Ecology for the National Adaptation Programme for Climate Change

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Background

Climate change poses a profound threat to biodiversity and ecosystems. Whilst larger reductions in greenhouse gas emissions are essential to avoid the worst impacts, the effects of climate change are already being seen and will increase under even the most optimistic scenarios. It is therefore essential to adapt to this changing world to reduce adverse impacts on our natural environment and, in some cases, take advantage of opportunities. There is also untapped potential to reduce the risks to people from climate change by management of the natural environment for 'ecosystem based adaptation'.

Adaptation to climate change isn't simply a good idea; it's also a legal requirement in the UK. The Climate Change Act was passed with cross-party support in 2008 and sets out a process for climate change adaptation as well as reducing greenhouse gas emissions. This requires a National Adaptation Programme (NAP) to be developed following an assessment of climate change risk, on a 5 year cycle. The first NAP was published in 2013 and a second is scheduled for 2018. The natural environment is an important element of the NAP and this workshop, hosted by the British Ecological Society Climate Change Ecology Group was organised to bring the ecological science community together to review the latest evidence to guide climate change adaptation. The idea was to ensure that when the NAP is developed in the coming months there will be a good understanding of the science available to support this. The starting point for the workshop was the UK Climate Change Risk Assessment (2017) which identified a series of risks that the NAP needs to address.

The main part of the workshop was given over to short (5 minute) talks and break out groups. The short talks covered either new scientific research or case studies of climate change adaptation to help us capture some of the key developments that have taken place since the last NAP was published. Unlike climate change impacts research, adaptation is a necessarily practical discipline and the lessons learnt from experience are at least as important as those from academic research. The breakout sessions were organised according to risks to natural capital identified in the CCRA. The breakout groups were typically composed of a mixture of experts in the specific fields and participants with more generalist knowledge and expertise.

Headline messages from introductory talks

Welcome, introduction and context - Mike Morecroft (Natural England)

- Climate change adaptation is adjustment in natural or human systems which moderates harm or exploits beneficial opportunities from climate change.
- There is a statutory approach to planning adaptation in the UK with the National Adaptation Programme developed in the context of a national Climate Change Risk Assessment, covering all sectors.
- The evidence base to support adaptation of the natural environment has increased substantially as has experience of adaptation in practice since the last NAP was published in 2013.

Adaptation principles for the natural environment - Olly Watts (RSPB)

- Adaptation for nature is guided by two overarching and complementary strategies: building resilience to impacts and accommodating change from new conditions.
- Consideration of climate change should be embedded in all nature conservation work, and actioned at across the range of timescales and spatial delivery.
- The increasing focus at landscape scale offers increasing opportunities for multi-partner and cross-sectoral engagement in nature conservation, including wider use of nature-based adaptation solutions, and the continued provision and engagement of the range of ecosystem services that help to connect people with nature and its conservation.

Short talks: New research results and Adaptation Case Studies

Embedding Climate Change Adaptation in National Nature Reserves - Simon Duffield, Natural England

- A practical and pragmatic climate change vulnerability assessment has been developed and tested on Natural England's National Nature Reserves (NNRs) to identify vulnerability and appropriate adaptive responses.
- It is now fully embedded into NNR management planning.
- In terms of adaptation responses, most fall into the building resilience category, but an increasing number relate to accommodating change and the need to develop the evidence base.
- The next stage is to monitor and evaluate the success of interventions.

Finding a home for climate refugees: birds and butterflies in Europe and the UK - Chris Thomas, University of York

- Preliminary risk assessments for Europe indicate that there will be zero overlap between the current distributions of 4% to 16% of birds, and of 12% to 47% of butterflies, and locations where the future climate is expected to be suitable for them (the variation depending on the climate scenario).

- Translocating species is the only realistic way to save some of these species because discontinuities in suitable climate space and geologies, and other geographic barriers, will prevent natural colonisation however many landscapes can be connected. Some of these species are endangered with high certainty (i.e., for all climate scenarios).
- The UK and Europe lack appropriate processes (risk frameworks and institutional) to determine the circumstances under which species should be translocated, and to apportion responsibility and costs between 'donor' and 'recipient' countries. These processes need to be established within the next few years, so that practical action can relieve the extinction risk by mid-century.

Seed Banking for Climate Change Adaptation - Clare Trivedi, Royal Botanic Gardens Kew

(Clare was unable to attend the event but kindly provided her presentation, which can be read alongside other presentations from the day)

Birmingham Institute of Forest Research (BIFoR)-free-air CO2 enrichment (FACE) facility - Debbie Hemming, Met Office Hadley Centre

- BIFOR-FACE is a 10 year elevated CO2 experiment in mature UK woodland in Staffordshire UK.
- The experiment addresses fundamental questions regarding the ability of mature woodlands to capture CO2 and how elevated levels of CO2 affects ecosystem functioning.
- Following two years of baseline measurements, in spring 2017 elevated CO^2 was switched on in three 30m wide 'treatment' plots within the woodland and measurements are currently underway to understand the ecosystem responses.

Climate adaptation in marine protected areas - Bryony Townhill, Cefas

- The Marine Climate Change Impacts Partnership (MCCIP) are producing cards for specific marine features outlining how climate change can be incorporated into management.
- Working groups formed of conservation agencies and academics are producing the cards.
- The aim is for the first cards to be available late summer or early autumn.

Climatic disequilibrium threatens conservation priority forests - Brian Huntley, Durham University

- Whereas the climatic conditions 200 years ago favoured the growth of Scots pine and other boreal trees in areas currently occupied by stands of Caledonian pinewoods, the present climate is more favourable for the growth of oak and other nemoral trees in these localities.
- Caledonian pinewoods, including those identified as Special Areas of Conservation (SACs), have accumulated a climatic debt that will be repaid after a stand-destroying disturbance, when oak and other nemoral trees will be favoured during regrowth. Many stands of other forest types are likely to have accumulated similar climatic debts.
- Long-term conservation of Caledonian pinewoods requires identification and protection of sites now more suitable for the growth of Scots pine, and active steps to encourage

development of pinewoods on these sites. Similar measures may be needed in order to conserve other forest types.

Species on the move: northern range margin shift in British taxa - Suzanna Mason, Centre for Ecology and Hydrology

- Many different species groups in Britain are shifting their ranges northwards in response to climate change.
- Different species and groups experience different rates of range shift which needs to be considered by ecologists and conservation managers.
- Species' range shifts will bring risks and opportunities, as laid out by the National Adaptation Plan.

Ecological responses to climate change: the importance microclimate - Ilya Maclean, University of Exeter

- Most assessments of threats to biodiversity from climate change rely on coarse-scale data, yet conditions experienced by many organisms vary over fine-scales.
- We have developed microclimate models that enable ecological impacts of climate change to be assessed at fine scale.
- Predicted impacts of climate differ greatly when microclimate is accounted for: range shifts are far more localised than predicted by coarse-scale models, with significant implications for adapting conservation to climate change.

Refugia from climate change: an adaptation tool? - Andrew Suggitt, University of York

- Variable microclimates have buffered cold-dwelling plant and animal species from adverse climate warming.
- Microclimatic buffering has reduced extinction risk by an average of 10-20% across the taxa, with almost half of the plant and invertebrate species we studied benefitting from these climate change 'refugia'.
- Protecting and prioritising refugia could therefore form part of a strategy to adapt conservation to a warming climate.

Is biodiversity conservation business as usual under climate change? - Tom Oliver, University of Reading

Information to be added.

Deploying the garden army: The role of green space in climate change adaptation and mitigation - Eleanor Webster, Royal Horticultural Society

- The RHS Gardening in a Changing Climate report (launched April 2017) concluded that gardening is a key way that government, scientists and policymakers can empower the general public in relation to climate change adaptation and mitigation, as opposed to intimidating them.

- Gardeners are a key demographic to target as published data shows that a substantial proportion of the UK population are engaged in gardening and, most pertinently, they are willing to adapt current gardening practices to benefit the wider environment.
- With populations rising and housing development set to continue into the future, how gardens are managed will greatly determine the degree to which health and environmental ecosystem services formerly delivered by the natural environment will continue to be delivered in the future.

Climate information for informing plant pest risk in UK - Debbie Hemming, Met Office Hadley Centre

- The UK Climate Change Risk Assessment 2017 identifies new and emerging pests and diseases as an area of immediate climate change risk in the UK, and a research priority.
- Climate (e.g. warmer, wetter winters) can have a major influence on the lifecycle and abundance of pests and therefore the risk of damage to our natural and agricultural systems from these pests. Under climate change this risk is also likely to increase as certain pests and pathogens that currently survive on the near continent become established in the wider UK environment.
- Results presented included estimated pest emergence dates and climate suitability maps for UK priority pests (from the Plant Pest Risk Register). The close collaboration between plant pest risk experts in Defra's plant health team and Met Office vegetation-climate interactions scientists ensured co-design of the project science with Defra's requirements, and therefore outputs were relevant and useful for practical plant pest management and planning in UK.

The Wallace Initiative Phase III – accessing data on the potential climate change impacts on more than 100,000 species of insects, plants and animals - Jeff Price, University of East Anglia

Information to be added

Wallasea Island: Adaptation for birds and people - Olly Watts, RSPB

- Adaptation at RSPB Wallasea Island provides a wide range of benefits including nature conservation, carbon storage, flood risk management, sea level rise, use of large volume of waste material, and public enjoyment and wellbeing.
- Ecological aims include providing new habitat for both current priority species and species likely to colonise the UK, for a wide range of future sea levels, with relatively inexpensive maintenance largely through management by water level control.
- Whilst Wallasea is a major project it provides a showcase for a range of adaptation management actions and techniques for nature that can adopted elsewhere.

Warming oceans and human health: it's the little things that matter - Camille Parmesan, University of Plymouth

- Many marine pathogens reduce the health and productivity of wild fish and shellfish populations, and some (e.g. Vibrio species) can also cause illness, and even death, in humans.
- NHS does not include Vibrio species as “reportable”, so this group of very dangerous bacteria is not tested for, e.g. in suspected food poisoning cases.
- Biodiversity assessments should include the little species: key disease organisms and their vectors and reservoirs. Currently, field surveys for historically “warm” water pathogens occur sporadically in space and time across UK waters.
- Together with a lack of reporting from the health community, this situation risks “surprise” outbreaks of disease occurring in both wild fish and shellfish populations and in human systems. Routine monitoring of marine life and mandatory reporting in the NHS would minimize impacts of increasing disease risk.

Sensitivity of UK Butterflies to local climatic extremes - Osgur McDermott Long

- UK butterfly crashes are linked to increases in extreme weather.
- Warm winters have the potential to drive future species declines and should be considered when thinking about butterfly conservation.
- We cannot take a ‘continue as normal’ approach when considering the conservation of our butterfly species to extreme weather events.

Breakout sessions

During the morning and the afternoon there was a breakout session when participants joined one of six groups to discuss a relevant 'Risk and Opportunity' as identified in the UK Climate Change Risk Assessment 2017 Evidence Report.

NE1 Risks to species and habitats due to inability to respond to climate change

(Note: NE stands for natural environment and natural assets.)

Headline messages

- Vulnerabilities and risks to both species and habitats are varied and widespread, and whilst some aspects are well understood and monitored, considerable knowledge gaps remain.
- More on-site adaptation action now should be taken, particularly on the variety of habitat management actions that can provide greater microhabitat and microclimatic conditions.
- Longer term, a more holistic approach to conservation across the UK needs to be developed, planned and actioned, encompassing protected areas and landscape scale areas and connectivity across this 'network'; designed not just for current UK biodiversity but also for the wider biogeographical implications of climate change, including migratory species and those for which the UK is likely to assume greater international conservation significance.

Risks

First we reviewed the risks that were in the Climate Change Risk Assessment, and made the following additional suggestions:

- Evidence for birds and plants shifting the core of their range (in addition to the evidence to northward leading range shifts and less evidence for southern range contraction).
- Risks may be over-estimated because of a lack of factoring in microclimate and refugia in projections.
- Montane species with southern limits are often already restricted to the most favourable microsites in the landscape.
- Is there evidence for increasing variability in species' populations in response to increased variability in the weather?
- There is evidence from North America and Europe that advancing phenologies may increase the vulnerability of species to late spring frosts. We were unclear of evidence for negative impacts on UK biodiversity, but there are reports of these impacting vineyards in England.
- Water availability is a key risk in dry regions.
- Water abstraction and climate drying negatively impacts wet woodland.
- Changes in large heath butterfly populations show interactions between water availability and temperature, which suggests potential for adaptation through restoring natural water levels.
- Some habitats may only persist if they are able to colonise new areas in landscapes that become (or are already) suitable.

- Risks to habitats from new species (e.g. disease, pests, changes in grazing pressure, resource use).

The following general points were also made during this discussion:

- There is a need for more natural history understanding.
- Conservationists need to be clear about definitions for colonists in response to climate change and invasive species.
- There is a lack of assessment of what species and habitat priorities should be in an international context, in the light of continent-wide projections and trends. Common species should potentially be prioritised over rare (often edge of range) species.
- Climate change may be used as an excuse to weaken conservation legislation.
- Contrasting directions of long-term climate change and extreme events may produce a double-bottleneck for populations.
- There is a distinction between acute and chronic extreme responses.

Adaptation

First we considered general priorities for adaptation, before then considering what we can recommend with confidence for specific species and habitats. The discussion about general priorities started by considering site-based management, before then considering wider issues of connectivity, which would be more of a focus for the afternoon discussion. We separated these into short-term, medium-term and long-term priorities. We ended by asking each person to identify a single top priority action.

Adaptation action to implement in the next five years

- There is potential for on-site manipulation of micro-climate variation and/or to create new micro-climates to assist species coping with climate change in-situ, increasing resilience. There is a lot of evidence for this.
- There are likely to be limits to the extent to which on-site manipulation will help species, and a danger that too much of an emphasis on site-based management could lead to mal-adaptation, but this may be an important approach for helping protect species and populations before they can shift.
- Increasing sward height to create cool microclimates may be detrimental to early-successional or pioneer species, which are often conservation priorities.
- The value of increasing variability (e.g. microclimate), can be scale dependent – it is difficult to prioritise at small sites.
- We need to promote wider public awareness / engagement of the climate change vulnerability of wildlife now.
- We need to increase public awareness that climate change will shift species ranges. Specifically this will lead to new exotic species coming into areas protected for native species. This does not mean they are invasive (bad) but conservation depends upon allowing their persistence.

Adaptation issues to consider now for mid-term requirements

- We discussed, and couldn't answer, whether site condition assessment of a site affects its ability to facilitate colonisation or resist extinction. We need to understand this.
- Current approaches to condition assessment can also constrain adaptation when fixed criteria may be inappropriate.
- We need climate change adaptation experiments to see what works.
- We need to prioritise physical connections in the landscape.
- Migratory species are likely to be particularly vulnerable to climate change. Adaptation for these species cannot be UK centric.

Adaptation issues to consider now for longer-term requirements

- By letting nature take over, rewilding may increase resilience to climate change.
- Protected areas should remain protected and be kept in good condition. These can be important stepping stones for species or as refugia.
- Habitat quality is a strong determinant of functional connectivity. Protecting high quality sites is important.
- There is a need for a holistic approach across designated / conservation sites, even where managed by different organisations – they need to function as a connected network.
- Connectivity planning needs to facilitate 'omnidirectional' movements of species responding to different, non-aligned climatic gradients (i.e. isotherms across Europe in winter run more north-south, whilst in summer, run east-west).
- Need to assess conservation priorities taking into account global ranges of species – prioritise those for which UK is globally important.
- Analysis of which species the UK will have increased global responsibility for under climate change, to ensure scarce resources are best deployed.
- Ecological Focus Area options – not all available in the EU are implemented in the UK, impact of those not available as an adaptation measure e.g. Southern Europe.
- There are limited to adaptation. We need to mitigate climate change.

Short term adaptation priorities

The following adaptation priorities for specific habitats were identified:

- In the urban environment we should renew campaigns for home owners to keep parts of their gardens messy (the back 1m) and allow common greenspace to flower and be messy for nature, rather than a closely mown lawn.
- In the urban environment, green roofing, wild margins and verges should be prioritised.
- Drain blocking on blanket bogs has high evidence for adaptation and mitigation.
- Riparian shading of chalk streams by trees (although possible impacts on invertebrates.
- Short-term catchment management may require reservoirs to capture excess water for use during summer drought.
- Pump water to maintain alder carr being lost to water abstraction.
- Evidence for habitat-climate interactions impacting the conservation of the great-crested newt.

Long term adaptation priorities

- Can we changes how we manage the uplands for conservation and particularly manage them for retreating species?
- Managing water quantity in wetland habitats is critical.
- Long-term catchment management to increase infiltration and slow water flow is valuable for adaptation to reduce flood risk and increase water availability to reduce drought risk.

NE2 Opportunities from new species colonisations

Headline messages

- A coherent, supra-national scale habitat network is required that enables species to move between as well as within local/regional networks; this will need local, spatially explicit prioritisation and an improved enabling legislative framework to assist colonisation.
- Developing nature conservation adaptation on privately owned land will be an essential component of achieving joined-up, UK-wide delivery; developing the post-Brexit nature conservation framework provides a unique and vitally important opportunity to do this.
- Evidence for, and monitoring of, such a network needs to be developed, including aspects of costs and benefits of retaining and encouraging species in and into particular locations, adaptation actions undertaken, and using citizen science to address gaps professional monitoring programmes.

Forenote

This topic over-lapped greatly with that for the workshop on NE1, which covered much of the relevant ground for this group. Indeed, there was some difficulty in clarifying the division between the two – we took the division to be that NE1 considered mainly adaptation with current range (adaptation for resilience), while NE2 considered adaptation to accommodate extension of range. We might equally have divided it along the lines of NE1 considering both resilience and accommodation of change for currently native species, while NE2 considered only species arriving on English shores for the first time. However we divide the topics, there is inevitable overlap – so we recommend that NE1 and NE2 are considered alongside each other.

Current and future risks

The 'risk' for NE2 was therefore expressed as the risk of not realising the opportunity for range expansion, either of currently native English species beyond their current range, or for new colonists of England. Note though that we also considered risks for species expanding their range, and risks to other native species of other native species expanding their range.

Opportunity was given for additional suggestions, but it was agreed that almost all had already been captured under the NE1 discussion. There was one additional suggestion:

- Risk of loss of genetic variation (and therefore adaptation potential) at expanding range fronts, associated with genetic bottlenecks during the establishment of new populations.

Adaptation objective: what should the NAP seek to achieve?

There were two main points, about (a) spatial prioritisation and (b) legislative frameworks for accommodation of new colonists:

- Government agencies (note we are thinking here not only of English agencies, but close working across national boundaries, with JNCC and other country agencies) should be charged with developing 'master plans' for a vision of a 'coherent supra-national scale habitat network that enables species to move between as well as within local/regional networks'. Specifically, local spatially explicit prioritisation is required, to influence spatial plans, if this is to have traction locally, but these local plans need to be nested within a broader international>national>local framework of spatial prioritisation.
- We need an improved enabling legislative framework for actions to enable/facilitate colonisation. This needs to be transnational, recognising the UK contribution to global conservation under a (more) climate change affected world. Currently, acceptance of colonisation conflicts with invasive species legislation. This needs to consider both deliberate translocation/assisted colonisation, and new arrivals where it is not always clear whether a species has colonised with human assistance or not. Generally, should we presume that new arrivals are 'acceptable' (i.e. would incur limited harm to other species / human interests) if they arrive from the same biogeographic region (i.e. Western Europe)?

What is the current adaptation shortfall, given this objective?

- We do not yet have the scale of coherent habitat network required. Realisation of any (mapped) plan for a coherent, resilient habitat network requires the co-operation of multiple actors interested in planning and decision-making within a landscape. It was noted that there are multiple actors producing landscape scale visions for habitat networks. Though there is some progress with integration of plans across these conservation actors, this integration needs to be improved and extended, to maximise effectiveness of co-operation with other landscape actors/land-owners that have a vital role to play in realising these habitat network ambitions.
- Realising a national-scale adaptation plan will depend on the condition and management of private (mainly) and publicly-owned lands. Present-day leverage at this scale is achieved by a combination of legislation (permitted activities, including protected area status) and inducements, the latter primarily stemming from CAP. Post-Brexit, there will be a need and opportunity for a strategy and inducements that facilitate the establishment and management of a coherent network.
- Any plan for adaptation will need to be adaptive, responding to change as we detect it. This highlights the continued need for monitoring information – the resourcing of data collection and central (accessible) curation, and enabling analysis to inform policy and management.

What adaptation action is required?

- Development of a national spatial prioritisation plan, and evaluation of legislation and levers to deploy it.
- Policy review of potential conflicts between invasive species and climate-change legislation and protocols, in relation to the arrival of (currently non-native) species into the UK.

The discussion then focused on evidence needs to underpin action, all of which are required in the short term:

- Assess the relative costs and benefits of keeping native species here versus translocation of new species to England.
- Given all of the landscape-scale interventions that are already happening, what evidence do we have for realised benefits? And how does this vary among taxa, for instance according to dispersal ability and habitat associations.
- A scaling up of engagement of citizen scientists to plug the growing gap in the capacity of professionals to collect and curate monitoring data.

NE4 Risks to soils from increased seasonal aridity and wetness

Headline messages

- Consideration of soils in the NAP needs to be long term, and focus on best practice management, soil quality and the ecosystem service co-benefits this can provide for climate change adaptation.
- A long term commitment to monitoring national change in UK soils is required to inform future delivery and land use policy.
- A coherent land use policy is required to address potential impacts to soil quality from changes to land suitability exacerbated by seasonal aridity and wetness.

Urgency score

More action needed

Rationale: More action needed to reduce existing pressures on soils, increase uptake of soil conservation measures and restore degraded soils.

Current impacts / risks (highlighted as missing by discussion group)

- The impact of changes to sulphate deposition in the uplands, and the potential impact this has regarding the resilience of degraded upland soils, water quality (dissolved organic carbon), nitrification and carbon balance on downstream habitats.
- The mobilisation of soil contaminants via changes to soil moisture regime. E.g. seawater ingress of landfills.

Future impacts / risks (highlighted as missing by discussion group)

- Increased aridity of wetland and upland habitats (and subsequent economic and climate policy changes) could cause agriculture production on sites where previously unsuitable / uneconomical leading to soil loss and degradation. E.g. agricultural management moving up hill slopes.
- Agricultural use of peatlands – eastern sites impacted by climate change while western areas impacted by land management changes. Future policy changes could make available to agricultural production and reduce peatland sites capacity to provide adaptation.

Adaptation objectives: what outcomes should the NAP seek to achieve?

- Move to a systematic consideration of soils rather than symptomatic. Promote the climate change adaptation and mitigation benefits that best practice management soils can provide.
- Make the case for increased efficiency in agriculture, rather than increases to productivity.
- Re-align expectations by the public for the future supply of goods provided by the natural environment. E.g. paludiculture management to provide products (such as sphagnum, reeds) as well as soil protection and adaptation benefits.

Adaptation shortfall expected

- Soils typically considered on a landscape scale – there is a lack of understanding of the role of soil microclimates in supporting climate change adaptation, and the risk to these sites from climate change.
- Current focus on mean average changes rather than extreme events. There is a lack of understanding of the impact extreme precipitation events have on soil organic matter.
- Increased aridity across eastern and lowland peatlands will mean physical erosional processes from volatile weather events (wind blow, extreme precipitation) will increase in significance.
- Urban soils, and the risks to the services they provide, are underrepresented. Greater attention should be given to the services urban soils provide to communities in climate change adaptation. This would help with the trade-off between environmental and housing policy.

Action required: things that need to be done in the next five years for short term delivery

- Specific soil legislation/strategy, to provide a mechanism to ensure long term consideration and protection of soils in UK land use policy.
- Direct engagement with Soil Security Programme (and other soil professionals e.g. BSSS, IPSS etc.) to deliver climate change adaptation co-benefits alongside improvements to soil quality.
- More accurate mapping of peat extent and condition. This also needs to include depth and bulk density attributes.

Action required: things that need to be set in train in the next five years for longer term delivery

- A long term commitment to monitoring national change in UK soils is required to inform future delivery and land use policy. This is currently a gap that urgently needs to be filled.
- Establish a coherent soil inventory to evidence the link between soil processes and the climate change adaptation and mitigation services they directly provide and support.

Action required: more general evidence needs

- Changes to soils aridity / increased seasonal wetness will not happen in isolation, but as a result of complex interactions between climate, vegetation communities and precipitation changes. Further research is needed to increase our understanding of this, and the impact on semi-natural habitats and managed sites.
- Effects of increased and/or periodic inundation on microbial diversity of lowland soils and the impact this will have on carbon / nutrient cycling and wider ecology.
- Impact of climate change on the land bank, and how this will influence land use policy.
- While the economic impact of soil degradation has been estimated there is a lack of understanding around how climate change will exacerbate this.
- Long term impact of reducing upland stocking densities and restoration management (grip blocking etc.) and the effect this has on reducing soil / carbon loss from upland habitats.

NE5 Risks to natural carbon stores and carbon sequestration

Headline messages

- Need more integrated knowledge about soil carbon stocks throughout the UK, not just extent, but depth and density.
- Need more surveillance/research on emerging pests and diseases risk to forest and woodland carbon stocks.
- Need more coherent land use planning to allow beneficial management of soil and tree carbon stocks in areas most likely to result in maintained resilience to changing climate.
- Need more knowledge of the role and extent of 'blue carbon' in coastal marshes in the UK carbon stock, better policy measures/recognition to aid resilience, and its potential as mitigation.

Urgency score

- More action needed to restore degraded carbon stores, particularly peatlands.
- More research needed to account for climate change impacts on carbon stores in the UK GHG projections.

Current/future impacts / risks

- Loss of coastal 'blue carbon' stocks through sea-level rise, coastal development and squeeze, exacerbated by lack of knowledge of the size (and permanence) of this stock and its relation to terrestrial and riverine carbon pools and loads.
- The degree to which changes to sulphate deposition in the uplands affect the resilience/chemistry of degraded upland peatland soils and therefore the stores of carbon within them – particularly with reference to dissolved organic carbon losses from peat.
- Loss of large forestry/woodland carbon stocks through effects of changing climate: storm frequency, novel pests and diseases. Possible exacerbation through inadequate biosecurity and trade policies.
- Stocks of carbon in forest/woodland mineral soils – particularly with reference to new woodland / forest creation (or lack of it).
- Large scale land use change driven by changes in rainfall/temperature and policy – encroachment of tillage/intensive agriculture onto upland deep peat areas encouraging drainage and loss of peat carbon. Specific peatland land use legislation/moratoria may ameliorate this (e.g. moratorium of planting new forestry on deep peat), but lack of detailed knowledge of deep peat distribution may hamper this. This may also drive soil carbon loss in lowland peat areas, largely in the east, but also in some western areas.

Adaptation responses

- More sympathetic management of agricultural peatland soils and marginal agricultural lands – either removal from production to protect carbon stores through water table management, or introduction of novel crops and techniques e.g. paludiculture on lowland peats, silviculture in upland areas. More integrated land use planning and policy tools to promote the above.
- Move to a systematic consideration of soils and therefore their carbon stocks – both peatlands and mineral soils. Promote the climate change adaptation and mitigation benefits that best practice management soils can provide.
- Consider national or regional accounting of non-tree carbon stocks as a lever to promote better management of (particularly) soil carbon stocks.

Adaptation shortfall expected

- Need for more knowledge of the role of both long term trends as well as severe events in altering carbon cycle in UK context.
- Lack of spatial and temporal monitoring of both soil and vegetation carbon stocks at national scale – including establishment of a sound baseline. This should be sensitive enough to pick up spatial heterogeneity of carbon stores, particularly in soils.
- Policy drivers are currently centred on biodiversity or carbon storage goals, particularly in agricultural landscapes, whereas they should look for synergies between these goals to prevent perverse outcomes.
- Uncertainty of the role of blue carbon, and its permanence in UK carbon stock is preventing the development of policy in this area.

Action required – and further evidence needs for best practice

Things that need to be done in the next five years – short term delivery

- Specific soil legislation/strategy, to provide a mechanism to ensure long term consideration and protection of soils in UK land use policy.
- More accurate mapping of peat extent and condition. This also needs to include depth and bulk density attributes.

Things that need to be set in train in the next five years for longer term delivery

- A long term commitment to monitoring national change in UK soils is required to inform future delivery and land use policy. This is currently a gap that urgently needs to be filled to establish baseline stock levels.
- More research into the long-term efficacy of peatland rehabilitation techniques to secure carbon stores remaining, and increase sequestration.
- Establish a coherent soil inventory to provide evidence of links between soil processes and the climate change adaptation and mitigation services they directly provide and support.
- Scenario-based modelling using climate change predictions to inform land use planning under climate change, to prioritise areas for rehabilitation/management optimisation for best resilience of habitats and carbon stocks.
- The establishment of 'carbon refugia' using the above – core areas where beneficial management has the best chance to maintain stocks and increase them through benign/optimum management of habitats.

More general evidence needs

- Long term impact of reducing upland stocking densities and restoration management (grip blocking etc.) and the effect this has on reducing soil / carbon loss from upland habitats. Also research into the interaction between these actions and continued climate change.

NE6 Risks to agriculture and wildlife from water scarcity and flooding

Headline messages

- Developing natural flood management presents significant opportunities for biodiversity – e.g. encouraging winter water storage on farmland could increase water availability for agriculture and also be beneficial for wildlife.
- Much greater catchment level management and governance is required to deliver coherent landscape scale adaptation for water management; post-CAP reform for agriculture, and other post-EU opportunities, must address this, incorporating novel incentives and funding alongside the current ones.
- Future supply and demand of water across England needs to be better understood, including landscape scale land-use modelling for the progression of climate change.

Risks

- Smaller water bodies and low order streams are under monitored (not covered by Water Framework Directive) and may see the first signs of climate change impacts.

- Intense rainfall events can lead to the dilution of pollutants but high risks of pollution can occur when an extreme rainfall event follows a drought period when the ground is hard and fertilizer/slurry/manure has recently been applied.
- Some evidence of both positive and negative impacts of major flooding events on biodiversity (e.g. March Brown mayfly– anecdotal evidence from anglers).
- Mismatch between UK demand for water (south and east) and supply (north and west) - need major transfer.
- Political implications (especially devolution) of transfer of water.
- New reservoir systems and increased connectivity could facilitate invasive species spread.
- Adaptation to climate change through changes in agricultural practice (new crops, varieties, tillage management, new altitudes) can feedback onto freshwater systems.
- Major absence of catchment planning and governance.

Knowledge gaps

- Need to better model landscape land-use under future climate change scenarios and the impacts of these on ecosystem service delivery and natural capital.
- Does water transport infrastructure help industry and agriculture adapt to climate change but bypass biodiversity?
- A focus on flow in isolation from other pressures on freshwater is artificial - more integrated multi-stressor research is needed.
- Need to look at the ecological impacts of risks to food security and self-sufficiency under climate change.
- Interdisciplinary research looking at how best to efficiently allocate subsidies toward climate change adaption could be improved if agri-environment scheme payment spatial data were made available for analysis (even if aggregated).

Opportunities/Potential actions

- Lots of win-wins from natural flood management.
- Adaptation strategies encouraging winter water storage on farmland could increase water abstraction by agriculture but could also be beneficial for wildlife.
- CAP and other legislation can constrain/de-incentivise local small scale water storage creation – opportunities post-Brexit.
- Insurance schemes could potentially leverage investment for payment for ecosystem service schemes.
- Tax relief incentives on green infrastructure, similar to that on farm buildings, could encourage local level adaptation investment.
- Need to better integrate adaptation knowledge exchange through existing facilitators e.g. FWAG, Rivers Trusts etc. to farmers and landowners.
- Adaptation could be incorporated into new UK agricultural policies.
- Evidence that reducing pollution increases resilience to climate change.

NE7 Risks to freshwater species from higher water temperatures

Headline messages

- A complex mix of ecological changes is underway, including species distribution shifts, trophic mismatches, community change, immunity stress, lifecycle responses.
- Adaptation at catchment and riparian system scale, enhancing connectivity and working with stakeholders to develop multi-sectoral understanding and cross-sectoral adaptation.
- Significant research gaps including how temperature affects populations; how temperature influences and combines with other stressors e.g. oxygen depletion and pollution; and the mechanisms of, and ecological changes in, new river regimes.

Urgency score

- The group agreed that the urgency score of 'more research' was inappropriate and inadequate to the impacts and issues faced by freshwater species.

Ecological

- Species shifting their distributions.
- Trophic mismatch.
- Food web structure: community changes, potentially with vulnerabilities to keystone species.
- Local extinction.
- Disease / pathogens increasing, leading to increase in immune 'stress' combined with metabolic effects – largely unknown.
- Lifecycle response to thermal regimes.
- Invertebrates can gain an extra reproductive cycle in a season.
- Earlier emergence times.
- Changing processes involved in warming rivers.
- Salmonids: all predicted changes are negative; warm winters impact on reproductive success and populations (5.7 degrees Celsius threshold), brown trout most sensitive; Storm Desmond impact.
- Decrease in salmonids leads to increase in other species: some will lead to increase in pest species; change in fishing habits and impacts.
- Salmonids may become more widespread but with lower numbers.
- Invasive species impacts and dispersal; cold winters very important in killing off invasives – typically a 5 degrees Celsius threshold.
- Increase in cyprinid fish – a positive for anglers, negative for ecology.
- There are dispersal issues to higher altitudes to seek cooler waters: for fish and insects
- Invertebrates in lakes are closely associated with temperature.
- Weed choking in lakes from higher night temperatures.
- Increase in eutrophication having much greater impact than increases in temperature.
- Range 0.1 to 1 degree Celsius increase per decade; increasing temperature leads to reduced oxygen concentration, increase in metabolic rate and increase in decomposition rate – all combining to reduce oxygen availability.

Physiological

- Potential switches in metabolic pathways (using different energy reserves).
- Potential metabolic stress; less energy to support reproduction / growth / immune function.

Physical

- Range of freshwater habitat types: e.g. river, ditch, stream and lake systems, extending into wetland habitat including flood meadows / plains.
- Lakes have different stratification patterns; and hotter water than rivers, although often with patchy areas of different temperature.
- Range 0.1 to 1 degree Celsius increase per decade; increasing temperature leads to reduced oxygen concentration, increase in metabolic rate and increase in decomposition rate.
- Increase in stratification.
- Deoxygenation.
- Winter warming faster than summer warming - M Elliot, brown trout and salmon vulnerability; other species?
- Storm Desmond: impact on wash out and temperature.

Opportunities

- Freshwater bathing.
- Mainland Europe is richer in river / freshwater fish, other species – the Channel is however a substantial barrier to movement.

Adaptation responses

- Learn to live with warmer and drier systems and get the best out of it.
- Develop future scenarios with stakeholders, with shared outcomes approach; increase and improve stakeholder engagement; seek to develop multi-sectoral and patch/area solutions and delivery.
- Catchment and riparian management approach – enhance connectivity within river systems and connect with their floodplains; address climate change impacts at catchment scale.
- Identify key areas to develop as refugia.
- Adapt how we use rivers.
- Make the edges of rivers rougher.
- Reduce additional stressors on the system very effective (e.g. pollution, water quality); assists species adaptation (oxygen, particularly).
- Translocation – Million Ponds Project – e.g. whitefish from Bassenthwaite to Scotland; intra Great Britain; limited evidence of need and success; pond species typically are good dispersers.
- Develop environmental DNA techniques to monitor changing population over time; more advanced than for terrestrial environments, develop techniques.

- Lakes – develop biological control, phytophagous species to control vegetation – need to assess species carefully re future conditions with climate change.
- Tree planting: provides shade and reduces summer water temperature – tree planting design is critical, with adequate buffer strip widths. Leaf fall adds nutrients and energy to river systems (benefit). Sailors want treeless lakes; increased sediment from bank erosion (from suppressed plant growth under trees and subsequent increased erosion from boat wash); increased sediment can have benefits; issues of tree planting perception in uplands.
- Address all land use changes that impact on rivers, ditches and lakes.
- Influence post-Brexit processes.

Research

- Develop riparian pathogen monitoring.
- Monitor / project change through temperature loggers or modelling – latter is effective.
- Increase evidence and monitoring.
- Lifecycle response to changing temperature.
- Need much better understanding of the mechanisms of population decline with increasing temperature.
- Physical impacts, effects, changes, mechanisms.
- Need to understand mechanisms in new river regimes.
- Use European analogues (even though there is much greater continental species richness) including to assess potential changes to / robustness of community function.
- More studies required on the impact - cumulative and in combination – e.g. oxygen and pollution.
- Freshwater Biological Association temperature records in Cumbria lakes – complicated, not definitive, and patchy.
- Difficult to separate to thermal effects from other stressors – more research?

NE8 Risks of land management practices exacerbating flood risk

Headline messages

- Land management has a significant impact on water flow and flood risk: degraded and compacted soils, and some particular crops e.g. maize, increase run-off flow and siltation; these effects are likely to be increased by climate change.
- Future agriculture policy should be based on a land use strategy and environment plan and all current perverse incentives (e.g. productive area payments) should be removed.
- Knowledge gaps on nature based approaches to flood management should be addressed, and effective techniques identified and promoted.

Urgency score: the group agreed with the CCRA score: more action needed

- Deliver wider uptake of natural flood management in high-risk catchments especially where there are likely to be carbon storage, water quality and biodiversity benefits.
- Implement catchment-scale planning for flood risk management.

- Review potential for adverse flood risk outcomes from land management subsidies.

Current risk

The group agreed with the following current risks:

- Degraded and compacted soils exacerbate flood risk by increasing run-off and river siltation. Land management practices contribute to this through use of machinery or presence of agriculture on waterlogged soils. However, no systematic study of national extent or severity.
- Particular impact on flood risk from maize cultivation on slopes and over-stocking of livestock. Maize production has increased from 7,000 hectares in 1988 to 196,000 hectares in 2014.

And added the following additional current risks:

- Straightening, widening and dredging of water courses in the wrong place can increase the speed of rain water leaving the land, adding to the volume and velocity of flood water further downstream.
- Drainage of uplands leads to degradation of deep carbon soils which reduces their flood storage capacity and speeds up water leaving the upland.
- The EMBER project shows that burning in the uplands increases overland flow.
- Protecting flood plain land from flood water divorces rivers from their flood plains and moves the problem to elsewhere in the catchment.
- Loss of open space to development (soil sealing) reduces the capacity to absorb rainfall, increasing run off.
- The cost of pump draining agricultural land is likely to increase in the future due to the impacts of soil loss (from land and into water courses) and sea level rise.

Overarching comment

- Evaluate all of the benefits of catchment interventions, not just flood risk, to provide a cost benefit analysis.

Future risk

The group agreed with the future risk:

- Warmer, wetter winters and drier summers in the future could increase rates of soil weathering and increase soil erosion, which could in turn increase downstream flood risk.

And added the following additional future risks:

- Increased storminess and intensity of rainfall events increasing soil erosion and run off.
- New high risk crops e.g. sunflowers which leave bare soil due to late sowing.
- Increased pressure on land for food production due to population rise (northward migration) and consumer demand for food leading to poor soil management. Also increased pressure on land for housing (soil sealing).

- A combination of all factors could increase flood risk considerably e.g. an intense rain storm falling onto dry and compacted soils.
- There may be a spatial element to the risks, e.g. some regions will have a higher risk from winter rainfall or drought.

Adaptation shortfall expected:

The group agreed with the following adaptation shortfalls:

- Beneficiaries tend to be located downstream.
- Agri-environment schemes and some catchment-scale initiatives incentivise appropriate management; however, inappropriate management practices remain.
- Increased interest in the adoption of Natural Flood Management schemes, however, uncertainty remains over influence on extreme flood events.
- Barrier of ongoing maintenance requirements not included in local authority capital costs.

And discussed the following:

- The post-EU CAP regime should remove the current perverse incentive from Basic Payments which requires recipients to keep land in productive condition; in the future unproductive land may naturally scrub up or famers may voluntarily choose to deliberately flood land to provide flood storage benefits.
- There is also potential for the market to pay for such ecosystem services / public benefits in the future.
- Need to improve the evidence base around Natural Flood Management including the role of trees in slowing the flow and increasing infiltration.
- In improving the evidence for Natural Flood Management effectiveness, there is a need to distinguish between 'slowing the flow' and 'flood plain storage'.
- Minimum tillage is promoted as good soil management but it can increase soil compaction (or at least fail to remove it); there is a need to balance the trade off by considering the soil type and farm specific risk.

Anticipated benefits of further action in next five years:

The group agreed with the anticipated benefits from the recommended 'more action needed':

- Need to better understand scale of land management practices that exacerbate downstream flood risk.
- Further action needed to deliver Natural Flood Management, designed to maximise co-benefits for carbon storage, water quality and biodiversity.
- Economic case for such management needs to be strengthened.

And added the following for further action:

- Assess and compare the impacts / contribution of commercial forestry versus natural woodland management on flood management.
- Increase soil carbon.

- Mowing instead of burning on blanket bog grouse moors.
- Contour ploughing.
- Precision farming could help identify where land is susceptible to compaction – incentives in high risk areas where not currently used and for grassland management where patterns of trafficking is more random.
- Assess the benefits / disadvantages of livestock husbandry e.g. indoor vs outdoor, grass fed vs. grain fed.
- Wider usage of LIDAR data.
- Rural SUDS and a broader look at blue / green infrastructure.
- Winter storage reservoirs.
- Under drainage for cattle track ways.
- Is minimum-tillage the right action?
- Knowledge exchange for farmers and managers.
- Land Use strategy – to incentivise the right management / right crop in the right place.
- Need a coherent soil framework.

From these the group felt that the priorities for the next 5 years should be:

- Future agriculture policy should be based on a land use strategy and environment plan. Any future funding should remove the previous perverse incentivises from CAP (e.g. productive area payments).

NE9 Risks to agriculture, forestry, landscapes and wildlife from pests, pathogens and invasive species

Headline messages

- Need to understand and accept the movement of species as population locations change in response to climate change.
- Need to assess the positives and negatives of species arriving in new areas and deploy a flexible yet effective response strategy and actions.
- The EU Invasive Alien Species regulation needs to be brought into domestic law post Brexit; the targeted approach and listing of invasive species should complement the 'natural' movement of species distributions, whilst keeping an eye open to the ecological potential of 'novel' species in the UK.

Risks and issues

- Rearrangement / movement of species across Europe is inevitable and will be necessary for some to respond to climate change. Therefore, need to stop policies conflicting i.e. climate change adaptation and the natural change in habitat range for some species, versus biodiversity targets and trying to maintain the status quo.
- A non-changing climate is not an option; therefore we have to manage the change.
- Biodiversity and the genetic pool should be considered at the continental scale and we need to be less strict as to the movement of species across countries within a continent to allow for the maintenance of the continental genetic pool.

- Impacts of introduced biodiversity need to be managed – but the question of whether we can manage some of the introduced species remains.
- Species should therefore be assessed on the basis of impacts not their origin (a principle the Invasive Alien Species Regulation is aligning with).
- Need to be a lot more targeted about which INNS we try and manage and eradicate in the future so why bother with the 1) losing battles and 2) with species that may have a value or an ecological place in the future.
- Invasiveness is discussed in the current context – what happens if the species will fill an ecological niche left by another species changing distribution pattern? How do we look to the future?
- Crop breeding programmes deal with pests and diseases at the moment. Should more being done to discuss adaptation opportunities?
- What will future trade agreements mean for the arrival of potential INNS, pests and diseases?
- Want to be able to allow for genetic movement, species distributions to change, species to move countries and non-native species to come to UK but then keep out the harmful and invasive species. Need flexible and discretionary measures to meet this need.
- How should native species that may become invasive under changed climatic conditions be dealt with?
- Need to ensure stricter use of terminology when speaking of a non-native species versus a truly invasive non-native species to stop the broad brush tarring effect of invasive non-native measures being applied to non-invasive non-native species.

Adaptation responses

- Need to identify which habitats / species are close to their southern or climatic limit in order to identify where non-native species may be required as a replacement to maintain ecosystem function.
- Need the flexibility at the local level to decide whether to use, manage or try and eradicate a non-native species as INNS may be damaging in one place but commercially important in another area.
- More flexible policy targeted at requirement for action i.e. forestry focus on carbon sequestration or nature reserve focus on maintaining resilience of existing species.
- Allow for flexibility of policy implementation on the ground.
- Better integration of multiple policies.
- We need more understanding and linking of long term planning with short term control and monitoring & emergency response actions.
- Species arriving into a new area needs to be assessed on both positive and negative potential consequences. Need to be better at reflecting the future benefits and ability to manage negative impacts (the latter is being undertaken by the non-native species secretariat).
- Suitability of climate / environmental controls on pests need to be better understood worldwide to help plan / allow species movement and gain a better understanding of which species the UK climate is becoming suitable for.
- In addition to above, horizon scans for risks to the UK.

- See the transposition of the EU IAS regulation into domestic law post Brexit – this has a much more targeted approach to which species are listed as invasive which should complement some of the points made above.

NE10 Risks to agriculture, forestry, wildlife and heritage from changes in frequency and/or magnitude of extreme weather events

Headline messages

- There are several types of extreme events and unusual or novel weather patterns that affect biodiversity and natural capital, which could have larger impacts on species communities than gradual climatic changes and may have considerable cumulative effects over time.
- Extreme event impacts on particular species and / or habitats are often further exacerbated by the impacts on and responses to extreme weather impacts on human interests including agriculture, water management (flood and drought), infrastructure and community requirements.
- There are currently only limited adaptation responses to extreme / unusual events yet there are opportunities for nature through linking with other interests, as well as though developing Lawton based large-scale ecological approaches.

Urgency score

- Extreme weather is actually how most of the climate impacts in other chapters are mediated so it stating that it has a low urgency score seems odd.

Risks

- Increased risk of 'false springs' with impacts on both wildlife and agriculture (e.g. crop death leading to yield impacts).
- Variability in frost length duration can have big impacts in frost rare areas.
- Agriculture is adapting well (changing varieties, crops, management) but not necessarily building resilience into systems.
- Extreme weather events may put smaller more vulnerable agricultural producers out of business leaving fewer, larger producers which has social, economic and environmental implications.
- Increase in the stochasticity in population dynamics due to extreme weather events can increase uncertainty for wildlife managers.
- Adapting to extreme weather events may be more difficult than adapting to changes in average temperature and rainfall.
- Increased chance of wildfires can pose risks to rewilding efforts (or is this part of rewilding?).

Knowledge gaps

- Accumulative effects of multiple events over several years.

- There is emerging evidence on the impacts of heat stress on crop production but a lack of understanding about behavioural responses of wildlife to heat stress (some evidence in birds that heat stress alters their behaviour and makes individuals more vulnerable to predation).
- Indirect effects mediated through other species e.g. impacts of heat stress on food webs and subsequent cascade effects throughout the food web.
- Loss of habitat or habitat change resulting from storm surges in coastal areas.
- Interactions between land uses and industry e.g. water abstraction and drought as well as sea defences built for flooding.
- Interactions between land management and extreme weather events - poor quality, fragmented habitats have higher vulnerability.

Opportunities/Potential actions

- In the UK having a heavily human impacted environment means that changes are generally more acceptable in contrast with the conservation culture amongst park managers in US national parks.
- John Lawton's principles (more, bigger, better, more connected) will be useful in adding resilience to extreme weather events but current measures are inadequate.
- Genetic rescue in wildlife populations – introducing genotypes from areas with more weather variability (as already occurring in agriculture).
- Current adaptation measures are limited but there are novel approaches such as encouraging micro-evolution, translocating populations and focusing on improving genetic diversity.
- Fire not necessarily bad for biodiversity – can favour rare pioneer species.

NE11 Risks to aquifers, agricultural land and freshwaters habitats from salt water intrusion

Headline messages

- Realignment schemes and coastal effort lagging significantly behind the extent of action required.
- New models for understanding change and making change happen are needed, developing action with communications to bring different interests together to develop realistic future options and outcomes of mutual benefit.
- There are significant opportunities for biodiversity through increased area of coastal saltmarsh; alongside the loss of freshwater and other habitat for which replacement habitat may need to be created.

Urgency score

The group felt that the CCRA2 urgency score to 'sustain current action' is not sufficient to the required action to address the impacts and issues.

General / scene setting comments

- The Wetland Vision under-achieved because it underestimated both the time required to make deals and the funding needed for compensatory agreements.
- The '770 ha of reeds and coastal grazing marsh' in the CCRA2 headlines requires clarification – identify the areas in each of freshwater and coastal habitats (i.e. not combined!).
- The Adaptation Sub-Committee Managing Land report identified a five-fold increase in the rate of managed realignment is needed.
- Current coastal effort is not adequate; realignment schemes are lagging massively behind what is needed: requires much more effort and resource.
- The mechanism for addressing and balancing intrusion in England is OK – e.g. compensatory habitat - provides good biological opportunities.
- The land area is shrinking: need to develop thinking and have a bolder view about land-use, choices etc. for the longer term. Need a land use plan for England / UK – what do we need to achieve from land, where are the pressures and opportunities?
- We will need further investment from private / personal sectors – what channels are possible? Who is looking into developing this – who's role is it?
- Transparency of costs and benefits e.g. where IDB decisions influence saline intrusion – are all the costs considered in decision making?
- Habitat creation: to get it right takes time and money; could seek to provide new benefits (use the opportunity route).
- Meeting compensatory requirements for saline intrusion can also contribute to other adaption outcomes - i.e. deliver Lawton principles.

Adaptation responses

- Integrate natural environment needs with people / community needs.
- Develop more 'grown-up' attitudes to change and responses that accommodate change – this would be a useful generic action across the whole NAP.
- Encourage and accept natural processes, develop freshwater replacement elsewhere in the wider countryside; develop attitudes to more dynamic systems, particularly in intertidal areas and habitats.
- New models for change are needed – change can be accepted if (often, personal) objectives can still be met. So farmers can manage land for environmental gain and should be paid accordingly, with public money for public goods.
- Develop communications programme to bring different interests / outcomes together, towards developing greater understanding about realistic future options.
- Re-invigorate Shoreline Management Plans recognising also the need to compensate for lost freshwater habitats.
- Consider opportunities to address changes in future epochs through SMPs ahead of time, to balance the cost of delivery and take the opportunities where they arise
- Increase acceptance of the inevitability of change: sea level rise...
- The potential for increasing coastal habitat goes against the current hold the line / maintain freshwater systems ethos: need to start to think about moving thoughts forward, toward accepting alternative outcomes and developing appropriate funding.

- Scope what 2 degrees Celsius / 2040s look like: bring interest together and develop appropriate shoreline management plans.
- WFD: address the 13 failures to meet good ecological status for saline intrusion – more action needed.
- 'Release the coast to be coast' move and / or abandon coastal freshwater infrastructure?
- Scope and deliver the amount of inland freshwater habitat required to offset / replace the loss of freshwater habitat in coastal regions, in timescale appropriate to replace lost habitat. This needs more focus / effort / action.
- Different change prompts different responses. For freshwater nature sites becoming saline – there's no big public interest or cost; whereas compensating for the cost of losing freshwater raises potential public interest and has significant cost. Need to understand the wider repercussion of change / impacts with the personal, community, cultural and financial implications.
- Re-alignment schemes could be more cross-sectoral, involving relevant economic developments e.g. marinas, tourist attractions etc.
- Introduce salt barrier systems - refer to the River Po system in Italy
- Compensatory freshwater wetlands could also perform a water storage function to provide other services, e.g. summer water shortages, flood retention, etc. – develop cross sectoral adaptation opportunities for new habitat.
- Develop new mechanisms to increase, and find new, partnership funding to address saltwater intrusion, sea level rise related infrastructure loss etc., and to develop private investment in habitat change, supported by public finance to support new risks.
- Increase efforts to address / adapt to extreme weather events.
- The deficit in post-2020 action planning needs to be addressed in the next NAP period.

Research

- Scope what 2 degrees Celsius / 2040s looks like re saline intrusion, coastal change, etc.
- Model how much salt intrusion will be happening (scale, frequency and reach) in the medium to long term, to inform compensation need. We have the skills to do good coastal modelling.
- Develop land use map at regional / national / UK scales to identify areas a) of coastal change and b) for compensatory habitat c) for particular multi-functional benefits of a) and b).

NE12 Risks to habitats and heritage in the coastal zone from sea-level rise and loss of natural flood protection

Headline messages

- Complex situation of increased impacts affecting a range of coastal issues, both natural environment and societal, needs a more holistic and strategic approach to shoreline management planning.

- Research needed to better understand coastal processes, assess risk of designated areas and habitats.
- Communications programme needed to develop awareness of issues and potential responses and techniques, the requirements for statutory obligations, and to find optimal balance of interests in developing adaptation both locally and strategically.

Current / future impacts and risks

- Risks will be site and region specific.
- Loss of species in coastal communities.
- Effects of fluvial flows, waves, storms and surge exacerbating sea level rise.
- Net loss of intertidal rocky shore and sea cliff habitat – cannot roll back.
- Large storm surges and tsunamis – severe flood events.
- Erosion of fossil cliffs (heritage) and loss of local interest.
- Health and safety risks and impact on tourism due to erosion.
- Change in characteristics of coastal lagoons.
- Tourism affected by eroding beaches.
- Saltmarsh, mud and sand flats. Can they keep up with sea level rise? Loss of habitat for breeding birds, fish etc.
- Rainfall events inland can bring pollutants and microbes into the coastal zone in large numbers.
- Risk to terrestrial/fresh water habitats from saline incursion/storm erosion etc.
- Drowning of seagrasses and loss of their flood protection properties.
- Loss of agricultural land with reduced potential for rollback.
- Conflicts between renewable energy/tidal lagoon/barrage developments and nature conservation at coast.
- Risks to migratory fish (conservation interest and economic interests).
- Tidal block.
- Economic and social impacts in coastal areas.
- Risks associated with implementation of Shoreline Management Plans (SMPs). Trade-off between coastal flood defence/community preservation with habitat/nature conservation. Requirement to compensate for habitats lost to 'hold the line' policies. Complex social/economic and political issue.
- Need more holistic/strategic approach to SMPs.
- Gradual change vs extreme events.
- Risks to birds and supporting habitats (SPAs and outside SPAs).
- Remobilisation of contaminants in sediments due to increased wave action/storms.
- Loss of emergent sea caves and platforms used by seals.
- Salination of freshwater aquifers.

Adaptation

- Whole coast approach vs site-based (short-term).
    - Natural resource management plan as a template for landscape scale management and focus areas (short-term).

- Analyse and change existing infrastructure that may block rollback or increase risk (R&D, short- and long-term).
    - Coastal infrastructure e.g. railways/roads along coast that form hard defence but are key access routes. Need long-term strategic plan/adaptation strategy.
- In combination impact of climate change in coastal development (short-term).
- Compensation for compensation! How much rollback? – natural capital + relative value for biodiversity and flood defence.
- Cuckmere example: - natural meanders and functionality of river/river mouth restored. Also allows growth of salt marsh etc. and natural protection.
- Case study for application (i.e. Rivers Trust) (short- and long-term).
- Ensuring quality and resilience of natural flood defences (e.g. sea grasses and salt marshes) (short-term; some climate change mitigation benefits).
- Sediment replenishment and beach recharging (short- and long-term).
- Remobilisation of sand dunes (natural sediment recharge (short-term)).

Research for adaptation

- Identify / prioritise risk areas in designated site network.
- Sand dune research and development needs to look at coastal sediment transport systems. Mapping and modelling of sediment transport processes to plan efficiency for accretion.
- Artificial lagoons in shallow water could be a wave break.
- Ranking habitats on vulnerability and relative value to allow for rollback and defence.
- Relocating/transplanting sea grasses.

Communication

- Effective and proactive communication strategies for land-owners and communities adjacent to the coast (short-term).
    - Engagement and communication plan to be time appropriate (i.e. on a scale that can be understood (short- and long-term)).
    - Include at risk areas in designated site network to allow for rollback (short- and long-term).
    - Land purchase/offsets/legacy to ensure natural rollback (short-term).

NE13 Risks to, and opportunities for, marine species, fisheries and marine heritage from ocean acidification and higher water temperatures

Headline messages

- Marine life is already facing a complex mix of climate-induced impacts - probably with greater impacts than for terrestrial ecosystems.
- Adaptation is fundamentally more difficult in the marine environment than on land and requires increased partnership among the many marine stakeholders, with clear leadership from Government.

- There are significant knowledge gaps, to understand impacts and to develop adaptation responses, which need increased research effort to address climate change in marine environments.

Species and Ecosystems

- Shifting distribution of species (northward movement of cold water species north and out of UK waters, warm water species into UK). Especially relevant for zooplankton. Shift in "winners and losers" in species competition.
- Hypoxia – fish population effects. Ocean deoxygenation forcing deep water species closer to the surface, with increased vulnerability to fisheries.
- Changes in global ocean currents.
- Ecosystem services impacted – e.g. carbon/nutrient cycling, cloud formation.
- Trophic mismatch.
- Invasive species.
- Increased frequency of storm events – impacts on shallow water communities/mammals/birds.
- Changes in food webs.
- Diseases and pathogens – increase in frequency, changes in frequency.
- Regime shifts and tipping points.
- Changes in migration timing and spawning timing.
- Storms and waves changing sediment processes.

Fisheries

- Increase in harmful algal blooms – affect shellfish stocks.
- Conflict over fish stocks as ranges change (national and international).
- More, bigger storms – small boat fishermen may be more restricted to the coast.
- Fish farming – new species, new techniques. Also risk from increased diseases and pathogens leading to potential inedibility.
- Increased storm damage to fishing nets.
- Opportunities for new stocks with shifting distributions e.g. squid, sea bass.
- Jellyfish blooms taking out aquaculture stocks.

Marine heritage

- Loss of ecotourism and recreational fishing.
- Increased ecotourism, for example more turtles off the English coast.
- Damage to wrecks, archaeological sites e.g. from more storms.

Indirect impacts

- Deep see mining – may harm deep sea organisms and vent communities.
- Increased nutrient run off from increased rainfall on land, leading to eutrophication
- Failure of Paris agreement (USA) – increased fossil fuel use.
- Increased marine renewables and geoengineering in response to climate change – possible effects on marine species and ecosystems.

- Lack of political will to further develop Marine Protected Area network or to adapt it to climate change.

Adaptation and mitigation actions, and research needs

- General point – adaptation fundamentally more difficult in marine environment.

Adaptation actions

- (Short term) Preparation for new species moving into UK waters.
    - Better definition of native/non-native species under climate change – if a protected non-native species enters UK waters, should it be protected?
    - Pre-emptive management of protected species entering UK waters e.g. tuna.
    - Better stakeholder communication of the species expected and potential restrictions, conflicts.
- (Short term) Blue carbon – key habitats for carbon sequestration identified and refugia for these identified as part of MPA networks. Also has a mitigation benefit. SNH work on blue carbon storage. E.g. kelp. Ecosystem based mitigation can offer win-wins.
- (Short and long term) Adaptation of fisheries – location, gear, safety.
- (Short and long term) Development of undersea/marine carbon sequestration and storage technology.
- (Short term) Government leadership required – increased renewables, less oil and gas.
- (Short and long term) International co-operation required on site-based approaches e.g. Dogger Bank.
- (Short and long term) Better marine spatial planning techniques to reconcile energy, planning and nature conservation objectives (i.e. trade-offs and win-win scenarios). E.g. wind farms and buffer zones. Need to develop the information needed to inform this decision making process and optimise decisions. Statutory bodies should be able to advise with climate change in mind.
- (Short and long term) Broader protection for species outside of MPAs.
- (Short term) Include climate change impacts in standard environmental impact assessments.
- (Long term) Designation, management process of MPAs needs to be more flexible to potentially shift MPA boundaries in the future. Currently particularly difficult especially with SACs – need to de-designate, consult, re-designate. Could change which species are designated with an MCZ. Brexit could be an opportunity to add flexibility, but also risks with this approach being open to abuse, especially where information to support decisions is poor.
- (Short term) Use technological developments e.g. remote sensing to survey more intensively to monitor and manage MPAs and adaptation responses.
- (Short term) Need better collaboration between industry, government, NGO and academia to share data and resources.
- (Short term) Consider moving from feature to site-based adaptive management.
- Potential benefits of shift to renewables e.g. decommissioning of oil rigs providing conservation refugia.

Research needs

- (Long term) Better understanding the ecological impact of geoengineering interventions e.g. adding iron to the sea to increase biomass, olivine experiments. Potential for adverse impacts through maladaptation/malmitigation e.g. untested geoengineering.
- (Short term) Monitoring of non-native species to ascertain if spreading through MPAs.
- (Short term) Need evidence to explain/refute/support whether MPAs help deliver adaptation and resilience – information out there but needs bringing together.
- (Short term) Identify biological refugia for climate change and consider overlap with MPAs (may not be MPA or heritage site).
- Understanding of microclimates in marine environment.
- (Short term) Improved understanding of cumulative and combination impacts on marine species.
- (Short term) Develop understanding on network connectivity regarding protected species dispersal ability and overall oceanography. Assess the MPA networks' principles – do they work? Networks required to support species where they are, are different to supporting species to move. Also need to understand connectivity risks for invasives.
- (Short term) Better models required to understand/predict species distributions and relationship to MPAs.
- (Short term) Climate change vulnerability assessment required for the marine environment.
- (Short term) More stock assessments required. Many regions lacking good fish stock projections e.g. outside of North Sea. Need to account for uncertainty of projections and build in flexibility.

Wrap-up: How to we make adaptation more cross-cutting?

Headline messages

- Adaptation measures, especially nature-based ones, can be empowering, enhancing and embracing of change, taking positive steps into the future.
- Coherent, wide-reaching land-use strategies can help drive both direction and specific projects.
- Communication effort is needed to spread awareness of possibilities, increase understanding of climate impacts and responses, and build acceptance to nature-based adaptation for people's particular interests in their communities, infrastructure and economic activities in the natural environment.
- Significant opportunities through integrating with wide range of public funding streams, several of which will be developed in the coming months to replace EU funding sources (e.g. CAP).

Connect and communicate

- Improve communication and education of the benefits people receive from being and enjoying the natural environment.

    - Potential to engage with health sector – recognising co-benefits of getting people into nature, improving access, wellbeing benefits.
    - Wider ecosystem services, continuing delivery, build ecosystem service delivery into adaptation.
- Make adaptation measures resonate with what people care about.
- Help achieve climate change adaptation objectives by encouraging others to be enthused by the adaptation measures.
- Need to start talking about why some current farming practices or crops won't be as suitable under different future climate. Thereby, encourage the adaptation in practices now for the future. Communicate the changes through stories.
- Becoming 'future smart' - when you need to make a change, make it a big change for the future.
    - Encourage the message that the next time someone changes their garden or farming practices – they should do so to help mitigate / adapt to a changing climate.
- Empower don't intimidate – build support for positive outcomes.
- Show people how they can help – practical action for people to take.

Policies to integrate with

- Highlight the links between adaptation and ecosystem service delivery – continuation of ecosystem services in climate change.
- Adaptation and soil improvement measures are often complementary, cross-cutting, underpinning.
- Employ the Lawton principles and build on landscape connectivity – fundamental to adaptation for nature.
- Agriculture, forestry, and water management are key policy areas; post-Brexit CAP framework (and for other post-EU areas e.g. rural development plans and funding, post-LIFE funding; HLF landscape and other projects).
- Development of Defra's 25 Year Plans (and other Departments' similar plans?).
- A land management / land use strategy would help facilitate a joined up approach and optimise multi-functional land-uses. A proper land-use strategy should help reduce the conflict between competing land-uses in order to meet various goals and objectives.
- Urban design: many opportunities including shaded recreation for people, SUDS and other water management, landscaping and fringe land around transport networks, etc.
- Link into health science and policies.
- Need to think about adaptation actions in the context of the future – so all future policies.