the rock mass to surface energy-infrastructure. Unfortunately there are major knowledge gaps in terms of understanding thermally-driven processes in the natural, subsurface environment. This SPA aims at fostering a fundamental reappraisal of these, with a view towards quantification of: overall heat resources, rock-fluid behaviour in controlling the movement of subsurface heat and fluids, the size of the actually exploitable geothermal resource. The significant range of environments from which heat could be derived, the range of processes involved, and the broad temperature range that can be utilised by current technology, warrant investigation through multiple projects – hence the suggestion of this idea for an SPA.
The future behaviour of the North Atlantic storm track and its implications for environmental risk and resilience to natural hazards	The natural environment of the UK reflects its temperate climate, which results from the moderating influence of the North Atlantic ocean, conveyed by the jet stream. The jet stream is also the source of atmospheric storms, the tracks of which vary chaotically over time. Weather and climate variations over the UK are strongly determined by the behaviour of the North Atlantic storm track: persistent rain and flooding can result (e.g. as in January 2014) when the storm track is 'stuck' over the UK for a sustained period; both winter cold spells and summer heat waves are generally associated with a 'blocked' storm track that avoids the UK and leaves it isolated from the influence of the North Atlantic. *The latest IPCC assessment report concluded that the future behaviour of the North Atlantic storm track is one of the most uncertain aspects of climate change*. This uncertainty propagates directly to climate-related risks over the UK. The focus of this idea is to treat uncertainty in North Atlantic storm-track changes and their impacts as an end-to-end, inter-disciplinary scientific challenge, capitalizing on the research investments within the UK directed towards particular aspects

	of the problem, but which have never been joined up.
Peatland resilience programme	UK peatlands provide ecosystem services that are crucial to UK society and impose huge cost if allowed to deteriorate. There are several major land use policy and environmental drivers affecting peatlands, including climate change and agriculture support, many of which are likely to change significantly over the next decade. At the same time we face an urgent problem of past land use having left many peatland ecosystems in a degraded state. Process-based, multi-site and long-term studies are urgently needed to better understand the impacts of peatland degradation and restoration, and support the development and improvement of policies that can contribute towards the long-term resilience of peatlands under climate change.
Understanding Environmental, Ecosystem and Socio-Economic Effects of Large-Scale Marine Renewable Energy Exploitation	The UK has a wealth of Marine Renewable Energy (MRE) resources including 50% of Europe's tidal energy as well as waves, offshore wind and other potential sources, such as marine biomass and thermal energy. However, the deployment of MRE devices (MREDs) in the UK (apart from offshore wind) has been slower than hoped due to many factors, including the economic climate for large-scale investment but also uncertainty about the environmental impacts of large scale developments. There are still significant unanswered questions about these potential effects, which leads to uncertainty in consenting procedures, and hence to increased costs and long delays for developers. In fact, there is a critical need for empirical data, especially to resolve issues of impacts on wildlife. The options for multi-use of MRE infrastructure e.g. for coastal protection, which could lead to reduced relative cost of electricity generation, have not been fully explored. In order to solve the key outstanding problems and to facilitate the necessary policy and investment decisions to be made, a concerted interdisciplinary research programme is required which combines engineering, environmental and socio-economic disciplines, allowing the nascent industry to make a substantial leap forward and UK research to maintain its world-leading position.
Resilience of Biodiversity and Ecosystem Services to Earth System Changes	Climate change, increasing food and biofuel production, land abandonment, and other Earth system changes are altering the biophysical and hydro-environmental processes and their scales of variability, leading to more frequent and more intense extreme events. Managing the natural environment under these new conditions necessitates radical changes in the understanding and the quality and quantity of information on the states and trends of biodiversity and ecosystem services (BES) at regional, national, and global scales. Advances in genetic metabarcoding have enabled a rapid assessment of biodiversity. Earth Observation (EO) sensors, in particular the new European Copernicus satellites, deliver unprecedentedly high-resolution spatial and temporal observations of biophysical parameters. Harnessing these Big EO and Genomics Data for understanding how the changing biophysical environment affects BES, and for managing ecosystems sustainably to enable continued benefits from the services they provide, requires an interdisciplinary strategic science programme leading to breakthroughs in the integrated analysis of Big EO Data with ecological models and genetic data, in the context of socio-political value systems. This Strategic Programme Area will bring together the ecology and ecosystems communities with genomics and EO experts to develop new and open-source methodologies for linking EO data to ecological models, demonstrating the use of new ecological and biological techniques for high volume and spatially extensive in-situ data and provide up-to-date information on the status and resilience of BES for ecosystem management and conservation, linking to practitioners and end-users.
Redesigning agricultural	Crops are highly vulnerable to attack by adapted pests, weeds and diseases. When selected for yield and quality in a pesticide treated background they can

ecosystems to prepare for a post-pesticide world	lose the resistance traits that existed in their ancestors. Agricultural systems need to be redesigned to reduce their intrinsic vulnerability. The idea is to "learn from nature" by 1. Identify factors limiting herbivore population densities in wild ecosystems and 2. Apply these to develop new interventions to increase the resilience of agricultural ecosystems to pests, weeds and diseases. There are strong societal drivers for reducing dependency on pesticides but currently pesticides are being restricted at a much faster pace than alternatives are being developed. There is a huge challenge to develop new solutions to reduce crop losses to pests. innovation is needed to make agricultural ecosystems less vulnerable to attack by pest, weeds and diseases. If the answer to environmental challenges is to produce more 'crop per drop' then there are huge opportunities to reduce losses to pests, weeds and diseases
NERC *Global Atmosphere Watch* Baseline Observatory on Ascension Island	Understanding the atmosphere depends on measurements. This proposal is for a UK Atmospheric Greenhouse Gas Observatory on Ascension Island, in the equatorial Atlantic, to provide an Atlantic equivalent to the US Mauna Loa Observatory. The proposal is to sustain high quality greenhouse gas measurements on Ascension Island, both on the surface sampling the marine boundary layer in the SE Trade Winds, and by drone sample collection of tropical air above the Trade Wind Inversion at 1.5km. Data gathered from observation networks provide the fundamental basis of our understanding of climate change. In particular, greenhouse gases are measured in remote clean-air sites, such as the US observatory at Mauna Loa, or the South African observatory at Cape Point. Globally, these measurements, coordinated by the UN / World Meteorological Organisation's Global Atmosphere Watch (GAW), are extremely inadequate in the tropical heart of the biosphere. Currently, the UK's formal role in UN/WMO GAW's CO_2 and CH_4 measurement is limited to Halley Bay in Antarctica, although NERC and DECC support measurement at other sites such as Ascension and Mace Head, Ireland. Ascension is superbly located. The island is UK sovereign territory, and very accessible with frequent UK flights. At ground level, the SE Trade Winds are steady, derived from the deep S. Atlantic, S. America and the Southern Ocean. Above the Trade Wind Inversion (1.5km altitude), the air is tropical, variably from Africa and S. America. This air has been successfully sampled by drones, in a NERC project. The proposed Observatory would significantly improve tropical greenhouse gas data gathering, critical in better modelling of global carbon budgets and understanding of tropical climate change.
Supporting COP21: Understanding the European Greenhouse Gas Budget.	Minimizing the multiple impacts of increasing atmospheric Greenhouse Gas (GHGs) concentrations demands a structured timetable of emission reductions leading to zero or negative net emissions by 2100. At the 2015 Paris Conference of the Parties (COP), 195 countries agreed to achieve net zero emissions later this century. Achieving this demands accurate understanding and precise knowledge of natural and anthropogenic GHG emissions and sinks, elements which support the ability to do GHG accounting at the continental and ultimately global scale using both the understanding (to model the evolution of GHG sources and sinks) and the knowledge of source and sink strength. Building on the integrated UK GHG programme we are now at the stage where the UK can play a leading science role in a new pan-European GHG observing system (the Integrated Carbon Observing system, ICOS) via a coherent programme of measurements and

	data analysis activities to improve understanding, reduce uncertainties and underpin policy decisions. Together with EU colleagues we will use ICOS and related networks (including space-borne assets) to deliver the first big-data driven GHG budget for Europe and to ensure that key processes are represented in Earth System models. We will address key questions regarding the drivers of regional variability in emissions and uptake, their likely durability, appropriate strategies, and the methods and infrastructure for evaluating future mitigation strategies.
Urban Water Environment and Management in the Eco-city 2100	Environmental change and the trends towards expansion and intensification of urban living present many research challenges for the environment and society in towns and cities, in the UK and globally. The management of urban water, as a resource, vector for waste and as a natural hazard, is critical to human health and wellbeing. By 2100, a mainly urban world population may reach 9-10 Billion. A new NERC programme is urgently needed to provide new multidisciplinary understanding and innovative approaches to management of the urban water environment. The scope should progress beyond present day issues, to examine future trends and pressures upon ecosystems, infrastructure, economy, population and health. It would encourage research which combines scientific understanding and technological innovation at a wide range of scales from domestic properties and local communities up to City regions, and the surface and geology of catchments from daily to multi-decadal time-scales. Research would focus on whole system approaches and interactions between the urban ecosystem, blue-green infrastructure and water availability and quality, as well as between the natural, built and human environment of urban living.
Reducing uncertainty regarding the potential impacts and benefits of a commercial scale marine energy industry in the UK	The sustainable development of marine renewable energy in the UK has the potential to create a new renewable energy industry, significantly reducing our reliance on fossil fuels and our national carbon emissions whilst creating secure, long term employment opportunities and investment in strategic infrastructure and science in the UK. Uncertainty regarding the potential environmental effects of medium and large scale wave and tidal developments is one of the key challenges facing the industry, regulators, advisors, researchers and other stakeholders. This is currently limiting development of the sector in the UK and worldwide. Through efforts such as the UK Offshore Renewables Joint Industry Programme (ORJIP) for Ocean Energy, there is increasing recognition in the marine energy industry (developers, regulators, their advisors and the research community) that a coordinated approach to strategic environmental research activities to reduce uncertainty regarding the potential effects of wave and tidal arrays on the marine environment, would help de-risk and accelerate the consenting of wave and tidal projects in the UK. This idea will help address the strategic environmental research priorities for the sector and reduce consenting risks for the wave and tidal sectors across the UK, facilitating the sustainable development of one of the EU's Blue Growth Industries in the UK.
Glacial retreat, risk and resilience - Grrr	Methods for monitoring glaciers in mountain regions around the world have improved enormously in recent years, and with this, so has our recognition that glacier retreat is now a global issue with imminent and profound consequences. In 2013, the Intergovernmental Panel on Climate Change concluded that since its previous assessment (2007), "almost all glaciers worldwide have continued to shrink", and "current glacier extents are out of balance with current climatic conditions". With vast populations around the world, reliant on glacial melt water for the irrigation of their crops, and hydropower, the implications of future glacier-retreat, and likely disappearance, of glaciers from entire mountain ranges, will increase risk and

	decrease opportunity, around the world. We propose the development of a Strategic Programme Area, to improve the our understanding of glacier change, the science underpinning glacier projections, to align scientific effort across a wide range of disciplines, to deliver a framework for risk mapping, and to deliver specific projections of glacier change and hydrological impact for key glacial regions (e.g., High Mountain Asia, and Andes).
Making space for nature in a new policy landscape	With Britain poised to leave the European Union, we may be about to experience one of the biggest revolutions ever seen in how we use our land. The loss of the habitats directive, the birds directive and the common agricultural policy, are widely seen as a threat to UK biodiversity, but it is possible they could be replaced by both radical and *better* policies. NERC could help the government towards optimal, evidence-based land-use policy. We propose a strategic programme area to generate new scientific evidence to assess the most effective spatial arrangement of landscapes to maintain biodiversity and food production. This will be a globally unprecedented, hypothesis-based combination of large-scale experiments and modelling to determine how to optimize land use, with relevance to wildlife conservation, food security, human health and climate change. The SPA would focus specifically on the spatial synergies between different land-use types (primarily farms and traditional conservation areas) that come about because organisms move between them. This focus ensures a unique contribution to relieving one of the biggest technical limitations of most current natural capital and ecosystem service assessments. It would bring together researchers who have previously focused on only small parts of the overall question, and break down the artificial disciplinary barriers between agro-ecology, restoration ecology, dispersal and movement ecology, macroecology and conservation ecology.
Current and emergent climate risks in the UK	There is an urgent need to investigate *emergent climate risks in the UK*. A number of well-defined risks and impacts have been identified through research within a sectoral or disciplinary framework, but of course the real world does not operate along such neat lines. In reality, impacts of climate change emerge from a complex *web of risk* involving numerous events and trends including river and coastal flooding, drought, food production, biodiversity, air quality, and temperature extremes, and will also include synergies with adaptation and mitigation actions such as flood protection measures and expansion of bioenergy. The standard sector-based approach to impacts assessment is not capable of addressing these issues. Moreover, examining the problem through a series of individual lenses focused on particular issues tends to encourage incremental responses, whereas addressing all risks acting in synergy may require a transformational response. We therefore propose a ground-breaking integrated programme of research with a strategic framework facilitating a high level of integration, internal consistency and identification of emergent risks. This will substantially deepen our understanding of multiple, interacting risks, including explanation and attribution of past impacts and improved foresight of future risks in both the near-term (years to decades) and long-term (decades to centuries). Climate risks will be researched from five complementary perspectives: (i) process understanding; (ii) attribution of recent trends and events and understanding of contemporary risks (iii) forecasting of near-term impacts of climate change and variability; (iv) characterization of UK consequences of specific levels of global warming of interest to policy; (v) assessment of the UK impacts of non-linearities in the global climate system. The role of adaptation in reducing risks will be a particular focus. This will build on new observational datasets, new climate modelling and Climate Change Impacts, Adaptation and Vulnerability (CCIAV) research, potentially including (but not necessarily limited to)

	UKCP18, CMIP6, monthly to decadal initialized forecasting systems, and uncertainty quantification.
Resilience coastal futures	Our coastline and estuaries are especially vulnerable to flood and erosion hazards, now and in the future, posed by waves and surges and expected future sea level change. Coastal landforms offer a significant amount of natural capital via their mediating effects on these hazards eg salt marsh attenuating wave action, barrier beaches acting as significant flood defences, healthy beaches stabilising flood and coastal protection structures etc. Our desire to maximise this capital by working with these natural processes is captured in aspirational long-term shoreline management policies (SMPs) where retreat the line or no active-intervention options are specified. In reality, those working to deliver these policies and the communities living on the coast, face considerable challenges when trying to realise these changes. For example: • How do we encourage communities and businesses to take action now to adapt to an uncertain future when they are reluctant to change the status quo? • How do we address legacy issues such as historic landfill, contaminated land and aging infrastructure? • How can we best describe the benefits of decisions when those benefits may not readily be described in economic terms?