# UK National Ecosystem Assessment Follow-on

## Work Package Report 7:

### Operationalising scenarios in the UK National Ecosystem Assessment Follow-on

**Principal Investigator:** Roy Haines-Young[1]*

**Authors:** Roy Haines-Young[1]*, Jamie Tratalos[1]

**Contributing Authors:**
Stephen J. Birkinshaw[2], Simon Butler[3], Simon N. Gosling[4], Stephen Hull[5], Gary Kass[6], Elizabeth Lewis[2], Richard Lum[7], Ken Norris[8], Marion Potschin[1], Suzannah Walmsley[5]

**Report Review Editor**: Duncan Russel[9]

**Affiliations**:
[1] Centre for Environmental Management, University of Nottingham
[2]School of Civil Engineering and Geosciences, Newcastle University
[3]School of Biological Sciences, University of East Anglia
[4]School of Geography, University of Nottingham
[5]ABPmer
[6]Natural England
[7]Vision Forsight Strategy LLC
[8]Centre for Agri-Environment Research, University of Reading
[9]University of Exeter

*Correspondence to: Roy Haines-Young, Roy.Haines-Young@nottingham.ac.uk

**Suggested citation:** Haines-Young, R., Tratalos, J., Birkinshaw, S., Butler, S., Gosling, S., Hull, S., Kass, G., Lewis, E., Lum, R., Norris, K., Potschin, M., & Walmsley, S. (2014) UK National Ecosystem Assessment Follow-on. Work Package Report 7: Operationalising scenarios in the UK National Ecosystem Assessment Follow-on, UNEP-WCMC, LWEC, UK.

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## Abbreviations and Acronyms

| | |
|---|---|
| **BBN** | Bayesian Belief Network |
| **BBS** | British Bird Survey |
| ***CAMERAS*** | Coordinated Agenda for Marine, Environment and Rural Affairs Science |
| **Cefas** | Centre for Environment, Fisheries & Aquaculture Science |
| **CEH** | Centre for Ecology & Hydrology |
| **CES** | Cultural Ecosystem Services |
| **Defra** | Department of Environment Food and Rural Affairs |
| **DPSIR** | Drivers-Pressures-State-Impact-Response tool |
| **EFF** | Ethnographic Futures Framework |
| **FAO** | Food and Agriculture Organisation |
| **FBI** | Farmland Bird Index |
| **FSMs** | Functional Space Models |
| **GF** | *Go with the Flow* |
| **GIS** | Geographic Information Systems |
| **GPL** | *Green and Pleasant Land* |
| **GVA** | Gross Value Added |
| **HUGIN** | Expert software |
| **IHDTM** | Integrated Hydrological Digital Terrain Model |
| **IUCN** | International Union for Conservation of Nature |
| **JNCC** | Joint Nature Conservation Committee |
| **LS** | *Local Stewardship* |
| **LUES** | Land Use and Ecosystem Services |
| **MCCIP** | Marine Climate Change Impacts Partnership |
| **MCZs** | Marine Conservation Zones |
| **MENE** | Monitor of Engagement with the Natural Environment survey |
| **MPAs** | Marine Protected Areas |
| **MSFD** | Marine Strategy Framework Directive |
| **NRFA** | National River Flow Archive Index |
| **NS** | *National Security* |
| **NSE** | Nash Sutcliffe Efficiency |
| **NW** | *Nature@Work* |
| **ONS** | Office for National Statistics |
| **PET** | Potential Evapotranspiration |
| **RDPE** | Rural Development Programme for England |
| **SAMS** | Scottish Association for Marine Science |
| **SEPA** | Scottish Environment Protection Agency |
| **SHETRAN** | Spatially distributed hydrological model |
| **UK NEA** | UK National Ecosystem Assessment |
| **UK NEAFO** | UK National Ecosystem Assessment Follow-on |
| **UKCP09** | UK Climate Projections 2009 |
| **UKCS** | UK Continental Shelf |
| **VERGE** | Ethnographic Futures Framework |
| **WFBS** | Winter Farmland Bird Survey |
| **WM** | *World Markets* |

## Key Findings

**In work which sought to operationalise the UK NEA scenarios, the UK NEAFO shows that there is a complementarity between the roles of scenarios as 'processes' and as 'products'.** The 'process' approach uses scenarios as deliberative tools that enable experts and non-experts to discuss issues and learn from each other. In contrast, the 'product' approach aims to produce a series of outputs describing and, if possible, quantifying the implications of a series of plausible futures.

**Stakeholder engagement exercises show that the UK NEA scenarios are both plausible and relevant.** They also have significant potential as tools for developing dialogues between stakeholders holding differing interests and perspectives. This is a two-way process: the contributions of stakeholders enrich the scenarios and allow experts to see new perspectives and insights within them.

**The UK NEAFO shows that the original UK NEA scenarios have developed a life of their own.** They are already being used by Forest Research, the Defra Noise Futures Project and the Scottish Government. Although they 'work' when people are exposed to them, more needs to be done to bring them to the attention of the broader stakeholder community if their full potential is to be realised.

**UK NEAFO hydrological modelling work presents evidence of differences between scenarios in our capacity to reduce flooding or drought.** Our study looked at 34 UK catchments. The results suggest that whether a scenario is 'preferable' or not varies by location; the majority of catchments are little affected by changes in land cover under the scenarios, but flooding or drought does get worse in some areas. The results indicate that, when managing land cover change, a balance needs to be struck between alleviating the likelihood of increased drought and the likelihood of increased flooding, depending on the possible effects of these phenomena in the catchment.

**The UK NEAFO presents evidence of both trade-offs and co-benefits between the abundance of farmland birds and other ecosystem services, based on an examination of expected differences between each of the scenarios**. These derive from *functional space models* of the relationship between land use and the annual rate of population growth rate of 19 farmland bird species included in the Farmland Bird Index, as well as mechanistic models of the relationship between land use, food availability and abundance for two of these species, which represent distinct types of seedeaters - the linnet and yellowhammer. By focusing on food availability and the abundance of farmland birds, rather than species number, the study shows that biodiversity outcomes are more adversely affected by the scenarios with the highest monetised value than previously thought. Therefore, our results challenge some of the findings of the impact of land cover change on conservation values put forward in the original UK NEA. This suggests that there is a greater need to consider the specific impacts of land-use change on biodiversity, alongside other ecosystem services.

**Work on marine ecosystem services shows that, of four scenarios considered, only the free market-driven *World Markets* scenario appears to result in a marked decline in fish stocks by 2060.** This is offset to some degree by the higher levels of investment in aquaculture we would expect under this scenario. However, this study also highlights the gaps in data and knowledge about drivers which is needed to examine the effects of possible future change on marine environments; so these conclusions are tentative.

**In its analysis of cultural ecosystem services, the UK NEAFO finds that people tend to prefer environmental settings with higher woodland cover than the average for the surroundings when they travel intermediate distances from their home; but this tendency declines when people travel longer distances.** The UK NEAFO work is based on the Monitor of Engagement with the Environment

(MENE) survey for England. An analysis of the spatial changes in woodland cover under the different scenarios suggests that woodland expansion targeted to enhance conservation value also benefits the delivery of cultural ecosystem services in the areas close to where people currently live. We found that tools based on Bayesian Belief Networks maybe an effective way of operationalising the conceptual framework for cultural ecosystem services developed by the Work Package 4, and of rapidly visualising key relationships in the MENE data.

**The development of targeted analytical studies within the qualitative framework of the UK NEA scenarios is required in order to understand, manage and communicate the consequences of changes in ecosystem services across different scales and in different contexts.** Such studies can enrich our understanding of today's issues and how we might respond to future change.

# Summary


***Study aims and approach***

An aim of the UK NEA Follow-on (UK NEAFO) is to develop and communicate the evidence base of the UK NEA and make it relevant to decision and policy making. It also provides an important opportunity for those working on scenario methods and concepts to scrutinise the role of futures thinking in the management of ecosystem services and so develop their effectiveness as decision support tools. In this study we have therefore asked: *how can the UK NEA scenarios help us to understand, manage and communicate the consequences of changes in ecosystem services across all scales?*

There are many different understandings about what scenarios are, and what they should be used for. To clarify the issues surrounding the role of scenarios, we have approached this work from two angles. We have firstly looked at the way the storylines can support decision making ***processes***. Secondly, we have looked at the content of the scenarios themselves and explored how through the use of models the UK NEA scenarios as ***products*** might be refined to enhance their value as analytical tools.

***Scenarios in Action***

We used the opportunity of a series of meetings with stakeholders to develop the UK NEA scenarios from a **process** perspective. These meetings took various forms, but throughout the main aim was to find out whether people found the scenarios sufficiently believable, challenging and relevant. In workshops organised by the scenario team in Leeds, Edinburgh and Belfast, we worked with participants on a series of tasks designed to help them immerse themselves in the scenarios and reflect on them critically. While those we worked with had many comments about the scenarios in detail, the evidence we collected from these meetings suggests that the majority of people found the scenarios to be plausible and the projections consistent. The majority also agreed with the proposition that the suite of scenarios as a whole addressed a relevant ranges of issues.

We explored with the workshop participants several ways in which the storylines could be enriched, by: developing the narrative about the way people might live in the different scenario worlds; developing time-lines for the scenarios; thinking more deeply about regional and local differences; and, exploring how the scenarios would frustrate or facilitate the embedding of the ecosystem approach in decision making. We found that while all of these elements had value in terms of stimulating discussion and understanding of the scenarios, they were not needed in order to address deficiencies in the original storylines in terms of plausibility or credibility.

The evidence we collected therefore suggests that the existing narratives are probably sufficient as an entry point for discussions about the future of ecosystem services in the UK. What was apparent from the observations that we made in the workshops was that it would probably be a mistake to 'over-engineer' or 'over-specify' the narratives because there needs to be room for discussion and probing. We were struck how people took the existing scenarios and found new features and ideas in them than had not been identified by in the original work. For example, in one session *National Security*, with its emphasis on resource efficiency, was found to be 'greener' than it initially looks. In another *Local Stewardship* was discovered to need some degree of central control and regulation to work efficiently. These kinds of discussion are evidence of the reflection, deliberation and social learning that can be promoted by using the UK NEA scenarios.

In the workshop we organised in Belfast we found that the presentation of the scenarios could be tailored to a specific region (i.e. Northern Ireland) and, through area-specific breakout groups during the workshop, to specific localities within it. However, our experiences here emphasised the need for considerable preparation, consultation with the stakeholder community, and changing of the workshop format to make the scenarios intelligible and engaging to local stakeholders.

Work on the use of the scenarios in a more explicit decision support role will be reported via the work on response options (WP8), which considered how they could be used to 'stress-test' policy response options. The experience gained from the work undertaken in the early stages of UK NEAFO was that the scenarios appeared to provide a suitable platform for the work, but that the stress-testing methodology needed to be refined. During the follow-on we have also interviewed policy leads in Defra, for example, to gain a better picture of policy needs, and the way scenarios might usefully serve them. Apart from the challenge of 'relevance' it is clear that the time needed for people to work with scenarios probably means that they are less useful to policy customers in the context of their everyday work but can be useful at a very broad and strategic level. However, there is clearly an opportunity for scenarios to be used more extensively through commissioned work. The importance of commissioned work has been emphasised during the follow-on phase by invitations to observe the work of the CAMERAS[1] work in Scotland, and the Noise Study being undertaken for Defra. Both are actively using the UK NEA scenarios. The outcomes of these on-going studies will be reported elsewhere by others. Nevertheless, even though these projects are at a preliminary stage they help us better understand how scenarios can be used to communicate the consequences of changes in ecosystem services to different groups and individuals.

**Scenarios as products: d*eveloping the model base***

The UK NEA scenarios were initially used to make both qualitative and quantitative projections. The quantitative work mainly involved modelling how land cover would change under the different scenarios (Haines-Young *et al*. 2011). Although these data were used to make an analysis of the changes in marginal economic values for some ecosystem services during the initial phase of the UK NEA, they have not been fully exploited. At the time it was recognised that there were many gaps in our understanding of the links between land cover and ecosystem services; UK NEAFO has provided the opportunity to address some of these deficiencies.

Thus in the follow-on work we have sought to extend the range of models that can be used to explore the UK NEA scenarios. The modelling work has not sought to change the scenarios fundamentally, but to enrich the insights that can be derived from exploring the differences between them in a systematic, and quantitative way. The goal, has been to extend the analysis that can be built up around the narratives and hence enrich the scenarios as 'products'. Four topic areas were selected as the focus for this work: flood and drought risk (based on an analysis of changes in river flows), biodiversity (farmland birds), marine and cultural ecosystem services.

*Catchment modelling*
We looked at the effects of land-use change on river flows under each of the UK NEA scenarios. We modelled hydrological discharge within 34 UK catchments and calculated four hydrological indicators for each catchment: average annual discharge, flood hazard, and Q5 and Q95 (measures of the magnitude of unusually high (Q5) and unusually low (Q95) flows). For our flood hazard indicator we calculated the interval between floods of a size currently occurring every 30 years. Although we kept climate constant in the models, as we wanted to isolate the effects of land cover change, we ran them for both the high and low climate change land cover variants for each scenario.

[1] A Coordinated Agenda for Marine, Environment and Rural Affairs Science, 2011-2016. http://www.scotland.gov.uk/Topics/Research/About/EBAR/CAMERASsite

In general, the 'green' scenarios, *Nature@Work* and *Green and Pleasant Land*, as well as *National Security*, were associated with lower flows than currently occur (when measured using any of the four indicators). However, for a given scenario there was a great deal of variability between catchments in terms of the size and statistical significance of the differences. The magnitude of change across all scenarios and catchments ranged from -13% to 6% for average annual discharge, -14 to 7% for Q5, -24 to 27 % for Q95 and -16 to 36 years for flood hazard. Differences were particularly evident between *Nature@Work* and *World Markets*, with the latter associated with higher flows than occur currently, and the majority of the statistically significant increased flows. Some catchments showed significant changes that were different in sign between these two scenarios.

Taken together, our results indicate that that in managing change a balance needs to be struck between alleviating the likelihoods of increased drought and increased flooding, depending on the likely effects of these phenomena in the catchment.

*Farmland birds*

We looked at the relationship between land use data produced during the first phase of the UK NEA and models of farmland bird populations, in 1kmx1km squares covered by the Breeding Bird Survey (BBS) and Winter Farmland Bird Survey (WFBS).

We used Functional Space Models to estimate the annual population growth rate under each scenario of each of the 19 farmland bird species used to calculate the farmland bird index (Gregory *et al*. 2004). We used this to look at the relationship between land use under the scenarios and: i) the average population growth rate for all 19 species, and ii) a subset of 11 species showing declining population trends under current land use. Overall we found that land use change across the scenarios had relatively little impact. However, the only statistically significant change was for declining species under *Green and Pleasant Land*, where population growth rates became significantly more negative.

We used Mechanistic Models to estimate the number of over-winter 'bird-days' for two types of seed-eating farmland birds, a yellowhammer-type and linnet-type These species were chosen because they differ in their food preferences with respect to cereal, oil and weed seeds, but between them are representative of the diversity of seed-eating farmland birds as a whole. We found a significant decline in the ecological value of lowland agricultural areas for these species across all UK NEA scenarios, but the greatest impact was for scenarios with the highest monetised values for ecosystem services, as measured by the first phase of the UK NEA (*Nature@Work*, *Green and Pleasant Land*). This appears to be due to the fact that, compared with the baseline, the area of arable crops declines most sharply under these scenarios, due partly to changes in land use but also because of conversion of arable land to other habitats important for ecosystem services (e.g. woodland).

Taken together these results imply a trade-off between overall value for ecosystem services and conservation of farmland birds, and highlight the need to consider the specific impacts of land use change on biodiversity, alongside other ecosystem services.

*Marine ecosystem services*

Only a limited attempt was made to model marine ecosystem services during the first phase of the UK NEA. In the follow-on we have conducted preliminary work to produce spatially explicit models for three important marine ecosystem services: fisheries landings, aquaculture production and carbon sequestration. We made comparisons between baseline data and time slices for 2015, 2030 and 2060 under four of the UK NEA scenarios that were considered most relevant for the sector, and mapped these across UK territorial waters.

There is a high degree of uncertainty associated with the models, mainly due to a lack of suitable data and poor knowledge of the drivers of change. In many cases, in the absence of robust quantitative models, we needed to take the qualitative descriptions of the UK NEA scenarios and combine these with expert knowledge to estimate changes in the three types of ecosystem service. We estimated that in three of the four scenarios: *Nature@Work*, *Local Stewardship* and *National Security*, fisheries landings would be, by 2060 only slightly lower or at higher levels than they are today. Under *World Markets*, however, projected landings would decline significantly by 2060, due to a lack of regulation combined with high levels of investment from private capital. In the light of this, it was interesting that aquaculture was at higher levels under *World Markets* than under any of the other scenarios, although all of them showed higher levels than the baseline. This was because under this scenario more investment capital would be available to invest in fish farms.
We believe that carbon sequestration would be most likely to be impacted by the *World Markets* and *Natural Security*, due to higher $CO_2$ emissions causing an increase in ocean acidification.
Our results, although tentative, mark a significant first step in attempts to map and project the impact of possible future change on marine ecosystem services.

*Cultural Ecosystem Services*
In the first phase of the UK NEA, the relationship between the drivers of change and cultural ecosystem services (CES) was mainly explored through the impact they had on land cover. For UK NEAFO, we additionally used the Monitor of Engagement for the Natural Environment (MENE) dataset. We examined how the UK NEA scenarios can be used as a framework to explore the relationship between the supply of cultural spaces in the landscape and peoples preferences for different types of natural spaces and practices in them. We have developed a Bayesian Belief Network (BBN) that allows users to explore these relationships interactively and look at the potential impacts of changes socio-demographic structure of the kind described by the UK NEA scenarios.

Our spatial analysis of the MENE data showed that people tend to select locations with higher woodland cover than the average for the surroundings, when they travel intermediate distances from their home, but that this tendency declines when they travel longer distances. Woodland cover is projected to double under both *Nature@Work* and *Green and Pleasant Land*, and both provide more opportunities to visit woodland close to home than under scenarios such as *World Markets*. However, our analysis shows that on the basis of the current geography of people and woodlands, the way planting is targeting under *Green and Pleasant Land* has the potential to deliver greater joint benefits from biodiversity change and cultural ecosystem services than *Nature@Work.*
The BBN we have developed using the HUGIN Expert software allows the relationships within the MENE data to be explored interactively; it is hosted on a prototype website that is open to the wider community. By examining the relationships between socio-demographic characteristics of the MENE respondents, the types of natural spaces they visit and the activities they do in them, this BBN tool allows users to explore the impacts of possible future change on the supply and demand of CES.

***Conclusion***

*How can plausible future scenarios help understand, manage and communicate the consequences of changes in ecosystem services across all scales?* In this work we have shown that they can be used to promote understanding by the deliberative processes that they engender. The UK NEA scenarios appear to be sufficiently rich and comprehensive to support debate across a wide range of topic areas relevant to current policy concerns. The scenarios can also help understanding by providing a framework in which current models can be applied and the outcome used both to test the plausibility of the scenarios themselves and to deepen the insights that can be derived from them. These analytical 'scenario products' can be equally important both in terms of deepening our understanding of the assumptions on which the scenarios are built and in stimulating debate about their implications.

We have shown that the distinction between the 'process' and 'product' dimensions of scenario thinking is a useful one, given the many ways scenarios can be used. The distinction clarifies some of the different purposes and problems that scenarios work seeks to address. However, our work also demonstrates that both components have their strengths, and neither can be taken isolation. If we are to use scenarios to understand, manage and communicate the consequences of changes in ecosystem services across different scales and in different contexts, then targeted analytical studies developed within the qualitative framework of the UK NEA scenarios, can enrich our understanding of today's issues and how we might respond to them.

# 7.1 Introduction and Context

## 7.1.1 Building on Experience

Scenario building has many purposes. These range from identifying future goals and the paths that might take us there, to exploring the ways in which the situations we currently face might develop over time. As a result, there are often divergent views about how to construct scenarios and what can be achieved with them (Haines-Young *et al.* 2011). To clarify some of these issues, and to help people use the scenario outputs from the UK NEA, we have revisited the scenario work that was done in the initial assessment. Our goal has been to show how the scenarios can help people understand, manage and communicate the consequences of changes in ecosystem services.
Our goal is consistent with the focus of the UK NEA Follow-on (UK NEAFO), which is to further develop and disseminate the evidence base of the UK NEA and show its relevance for decision-making and policy. However, the work is also relevant more generally because it provides an opportunity for those working on scenario methods to scrutinise the role of futures thinking in the context of ecosystem services, and to judge its effectiveness in decision making. In planning the work described here, the charge made by Wilkinson and Eidinow (2008) that often '…environmental scenarios are produced with enthusiasm but deployed with limited effect', echoed in our thoughts. If earlier stages of the UK NEA can indeed be characterised in terms of enthusiasm – then a key task for the follow-on must be to understand the impacts of such work and how to ensure that the investment made in scenarios was worthwhile.

A range of stakeholders were involved in the initial design and discussion of the UK NEA scenarios. UK NEAFO has provided the opportunity of re-engaging with the user community to look at how the scenarios can be used in a deliberative way to explore the issues that surround ecosystem services, questions about sustainability and the importance of nature to human well-being. The purpose of the first block of work reported here (Section 7.2) has therefore been to look at how people have reacted to the scenarios and what kinds of discussion about the future they might stimulate. The work also provided the opportunity to look at how the UK NEA fitted into and supported the other initiatives with which the stakeholders were involved.

In parallel with the work we have done with people using the scenarios, we have deepened the analysis of issues contained in the scenarios. The intention here was to develop the storylines so that their impacts could be considered for a wider range of ecosystem services and their implications for human well-being better understood. While all of the ecosystem services identified as relevant for the UK were discussed in the original scenario chapter, the analysis was largely qualitative (see Haines-Young *et al.* 2011). The valuation of the scenario outcomes (see Bateman *et al.* 2011) used quantitative models to explore the impacts of the different land cover projections on ecosystem services, but estimates of marginal changes in value were only made for six sets of goods (market agricultural output, non-market greenhouse gas emissions, non-market recreation, and non-market urban green space, bird biodiversity) (see also Bateman *et al.* 2013). Our work during the follow-on has therefore looked at the use of quantitative models for some of these and other services to see how they can help to further explore the implications of the UK NEA scenarios. The topics considered were flood and drought risk (based on an analysis of changes in discharge and evapotranspiration), biodiversity (farmland birds), marine ecosystem services (fisheries landings, aquaculture production and carbon sequestration), and cultural ecosystem services. Although the economic analysis undertaken during the follow-on (WP3 and 4 Reports) has continued to develop the model base for assessing ecosystem services in the UK, the work reported here makes a distinct and separate contribution. By linking more directly to the existing storylines, and using the scenario assumptions to make quantitative projections, the contribution that such models can make to the plausibility, consistency and saliency of scenarios can be considered. The scenarios also provide a useful framework in which the adequacy and performance of existing models can be considered. The development of the models and the lessons that we can take from them for the UK NEA scenarios will be discussed in the final major section of this report (Section 7.4). As part of this we also describe the work that has been undertaken on scenarios for the marine sector. This was an area that we recognised as needing further research in the 2011 study. While we are still some way from modelling the full range of marine ecosystem services, this section identifies what is possible and what the next steps might be in achieving a more complete picture.

The motivation for the work undertaken on the UK NEA scenarios in this follow-on study has therefore to *build on* and *learn from* the earlier achievements. No set of scenarios, including those of the UK NEA, is ever perfect. However, we have not sought to change them fundamentally. Rather we have looked at what is needed to help people discuss them constructively, and have sought to identify strategies that might be useful to enrich and deepen the debate. UK NEAFO provides an important opportunity for resolving some of the difficult methodological questions that surround the use of scenarios at the interface of science and policy. In this context we have worked closely with the team looking at policy response options and their future viability (WP8). Our results are also of more general interest in relation to the work done in UK NEAFO on how and to what extent ecosystem knowledge is embedded in policy decision-making (WP9), and what tools are needed to embed it further (WP10).

### 7.1.2 Scenarios: Product or Process?

Before the different elements of the work undertaken in WP7 are reported in detail, it is important to look at some of the key conceptual issues relating to scenarios, so that both the aims and contribution of this work can be more clearly seen. WP7 is made up of a number of different elements, and it may, at first be difficult to see how they fit together. In this section we therefore consider the cross-cutting methodological questions that have influenced the design of the work programme and which ultimately provide its unity.

Negotiating the dichotomy, recognised by O'Neil and Nakicenovic (2008) and others (e.g. Hulme and Dessai, 2008), between 'scenarios as products' and 'scenarios as processes', was a major concern of the work leading up to the creation of the UK NEA scenarios. The contrast between these two positions was, and continues to be, an important one, because it is at the heart of many of the difficulties confronting those who seek to develop and use scenarios.

The view of scenarios as products is, perhaps, the more conventional one. It regards scenarios as tools to help people understand the implications of different assumptions about the future, and places emphasis on their *content.* While it is recognised that scenarios are projections of assumptions, rather than predictions of what the future will be, the attention to content is usually paramount. Getting the internal logic 'right' is therefore one of the important steps according to this perspective, and such work is often supported by the use of quantitative theoretical and empirical models. The idea of scenarios products is also encouraged by the notion that building them involves a series of prescribed steps that ultimately leads to some well-defined and coherent construct. Although this is something of a caricature of what scenario work involves, it is useful as a contrast to the *process* perspective. While people clearly need some content to discuss, those who hold this contrasting view of scenarios claim that it is the discussion that is ultimately important. They emphasise the need to stimulate both individual and group learning by creating a space for deliberation. By promoting dialogue the use of scenarios can lead to a better group understanding of today's issues and an appreciation of the positionality of different parties to the debate.

The difference between the product and process perspectives is fundamental, and hinges on the claim that scenarios cannot be divorced from the societal contexts that have generated them. The problem with treating scenario as products is that they can become divorced from the processes that generated them' (O'Neill and Nakicenovic, 2008), whereas we need to recognise that they actually embed important and unique sets of social relationships. As Pulver and VanDeveer (2009), observe, for example, their construction both emphasises some aspects and issues and hides others. Thus there is a need to understand the context in which they are developed. This situation leads on to a number of important social science questions, not least how we judge their *effectiveness*.

The question of how to judge the success of a scenario exercise was touched upon in our 2011 work. It continues to be a general topic of active debate in the wider literature. Several authors (e.g. Pulver and VanDeveer, 2009; Tourki *et al.* 2013) have noted the contrast between the large volumes of published material on scenario methods and the paucity of that dealing with their evaluation. In fact, according to Tourki *et al.* (2013) while the numbers of papers on the broad topic are expanding rapidly, the count for papers dealing with more theoretical issues is small and constant. This situation does not reflect the fact that there are no theoretical issues remaining, but rather the complexity of the problem. Wright *et al.* (2013) confirm that there is little literature that makes a 'retrospective examination and evaluation of the effectiveness of scenario interventions within organizations'.

Recent discussions of the ways we might evaluate the success of scenario studies start with the critical review of potential criteria by Hulme and Dessai (2008), namely whether scenarios are good in a predictive sense, whether they actually lead to better decisions, or whether they generate significant social learning. In order to identify the research questions that form the basis of this study, we review each of these criteria in turn to show how they have been treated in the follow-on work.

### 7.1.3 The predictive power of scenarios

The problem with judging scenarios by their predictive power is that they are not usually intended as prophecies of what will happen, but only what *might happen under a particular set of assumptions or conditions.* We generally recognise from the outset that these projected outcomes may never happen, and in some cases we may even seek to intervene and so avoid them. Setting these issues aside, however, even if the predictive criteria were used, it would be problematic because the time horizons generally used for scenarios are too long to simply 'wait and see' if our predictions were right.

To some extent the notion of judging scenarios by their predictive power arises out of the idea that they are essentially products that perform in some way. While this criterion might be relevant in some situations, for UK NEAFO we did not consider it helpful, and rather reconstructed the notion of performance around the idea of the *plausibility*. Scenarios are, we suggest are logical constructs, and in the original work for the UK NEA we sought to use current scientific understandings to argue through the implications of different drivers for land cover and ecosystem services. Thus a key concern when evaluating them is whether across the suite of UK NEA scenarios, the projected outcomes are credible based on what we know about how socio-ecological systems 'work'. The UK NEA has sought to make an assessment on the 'best science available', and this aim applied equally to the scenarios. In the UK NEAFO we have therefore sought to test the plausibility of the scenarios in a critical way, by:

- engaging with stakeholders to find out if the projections and contrasts between the scenarios were credible; and

- working with models to determine whether their quantitative projections matched the more qualitative ones made in the original work, and to identify what implications any differences might have for the modelling tools and/or the scenarios themselves.

We report the outcomes in sections 7.2 and 7.3 respectively.

### 7.1.4 Scenarios and decision support

As Lempert (2013) observes, if the future were easy to predict then there would be no need for scenarios. Along with Parson (2007) he argues that fundamentally scenarios are used where people making decisions and those who support them want to make statements about the future that do not claim to have the same confidence attached to them as would 'predictions', 'projections', and 'forecasts'. Lempert (2013) goes on to argue that the primary purpose of scenarios is to highlight the weakness or 'vulnerabilities' of proposed policies and to determine under what kinds of future a proposed policy might fail to meet its goals. This position has also been argued by a number of commentators in the field (e.g. Berkhout *et al*. 2002; Weaver *et al.* 2013); we might add that they also provide a way of looking at the opportunities that current policies might offer to improve situations.

If we see scenarios, not as products designed to deliver information about the 'future' to decision makers, but rather devices that can help the *practice of decision making* in the face of uncertainty, an alternative measure of their success is whether they actually achieve this aim. However, the literature suggests that there is probably no simple relationship between having more information and making better decisions (Weaver *et al.* 2013). In any case, as Hulme and Dessai (2008) have pointed out, the criterion of scenarios leading to better decision is also a difficult measure to apply. Once again it not really practical to wait and see if decision outcomes were 'successful' (however that could be measured), and even if we did there would be nothing like an 'experimental control' for comparison against some other course of action. For those who seek to apply this criterion, the emphasis of evaluation is therefore on the benefits that scenarios bring to the *process* of decision making rather than its *outcomes*. Do they, for example, help decision-makers project themselves into different situations so that they can explore the implications of their assumptions (cf. Gregory and Duran, 2001)? Do they help people to better 'envision', 'understand', and 'plan' for the future (Pulver and VanDeever, 2009)?

Reviews, such as Lempert (2013) and the EEA (2009), argue that to explore performance in terms of aiding the decision making process, we need to examine such things as the extent to which scenario thinking can help people restructure problems and better anticipate the consequences of their actions. Bryson *et al.* (2010) found that the decision makers they interviewed agreed that that scenarios can support more 'robust decisions', if they were used appropriately, especially in terms of testing the adequacy of different potential decisions. Saliency or relevance is therefore an important characteristic by which we might judge the success of any scenario study. Given that not all scientific information is likely to be policy relevant (Weaver *et al.* 2013), we might take the fact that a set of scenarios can be used as part of the decision making or policy process to be some measure of their success.

Alongside salience, those advocating the contribution to decision making as an evaluation criterion also identify transparency as a key success factor. Contemporary approaches to decision making generally stress the importance of participation, and the ecosystem approach specifically identifies it as a means of ensuring the sustainable or wise use of biodiversity and ecosystem services (Haines-Young & Potschin, 2014). If we accept the argument that scenario construction takes place in specific social contexts (see Pulver and VanDeveer, 2009; and above), openness during their construction and use is therefore essential if they are to have any claim to legitimacy. Parson (2008) argues that experience suggests that in the context of global change scenarios ‘extreme transparency’, in communicating the underlying reasoning and assumptions, is in fact required if stakeholders are to be fully engaged in debates.

The UK NEA sought to make an assessment that was relevant to current policy debates in the UK. In the follow-up work on scenarios we have sought to find out whether this *has* or *is* being achieved. Thus the main tasks have been to:

- work with the policy community to review and test the saliency of the existing scenarios; and,
- identify the ways in which the scenarios might support decision making and to explore how the materials might be developed to increase their relevance and utility.

The work undertaken in relation to these tasks is partly reflective, in the sense of trying to understand what the user community made of the earlier work, and how they are incorporating it into their current activities. The work has also been proactive, in that it has involved engaging with others to explore if and how the UK NEA scenarios could be used by them. Both these elements are reported in Section 7.2. This task has also involved working with others in the UK NEAFO consortium.

A particularly close link has been made with the team looking at response options (WP8). As part of their work, they have been developing and evaluating a ‘wind-tunnelling’ or ‘stress-testing’ methodology that could be used to examine the robustness of different policy responses. The UK NEA scenarios are an important component of this work, because they provide the set of contrasting situations against which the viability of a given policy strategy can be scrutinised. The idea of using scenarios as a kind of test-bed for evaluating policies is well established (see for example van der Merwe, 2008; Evely *et al.* 2013), the goal being to identify risks and opportunities, as well as synergies and conflicts between different policy sectors. Although we report some of this work here, because some of the workshops were held jointly with WP8, a detailed discussion of the UK NEA scenarios and the stress testing approach can be found in the Work Package 8 report.

### 7.1.5 Scenarios and social learning

The final criterion for evaluating the success of any scenario study that was suggested by Hulme and Dessai (2008) is whether they lead to significant social learning. The argument here is that given that it is impossible to predict the future, or show that scenario thinking by itself can lead to better decisions, it is argued that the main role of scenarios is to help people ‘work with the future’ to better understand today (cf. Kahane, 2002). To some extent this overlaps with much of the discussion on the relationship between scenarios and decision making, except that the notion of learning brings a rather more informal and exploratory aspect into the open. While refinement of scenarios as decision support tools emphasises their role in facilitating a deliberative process, the notion of learning goes further and stresses their role in stimulating behavioural change. Berkhout *et al.* (2013) have described scenarios as ‘learning machines’, while Pulver and VanDeever (2009) have suggested that in the arena of global environmental politics, they can even be devices that can be used to frame and mobilize social action. Whether ecosystem service scenarios can ever be used in this way is uncertain. However, what is clear is that the learning dimension may be important in the context of the kinds of adaptive management that is seen as a key part of the Ecosystem Approach (Haines-Young and Potschin, 2014; see also Tourki *et al.* 2013).

Despite the overlap of questions about scenarios and social learning and their wider role in decision making, it has been useful in this initial phase of our work to try to distinguish between them. While ‘decision making’ probably requires us to make any set of scenarios as robust as possible, as tools for learning they could be looked at in another way. If we accept, following Parson (2008), that scenarios should partly challenge the terms of current debates, then those engaged in the process of scenario construction do not automatically have to defend them against any criticism that they are 'wrong'. As Parson (2008) concludes, we should not eschew the speculative character of scenarios and accept that they attempt to 'stipulate future conditions that science cannot specify'. Since they 'always blend knowledge with judgment and speculation', they may be wrong; the challenge is learn from the attempt to speculate in a more 'disciplined way', and cope with the uncertainties that surround the types of wicked problems that typically arise at the interface of people and nature.

Again we have explored these kinds of issue in the follow-on work in a reflective and qualitative way, as part of our re-engagement with the wider stakeholder community. And so, following a similar research strategy to that of Bryson *et al.* (2010), we have:

- asked stakeholders at our workshops for feedback on the UK NEA scenarios and whether they found them plausible, engaging and sufficiently useful as a contribution to their general understanding of ecosystem service issues; and
- used our contact with other groups engaged in future thinking to find out whether the UK NEA scenarios can, following Pulver and VanDeever (2009), help build networks of individuals who are linked by some common concerns and shared understandings, or, following Bryson *et al.*(2010) to 'build capacity'.

Our findings are reported mainly in Section 7.2, although there are aspects of social learning that extend to the use of models in relation to the UK NEA scenarios, and so the topic will be revisited in Section 7.3.

### 7.1.6 Shaping the debate

Although we have, in this introduction, focussed on some key methodological issues from the current academic debate, they are directly relevant to the aims and objective of the follow-on phase of the UK NEA. If we are to operationalise scenario thinking then we need to understand the contexts in which they are used and the barriers to achieving successful outcomes. UK NEAFO provides an important opportunity to consider these issues and develop strategies for overcoming them. The results reported here therefore complement the efforts made in the work packages (WP 10) that have looked at the wider suite of decision-support tools needed to facilitate the ecosystem approach.

In setting the goals for this work the funders of UK NEAFO have asked us to consider the question:

*How can plausible future scenarios help understand, manage and communicate the consequences of changes in ecosystem services across all scales?*

As our introduction demonstrates, to answer this effectively we not only need to consider the content of scenarios but also the deliberative processes in which they are used both as communication and manage devices. In the two major sections that follow we provide our findings. In our conclusions we will return to this overarching question to discuss what has been achieved and where the new challenges for science and policy might lie in relation to scenarios.

# 7.2 Scenarios in Action

## 7.2.1 The geometry of the UK NEA scenarios

In the text that follows we will refer extensively to the six different UK NEA scenarios, each of which had a high and low climate variant. Although they are fully described in our earlier work (Haines-Young *et al.* 2011) it is helpful to summarise them briefly here (**Box 7.1**) to highlight the major differences between them. For they were developed as a suite, designed to explore some questions that the stakeholders we consulted in 2010-11 felt were important.

| **Box 7.1. Scenario Pen-sketches** |
|---|
| In ***Green and Pleasant Land*** **(GPL)** the conservation of biodiversity and landscape are dominant driving forces. The push for conservation is essentially cultural: living standards are high enough to allow policy focused on preserving the UK's natural environment and on protecting and improving its quality as an amenity resource for all to enjoy. This has led to a greater emphasis on habitat restoration and recreation and, consequently, a reduction in productive farmland. This has boosted tourism and leisure, which has increased its contribution to the UK economy. To some degree a pleasant environment at home is maintained at the expense of a reliance on imports of goods such as energy and food and export of waste materials. |
| In ***Nature@Work*** (NW) society takes a pragmatic view that values nature for what it provides or does and accepts the need to create multifunctional landscapes to maintain ecosystem services and quality of life. 'Balanced service provision' is key and many ecosystem services are the result of careful evaluation of the trade-offs through scientific and community review. Conservation of habitats and species remains desirable, but not at the expense of wider benefits—and the introduction of non-native species to provide food, energy, shade or habitat conversion are commonplace if they promote ecosystem-based adaptations that enhance society's resilience to climate change. |
| The ***World Markets*** (WM) scenario is driven by the push for economic growth through the complete liberalisation of trade. International trade barriers have dissolved, agriculture subsidies have disappeared and farming is industrialised and large-scale. Consumption in society is high, which results in greater resource use and more imports. Competition for land is also high, and this, coupled with the reduced rural and urban planning regulations on housing, agriculture and industry, means that biodiversity is often the loser. Technological development in all industries is mainly privately funded and is burgeoning. Food production has benefited from technological development and intensification and food is cheap and plentiful, but mostly of low quality. Land and sea are mainly seen as resources for exploitation and there is little effort to manage them sustainably. |
| The ***National Security*** (NS) scenario is driven primarily by increasing global energy prices that force most countries to seek greater self-sufficiency and efficiency in many of their core industries. This is not an easy transition for the UK and it relies on a heavy government hand in setting policy for ecosystem service provision and in creating a competition-free environment for industry within the UK. Trade barriers and tariffs have been increased to protect jobs and livelihoods, and immigration is tightly controlled. Technological development is state funded and many industries (including agriculture) are subsidised. Food, fuel, timber and mineral resources are prioritised over the conservation of biodiversity. Protectionism is a necessary response to the challenges posed by climate change but trade continues where it can. Nevertheless, life is uncomfortable and people work hard to get by. Economic growth is low and every last resource in the UK is utilised for the provision of services. Resource consumption is curbed and society is less profligate and more sustainable—though perhaps out of economic necessity as much as environmental concern. |

| |
|---|
| The ***Local Stewardship*** (LS) scenario is driven by similar external pressures to National Security, but society has made a more conscious effort to reduce the intensity of economic activity and the high levels of consumption that were a characteristic of the early years of the century. People understand the need to think and act differently and want to be responsible for managing resources for the future. Political power has been devolved and many major issues are decided at a regional or local level (except crucial national aspects like defence). Local timber and energy production is encouraged and there is great pride in the varied local food products. Consumption has reduced to more sustainable (and healthy) levels and societal equity fits alongside environmental equity. People are motivated to live in low carbon economies, and consequently travel less and depend more on their own locality for food and leisure activities. Technology supports sustainability and its development and is driven by a mix of private innovation and government funding. Increased local specialisation means that the UK is now less homogenised—landscapes are more distinctive and local economies vary considerably. Economic growth is slow but the economy is stable. |
| ***Go with the Flow*** (GF) describes a scenario in which the dominant sociopolitical and economic drivers acting on the UK at the end of 2010 continue. In this sense it is not a 'do nothing' storyline, but a projection of current approaches. Progress towards a low-carbon economy and better environmental standards across industry and society is slow and bumpy. Although there has been a marked improvement in the delivery of all ecosystem services, with a gradual shift away from provisioning services to regulating and cultural services, the battle between socioeconomic forces and environmental improvement continues. For now, access to ecosystem services is managed, but some regions (such as the South East, for example) are increasingly unable to meet their own needs and rely on other parts of the UK. |

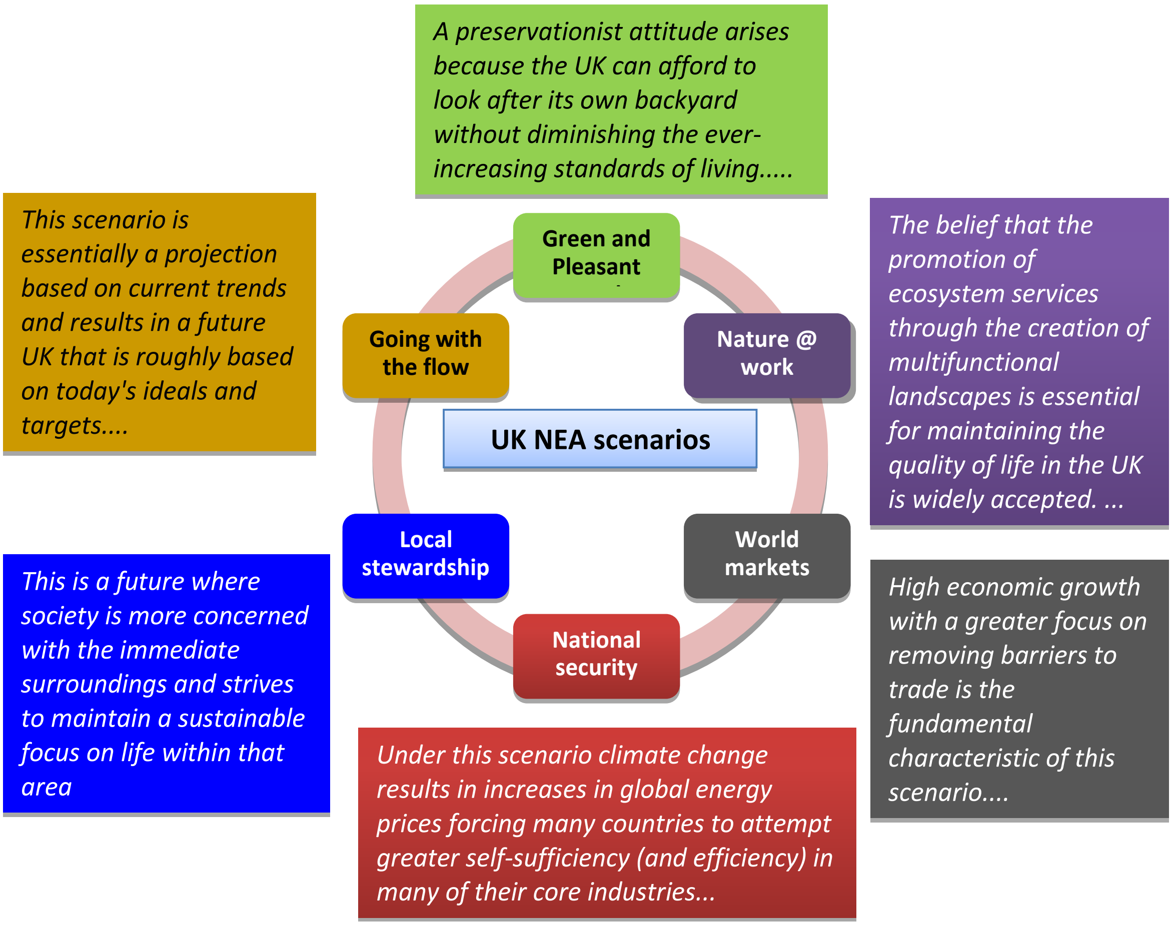


**Figure 7.1. An illustration of the 'geometry' of the UK NEA scenarios.**

**Figure 7.1** summarises the 'geometry' of the scenarios. This figure was used to introduce stakeholders to their principle characteristics and the rationale that led to their development. The idea that the set had some kind of geometry comes about because they were deliberately constructed to pose contrasts that stakeholders involved in the original work felt were interesting and wanted to explore. Thus the rationale underlying the development of *Green and Pleasant Land* and *Nature@Work* was that the stakeholders wanted to explore whether there were major differences between a future that prioritised biodiversity and one that focussed more on ecosystem services. The kind of question they were interested in, for example, was what will be the consequences of recasting biodiversity targets in terms of ecosystem services? *Go with the Flow* was developed as a 'baseline' or 'business as usual' scenario to provide a comparison with current trends. The *World Markets* story line sought to examine the contrasts that would develop if only economic growth is the primary goal, whereas *National Security* sought to examine the contrasts between this and a world that was more constrained by the need for access to food supplies and energy. Finally *Local Stewardship* attempted to explore a world in which localism was dominant, and how ecosystem services and human well-being might fare if decision making and responsibilities were highly devolved.

### 7.2.2 Methodological Approach

The purpose of the work described in this section was to re-engage with the UK NEA stakeholder community to explore the plausibility, consistency and saliency of the scenarios. To do this in 2013 we arranged a series of workshops, undertook interviews with policy customers and the wider user community, and joined other networks or groups that were actively discussing futures, to determine what value they saw in the UK NEA scenarios and any limitations. **Table 7.1** summarises the character of the meetings, the methods used and the profile of the people involved.

## Table 7.1. A brief description of each of meetings which we observed which used the UK NEA scenarios

| Workshop Description | Date | Purpose | Participant profile | Methods used |
|---|---|---|---|---|
| General UK NEA WP 7 Stakeholder Workshop (**'Leeds Workshop'**) | Jan 2013 | The aim of this two-day workshop was to familiarise the participants with the existing UK NEA scenarios and promote a critical discussion of them (Day 1). The scenarios were then used as the basis of the stress-testing work undertaken by the policy response option team in WP8 (Day 2) | 28 participants, mainly drawn from the government agency, research and consultancy sectors, with some representation from local authorities. The people involved were either directly involved with the UK NEA drawn from the wider stakeholder community identified for the UK NEA, the involvement of policy advisors from Central Government was negligible. | Mainly structured, issue-based group exercises and discussions with plenary feedback, with follow-up questionnaire. |
| Collaboration with the Defra Noise Futures workshop (**'Noise Workshop'**) | March 2013 | To derive a set of drivers, and futures under the UK NEA scenarios, for future changes in Environmental, Neighbour and Neighbourhood Noise. | 46 stakeholders from Defra and a wide range of national and local government, academic and business interests, including Department for Transport, The Welsh Government, Department of Environment Northern Ireland and BT. | Presentations and break-out groups. Groups identified using PESTLE system, and futures for each combination of driver and noise type (see 'see purpose') under each of the UK NEA scenarios. |
| Interviews with Defra personnel interested in the UK NEA scenarios (**'Defra Interviews'**) | April 2013 | A series of 30-60min face-to-face discussions with policy leads in Defra was arranged with WP8. The joint aim was to identify policy issues that could be included in the response option analysis and to explore the role of scenarios and future thinking in their day-to-day work, with a view to making the UK NEA set 'fit for purpose' | Policy leads and their associates in Defra (11 persons in all). Eight policy areas were covered: RDPE; Sustainable Development, Forestry, Climate Change, Biodiversity, Business and Biodiversity, CAP reform, Marine, and Water. | Semi-structured interviews |
| Participation at the UK NEA Work Package 4 Marine Scenarios Work Shop (**'Marine Workshop'**) | April 2013 | The aim was to derive a set of qualitative narratives and quantitative (Likert scale) estimates of what constrains marine ecosystem services under the baseline and four 2060 scenarios. Trade-offs between services and the effects of four wildcards were also considered. | 27 participants from SAMS, academia, The James Hutton Institute, government departments and NGOs. | Structured, issue-based group exercises and discussions with plenary feedback |
| Workshop with the Forestry Commission and other related WP 7 stakeholders (**'Forestry Workshop'**) | April 2013 | The aim was to explore the utility of the UK NEA scenarios with practitioners from a single sector, and to test the usefulness of the scenarios as a way of evaluating their management and policy strategies. | There were nine participants all with experience in planning and management within the forestry sector; some of the people involved had already used the UK NEA scenarios as part of their planning work. | Structured, issue-based group exercises and discussions with plenary feedback, with follow-up questionnaire. |
| Kick-off meeting and stakeholder workshop of the CAMERAS[2] Future of Scottish Environment Futures research project of the Scottish Government's (**'CAMERAS Workshop'**) | April 2013 and Oct. 2013 | This project has as its basis the UK NEA scenarios and will assess the viability and interaction of current policies, practices and institutions for delivering an Ecosystem Approach against the UK NEA scenarios, and therefore the implications for the design of future response options. | The kick-off meeting consisted of representatives from the Scottish Government, SEPA, Scottish National Heritage, Scottish Water and Cranfield University. The workshop in October consisted of a range of stakeholders from Scottish Government departments, Cranfield University and The UK NEA. | Kick-off meeting consisted of presentations and open discussions. The Workshop used structured, issue-based group exercises. |
| A workshop for the UK NEA scenarios stakeholders in Northern Ireland (**'Belfast Workshop'**) | June 2013 | One-day meeting was to use the UK NEA scenarios to explore a range of policy and management issues of relevance to Northern Ireland. The meeting was also used to explore the usefulness of futures thinking for the kinds of work that the delegates were involved with. | Organised by the Northern Ireland Environment Link. *c.* 100 participants from the devolved administration and its agencies, members of NGOs, and the research and academic communities. Followed on from a smaller preparatory meeting held in February | Short vignettes involving scripted interviews with people living in the UK NEA futures, Structured, issue-based group exercises and discussions with plenary feedback and follow-up questionnaires. |

[2] Coordinated Agenda for Marine, Environment and Rural Affairs Science

The evidence arising from the activities listed in **Table 7.1** is predominantly qualitative in character because the intention of the work was to observe and reflect on the 'scenarios in action'. An evaluation of scenarios from a process perspective requires an analysis of their *use* rather than any the simple elicitation of opinion about the content and character of the published set. Thus the work has sought to collect evidence from people about such matters as whether the UK NEA storylines helped change their thinking and whether working with the scenarios helped them to better understand or deal with issues linked to ecosystem services. As a result we have sought to identify what kinds of decision support role scenarios might actually have. The significance of the evidence provided therefore depends more on *who* was involved in this process rather than *how many* were consulted in a statistical sense.

In setting up these meetings we paid particular attention to who was represented and therefore what 'voices' were included in the discussions. As the work programme developed we adjusted the strategy of our consultations to try to ensure that a broad range of opinions and experience was considered by engaging with people who could be regarded as 'key informants'. For example, following the 'Leeds meeting', we were aware that, despite its policy focus, involvement of policy advisors from Central Government was poor. While the people involved could comment authoritatively on broader methodological issues and could draw on their general experience of working with policy customers, insights into specific issues was possibly limited. As a result we organised a set of face-to-face interviews with policy leads in Defra to understand current policy concerns and the role that scenario thinking might play as a decision support tool. Policy relevance was further explored in contact made through the *Coordinated Agenda for Marine, Environment and Rural Affairs Science* (CAMERAS) programme in Scotland (http://www.camerasscotland.org/).
The initiative for the workshops in Leeds, Edinburgh, and Belfast (**Table 7.1**), together with the interviews at Defra, arose from the work being done in UK NEAFO. The structure of each workshop varied, because of the different audiences and time available. However, in each case initial sessions were designed to familiarise the participants with the scenarios so that they could comment on them in an informed way. In the case of the meetings linked to CAMERAS and the Defra 'Noise Workshop', the stimulus for these meetings came from 'outside' UK NEAFO; in each case they were part of other initiatives that wanted to use the published UK NEA scenarios as part of their work, or at least consider the implications of doing so. The structure of these workshops was therefore determined by the organisers, and the role of the scenario team members was as 'participant-observer'. The position taken by the team was not to 'sell' the UK NEA scenarios to these groups, but rather to provide any briefing that was required, and to record and reflect on the resulting discussions and actions. Given the need to look at 'scenarios in action' we felt it important to consider the work of these outside groups, because while their concerns different from those of the UK NEA, they provided a 'real example' of the scenarios being used as a deliberative tool. If the UK NEA scenarios were found to have general relevance across different environmental sectors, then a stronger general case could be made for their plausibility, legitimacy and salience.

The workshop on marine scenarios undertaken with team members working on marine economics (WP4) requires special mention from a methodological perspective, because it had something of a hybrid status between the two types of meeting described above. The Marine Team brought their past experience to the problem of valuing ecosystem services, which included existing scenario work on coastal and marine futures, which was developed independently of the UK NEA process. As part of our work we therefore took the opportunity of attending meetings where marine futures were being considered, to investigate whether the UK NEA set were 'fit for purpose' given the particular concerns of this group, which included a focus on the linkages between the terrestrial and marine environments. As noted in our introduction, the need to develop and refine the existing UK NEA scenarios for the marine sector was part of our brief, and we considered that the experience gained with the economics group would be helpful in taking this objective forward.

The sections that follow draw on the material obtained from the workshops and meetings shown in **Table 7.1**. Rather than report on the events sequentially, the material is organised thematically so that an evaluation of the UK NEA scenarios can better be made. Thus we first look at general awareness of the original UK NEA scenarios and people's reactions as they began to work with them for the first time. We then examine ways that UK NEA scenarios can be used to support different deliberative processes so as to better understand how they can be deployed in a decision-support role.

### 7.2.3 Awareness and use of the UK NEA scenarios

The creation of scenarios is one step in a longer deliberative process. Even though their construction may be based on participatory processes, unless they are *used* in decision making they serve little purpose. As a first step in the follow-on work we therefore wanted to understand how familiar stakeholders were with the published UK NEA scenarios, whether they were including them in their work and if not, what the barriers were.

Through the contacts we made at the workshops and meetings, it was evident that many of the people involved had knowledge of the UK NEA and the contribution that it had made, few had used the scenarios in their work. For example, at the end of the Leeds and Belfast workshops we circulated a questionnaire (WP7 Report: Supplementary Material 1), and, of the 34 people who answered the question, 13 said they had used scenarios of some kind but only six had specifically used the UK NEA set. However, it was evident that UK NEAFO had stimulated wider interest. The Forestry Workshop in Edinburgh was organised through the auspices of the Forestry Commission, who were actively using the UK NEA scenarios as part of their Land Use and Ecosystem Services (LUES) Programme. The CAMERAS and Noise initiatives had also been initiated independently; both were exploring the use of the UK NEA scenarios as one of the elements of their work.

It is important to note that the search for people or groups actively using the UK NEA scenarios was not exhaustive; the contacts were made as a result of networking with the current UK NEAFO stakeholders or by people approaching the scenario team to flag up their work as a result of the UK NEAFO initiative. Nevertheless, the evidence gathered does give some insight into the nature of the 'community of users'. The people attending the meetings were predominately researchers, academics and members of NGOs; few identified themselves as 'policy advisors'. One of the attendees at the Leeds meeting (Workshop participant 14) put it succinctly: 'workshop was much too long and difficult to get the involvement of the people you need. Policy-makers are trained to pick up complex issues in a very short amount of time. Being immersed in issues for a day is something very few people can afford to do'.

The barriers to engaging with the policy community were explored in the meeting with Defra and in the preparation for it, with the Defra leads for the UK NEAFO. The time commitment required to participate in such workshops was indeed identified as an important factor. The comment made by one of those interviewed at Defra is illuminating. He (Interviewee D2) observed that scenarios of the kind developed in the UK NEA probably would not be used directly in his work, but that indirectly they may be exploited by the research commissioned by Defra. The main barriers, he added were 'timelines' and 'budgets'. He suggested that Defra's role was to lead, by encouraging other people to embed the findings of the UK NEA and its methods in the work they do. Another Defra interviewee observed that while she was aware of the scenarios, they were mainly helpful in terms of thinking about 'high level' and 'strategic issues' (Interviewee D3). Given the current stage in the seven year policy cycle for the England Rural Development Plan, she felt that her current needs were more 'short term' and 'practical'.

Many of the comments made by the Defra interviewees emphasised that there was a need to make the UK NEA work practical, relevant to the everyday concerns of the public and policy makers, and accessible. A typical response was from someone (Interviewee D6) who said that he was aware of the UK NEA and the Follow-on, and had 'high hopes of what the approach can offer.' However, he observed that it was difficult to 'get to grips with', to 'operationalise' and 'hence to make it real'. The conclusion was that there was 'still a gap between concept and delivery' that needed closing, and we needed ways to explain the concept in 'easy terms' that relate to 'everyday life'. It is important to note that these referred to the UK NEA and the ecosystem service concept as a whole, and not especially to scenarios, although the need for practical solutions applied to them as well. In fact, of the nine people interviewed, only three reported that they had much exposure to the UK NEA scenarios, and while they confirmed their usefulness only one felt that scenarios were important for their future work.

These findings on the level of engagement of policy advisors with scenarios echo those from WP9, which looked at the barriers and enablers to embedding an ecosystems framework in appraisal. This work found that institutional culture and behaviours are major factors that determine how knowledge is used, and indeed whether it is used at all. It is suggested that communication between knowledge producers, knowledge brokers and knowledge users is therefore critical. Thus the limited engagement of the 'policy community' that we found is perhaps hardly surprising, given the nature of their current concerns.

If the scenarios are to have any influence at all, the evidence collected suggests that it is more likely to come through work commissioned by policy leads and the discussion they have with their wider contacts. Thus the position taken on the UK NEA and the scenarios by the kinds of people who attended our meetings (researchers, academics and NGOs) is likely to be significant; the importance of knowledge brokerage in the wider context of embedding the  in policy and management has been discussed by Haines-Young and Potschin (in press). We therefore investigated the opinions of these 'knowledge brokers' (or key informants) following their exposure to the scenarios in more depth.

Although many of the people attending our workshops had not used the UK NEA scenarios, as part of our aim of testing the plausibility of the storylines we designed the meetings so that people would become familiar with them and be able to reflect on them in a critical way. The two day Leeds Workshop was the most sophisticated of those organised. On the first day, after an introduction to the suite of scenarios, people worked in groups on a single scenario and looked at its assumptions about the direct and indirect drivers of change, and the projected impacts on ecosystem services and well-being. On the second day the participants used the scenario to 'stress-test' different policy response options. The one-day Forestry meeting had a similar, but more streamlined format that focussed on the forestry sector. At the Belfast workshop, participants were introduced to the scenarios and then used them in groups to explore issues in relation to specific sites, habitat or types of Ecosystem Services (see WP7 Report:  Supplementary Material 2). The main difference here was that the participants at these two meetings considered a suite of scenarios simultaneously.

At each of the Leeds, Forestry and Belfast workshops we asked participants about their views on the UK NEA scenarios. Of the 30 people who responded to this question across the three meetings, 19 said they were more likely to use the scenarios in their work, while a further ten were undecided; only one said they were less likely. In response to the question about what types of application they were considering, the topics ranged from using the scenarios to structure discussions about drivers and policy opportunities, to combining the UK NEA storylines with UKCIP predictions as part of their research on developing river basin management strategies and land management planning.

The fact that people felt that they would be more likely to use the scenarios having attended the workshops supports the notion that scenarios can be a tool for social learning. When asked '*has working with the UK NEA scenarios made you think differently about future issues?'* of the 31 who answered, 18 said it had, with a further 10 undecided; three said that the experience had not changed their views. In the wrap-up session at Leeds, one participant expressed the belief that the use of the scenarios helped to 'get everyone on the same page, facilitating the casting aside of ideology and "yesterday's battles", and allows governance to be viewed through different lenses'. At the Edinburgh workshop another participant (Workshop Participant 15) observed that the scenarios would be useful for him in stimulating discussion with new colleagues following the establishment of Natural Resources Wales (NRW), because it provided a 'wider vocabulary' that was not restricted to Forestry. He went on to observe that future success is likely to depend on developing a shared vision across the different parts of the new organisation.

During the Leeds workshop in particular we asked people what kind of thing would help them and the people they work with to use the scenarios more effectively. The most frequent comment was that the material had to be accessible and simple. This echoed the comments made by the interviewees at Defra, who needed them to be easy to use and relevant to their needs. The respondents at the Leeds workshop (e.g. Workshop participant 4) suggested that, if they could be made available, videos and podcasts might help people to quickly understand the contrasts between the scenarios. It was also thought (Workshop participant 8) that 'short vignettes' and 'stories about people's lives in the different worlds' might be helpful as a way of engaging the wider community of researchers and policy customers. Such ideas about simplicity of presentation and its influence over the way people interpret the scenarios have important consequences in terms of judging plausibility, consistency and saliency, and so we explore these issues in more detail in the sections that follow.

## 7.2.4 Testing and developing the UK NEA scenario framework

### 7.2.4.1 Plausibility and coverage

As noted above, key tests for any scenario study include consideration of their plausibility, consistency and saliency (Ash *et al.* 2010). With this in mind, we therefore sought feedback at the workshops on the degree to which the UK NEA scenarios were 'reasonable', in the sense that they were within the limits of what might conceivably happen, that they were internally coherent and that the scenario set included a range of possible futures that were relevant to current concerns.

Out of 31 respondents at the Leeds, Edinburgh and Belfast workshops, 18 said they found the scenarios plausible and a further 11 partially so; only one felt that they were not plausible. Examining such issues through a questionnaire is, however, simplistic and deeper insights can be obtained by reporting on the issues that emerged in the workshop as well as other evidence from the literature. There was, for example, no evidence that delegates at any of the meetings thought the suite UK NEA scenarios was too limited in their coverage, in the sense that additional story-lines were needed to cover the range of possibilities relevant to current debates. Further support on the comprehensive nature of the UK NEA scenarios is also provided by the outputs from the marine work undertaken during UK NEAFO.

As noted in our introduction, one of the aims of UK NEAFO was to further develop an understanding of ecosystem services in the marine environment. Thus further work was commissioned in WP7 (See section 7.3) and WP4 (see WP4 Report). Both drew on previous work undertaken by Pinnergar *et al.* (2006) for *Cefas*, which looked at marine futures in terms of four scenarios called: '*Global Commons', Local Stewardship', 'Fortress Britain' and 'World Markets'*. The correspondence of these scenarios to the UK NEA set was discussed in the report on our initial work (Haines-Young *,* 2011; Table 25.3[3]), and the main difference with the UK NEA set was a move away from the 'two axis model' to a more nuanced differentiation of issues. In relation to the *Cefas* storylines '*Global Commons'* and *'Local Stewardship'* were sub-divided in the UK NEA into the *Nature@Work*, *Local Stewardship* and *Green and Pleasant Land* scenarios. The marine work in UK NEAFO re-confirmed these equivalences to the *Cefas* approach in the marine sector and the idea that a narrower subset of scenarios was probably sufficient given current concerns for this sector.

This conclusion about plausibility and coverage of the UK NEA scenarios is also supported by the observation that they in fact span the six general families of scenarios that van Vuuren *et al.* (2012) have identified from a review of recent work on global environmental assessments. In the context of this study, it could be argued that their 'economic optimism' family has equivalences with the UK NEA *World Markets*, 'regional competition' with *National Security*, 'regional sustainable development' with *Local Stewardship*, and 'business as usual' covers our *Go with the Flow*. The correspondences for *Green and Pleasant Land* and *Nature@Work* are more debateable, but each could probably be nested with the 'reformed markets' and 'global sustainable development' respectively, given the stronger governance and institutional arrangements of the latter pairing.

It is pertinent to note that, although the UK NEA scenarios have now been used in a number of futures related projects by a variety of bodies, and have generally been found to be suitable for such work, each group has chosen a different set of four or fewer scenarios out of the original six. Most of the groups we observed used *Nature@Work*, *World Markets*, *National Security* and *Local Stewardship*. However, the CAMERAS group used *Go with the Flow*, instead of *National Security* within the suite of four*,* while and Forest Enterprise used *Nature@Work*, *Green and Pleasant Land* and *Go with the Flow* for their Land Use and Ecosystem Services (LUES) project.

#### 7.2.4.2 Leaving space for discussion

Most of the comments generated in the workshops were in fact about the internal consistency and completeness of the scenarios rather than overall plausibility of the set. At the Leeds workshop, for example, people had more time to work through the material, and it was clear from the discussions we observed during the facilitated group sessions that opinions evolved during the meeting. Early difficulties of understanding were addressed by the facilitators explaining in detail the underlying assumptions of the scenarios and the contrasts within the scenario set. Nevertheless some reservations appeared to remain. For example, after working with the *Local Stewardship* scenario one delegate (Workshop participant 4) suggested that while it was generally consistent, it was 'too rural' and it needed to consider 'the majority of people who lived in urban areas'. Another delegate (Workshop participant 6) felt that the assumptions made in the *National Security* scenario contained 'inconsistencies' and felt that it eventually would be more 'resource efficient' than implied by the storyline. Workshop participant 10, from Leeds, suggested that as a set the scenarios 'needed more discussion to hone them', because they were a little too 'stereotyped'. In contrast, Workshop participant 11 argued that the material describing them should be 'simplified' so to '… avoid fruitless discussion about details'. At the Belfast workshop there was also a view that the scenarios overall were rather too pessimistic. Workshop participant 29 added that we 'need to build in policy/ legislative controls - we are not on a run-away train'.

An examination of these comments suggests that there is in fact a tension between participants who felt the need for a more complete description of each scenario storyline, and others that felt the pictures needed to be more 'broad-brush'. In fact, when the scenarios were developed it was not

[3] Note there was a layout error in the equivalent table published in Haines-Young et al. (2011) and so it has been reproduced in its corrected form in WP7 Supplementary Material 3

the intention to make the storylines complete, so as to give room for further discussion. The evidence collected from the Leeds, Edinburgh and Belfast workshops seems to suggest that completeness is mainly an issue if we take a product perspective on what scenarios represent; from a process perspective, over engineered storylines might actually stifle debate.

As an example of the kind of rich discussion that built up around the consistency and implications of the scenarios, we can report some of the discussions of the group that worked on *National Security* at the Leeds workshop. On first encountering this storyline the group reported that it may appear that environmental concerns are subordinated in this future to other more pressing issues. However, as the comment noted above indicates, the group suggested for this world to 'work' there would have to be a greater emphasis on the efficiency of land and resource use, and that eventually a number of green outcomes would probably be realised. In contrast, the group working on *Local Stewardship* at Leeds found that in working through the implications of greater 'localism', there would probably be a need for quite strong regulation from the centre, to ensure that conflicting goals that different communities might have could be resolved. The group went on to characterise the *Local Stewardship* in terms of an 'open source' world, so that things could be shared and reused. They also started to think through what *Local Stewardship* would mean for urban areas.

The point of describing the experiences of these two groups is to suggest that in judging their success or value of scenarios, we should consider their ability to stimulate these kinds of discussion as well as the consistency of their internal logic. As argued in our introduction – the point of scenario thinking is to challenge the terms of current debates and understandings, and to develop new perspectives. It is, we suggest, precisely this kind of learning process that are observing in the experiences of two groups described above. The experiences we report above also seem to support the idea that 'social learning' was occurring, as people thought through and questioned what the scenarios were saying.

Probably the most severe test of the plausibility, consistency and relevance of the UK NEA scenarios has come from the experience of observing the discussions of the CAMERAS group and the Noise workshop. Both these initiatives have taken place independently of UK NEAFO and required some kind of scenario work to be undertaken as part of their remit. The two meetings that we report here took place at early stages in the work programme of each group, at the point where they were deciding whether to develop scenarios for themselves, or to use some pre-existing set of storylines. We were invited to the meetings so that they could consider the suitability of the UK NEA material, and to clarify issues.

The meeting that took place in relation to the Noise study involved over 50 stakeholders. The UK NEA scenarios were then used as the basis of the meeting which was attended by delegates drawn from government, NGOs, local authorities and academia. All had an interest in environmental, neighbour and neighbourhood noise. The workshop sought to identify all drivers of noise in the UK and which of them was most important, and to investigate the impacts of these changes to the noise environment through to 2060. In the draft report prepared after the workshop (Centre for Environmental Risks and Futures, 2013) it was recorded that in preparing for the event an initial literature review had identified four key sets of scenarios, each of which was assessed on the basis of their relevance to noise in the UK and the robustness of their method. The review found that the UK NEA scenarios were the 'most applicable' to the noise environment.

The first CAMERAS meeting that we observed involved fewer people. The meeting in April 2013 was a project steering group that comprised the research team of three from Cranfield University, and six policy customers from Scottish National Heritage, SEPA, Scottish Government and Marine Scotland. Part of the brief for the meeting was to 'agree the use of a single set of scenarios and reflect on the differences between, and inherent benefits of, the UK National Ecosystem Assessment (UK NEA) scenarios'. As a result of it was agreed that the analysis of changes to Scotland's environment should be explored using the UK NEA scenarios, by looking in detail at four of the storylines: *World Markets*, *Nature@Work*, *Local Stewardship* and *Go with the Flow*, with the latter serving as the reference condition. This in turn was tested at a larger stakeholder workshop held in October 2013. Although this work is on-going, the fact that the UK NEA scenarios have been selected as a framework for discussion supports claims as to their value as a deliberative tool.

## 7.2.5 Stimulating debate

When planning the UK NEAFO scenario work, we identified a number of strategies that might be used in group discussions to stimulate thinking and debate. The workshops gave us an opportunity to test these ideas and we now report the results. The options we considered include looking at ways to help people better imagine the implications of the different futures for human well-being, through to the way the storylines might unfold over time or lead to different spatial outcomes. Finally, we considered what strategies might be useful for using scenarios to explore approaches to governance and the robustness of different policy response options.

### 7.2.5.1 Living in different futures

The ability to engage with and understand the qualitative storylines associated with any scenario is important if people are to use them in discussion. However, as the discussion on plausibility and consistency showed, there is a tension between those who would argue that storylines need to be 'detailed' and 'complete' in order to be plausible, and those who argue for simplicity so that scenarios can be easily understood and quickly used.

To test whether the existing scenario storylines were sufficient for users or whether additional material was needed to make them more understandable and usable, we considered the possibility of enriching the narratives though a discussion of what the futures might mean for people's lives. To do this we commissioned work on how society might function under each of the scenarios, using a version of the Ethnographic Futures Framework (EFF), also called VERGE, that was employed by Natural England as part of their futures work (see Creedy *et al*. 2009; Kass *et al*. 2011). The VERGE methodology identifies 'six domains' that can be used to ask questions about people and their lives in different futures (see Lum, 2013, WP 7 Report: Supplementary Material 4). The thematic domains cover: the way people define their world; the ways they relate to it; how they connect to what is going on around them; what they create; what they consume; and what they destroy.

Application of the VERGE methodology by the scenario team generated a set of descriptive materials that were tabled at the Leeds workshop. Participants were asked to comment on whether such materials helped them to understand the scenarios better, and whether, setting these materials aside, the questions that formed the basis of VERGE were a useful stimulus to discussion.

Reactions by workshop participants to the VERGE framework were mixed. While some (e.g. Workshop participant 9) said that it 'helped emphasise the more social dimensions of scenarios' many other comments were ambivalent or negative. Thus another delegate (Workshop participant 8) said 'Framework good' but the 'specific text at least for *Nature@Work* was of very limited value'. Another observed that the methodology 'seemed rather laborious and wasn't convinced that specifically addressing 6 questions individually was needed'.

The conclusion that we took from the feedback was that the questions associated with the VERGE domains may be a useful stimuli in general discussion or introduction to the scenarios. However, to present the framework formally, and ask people to apply it for themselves, was probably not helpful in a workshop which aimed to get people to use the scenario rather than develop their detail. The method is probably more useful as a participatory tool during the development of the scenarios rather than in the application phase.

In contrast to the VERGE approach, a different method of 'bringing the scenarios alive' was tried at the Belfast workshop. Using a 'chat show format', short vignettes about each scenario world were presented to the audience. The scripts about life in each of the futures that would be used in the workshop[4] were developed by students who had studied the scenarios. Feedback (via an online SurveyMonkey questionnaire) showed that the method was engaging but its effectiveness clearly dependent on the interpretation made by the presenters. Of the 17 comments we received, many thought the approach worked well, e.g. "Different way of doing a presentation really paid off, thought provoking" (DB2) and 'Very interesting and novel approach. Made me think more seriously about the NI my 2 year old will inherit' (DB5) but others less so (e.g. 'I don't feel these were a particularly effective way of communicating the scenarios' (DB7). Many of the comments were not critical of the technique per se, but rather suggested ways it could be improved, e.g. 'Although setting the scene was good they were too biased and pessimistic as pen portraits for the future' (DB16).

#### 7.2.5.2 Development of timelines

The 'end point' for the UK NEA scenarios is 2060. Although they were devised with an awareness that there needed to be a credible trajectory from 2010 to 2060 the timelines were only specified when and where it made the storylines more plausible. We therefore sought to test whether people thought that the lack of any explicit timeline for the scenarios was a limitation during the workshop at Leeds. The question was especially important because the team working on the response options in UK NEAFO (WP8) felt that more explicit timelines would be needed for their work. The aim at the workshop was to test the proposition that time lines helped people understand the detail of the scenarios better, and to deepen the experience of the group in the run-up to the stress-testing exercise that took place on Day 2 of the meeting.

In the Leeds workshop we used breakout groups to devise scenario trajectories in the form of time series charts for a number of key drivers selected by the WP7 and WP8 Teams. The delegates were asked to assign coloured dots on a plot, to indicate the relative contribution over time of Demographic, Social and Political, Economic, Science and Technology, and Cultural and Religious Drivers. This information was then used as a basis for group discussion to arrive at a consensus time series for each driver, and to examine alternative drivers where these were agreed to be important.

In general, although some groups said that they would be useful in enriching the scenarios, by allowing a tighter link-up with present day concerns, it was apparent that they struggled to formulate compelling and well thought-out timelines. The problem appeared to arise from a combination of lack of expertise and lack of time for the task. While there was some scepticism about the utility of the timelines, this was a minority view, and all groups arrived at timelines which they were satisfied with. Most agreed with the proposition that the attempt to create timelines was probably justified in the programme as a 'learning mechanism'.

The act of thinking through timelines enabled groups to generate new ideas about the scenarios that were not explicit or absent in the original narratives. For example, the group dealing with *Local Stewardship* identified separate drivers for national and local mobility, with the former decreasing, the latter steadily increasing, over time. This group also saw a rapid increase in the influence of

4 At the Belfast workshop only Nature@Work, National Security, Local Stewardship and World Markets were used as the basis for discussion

social technologies in the first half of the scenario period, with the rate of increase decreasing towards an asymptote. In the case of the group working with *Nature@Work,* four new drivers were identified: food security, water scarcity, biosecurity and wellbeing. The group suggested these would follow a 'hockey stick' pattern, initially diminishing to a trough and then rapidly rising out of it as 2060 approached. 'Innovation' also emerged as a candidate for a new driver, separate from the role of science and technology. Finally, an idea to emerge from the group working on *World Markets* was that the free market situation might develop via a period of weak government, which enabled control increasingly to be concentrated in the hands of 'big business'.

As with the VERGE exercise, the conclusion that we drew from the exercise was that it was another way in which people could immerse themselves in the scenario narratives and develop their thinking about them. However, at no point did the initial absence of a time line seem to be an issue in terms of people's views on the plausibility of the original narratives. Although timelines were not considered at the Belfast workshop some participants did highlight the issue in their feedback as being something that would be helpful. Echoing comments from the Defra interviewees, one delegate observed that policy customers were often most interested in relatively short timescales which matched with their own planning timeframe and that of the political and policy environment in which they worked. 'Shorten the time frame e.g. 25 years' to 'help people to "buy in" more to concept' (Workshop participant 33). The need to look at scenarios in relation to the timing of the 'policy cycle' was also a theme to emerge from the Defra interviews.

#### 7.2.5.3 Regionalisation and downscaling

The UK NEA scenarios were created as a set of UK-wide descriptions. They were spatially explicit, in that land cover changes was estimated at a 1km x 1km resolution. However, there has been little attention to the analysis of regional patterns or the examination of whether the drivers and therefore outcomes would play out differently at the country level. The scenario team were especially conscious, for example, that Northern Ireland was not covered to the same depth as the rest of the UK in the early work.

We have sought to examine the issue of regionalisation in several ways. At the Leeds workshop, for example, we asked delegates to consider what role geography might play when they were looking at the impact of different drivers over time. While there was general agreement that these issues were important, we found that it was difficult to find sufficiently authoritative voices to enable the groups to develop a rich enough picture of how the scenarios would look in different regions or in each of the devolved nations. In the context of workshops such as the one in Leeds, discussion of the geographical implications is probably more useful in helping people think themselves into the scenarios rather than for developing concrete results.

In terms of understanding the regionalisation issue further the workshop in Northern Ireland and the CAMERAS Project in Scotland are perhaps more useful, as they addressed specific areas of the UK. At the Northern Ireland workshop participants split into groups that considered each of four scenarios from the perspective of a specific habitat (peatland, woodland, or farmland), a service types (provisioning, cultural, regulating) or a specific geographical location (Causeway Coast, Mourne Mountains, Strangford Lough). Two key messages emerged from the event (see WP7 Report: Supplementary Material 2). First, the organisers found that when organising the workshop would not be possible to ensure 'buy in' from stakeholders without making sure that the workshop was tailored to the Northern Ireland context; in this sense the ability to downscale and regionalise the UK NEA scenarios was vital. Second, that the groups that dealt with a specific location were the most successful and productive. The organisers felt that this was because the delegates at these tables had a good understanding of the important issues and that by concentrating on a specific and familiar location they could more thoroughly explore the implications of the scenarios.

The Northern Ireland workshop confirmed that although the UK NEA scenarios were developed at the UK scale, they appeared to be sufficiently rich and flexible to enable them to be looked at through the lens of a region or set of more local places. The CAMERAS exercise also demonstrated their value, but this time as more of an analytical device. Having selected the UK NEA scenarios as a framework for discussion, during the second workshop that we observed participants were asked to identify the main political, economic, social, technological, legal and environmental (PESTLE) drivers relevant in the Scottish context, and assess their effects on Ecosystem Services under each of four UK NEA storylines.

#### 7.2.5.4 Governance and policy analysis within the scenarios

As a further strategy to help people use the scenarios to enrich their thinking, we also looked at ways of encouraging them to think about governance issues though the storylines. At the Leeds workshop, for example, we asked delegates to examine how the Ecosystem Approach would play out in the different worlds in both the short and long term. Groups were asked to provide feedback in terms of the implications for provisioning, regulating or cultural services.

As well as eliciting structured feedback, these sessions were used to promote discussion on the practical implications of governance of each of the scenarios. As we observed in the case of the VERGE material, timelines and regionalisation, the topic generated many ideas. For example, the group dealing with *Nature@Work* raised the issue of whether the 'anticipatory governance' that it envisaged would stifle innovation. The *Local Security* group argued that despite the goal of localism in this storyline, it may well lead to centralized planning and regulation in order that de-centralised delivery could work efficiently.

Issues related to governance were, however, also a key topic of conversation at many of the other meetings, especially at the Forestry Workshop. There was much discussion there of the role of ownership of land in setting priorities, and whether the 'green' aspects of *Nature@Work*, and, especially, *Local Stewardship*, would be possible without changes in ownership and property rights, or whether regulation or incentives such as Payments for Ecosystem Services could circumvent this. Other discussions included whether the strong national governance framework of *National Security* could mean that this scenario would have the potential to be relatively 'green', or that, conversely, the devolution of power to the local level envisaged under *Local Stewardship* might lead to inefficiencies, inequality and poor performance for ecosystem services.

In addition to using the Ecosystem Approach as a way of stimulating discussion about governance issues, we have also worked closely with the UK NEAFO Team on Policy Response Options, to develop a more analytical approach around the scenarios. This work is especially important in the context of the issue of *saliency*, because unless people feel scenarios are relevant to current needs and requirements, then it is unlikely that they will be actively used operationally.

As part of their work, the WP8 Team have been developing a 'stress testing' or 'wind-tunnelling' methodology that can be applied to different types of policy response to determine and understand their associated risks and vulnerabilities. The goal is to identify policy responses that would be viable across a range of potential futures, and therefore identify what kinds of strategy might be more robust in the face of uncertainty. Given the structure of the UK NEAFO work programme, the methodology and the results of this exercise will be described elsewhere (WP8 Report). In the context of this chapter, we focus only on how such a device can be used as a deliberative tool and hence the suitability of the existing scenarios for such work. The motivation for this is that if scenarios can be shown to support this kind of policy evaluation then they could be seen as making a distinct and valuable contribution as a decision-support tool.

During the Leeds meeting delegates were asked to ‘stress-test’ ten response options under each of the scenarios, assigning separate scores for provisioning, regulating and cultural services according to their performance and level of dependency (see WP8 report for details). Although this mechanism worked well at the workshop, some difficulties were detected and the WP8 team have subsequently revised their approach. One problem was the confusion between ‘dependency’ and ‘likelihood’ of uptake, and whether a high score for dependency meant the option was highly dependent or highly independent of other factors or pre-conditions. On the basis of our observations at Leeds, we applied a modified and simplified version of the stress-test approach at the Forestry workshop at which the WP8 Team was absent. In an open discussion, delegates were asked to identify two key response options (they chose Markets and policies for Biodiversity in the face of Climate Change) and place coloured dots, one colour for each of four scenarios, and one dot for each delegate, according to the potential performance and potential uncertainty. This proved to be an easier to understand exercise but was less informative – delegates generally agreed that the more ‘green’ a scenario was, the better it would perform and the least uncertainty there would be about its performance.

At the Leeds workshop, all bar one respondent felt that the stress-testing exercise was useful, although some had reservations about the details of the methodology. One (Workshop participant 5) for example, said that he ‘found it quite difficult to understand as a non-professional academic’, and another (Workshop participant 8) felt that it needed ‘stronger ground rules’. At the Forestry meeting Workshop participant 15 observed that even with the simplified methodology we probably needed ‘less spot sticking because the responses needed more thinking through to clarify’. An interesting point to emerge in the discussion of the method at the Forestry Workshop was whether the evaluation of responses was to be made at the higher, programme or strategic level, or whether particular and specific measures and interventions ought to be considered. The latter would require more detailed background information and so the number of people capable of doing this would be more limited than if a more strategic focus was being considered.

From the perspective of using the stress-testing concept as a way of helping people to work with scenarios and potentially learn from them, it did seem that it could provide a fruitful basis for discussion. The experience at the workshops, and the findings of WP8, suggest that the existing set of scenarios had sufficient detail in them to enable them to be applied to a range of different policy responses. However, the task was found to require considerable time to be done properly. It may well be that the requirement for specialist knowledge and sufficient time to consider issues in depth, would make this a task for dedicated groups rather than more general meetings such as the one at Leeds and Edinburgh.

In the context of developing tools for making assessments of different policy responses further using scenarios, it is interesting to note that the participants at the Noise Workshop were able to identify the policy implications arising for each scenario using a more fluid approach, rather than one based on a formal scoring system such as the one developed in the stress-testing exercise. The experience from this workshop demonstrates that the UK NEA scenarios are sufficiently flexible and relevant to support this kind of consultative work, and can have a useful decision support role.

# 7.3 Developing the model base

## 7.3.1 Introduction

Quantitative models have an important role to play in scenario work. They can help, for example, to ensure that the future projections made are credible and 'science-based'. However, since models tend to be built on assumptions about the present day there is a danger that they may only extrapolate from what we already know (cf. Hulme and Dessai, 2008). If scenarios are to challenge assumptions and expand our ideas, then it could be argued that we need a mixture of qualitative and quantitative approaches. In this context, the use of model may serve to extend the insights provided by scenarios rather than simply be used to generate them. Scenarios can therefore be enriched by the use of models, and at the same time enrich our understanding of models by testing their relevance and sensitivity in different kinds of situation.

A focus of the work in UK NEAFO has been to explore how quantitative modelling and analysis tools might be used to extend and deepen the insights offered by the scenarios, thereby extending the relevance and utility of the qualitative storyline. Given the time and resources available for the follow-on work, we focused on four topic areas: flood and drought risk (based on an analysis of river flows), biodiversity (farmland birds), marine and cultural ecosystem services. Although the results of the modelling exercises are interesting in themselves, in order to identify the broader lessons for scenarios work in general, we have also reflected on their findings by posing the following general questions:

- Are the scenarios sufficiently rich and well defined that their impact can be modelled for the topic area?
- Does the modelling produce significantly different projections compared to the first phase?
- What does the modelling tell us about the differences between the scenarios - can we identify important trade-offs etc.?
- Can the analytical framework of the UK NEA scenarios stimulate 'social learning' by helping to identify new and challenging scientific and policy relevant questions?

## 7.3.2 UK River flows under the scenarios

### 7.3.2.1 Aims and Methods

***Selection of catchments***

In this section we examine the effects of possible changes in land cover under each of the UK NEA scenarios on river flows for a number of catchments in the UK. We used a hydrological model to simulate the effects of land cover change, as represented by each of the two high and low climate change variants (hereafter referred to as "H" for "High" and "L" for "Low" respectively) of the six UK NEA scenarios (see Haines-Young *et al*. 2011). Although the current status of the UK's water resources were described in Chapter 9 of the UK NEA (Maltby *et al*. 2011), this study is the first examination of how river flows might look under the scenarios.

We selected 34 catchments across the UK from the National River Flow Archive (NRFA) (CEH 2013) (see **Figure 7.2** and **Table 7.2**). The selection was made on the basis of: i) consistency with previous UK studies (Bell *et al.* 2007; Christierson *et al.* 2012; Hannaford and Marsh 2006; Hannaford and Marsh 2008); ii) availability of rainfall, temperature and discharge data; iii) low levels of anthropogenic influences such as discharges and abstractions; iv) good hydrological model performance; v) elevation; vi) land cover variability under the scenarios; and, vii) geographic spread across the UK (see **Figure 7.2** and **Table 7.2**). Thus the 34 catchments are broadly representative of the diversity of those across the UK in terms of size (9 – 1363 $km^2$), mean daily river flow (0.5 – 23.6 $m^3/s$) and catchment elevation (39 – 496 m). A more detailed description of the aims and methods can be found in WP7 Report: Supplementary Material 5.

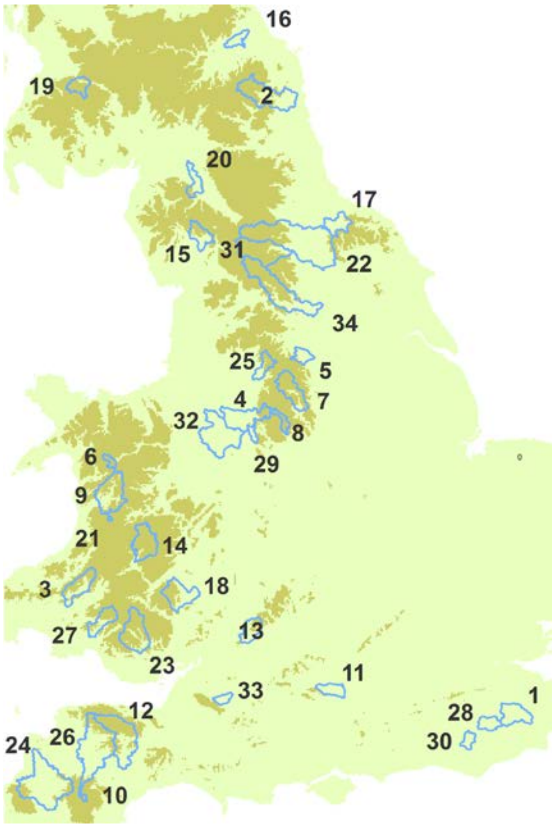


**Figure 7.2. The 34 catchments selected for study. The catchment names are shown in Table 7.1 The 1km x 1km grid cells where the mean altitude is >= 200 m are dark shaded.**

**Table 7.2. Catchment characteristics for the 34 study catchments.**

| ID | Catchment and gauging station | NRFA station No. | Area ($km^2$) | Gauge elevation (m) | Catchment elevation (m)[a] | Mean flow ($m^3/s$) | Ref [b] | Rank land-cover var [e] | NSE |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Beult at Stile_Bridge | 40005 | 277 | 12 | 39 | 2.06 | 1,2 | 911 | 0.75 |
| 2 | Coquet at Morwick | 22001 | 570 | 5 | 192 | 8.60 | 1,3 | 920 | 0.70 |
| 3 | Cothi at Felin_Mynachdy | 60002 | 289 | 16 | 229 | 11.61 | 3 | 611 | 0.76 |
| 4 | Dane at Rudheath | 68003 | 407 | 13 | 94 | 5.00 | 1 | 284 | 0.78 |
| 5 | Dearne at Barnsley_Weir | 27023 | 119 | 43 | 140 | 1.37 | 3 | 330 | 0.74 |
| 6 | Dee at New_Inn | 67018 | 54 | 164 | 394 | 3.12 | 1,3 | 347 | 0.77 |
| 7 | Derwent at Chatsworth | 28043 | 335 | 99 | 326 | 6.40 | 1 | 484 | 0.80 |
| 8 | Dove at Izaak_Walton | 28046 | 83 | 131 | 315 | 1.93 | 1 | 353 | 0.77 |
| 9 | Dyfi at Dyfi_Bridge | 64001 | 471 | 6 | 261 | 23.55 | 1 | 785 | 0.81 |
| 10 | East_Dart at Bellever | 46005 | 22 | 309 | 458 | 1.25 | 1 | 1130 | 0.70 |
| 11 | Enborne at Brimpton | 39025 | 148 | 59 | 113 | 1.31 | *c* | 834 | 0.74 |
| 12 | Exe at Thorverton | 45001 | 601 | 26 | 235 | 15.92 | 2 | 298 | 0.79 |
| 13 | Frome at Ebley_Mill | 54027 | 198 | 31 | 182 | 2.56 | 2 | 613 | 0.70 |
| 14 | Ithon at Disserth | 55016 | 358 | 150 | 318 | 8.10 | 3 | 451 | 0.86 |
| 15 | Kent at Sedgwick | 73005 | 209 | 19 | 205 | 9.29 | 1 | 544 | 0.83 |
| 16 | Leet_Water at Coldstream | 21023 | 113 | 12 | 74 | 1.01 | 1 | 773 | 0.79 |
| 17 | Leven at Leven_Bridge | 25005 | 196 | 5 | 92 | 1.89 | 1 | 518 | 0.85 |
| 18 | Monnow at Grosmont | 55029 | 354 | 58 | 183 | 5.94 | 1 | 297 | 0.80 |
| 19 | Nith at Hall_Bridge | 79003 | 155 | 173 | 309 | 5.79 | 1 | 268 | 0.79 |
| 20 | Petteril at Harraby_Green | 76010 | 160 | 20 | 158 | 2.18 | 1 | 700 | 0.78 |
| 21 | Severn at Plynlimon_flume | 54022 | 9 | 331 | 496 | 0.54 | 3 | 275 | 0.77 |
| 22 | Swale at Crakehill | 27071 | 1363 | 12 | 104 | 20.75 | 1 | 561 | 0.81 |
| 23 | Taff at Pontypridd | 57005 | 455 | 45 | 317 | 20.67 | 2 | 560 | 0.86 |
| 24 | Tamar at Gunnislake | 47001 | 917 | 8 | 145 | 22.35 | 3 | 526 | 0.76 |
| 25 | Tame at Portwood | 69027 | 150 | 43 | 238 | 4.13 | 3 | 198 | 0.75 |
| 26 | Taw at Umberleigh | 50001 | 826 | 14 | 168 | 18.01 | 2 | 869 | 0.85 |
| 27 | Tawe at Ynystanglws | 59001 | 227 | 9.3 | 259 | 12.33 | 2 | 349 | 0.80 |
| 28 | Teise at Stone_Bridge | 40009 | 136 | 25 | 91 | 1.35 | *d* | 553 | 0.71 |
| 29 | Trent at Stoke_on_Trent | 28040 | 53 | 113 | 182 | 0.63 | 2 | 562 | 0.79 |
| 30 | Uck at Isfield | 41006 | 88 | 11 | 67 | 1.12 | *d* | 1016 | 0.71 |
| 31 | Ure at Kilgram_Bridge | 27034 | 510 | 88 | 368 | 16.08 | 3 | 506 | 0.81 |
| 32 | Weaver at Ashbrook | 68001 | 622 | 16 | 75 | 5.61 | 1 | 295 | 0.74 |
| 33 | Wellow_Brook at Wellow | 53009 | 73 | 44 | 135 | 1.29 | 1,3 | 935 | 0.85 |
| 34 | Wharfe at Flint_Mill_Weir | 27002 | 759 | 14 | 258 | 17.52 | 2 | 188 | 0.79 |

*a*. Median catchment altitude is calculated from a 50 m grid across the catchment with a 0.1 m vertical resolution and is derived from the Centre for Ecology & Hydrology's Integrated Hydrological Digital Terrain Model (IHDTM) (CEH 2013).

*b*. References refer to Hannaford and Marsh (2008) (1), Bell *et al*. (2007) (2) and Christierson *et al*. (2012) (3).

*c*. Added to represent a lowland southern UK catchment.

*d*. Added to improve inclusion of catchments in the south-east of the UK.

*e*. Rank (amongst all NRFA catchments) in variability in land-cover change across the UK NEA scenarios. We calculated the variance in the proportion of total area comprising each land cover class across all scenarios in each catchment, multiplied these values by the mean proportion (across all scenarios) of the land cover in the catchment comprising each land cover class, and then took the mean of these values for each catchment. We then ranked these values against all other NRFA catchments (N = 1,263, Rank 1 = high variability).

***The hydrological model***

We used SHETRAN, a spatially distributed hydrological model (Ewen *et al.* 2000; Birkinshaw *et al.* 2010), as the basis for the study. It has been used in previous hydrological modelling exercises to assess the effects of land cover change (Bathurst *et al.* 2004; Dunn and Mackay, 1995) to describe the vertical, horizontal and temporal flow of water, as well as sediment transport and contaminant migration at the scale of the river catchment. It represents the spatial distribution of catchment properties such as topography, channel network, soils and vegetation, rainfall input and hydrological response using a grid network; in the vertical direction flow is represented by a column of horizontal layers at each grid cell (Bathurst *et al.* 2004). The version of SHETRAN used here operates with a horizontal grid of 1km x 1km resolution to match the UK NEA land cover scenario datasets.

Hydrological models are usually calibrated, by fine-tuning parameters until the model produces an acceptable simulation of observed river discharge. This is a complex and lengthy process. While calibrating a model for a single-catchment is feasible, calibration for multiple catchments presents a major challenge. As a result previous UK river flow assessments have run simplified versions of complex hydrological models, where the model parameters are generalised spatially across the UK (Kay *et al.* 2006a; Kay *et al.* 2006b) instead of being individually calibrated for each catchment. We adopted this approach by using a spatially generalised version of SHETRAN and assigning the same parameters for each land cover across the UK. Many macro-scale hydrological models operate in the same way, e.g. Mac-PDM.09 (Gosling and Arnell, 2011). Model parameters were selected based upon derived relationships to catchment properties across the UK.

While SHETRAN was not calibrated for each of the selected catchments, its performance was checked. We did this by running the model for the period 1992-2002 for 354 catchments and sub-catchments across the UK, for which data is available from the NRFA website[5]. This period was chosen because almost all of the catchments had a complete flow record for this period. We then calculated the Nash Sutcliffe Efficiency (NSE; Nash and Sutcliffe, 1970) for each catchment, and only selected catchments for further analysis if they had a NSE > 0.7 (model performance is defined as "very good" for 0.75<NSE<1.00, and "good" for 0.65<NSE<0.75 (Moriasi *et al.* 2007)) (see **Table 7.2**). Three of our SHETRAN simulations runs did not complete and so are excluded from the analysis; these were the Dane at Rudheath for *Nature@Work* (L), Ithon at Disserth for *National Security* (L) and Monnow at Grosmont for *Go with the Flow* (H).

***Climate data inputs***

SHETRAN requires daily climate data for precipitation and potential evapotranspiration (PET). Observed values of daily precipitation on a 5x5 km grid were sourced from the latest UK Climate Projections, UKCP09 (UKCP09 2013). Precipitation for the 5x5 km grid cells located within the catchment boundaries (**Figure 7.2**) were extracted and used as a SHETRAN input. PET was calculated following the FAO Penman-Monteith method (Allen *et al.* 1998) using gridded (5x5 km) values of maximum and minimum temperature, sunshine hours, relative humidity and wind speed from UKCP09. For both precipitation and PET, the 5x5 km gridded values were overlain on the SHETRAN 1x1 km grid. While this means that some grid cells will include identical climate data, the application of gridded climate data represents a more advanced treatment of input data when compared with the *lumped* hydrological modelling approach, which tends to calculate a single value of input climate data for the entire catchment instead of considering the spatial distribution of input climate parameters across a grid.

An aim of this investigation was to explore how sensitive catchment hydrology is to possible future land cover change. To achieve this, we held the climate constant at present-day conditions when running SHETRAN with the land cover change scenarios. Thus the climate in 2060 is the same as in

[5] http://www.ceh.ac.uk/data/nrfa/data/access_data.html

present in our simulations. This 'fixing-changing' method (Wang *et al.* 2009) is a technique that involves setting one factor and changing another factor to assess the effects of the changed factor on model performance and it has been applied previously to assess the impact of land cover change on catchment hydrology (Tang *et al.* 2011; Yan *et al.* 2013). Furthermore, research shows that one of the largest uncertainties in quantifying future river flows arises from the application of climate change scenarios (Arnell and Gosling, 2013; Gosling *et al.* 2011; Haddeland *et al.* 2011; Hagemann *et al.* 2013). For the UK, Kay *et al.* (2009) found that climate modelling uncertainty is by far the largest source when compared against five other sources of uncertainty. This major source of uncertainty is incorporated into the UKCP09 weather generator climate projections, which are available as ensembles with between 100-10,000 members. Thus the application of climate change scenarios would introduce significant noise that would mask the signal of hydrological response in relation to land cover change scenarios.

***River flow indicators***

We explored the effects of land cover change on simulated discharge by investigating three indicators of river flow commonly analysed in hydrological studies: i) average annual discharge (Christierson *et al.* 2012); ii) statistics of high and low flows (Arnell and Gosling, 2013); and iii) flood hazard (Dankers *et al.* in press). As the Lilliefors tests indicated that simulated discharge for baseline and all scenarios was not normally distributed, Wilcoxon's Rank Sum tests were used to test whether mean annual discharge were significantly different between baseline and each scenario, for each of the 34 catchments (Wall, 1986). The statistics of high and low flows that we calculated were Q5 and Q95 respectively, where, for instance, Q95 is the daily discharge exceeded 95% of the time and is therefore an indicator of low flows (e.g. drought).

As an indicator of flood hazard we first estimated the 30-year return level of daily river flow (R30) at each catchment for the baseline (Coles, 2001). R30 is a moderately extreme discharge level that will be exceeded only very infrequently. The probability of the river flow level associated with R30 being exceeded in any given year is 1 in 30, and it is therefore also referred to as the '1 in 30 years flood'. It is possible to calculate other return levels but we selected R30 because this has been used in previous work (Dankers *et al.* in press; Dawson *et al.* 2006; Huang *et al.* 2013) and because there is a high degree of uncertainty in the estimation of higher return levels (e.g. the 100-year return level) from relatively short datasets.

To examine how land cover change affected flood frequency and probability, the return period of the baseline R30 flood level was calculated for the simulated discharge from each scenario. Thus if land cover change had no effect on flood frequency, the return period of the baseline R30 level would also be 1 in 30 in the scenario. If flood frequency increased due to land cover change, then the return period of the baseline R30 would be lower in the scenario.

### 7.3.2.2 Results

**Table 7.3** shows the differences between each UK NEA scenario and baseline for average annual discharge, Q5 and Q95 discharge, and return period (years) of the R30 flood level, showing 408 catchment-scenario combinations for each indicator (34 catchments x 12 scenarios).

***Average annual discharge***

Annual discharge is significantly different from baseline ($p<0.05$) for 25% (101) of combinations, with *National Security* (L) showing the highest number - almost half (15). Other scenarios associated with significant differences across several catchments include *National Security* (H; 11), *Nature@Work* (12 for H and L) and *World Markets* (H; 9). Annual discharge is least sensitive to land cover changes associated with *Local Stewardship* where between 4 and 5 catchments observe significant differences. The majority of significant ($p$<0.05) catchment-scenario combinations (75) show declines in discharge under the scenarios, ranging between -13 % (Uck at Isfield, *Nature@Work* (L)) and -0.5 % (Leet Water at Coldstream, *Nature@Work* (L)). Only 26 of the 101 significant catchment-scenario combinations show increases in discharge and 16 of these are under the *World Markets*, where all the significant differences are for increases in discharge. The other 10 significant increases in discharge are simulated exclusively for the Trent at Stoke on Trent.

**Figure 7.3** shows how the direction of change in annual discharge is affected under two of the scenarios. Significant declines ($p$<0.05) in annual discharge are observed for some catchments in the south of the UK under *Nature@Work* whereas under *World Markets* the same catchments experience significant increases ($p$<0.05) in discharge. The same pattern is observed for several other catchments across the UK but the differences in discharge are not always statistically significant ($p$<0.05).

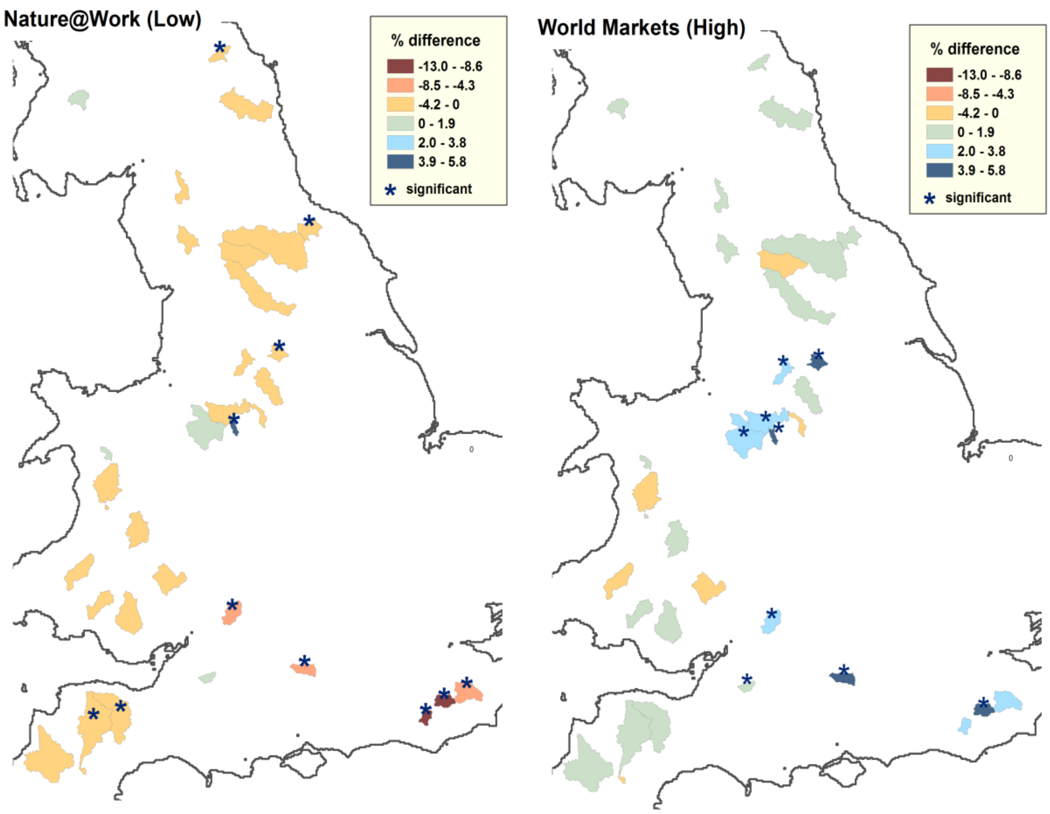


**Figure 7.3. Differences in average annual discharge from baseline (%) under *Nature@Work* (L) (left) and i (H) (right). Significant differences ($p$<0.05) are denoted *.**

**Table 7.3. Percentage differences between each UK NEA scenario and baseline for average annual discharge, Q5 andQ95 discharge, and return period (years) of the R30 flood level , e.g. +10 indicates that the baseline 30-year return level is equivalent to a 40-year return level in the scenario (indicative of a decrease in flood hazard). For average annual, Q5 and Q95 discharge, catchments where average annual discharge shows significant differences with the baseline ($p$<0.05) are shaded according to the relative magnitude of change. For return period, catchments where the period increases or decreases by more than 5 years are shaded according to the relative magnitude of change. ID numbers link to catchment name and gauge number in Table 7.2.**

**Average Annual Discharge**

| | High | | | | | | Low | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | GwtF | GPL | LS | NS | N@W | WM | GwtF | GPL | LS | NS | N@W | WM |
| 1 | -1.8 | -3.6 | -4.2 | 0.8 | -4.1 | 3 | -1.1 | -6.2 | -2.8 | 1.1 | -4.4 | 3.3 |
| 2 | 0.2 | 0.7 | 0 | -6.2 | -0.2 | 0.5 | 0.1 | 0.8 | 0.1 | -5.8 | -0.3 | 0.3 |
| 3 | -0.1 | 0.1 | 0 | -1.9 | -1.4 | -0 | -0.2 | 0 | 0 | -2.1 | -1.4 | -0.1 |
| 4 | 0.8 | 0.5 | 0.3 | -1.7 | 1 | 2.6 | 1.3 | 0.4 | 0.6 | -1.1 | | 2.7 |
| 5 | -0.7 | -2.9 | -1.2 | 0.1 | -4 | 4.4 | 0.1 | -2.2 | -1.5 | -0.1 | -3.5 | 4.6 |
| 6 | 0.2 | 0.8 | 0.3 | -0.7 | 0.2 | 0.1 | 0.2 | 0.7 | 0.3 | -0.7 | 0.2 | 0 |
| 7 | -0.2 | -0.1 | -0.1 | -7.6 | -0.4 | 0.6 | -0.2 | -0.1 | -0.1 | -7 | -0.5 | 0.5 |
| 8 | 0 | -0.1 | 0 | -0.7 | -0.3 | 0 | 0 | -0.1 | 0 | -0.7 | -0.4 | 0 |
| 9 | -0.1 | 0.1 | 0 | -1.3 | -0.5 | 0 | -0.1 | 0.1 | 0 | -1.5 | -0.5 | 0 |
| 10 | 0 | 0.3 | 0 | -4 | 0.1 | 0 | 0 | 0.6 | 0 | -4.2 | -0.3 | 0 |
| 11 | -3.9 | -3.5 | -2.5 | 1 | -7.4 | 5.8 | -2.8 | -6.2 | -2.3 | 0.5 | -7.3 | 4.9 |
| 12 | -0.6 | -0.3 | -0.5 | -1 | -2.2 | 0.1 | -0.5 | -0.7 | -0.5 | -1 | -2.7 | 0.2 |
| 13 | -2.5 | -2.8 | -1.5 | -1.1 | -7.5 | 2.4 | -2.5 | -6.2 | -0.8 | -3.5 | -7.9 | 2.2 |
| 14 | 0.2 | 0.3 | 0.1 | -0.8 | -0.1 | 0.2 | 0.1 | 0.2 | 0.1 | | -0.1 | 0.2 |
| 15 | 0 | 0 | 0 | -1 | -0.1 | 0.1 | 0.1 | 0 | 0 | -0.6 | 0 | 0.1 |
| 16 | -0.6 | -0.9 | -0.3 | -0.2 | -0.8 | 0.1 | -0.5 | -0.9 | -0.3 | -0.2 | -0.5 | -0.2 |
| 17 | -1.4 | -1.2 | -0.9 | -3.2 | -3.1 | 0.6 | -0.9 | -1.4 | -0.7 | -3 | -3.3 | 0.6 |
| 18 | | -0.8 | -0.5 | -0.7 | -1.4 | 0 | -0.4 | -1.1 | -0.3 | -3.2 | -1.9 | -0.2 |
| 19 | 0.2 | 0.4 | 0.1 | -3 | 0.4 | 0.1 | 0.2 | 0.3 | 0.1 | -2.6 | 0.4 | 0.1 |
| 20 | 0.1 | -0.3 | 0 | -0.7 | -1.4 | 0.1 | 0.1 | -0.3 | 0 | -0.8 | -1.2 | 0.2 |
| 21 | 0 | 0 | 0 | -0.6 | 0 | 0.1 | 0 | 0 | 0 | -0.6 | 0 | 0.1 |
| 22 | -0.1 | -0.2 | -0.2 | -2.5 | -0.5 | 0.2 | -0.1 | -0.2 | -0.2 | -2.3 | -0.4 | 0.2 |
| 23 | 0.2 | 0.2 | 0 | -0.2 | -0.2 | 0.8 | 0 | 0.1 | 0 | -0.8 | -0.1 | 0.8 |
| 24 | -0.2 | -0.5 | -0.2 | -0.4 | -2.1 | 0.3 | -0.2 | -0.4 | -0.2 | -0.2 | -1.7 | 0.2 |
| 25 | 0 | -0.1 | -0.3 | -3.5 | -0.1 | 2.7 | 0.1 | 0 | -0.2 | -3.6 | -0.2 | 2.4 |
| 26 | -0.7 | -1.1 | -0.4 | -0.8 | -2.4 | 0.2 | -0.7 | -0.7 | -0.4 | -0.8 | -2.6 | 0.1 |
| 27 | -0.1 | 0 | 0 | -0.5 | -0.2 | 0.5 | -0.1 | 0 | -0.1 | -0.7 | -0.2 | 0.4 |
| 28 | -3.1 | -5.2 | -3.5 | -0.3 | -9.2 | 5.8 | -3.7 | -12 | -1.6 | -2.5 | -12 | 0.1 |
| 29 | 4.7 | 2.9 | 2.1 | 3.8 | 4.7 | 5.7 | 3.8 | 2.9 | 2.6 | 3.8 | 4.7 | 5.7 |
| 30 | -6.8 | -3.1 | -5.1 | -2.4 | -12 | 3.1 | -5.4 | -8.3 | -3.1 | -4.5 | -13 | 0.1 |
| 31 | 0 | 0.1 | 0 | -3.2 | -0.1 | 0 | 0 | 0 | 0 | -2.7 | -0.1 | 0 |
| 32 | 0.6 | 0.4 | -0.1 | 0.4 | 0.2 | 2 | 0.8 | 0.2 | -0.1 | 0.8 | 0.2 | 2.2 |
| 33 | 0.7 | -0.3 | -0.1 | 1.2 | 0.9 | 1.9 | 0.8 | -0.7 | 0.3 | 0.2 | 0.4 | 1.6 |
| 34 | 0 | -0.1 | -0.1 | -4.2 | -0.5 | 0.4 | 0 | -0.2 | -0.1 | -3.8 | -0.5 | 0.3 |

**Q5 Discharge**

| | High | | | | | | Low | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | GwtF | GPL | LS | NS | N@W | WM | GwtF | GPL | LS | NS | N@W | WM |
| 1 | -3.4 | -5.6 | -5.5 | 1 | -5.6 | 2.8 | -2.4 | -7.7 | -4.2 | 1.3 | -6.1 | 3.1 |
| 2 | 0.1 | 0.8 | -0.2 | -6.6 | -0.3 | 0.4 | -0.1 | 1.1 | -0.2 | -6.2 | -0.9 | 0.4 |
| 3 | -0.2 | 0 | -0.2 | -2.2 | -1.4 | -0.1 | -0.2 | -0.2 | -0.2 | -2.4 | -1.3 | -0.2 |
| 4 | 0.7 | 0.5 | 0.3 | -1.9 | 0.6 | 2.2 | 0.8 | 0.5 | 0.5 | -1.3 | | 2.4 |
| 5 | -1.2 | -2.9 | -1.2 | 0.1 | -3.8 | 2.8 | -0.7 | -2.8 | -1.3 | -0.5 | -3.4 | 2.9 |
| 6 | 0.1 | 0.5 | 0.1 | -0.3 | 0.1 | 0 | 0.1 | 0.5 | 0.1 | -0.3 | 0.1 | 0 |
| 7 | 0 | -0.1 | 0 | -6.4 | -0.3 | 0.5 | 0.1 | 0 | 0 | -5.6 | -0.3 | 0.5 |
| 8 | 0 | 0 | 0 | -0.5 | -0.1 | 0 | 0 | 0 | 0 | -0.5 | -0.1 | 0 |
| 9 | -0.1 | 0.1 | 0.1 | -0.8 | -0.3 | 0 | -0.2 | -0.1 | 0.1 | -0.8 | -0.3 | -0.1 |
| 10 | 0 | 0.3 | 0 | -1.8 | 0.1 | 0 | 0 | 0.5 | 0 | -1.9 | -0.2 | 0 |
| 11 | -2.9 | -2.7 | -1.8 | 1.9 | -7.6 | 7 | -1.4 | -5.7 | -2 | 1.4 | -6.7 | 6.7 |
| 12 | -1.1 | -0.5 | -0.9 | -1.5 | -2.5 | 0 | -1 | -1.1 | -0.7 | -1.3 | -2.9 | 0.1 |
| 13 | -2.2 | -2.1 | -1.6 | -1 | -5.4 | 1.3 | -2.7 | -5.2 | -0.9 | -2.7 | -5.8 | 0.8 |
| 14 | 0.1 | 0.1 | 0 | -0.8 | 0 | 0 | 0 | 0.1 | 0 | | 0 | 0 |
| 15 | 0 | 0 | 0 | -1 | -0.1 | 0 | 0 | 0 | 0 | -0.7 | -0.1 | 0 |
| 16 | -0.2 | -0.4 | -0.2 | -0.1 | -0.4 | 0.1 | -0.1 | -0.4 | -0.2 | -0.1 | -0.1 | -0.1 |
| 17 | -1.2 | -0.9 | -0.5 | -2.9 | -2.6 | 0.6 | -0.8 | -1.2 | -0.5 | -2.6 | -2.8 | 0.7 |
| 18 | | -0.7 | -0.6 | -0.3 | -1.2 | 0 | -0.2 | -1 | -0.3 | -2.7 | -2.2 | 0 |
| 19 | 0.2 | 0.3 | 0.1 | -2.4 | 0.4 | 0.2 | 0.2 | 0.2 | 0.1 | -2.2 | 0.4 | 0.2 |
| 20 | 0 | -0.2 | 0 | -0.4 | -1.2 | 0 | 0 | -0.2 | 0 | -0.8 | -1.1 | 0 |
| 21 | 0 | 0 | 0 | -0.2 | 0 | 0 | 0 | 0 | 0 | -0.2 | 0 | 0 |
| 22 | 0 | -0.1 | -0.2 | -2 | -0.2 | 0.2 | 0 | -0.1 | -0.1 | -2 | -0.2 | 0.2 |
| 23 | 0.1 | 0.2 | 0.1 | -0.4 | -0.1 | 0.3 | 0 | 0.1 | 0.1 | -0.9 | -0.1 | 0.3 |
| 24 | -0.6 | -0.9 | -0.6 | -0.8 | -1.8 | 0.1 | -0.6 | -0.8 | -0.6 | -0.7 | -1.6 | 0 |
| 25 | 0 | 0.2 | 0 | -3.5 | 0 | 2.3 | 0 | 0 | 0 | -3.3 | 0 | 2.3 |
| 26 | -0.7 | -1.3 | -0.6 | -1.1 | -2.7 | 0 | -0.8 | -0.7 | -0.6 | -1 | -2.7 | 0 |
| 27 | -0.1 | 0.1 | 0.1 | -0.3 | -0.2 | 0.1 | 0 | 0.1 | -0.1 | -0.4 | -0.1 | 0.1 |
| 28 | -2.9 | -4.7 | -2.9 | -0.9 | -11 | 3.7 | -4.1 | -14.8 | -0.6 | -3.5 | -12.4 | -1 |
| 29 | 1.9 | 1.2 | 0.6 | 1.5 | 1.9 | 3 | 1.5 | 1.2 | 0.8 | 1.5 | 1.9 | 3 |
| 30 | -7.1 | -3.2 | -4.8 | -2.2 | -13 | 3.5 | -4.7 | -8.2 | -1.9 | -4.5 | -13.3 | 0.4 |
| 31 | -0.1 | 0.3 | 0.1 | -2 | 0.1 | 0 | 0 | 0.3 | 0.1 | -1.7 | -0.1 | 0 |
| 32 | 0.1 | -0.2 | -0.3 | 0.3 | -0.4 | 1.5 | 0.6 | -0.2 | -0.1 | 0.7 | -0.4 | 1.8 |
| 33 | -0.3 | -1 | -0.3 | 0.7 | 0.3 | 1.7 | 0.2 | -1.1 | 0 | 0.2 | -0.5 | 0.9 |
| 34 | 0 | -0.1 | -0.1 | -4 | -0.4 | 0.3 | 0 | -0.2 | 0 | -3.8 | -0.5 | 0.3 |

**Q95 Discharge**

| | High | | | | | | Low | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | GwtF | GPL | LS | NS | N@W | WM | GwtF | GPL | LS | NS | N@W | WM |
| 1 | -5.7 | -4.2 | -9 | 2.3 | -11 | 7.5 | -5.7 | -14 | -2.8 | 2.3 | -12.7 | 7.3 |
| 2 | 0.5 | 1.6 | -0.1 | -11.7 | -0.4 | 0.9 | 0.3 | 2 | 0.4 | -10.9 | -0.6 | 0.5 |
| 3 | -0.6 | 0.1 | -0.4 | -5.5 | -5 | -0.1 | -1.2 | -0.6 | -0.4 | -6.2 | -5 | 0.1 |
| 4 | 2.1 | 0.8 | 1.4 | -5.1 | 2.3 | 6.2 | 3.8 | 0.8 | 1.4 | -3.3 | | 6.5 |
| 5 | 0.6 | -3.9 | -1.5 | 0.1 | -6 | 11.4 | 2 | -1.4 | -1.6 | 0.6 | -5.1 | 11.3 |
| 6 | 1 | 1.8 | 1.4 | -6.6 | 1 | 0.6 | 1 | 1.3 | 1.4 | -6.6 | 1 | 0 |
| 7 | -1.3 | -0.3 | -0.3 | -16 | -1 | 2 | -1.4 | -0.5 | -0.4 | -15.4 | -1.8 | 1.2 |
| 8 | 0 | -1 | -0.1 | -2.6 | -1.6 | 0 | 0 | -1 | -0.1 | -2.6 | -1.8 | 0 |
| 9 | -0.3 | 0.8 | 0.2 | -4.7 | -1.6 | 0 | -0.6 | 0.4 | 0.2 | -5.4 | -1.5 | -0.1 |
| 10 | -0.2 | 0.6 | 0 | -12.7 | 0.3 | 0 | -0.2 | 1.6 | 0 | -12.8 | -1.2 | 0 |
| 11 | -11 | -11 | -7.1 | 7 | -18.2 | 26.7 | -11 | -17.7 | -9.5 | 0.8 | -19.3 | 22.1 |
| 12 | -1.3 | -0.5 | -1.3 | -1.4 | -5 | 0.4 | -1.2 | -1.6 | -1.2 | -1.5 | -6.1 | 0.6 |
| 13 | -4.4 | -5.4 | -2.6 | -2.2 | -14.6 | 4.8 | -4 | -12.5 | -1.1 | -6.7 | -15.3 | 4.7 |
| 14 | 1.3 | 1.4 | 0.4 | -3.1 | 0.8 | 0.7 | 0.9 | 1.6 | 0.4 | | 0.4 | 0.7 |
| 15 | -0.5 | -0.5 | 0 | -3.9 | -0.7 | 0.1 | -0.5 | -0.5 | 0 | -2.5 | -0.6 | 0.1 |
| 16 | -4 | -6.4 | -2.3 | -2.1 | -6.4 | 0.1 | -4 | -6.4 | -2.3 | -2.2 | -4 | -2.2 |
| 17 | -5.4 | -6.9 | -3.6 | -6.4 | -12.6 | 1.7 | -2.8 | -6 | -3.3 | -7.1 | -13.3 | 1.7 |
| 18 | | -1.9 | -1.5 | -2.2 | -3.6 | -1.1 | -1.6 | -2.6 | -1.3 | -9.4 | -4.6 | -1.5 |
| 19 | 0.9 | 1.1 | 0.3 | -8.6 | 1.5 | 0.1 | 0.9 | 1.1 | 0.3 | -7.5 | 1.4 | 0.1 |
| 20 | 0.1 | -0.9 | 0 | 0.1 | -2.5 | 0.1 | 0.1 | -0.9 | 0 | 0.1 | -2.5 | 0.2 |
| 21 | 0 | 0 | 0 | -3.9 | 0 | 0.3 | 0 | 0 | 0 | -3.9 | 0 | 0.3 |
| 22 | -0.4 | -0.5 | -0.4 | -8 | -1.3 | 0.8 | -0.4 | -0.6 | -0.4 | -7.5 | -1.3 | 0.5 |
| 23 | 0.7 | 0.8 | 0.3 | 0 | -0.3 | 3 | 0 | 0.3 | 0.2 | -2.1 | -0.3 | 2.2 |
| 24 | -0.9 | -1.6 | -0.6 | -0.8 | -5.8 | 0.7 | -1 | -0.9 | -0.6 | -0.7 | -4.5 | 0.6 |
| 25 | 0 | 0 | -1.2 | -10.4 | -0.3 | 6.8 | 0 | 0 | -0.7 | -11.1 | -0.6 | 6.2 |
| 26 | -2 | -4 | -1 | -1.8 | -6.8 | 0.5 | -1.8 | -2.5 | -1.1 | -1.8 | -6.9 | 0.4 |
| 27 | -0.7 | -0.4 | -0.2 | -1.2 | -0.7 | 1.8 | -0.7 | -0.5 | -0.4 | -1.7 | -0.8 | 1.7 |
| 28 | -3.2 | -9 | -7.3 | 4.9 | -11.1 | 8.3 | -7.8 | -19.3 | -2.7 | -2.7 | -19.8 | -0.4 |
| 29 | 13 | 5.2 | 3.7 | 8.5 | 13.4 | 17.7 | 8.5 | 5.2 | 4.7 | 8.5 | 13.4 | 17.7 |
| 30 | -18 | -9.7 | -16 | -6.2 | -24.2 | -2.2 | -14 | -18.8 | -8.8 | -14.5 | -24.3 | -6.1 |
| 31 | 0 | 0.2 | 0.1 | -6.5 | -0.1 | 0.1 | 0 | 0.1 | 0.1 | -5.5 | -0.2 | 0.1 |
| 32 | 3.4 | 2.8 | 0.3 | 1.2 | 1 | 7.2 | 3.2 | 2.6 | 0.4 | 1.5 | 1.1 | 7.3 |
| 33 | 1.2 | -1.1 | -1.1 | 2 | 1.3 | 3.2 | 1.2 | -1.9 | 0.7 | -0.6 | 0 | 3 |
| 34 | -0.4 | -0.6 | -0.8 | -9.3 | -2.1 | 1 | -0.3 | -0.9 | -0.4 | -8.5 | -2 | 0.5 |

**Flood Hazard**

| | High | | | | | | Low | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | GwtF | GPL | LS | NS | N@W | WM | GwtF | GPL | LS | NS | N@W | WM |
| 1 | 6 | 5.1 | 7.5 | -0.6 | 10.3 | -3 | 4 | 12.1 | 3.8 | -1 | 10.4 | -3.5 |
| 2 | -0.4 | -0.6 | 0.1 | 9 | 0.5 | -0.3 | -0.2 | -0.6 | -0.3 | 8.8 | 0.5 | -0.3 |
| 3 | 0 | -0.5 | -0.3 | 3.8 | 3.8 | 0.3 | 0.4 | -0.6 | -0.4 | 4.9 | 3.1 | 0.2 |
| 4 | -0.3 | -0.3 | 0 | 4 | -0.4 | -1 | -0.5 | -0.1 | 0.1 | 3.4 | | -1.1 |
| 5 | 4.7 | 5.4 | 1.9 | 0 | 18.7 | -4 | 1.3 | 4.7 | 2.5 | -0.2 | 14.3 | -4 |
| 6 | 0.5 | 1.7 | 1 | -1.3 | 0.5 | 0.6 | 0.5 | 1.2 | 1 | -1.3 | 0.5 | 0 |
| 7 | 0.1 | 0.1 | -0.2 | 36 | 0.8 | -0.5 | 0.2 | 0.1 | 0 | 30 | 0.9 | -0.5 |
| 8 | 0 | -1.2 | 0 | 0.2 | -1.2 | 0 | 0 | -1.2 | 0 | 0.2 | 0 | 0 |
| 9 | -0.3 | -0.2 | -0.1 | -0.6 | -0.9 | 0 | -0.5 | -0.4 | -0.1 | -0.4 | -1 | -0.1 |
| 10 | 0 | -2.4 | 0 | 4.2 | -0.1 | 0 | 0 | -2.6 | 0 | 4.3 | 2 | 0 |
| 11 | 2.5 | 2.1 | -1.3 | -9.2 | 14.7 | -16 | -0.4 | 23.5 | 2.2 | -7.5 | 15.4 | -15 |
| 12 | 1.8 | 1.1 | 1.1 | 2 | 3.2 | 0.4 | 1.3 | 1.3 | 0.9 | 2.5 | 3.5 | 0.5 |
| 13 | 2.2 | 1.9 | 1.7 | 0.7 | 6 | -0.2 | 2.7 | 6.3 | 1.1 | 2.3 | 5.9 | -0.2 |
| 14 | -1.3 | -1.3 | -0.3 | 2.3 | -0.6 | 0 | -0.6 | -0.6 | -0.3 | | -0.2 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 | 0 | 0 |
| 16 | 0.1 | 0.8 | 0.1 | 0.1 | 0.8 | 0 | 0.1 | 0.8 | 0.1 | 0.1 | 0.1 | 0.1 |
| 17 | 0.5 | 0.7 | 0.9 | 3.2 | 1 | -0.1 | 0.4 | 0.9 | 0.9 | 3 | 1 | -0.1 |
| 18 | | 1.7 | 0.9 | 0.4 | 3.4 | -0.2 | 0.3 | 2.5 | 0.2 | 5 | 3.6 | -0.1 |
| 19 | -0.5 | -0.2 | -0.4 | 4 | -0.3 | -0.1 | -0.5 | -0.2 | -0.4 | 3.9 | -0.3 | -0.1 |
| 20 | 0 | 0.3 | 0 | 0.2 | 0.4 | 0 | 0 | 0.3 | 0 | 0.2 | 0.3 | 0 |
| 21 | 0 | 0 | 0 | -0.8 | 0 | 0.1 | 0 | 0 | 0 | -0.8 | 0 | 0.1 |
| 22 | 0.5 | 0.7 | 0.5 | 5.5 | 1.3 | -0.4 | 0.3 | 0.9 | 0.4 | 5.4 | 1.1 | -0.2 |
| 23 | -0.3 | -0.6 | 0 | 0.7 | 0.6 | -1.3 | 0.1 | -0.2 | 0.1 | 3.6 | 0.5 | -1.1 |
| 24 | 0 | 0.2 | 0 | 0 | 1 | -0.1 | -0.1 | 0.1 | 0 | 0 | 0.9 | -0.1 |
| 25 | 0 | -0.6 | 0 | 12 | -0.2 | -1.6 | -0.1 | 0 | -0.1 | 11 | 0 | -1.2 |
| 26 | 0.4 | 1.8 | 0.5 | 0.8 | 2.1 | 0.2 | 0.5 | 0.6 | 0.5 | 0.8 | 2.6 | 0 |
| 27 | 0 | 0 | 0 | 0.2 | 0.1 | -0.2 | 0 | 0 | 0 | -0.2 | 0 | -0.2 |
| 28 | 5.7 | 3.9 | 5.8 | 1.4 | 15.1 | -0.7 | 3.7 | 12.7 | 1.6 | 3.5 | 17.3 | 2.2 |
| 29 | -3.3 | -1 | 0 | -1.4 | -3.3 | -4.9 | -1.4 | -1 | -0.4 | -1.5 | -3.3 | -4.9 |
| 30 | 7.3 | 0.1 | 5.2 | 3 | 11.2 | 1.3 | 3.8 | 6.9 | 3 | 3.7 | 11.4 | 1.4 |
| 31 | 0 | -0.2 | 0 | 3.5 | 0 | -0.1 | 0 | -0.2 | 0 | 3.1 | 0.1 | -0.1 |
| 32 | -0.5 | -0.4 | -0.1 | -0.2 | 0.3 | -1.5 | -0.5 | -0.2 | -0.1 | -0.4 | 0.2 | -1.7 |
| 33 | 0.9 | 3 | 1.6 | -0.8 | 0.4 | -2.2 | 0.5 | 3 | 0.8 | 1.1 | 1.9 | -1 |
| 34 | 0.2 | 0.3 | 0.1 | 8.9 | 0.9 | -0.2 | 0.2 | 0.5 | 0.1 | 7.7 | 0.9 | -0.2 |

***Q5 and Q95***

For Q5 and Q95, the differences between scenarios reflect the patterns observed for average annual discharge, i.e. *World Markets* is associated with significant increases in Q5 and Q95, whereas the other scenarios show significant declines. However, the magnitudes of change are greater than for average annual discharge, particularly with the indicator of low flows (Q95). The range for change in Q95 across all catchment-scenario combinations is -24 % (Uck at Isfield, *Nature@Work* (L)) to +27 % (Enborne at Brimpton, *World Markets*(H)). This compares with the range for average annual discharge of -13 % (Uck at Isfield, *Nature@Work* (L)) to 6% (Enborne at Brimpton, *World Markets* (H)) (**Table 7.3.**).

***Flood hazard***

The return period of the baseline R30 flood level was calculated for the simulated daily discharge from each scenario. The differences in return period years with the present baseline and scenario are shown in **Table 7.3.** Negative values indicate an increase in flood hazard in the scenario relative to baseline; e.g. -10 indicates that the baseline 30-year return level is equivalent to a 20-year return level in the scenario. Positive values indicate a decrease in flood hazard in the scenario relative to baseline; e.g. +10 indicates that the baseline 30-year return level is only equivalent to a 40-year return level in the scenario. If the flood hazard is unchanged then the value in **Table 7.3** is zero. A significant change in flood hazard was identified when the probability of the baseline R30 level being exceeded in the scenario in any given year is <= 1 in 25 (increase in flood hazard) or >= 1 in 35 (decrease in flood hazard).

There are significant changes in the return period of the baseline R30 flood level for 39 of the 408 catchment-scenario combinations. While this is a smaller number of catchments than the number that experience significant changes in average annual discharge, the two hydrological indicators are not comparable because “significance” was computed differently for each indicator.

Flood hazard increases significantly for only 4 catchment-scenario combinations. These are under *World Markets* and *National Security* for the Enborne at Brimpton. The return period of the R30 flood level decreases from 1 in 30 years to around 1 in 15 (*World Markets*) and 1 in 22 (*National Security*) years. Flood hazard declines significantly across 35 catchment-scenario combinations. Where the declines are significant, the return period of the baseline R30 flood level ranges between 1 in 35 (Beult at Stile Bridge, Green and Pleasant Land (H)) to 1 in 66 (Derwent at Chatsworth, National Security (H)).

The scenarios can result in large differences in the direction of change in flood hazard. **Figure 7.4** shows the change in the return period of the baseline R30 flood level under *Nature@Work* (L) and *World Markets* (H). Several catchments show increases in flood hazard under *World Markets* but decreases in flood hazard under *Nature@Work* (although many of the flood hazard changes are small and not significant). The most striking inter-scenario difference in **Figure 7.4** is observed for Enborne at Brimpton, where the R30 flood hazard increases from 1 in 30 to 1 in 15 years for *World Markets* but decreases to 1 in 45 years under *Nature@Work*.

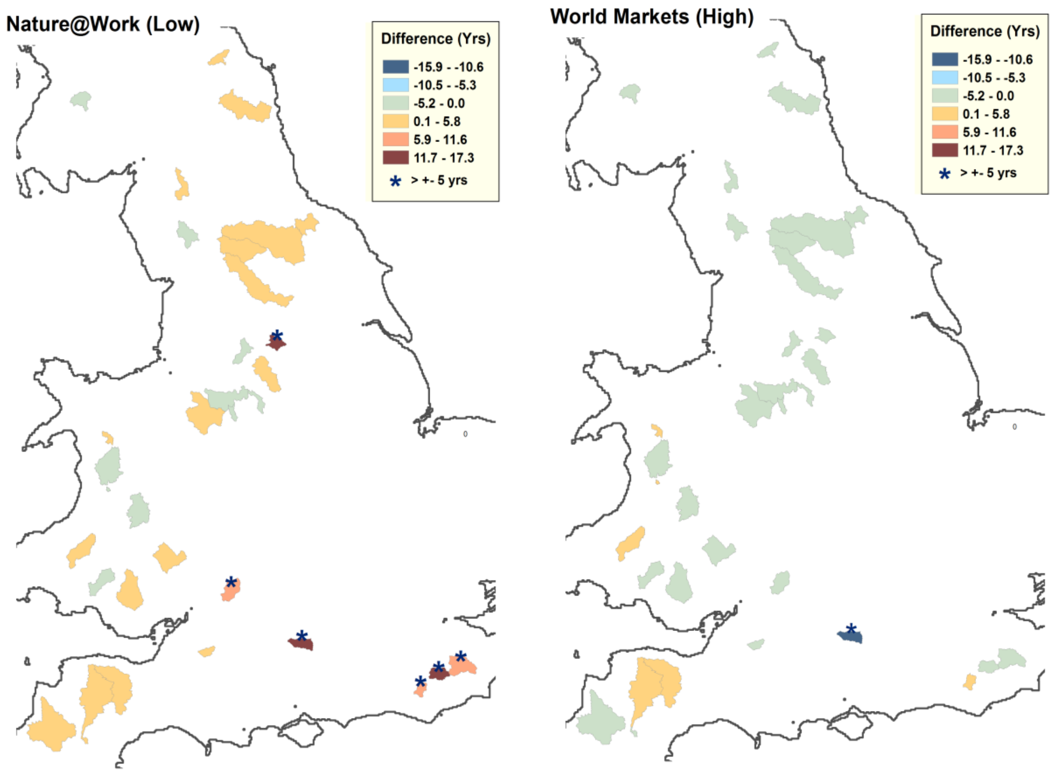


**Figure 7.4. The effect of land-cover change on the return period (years) of the baseline R30 flood level under *Nature@Work* (L) (left panel) and *World Markets* (H) (right panel), e.g. +10 indicates that the baseline 30-year return level is equivalent to a 40-year return level in the scenario (indicative of a decrease in flood hazard). Catchments where the return period increases or decreases by more than 5 years are denoted *.**

#### 7.3.2.3 Discussion and conclusions

The different plausible futures represented by the UK NEA scenarios have contrasting implications for simulated hydrological change. This is especially so for *Nature@Work* and *World Markets* for all river flow indicators. Importantly, for some catchments, both scenarios were associated with *significant* changes that were different in sign. The direction of change is generally plausible between scenarios - for example, *Nature@Work* and *Green and Pleasant Land* are scenarios where ecosystem services are generally better protected than under *World Markets* and *National Security*. The former two scenarios are associated with declines in flood hazard and extreme high flows (Q5) relative to baseline. *Go with the Flow* is somewhere between these two sets of scenarios in its environmental performance and simulated discharge. The high sensitivity to land cover change exhibited by some catchments emphasises the importance of considering the implications of modifications to land cover associated with different land management responses options.

The observation that differences between the 'green' scenarios of *Green and Pleasant Land* and *Nature@Work* and the ‘less green’ *World Markets, National Security*, and *Go with the Flow* scenarios are more pronounced for extreme hydrological events (e.g. Q5) than average annual discharge is especially interesting, because of its implications for flood and drought management. This is most apparent for the Enborne at Brimpton, which is a catchment underlain by impervious clays and so where surface and near-surface hydrological pathways are relatively important (Wade *et al.* 2012).

The analysis suggests that each of the selected catchments responds differently to the same UK NEA scenario. For some hydrological indicators such as Q95 this is particularly evident. To this end, it is not possible to infer from one catchment, what the same scenario might mean elsewhere. The variability in response across catchments is in large part due to the spatial variability in land cover associated with the scenarios. Hydrological response at the catchment scale is a function of many factors including climate, topography, soil types and vegetation cover and so to some extent, the hydrological response verifies the plausibility of the UK NEA scenarios.

The good fit between the simulated and observed discharge data (estimated by NSE) indicates that the land cover data can be used to calculate plausible representations of discharge under different land cover scenarios. The 1km x 1km resolution of the UK NEA scenarios was appropriate for this hydrological modelling exercise and represented a higher input spatial resolution than the best available climate data (5 km).

Although for some catchments changes in discharge were relatively small between the scenarios and between the scenarios and present baseline, this is what might be expected, as according to the scenarios land cover in most areas does not change radically. It should also be noted that discharge is affected by many other factors that we kept constant across the baseline and scenario simulations, including topography and climate.

An important finding is that in relative terms the changes in the magnitude of low flows are almost always greater than the changes in high flows. Increasing the discharge during periods of low flow, as well as the average flow, may be thought more important in catchments where drought is more of an issue than flooding. This would be important in catchments which supply major reservoirs. Specifically, there are differences between scenarios such as *Green and Pleasant Land*, which we have found likely to be associated with lower levels of high flows, higher risk of low flows and declines in average flows, and *World Markets*, where the opposite is the case. These differences need to be considered on a catchment by catchment basis, taking into account the main users of water within the drainage basins, current and projected water management strategies, and the role of water in general. To this end, our study, limited to 34 UK catchments, suggests that whether one scenario is “preferable” or not varies by location, with the majority of catchments little affected by changes in land cover under the scenarios, but with worsening of flooding or drought in some areas.

To some extent, this means that within the context of water resources management, qualification of ‘good land management’ is catchment-specific. Maltby and Ormerod (2011) noted the ‘slowing-down’ of water as a requirement in future water resource management; our results indicate that under the scenarios we considered the magnitude to which water can be ‘slowed-down’ by land cover change is catchment-specific. This conclusion supports the UK Government’s ‘Catchment Based Approach’ (Defra, 2013a) to river management, which aims to meet the targets under the European Water Framework Directive by encouraging greater local participation in decision-making at the catchment scale.

## 7.3.3 Farmland birds and ecosystem services in lowland agricultural systems

### 7.3.3.1 Aims and methods

Analyses of biodiversity in the UK NEA scenarios suggested that scenarios that had the highest total monetised value might also have the highest biodiversity value, and vice versa (Bateman *et al.* 2013), (see also Figure 22, p52; UK NEA Synthesis of Key Findings). If true, this would imply that land use change that reduced GHG emissions and improved recreational and urban green space values might also have biodiversity co-benefits. This could be crucially important for biodiversity conservation in the UK because it would mean that conservation could be a simple by-product of policies and practices that seek to manage land in a way that maximizes value across a range of ecosystem services. This possibility was not explicitly tested, however, within the original UK NEA. Furthermore, the measure of biodiversity value used (bird species richness) in Bateman *et al.* (2011, 2013) does not reflect UK conservation priorities, which are typically based upon the population (or range) trends of individual species (Gregory *et al.* 2004; Gregory and van Strien, 2010). It is unclear, therefore, whether measures of biodiversity value that better reflect current conservation priorities behave in a similar way to species richness measures used in the first phase of the UK NEA.

What are the potential implications of this broader ecosystems perspective for biodiversity? Since at a very general level biodiversity is an integral part of the processes that underpin ecosystem services (MA, 2005; TEEB, 2009; Mace *et al.* 2012), it is often assumed that protecting ecosystem services would also have biodiversity benefits (Foley *et al.* 2005). That is, that there are co-benefits between biodiversity value and the value of ecosystem services. Alternatively, biodiversity conservationists often express concern that an emphasis on ecosystem services might undermine existing biodiversity conservation priorities (Mace *et al.* 2012). This would be true if there were a trade-off between biodiversity value and the values of other ecosystem services. These possibilities have yet to be explored in any detail, but the UK NEA data provides an opportunity to do so.

Our aim here was to explore the relationships between the values of ecosystem services quantified by the UK NEA scenarios and biodiversity values to identify trade-offs and co-benefits between biodiversity and ecosystem services. To do this, we focus on lowland agricultural areas within the UK for two reasons. First, it is in these areas that the intensification of agriculture has led to substantial increases in the output of provisioning services (crop and livestock production) whilst resulting in significant biodiversity loss and ecosystem degradation (Vickery *et al*, 2001; Robinson and Sutherland, 2002; Foley *et al.* 2005; Stevens *et al.* 2010). Second, there is a substantial body of knowledge on the relationship between biodiversity and land-use change that can be used to assess biodiversity value. If co-benefits with other ecosystem services are important, we would expect to see biodiversity value increasing across the UK NEA scenarios as the total value of the other ecosystem services increases. That is, it should be highest for the *Green and Pleasant Land* and *Nature@Work* scenarios and lowest for the *National Security* and *World Markets* scenarios. In contrast, if trade-offs with other ecosystem services are important we would expect to see the opposite pattern – biodiversity value should decrease across the UK NEA scenarios as the total value of other ecosystem services increases. The aim of our analysis was to distinguish between these possibilities. Note that we excluded the values of urban green space from our analysis because these are not important in the context of agricultural landscapes.

Although farmland biodiversity consists of a wide range of plant and animal species (Foley *et al.* 2005; Butler *et al*. 2009), our analyses focus on farmland birds. This is because a range of modelling approaches exist that allow us to quantify how land-use change is likely to affect the ecological value of farmland for birds (Butler *et al.* 2010; Butler and Norris, 2013); and the long-term population trends of birds are well characterised in the UK (Fuller *et al.* 1995; Siriwardena *et al.* 1998; Fewster *et al*. 2000; Gregory *et al.* 2004; Gregory and van Strien, 2010). Such quantitative approaches are simply not feasible for other biodiversity groups at present. Specifically, we apply two approaches to the UK NEA scenario data. First, we use Functional Space Models (FSMs) to explore how the land cover/use changes predicted by the UK NEA scenarios might impact on the population trends of the 19 farmland bird species that make up the farmland birds index (FBI) (Butler and Norris, 2013). This approach translates agricultural land-use into the quantity and quality of nesting and feeding resources required by each species, and then explores how this functional space relates to population growth. In this way, it is possible to use FSMs to examine how land-use change is likely to impact on population trends due to the way it modifies the quantity and quality of available nesting and feeding resources. Second, we use a mechanistic model of seed-eating birds to explore how UK NEA land cover/use changes might impact on seed resources and hence on bird species dependent on these resources. This is potentially important because increased annual mortality linked to the loss of seed-rich habitats has been identified as a key demographic mechanism behind the declines of a number of farmland bird species (Siriwardena *et al.* 2000). Furthermore, increasing the availability of seeds during winter can improve survival and local abundance for certain species (Peach *et al.* 2001; Siriwardena *et al.* 2007). This means that seed-eating species are a sensitive ecological group to land-use change; hence their inclusion in our analyses.

***Functional Space Models***

Our FSMs were originally developed using the land-use classification system adopted by the Breeding Bird Survey (BBS) and Winter Farmland Bird Survey (WFBS) (Butler and Norris, 2013). The FSMs translate land cover/use data into the quantity and quality of nest and foraging resources available to each species (functional space), and then describe the relationship between functional space and the annual rate of population growth across all BBS squares occupied by a particular species. We have developed functional space models for all 19 species that make up the farmland birds index (FBI)) (Butler and Norris, 2013). Subsequently, we have tested our FSMs to see how well they are able to reconstruct current population trends based on functional space, particularly distinguishing species with a declining trend from those with a stable/increasing trend; and have shown the models are adequate as a basis for quantifying population trends across the 19 species (Hicks *et al*. unpublished data). This means we can use the models as a basis for assessing changes in biodiversity value associated with changes in land cover/use.

To apply our FSMs to the UK NEA land cover/use data associated with the scenarios requires the translation of the UK NEA classification into BBS/WFBS land-use classes. Since the BBS/WFBS classification used by our FMSs is finer-scale than the UK NEA system, we devised a set of rules that disaggregate the NEA land cover/use classes into the various BBS/WFBS land-use classes within them (see WP7 Report: Supplementary Material 6). We treated the BBS and WFBS data separately because our FSMs use these data to estimate the quality and quantity of functional space available during the breeding (BBS) and non-breeding (WFBS) periods (Butler and Norris, 2013). For WFBS data, we treated non-arable and arable land-use types differently. This is because an arable land-use type may change into a range of different habitats over the winter depending on the rotation system, and these different habitats are likely to have very different ecological values (see WP7 Report:  Supplementary Material 6 for a more detailed description of the methods used).

In this way we set-up our FSMs for the six UK NEA scenarios and a '2010 Baseline'; we used the high climate change variants of the scenarios' land use data described in Bateman *et al*. (2011, 2013), which were originally generated using the UK NEA scenarios land cover data (Haines-Young et. al. 2011, Bateman *et al*. 2011).  The baseline land use data was also the same as that used in Bateman *et al*. (2011, 2013). We estimated the annual population growth rate for each of the 19 farmland bird species in each scenario. For each species, the model was run for every 1km x1 km square in which the species was recorded as present in at least three or more years between 1994 and 2007. From these outputs we could estimate national population trends for each species, and for the farmland bird's index. A key assumption was that as land-use changed across the UK NEA scenarios the proportions of our BBS land-use types within each UK NEA land cover/use class would remain the same. This meant that as land-use changed across the UK NEA scenarios we assumed that the proportions of our BBS land-use types within each UK NEA land cover/use class remained the same.

***Mechanistic Models of Seed-eating Birds***

The mechanistic model of seed-eating birds we used is a spatial depletion model based on a series of patches (fields) within a landscape that vary in the type and quantity of seeds available to seed-eating birds based on crop type and management (Butler *et al.* 2010). The model tracks the availability of crop (oil and cereal seeds) and weed seeds through the post-harvest (stubble) period in these fields from summer through the subsequent winter on a daily basis. It incorporates seed mortality in the form of predation by birds and other losses, and seed input due to seed rain (weed seeds). The model can then be used to ask whether food resources are sufficient to support a specified number of seed-eating birds over the winter. This is usually expressed as bird-days (number of birds x number of days) supported over the winter, and hence this statistic provides a measure of the value of a landscape for seed-eating birds. The model recognises two types of seed-eating birds – a yellowhammer-type that preferentially forages on cereal seeds but will also consume weed seeds; and a linnet-type that avoids cereal seeds but forages on oil and weed seeds. This was done to reflect the ecological diversity among seed-eating bird species.

In previous work the model has been set-up so it can simulate seed dynamics and seed-eating bird populations for over 500 1km x 1km lowland agricultural squares covered by the Breeding Bird Survey (BBS) and Winter Farmland Bird Survey (WFBS) (Butler *et al.* 2010). By changing land-use within these squares according to the UK NEA scenarios we can explore the potential impacts on seed-eating bird populations. To do this we translated the UK NEA land use data into the availability of over-winter stubbles arising from the crop types recognised by our model (see WP7 Report: Supplementary Material 6 for a description of the methods used). In contrast to previous work (Butler *et al.* 2010), which used data in the WFBS survey on the areas of different stubble present during the winter, we needed to assume that after harvest the entire area of each arable UK NEA land cover/use class persisted as stubble until November. This would have overestimated the total but since the same assumption was made across UK NEA scenarios we are able to compare model outputs between scenarios, and look for spatial associations between model outputs and other ecosystem services within scenarios.

In this way, we set-up our model for the Baseline and six UK NEA scenarios using the land cover/use data generated by these. We populated each square with 500 individuals of each bird ecotype (i.e. ‘yellowhammer’ and ‘linnet’). This density was considered high enough to allow discrimination between landscapes in terms of resource availability and population persistence without being so high that resource availability was insufficient for populations to persist (Butler *et al.* 2010). Note that this bird density is higher than we used previously (Butler *et al.* 2010) but reflects the fact that we over-estimate seed availability (see previous paragraph). All other parameters, such as initial seed densities, levels of weed seed rain and seed survival were similar to those used in Butler *et al.* 2010). We ran the model for each UK NEA scenario and extracted the total number of bird-days supported over the winter for each square as a measure of its ecological value for seed-eating birds.

#### 7.3.3.2 Results

To explore changes in population growth rates across the UK NEA scenarios we used two statistics. We calculated the average population growth rate across all 19 species, which is equivalent to the farmland bird index (Gregory *et al.* 2004). This is widely used as a measure of the health of farmland bird populations. We also calculated the average population growth rate across a subset of species that had declining population trends (i.e. negative population growth rates) under the 2010 baseline because these species would be of greater conservation concern than those with a stable or increasing trend. We then compared changes in these population growth rate statistics between the Baseline and each of the other scenarios (**Figure 7.5**). We found no evidence of co-benefits between the population growth rates of farmland birds and the overall value of ecosystem services; but some evidence of trade-offs. Overall, the impact of land-use change across the UK NEA scenarios had a rather small effect on population growth rates – the changes estimated by our FSMs are small relative to the variation in population growth rates across species (**Figure 7.5**) (Baseline: -0.083

[turtle dove] to 0.026 [greenfinch]). The only statistically significant change was for declining species under *Green and Pleasant Land*, where population growth rates became significantly more negative (one-sample t-test: $t = -2.4$, $P = 0.037$)

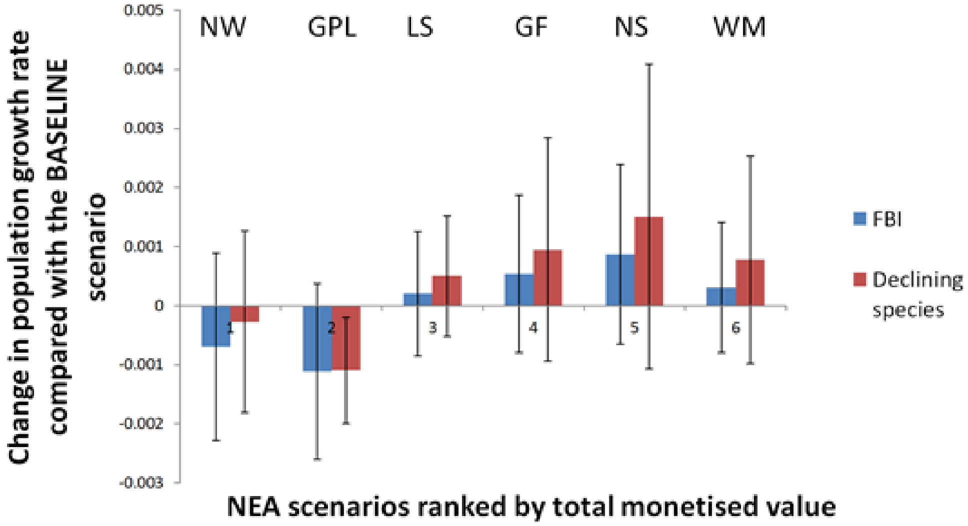


**Figure 7.5. The potential impact of the UK NEA scenarios on the ecological value of land for farmland birds. The UK NEA scenarios are ranked by total monetised value (1=highest). Scenario codes follow those used in the UK NEA. The plots show the difference in population growth rates between each scenario and the BASELINE. Bars show the mean change ± 95% CI. Negative values indicate a decrease in population growth rates between the scenario and the BASELINE.**

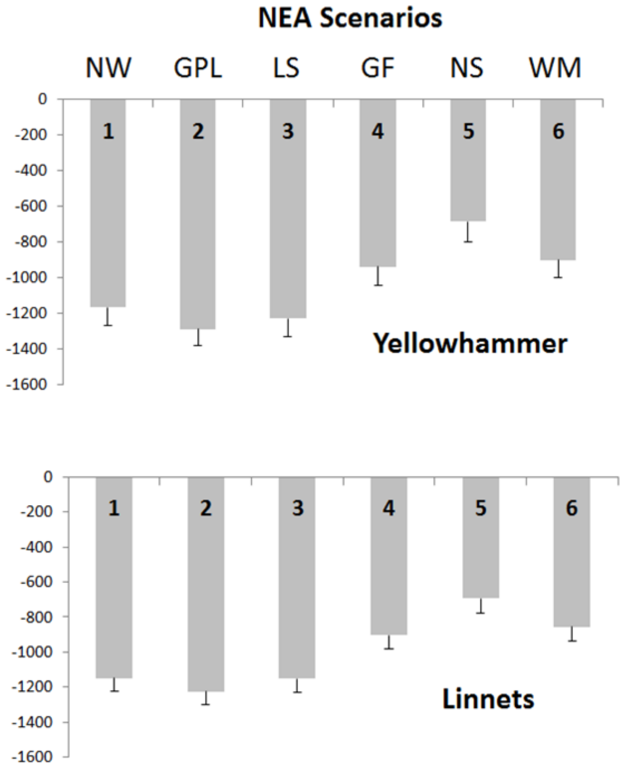


**Figure 7.6.The potential impact of the UK NEA scenarios on the ecological value of land for seed-eating birds. The UK NEA scenarios are ranked by total monetised value (1=highest). Scenario codes follow those used in the UK NEA. The plots show the difference in total bird-days over-winter between each scenario and the Baseline. Bars show the mean change and 95% CI. Negative values indicate a decrease in bird-days between the scenario and the BASELINE.**

To explore the potential impact of land-use change associated with each UK NEA scenario on seed-eating bird populations, we compared the change in yellowhammer and linnet bird-days over-winter between the Baseline and each scenario (**Figure 7.6**).The two bird ecotypes show comparable responses. There is a significant decline in the ecological value of lowland agricultural areas for seed-eating birds across all the UK NEA scenarios. Interestingly, this impact is greatest for the scenarios with the highest monetised values for ecosystem services (*Nature@Work, Green and Pleasant Land, Local Stewardship*) but lower for scenarios with the lowest monetised values (*Go with the Flow, National Security, World Markets*). Across scenarios, this suggests a trade-off between the ecological value of land for seed-eating birds and the values of other ecosystem services within UK lowland agricultural areas.

The evidence from our models suggests that land use change associated with the scenarios that have the highest monetised value for ecosystem services have the lowest ecological value for farmland bird populations (**Figure 7.5** and **Figure 7.6**). These changes seem to largely reflect changes in the area of major arable crops (oil seed rape, cereals, and root crops) (**Figure 7.7** and **Figure 7.8**). Compared with the Baseline, there is a decrease in the area of these crops across all scenarios, but this decline is greatest for those scenarios that have the highest total monetised value (i.e. *Nature@Work, Green and Pleasant Land*). This is because of changes in the way agricultural land is used but also because of land cover changes to non-agricultural habitats (e.g. woodlands), which are less suitable for farmland birds but important for other ecosystem services (e.g. greenhouse emissions and recreation values). Both the changes in population growth rates **(Figure 7.7)** and the total bird-days over-winter for seed-eating birds **(Figure 7.8)** are strongly correlated with the changes in arable area, so the impact on farmland birds is the least for scenarios in which the decrease in the area of major arable crops is relatively small. This explains the trade-off between total monetised value and the value of land for farmland birds across the UK NEA scenarios.

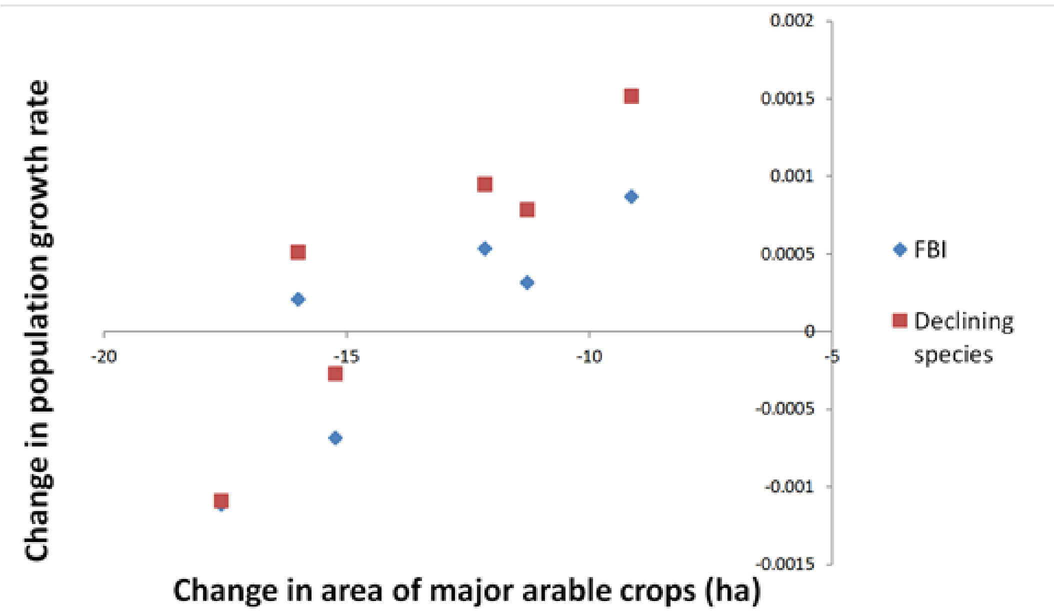


**Figure 7.7.The relationship between the change in the population growth rates of farmland birds and the change in area of major arable crops for each UK NEA scenario. The correlations for all 19 species (FBI) and declining species are highly significant (FBI: $r$ = 0.85, $P$ = 0.031; Declining species: $r$ = 0.89, $P$ = 0.017).**

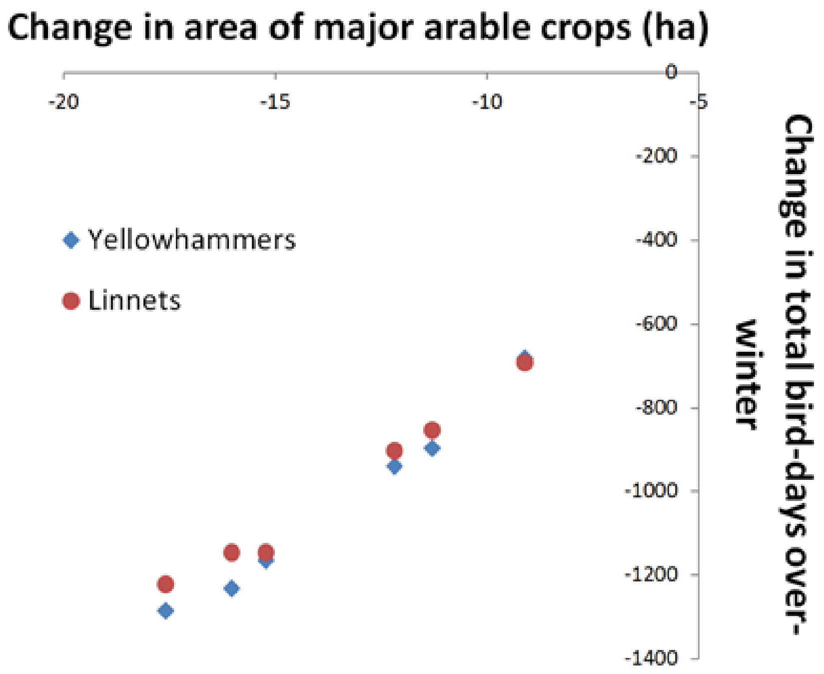


**Figure 7.8. The relationship between the change in the ecological value of land for seed-eating birds (bird-days over-winter) and the change in arable area for each UK NEA scenario. The correlations for yellowhammer and linnet are highly significant (*r*>0.9, *P*<0.0001).**

#### 7.3.3.3 Discussion and Conclusions

The significance of the potential impacts of land cover/use change on farmland birds reported here rests on the ecological efficacy of the models we used in the impact assessment. Our original FSMs and mechanistic model of seed-eating birds were developed with land use data from the Breeding Bird Survey (BBS) and Winter Farmland Bird Survey (WFBS) (Butler *et al.* 2010; Butler and Norris, 2013). Here, we have used UK NEA land-use data generated from an econometric model (Fezzi and Bateman, 2011), which we have subsequently disaggregated into the land use types recognised by our models. This required us to assume that the relative areas of different land-use types within UK NEA land use classes remained unchanged across scenarios, and required the use of large-scale data for the disaggregation process for some squares because of discrepancies between the observed and model-generated UK NEA land use data. However, performance tests of our models, which we report on in the supplementary material, suggests that they matched real data well and showed similar relationship to those reported by Butler & Norris (2013) (see WP7 Report: Supplementary Material 6).

Our analyses found no evidence of co-benefits between farmland biodiversity and the value of ecosystem services across the UK NEA scenarios, but some evidence for trade-offs. The ecological value for farmland birds was lowest for the scenarios that had the highest total monetised value for ecosystem services (i.e. *Nature@Work, Green and Pleasant Land*) (**Figures 7.5** and **7.6**). We found rather small changes in the population growth rates of farmland birds across the UK NEA scenarios, but we did document a significant deterioration in the population growth rates of species of conservation concern under the *Green and Pleasant land* scenario. We found stronger but comparable patterns for seed-eating birds. The health of farmland bird populations is widely used as a measure of the conservation value of farmland and hence the sustainability of farming practices (Gregory *et al.* 2004; Gregory and van Strien, 2010). Furthermore, significant public funds are invested in agri-environment schemes that are designed to improve the biodiversity value of farmland in general (Kleijn *et al.* 2011), and halt and reverse population declines among UK farmland birds in particular (Kleijn *et al.* 2011). Our results suggest that scenarios associated with significant improvements in the value of ecosystem services are not well aligned with these conservation priorities in lowland agricultural landscapes. In general terms, biodiversity conservation may not be a simple by-product of improved policies and practices that protect the values of other ecosystem services, at least in the context of farmland birds in UK lowland agricultural landscapes.

Why does this trade-off exist? Changes in land-use and land cover associated with the UK NEA scenarios with the highest monetised value for ecosystem services result in the loss of important agricultural habitats for farmland birds (**Figures 7.5** and **7.6**). Major arable crops provide key nesting and foraging resources for a range of farmland bird species, particularly when spring-sown crops form part of the rotation system (Gillings *et al.* 2005; Baker *et al.* 2012). The loss of these resources drives the changes in farmland bird populations described by our models. The loss of arable habitats is caused by changes in land cover, particularly an increase in the area of woodland. These changes result in major benefits to ecosystem services: they reduce greenhouse gas emissions and increase recreational values significantly (Bateman *et al.* 2013). These land cover changes may have biodiversity benefits, particularly for woodland species, but this is not assessed here. Nevertheless, the key point is that land cover/use changes that benefit ecosystem services the most have a detrimental impact on the conservation value of farmland across the UK NEA scenarios.

One option for dealing with this type of trade-off in terms of land use planning would be to consider minimizing the impact of land-use change on conservation values as a constraint (Bateman *et al.*, 2013). For example, in lowland agricultural landscapes the *Local Stewardship* scenario has a minimal impact on population growth rates across farmland bird species (**Figure 7.5**), a negative impact on the provision of arable habitats for seed-eating birds (**Figure 7.6**), but positive impacts on ecosystem services and farm gross margins (Bateman *et al.* 2013, WP7 Report: Supplementary Material 6, Table 1). If agri-environmental management could be deployed to reduce the impacts on seed-eating birds, then the land use changes under the *Local Stewardship* scenario would improve the profitability of farms and increase the value of ecosystem services; whilst minimizing any adverse impacts on farmland biodiversity. This shows that linking biodiversity modelling with the spatial analysis of ecosystem services can provide a powerful framework for identifying and addressing potential conflicts caused by land use change.

In summary, our results suggest that outcomes for ecosystem services and biodiversity will depend critically on the specific impacts of the land cover/use changes involved. An Ecosystems Approach enables biodiversity values to be considered alongside the values of other ecosystem services in decision-making (Bateman *et al*. 2013).

## 7.3.4 Modelling Marine Ecosystem Services under the Scenarios

### 7.3.4.1 Aims and Methods

The UK NEA provided monetary estimates for some marine and coastal ecosystem services in the form of UK or national totals. However, in contrast to work conducted for terrestrial environments, it did not seek to make these values spatially explicit nor attempt to value marginal changes (Austen *et al.* 2011). Mapping of marine ecosystem services will be an important information source for the UK implementation of the Marine Strategy Framework Directive, and to support the development of sustainable policies within marine plans, and so it is important that further work is done in this area. In this section, we explore how marine and coastal ecosystem services values can be allocated spatially, and explore how changes in the distribution and intensity of marine and coastal ecosystem services might be modelled in the context of the UK NEA scenarios (see also Hull *et al.* in press, and WP7 Report: Supplementary Material 7).

Scientific understanding of the ecosystem services delivered by marine and coastal habitats is poor (Austen *et al.* 2008; Bournemouth University & ABPmer, 2010; Potts *et al.* 2013). Particular difficulties arise from the coarse scale at which habitats and marine features have typically been mapped (Medcalf *et al.* 2012; Cefas & ABPmer, 2010), large gaps in the availability of data, especially for sea bed habitats (Cefas & ABPmer, 2010), and a lack of information on habitat condition and ecosystem processes (Austen *et al.* 2008). Furthermore, mapping is complicated by the need to include a variety of abiotic and biological factors, including processes occurring in the water column (eftec and ABPmer, in prep.). In addition, the effect of human pressures on the delivery of marine and coastal ecosystem services is not well understood (Austen *et al.* 2008; ABPmer & eftec, 2012); the open nature of marine systems and wider public rights of access also mean that the effects of human pressures on ecosystem service delivery can be more significant than in terrestrial environments.

Some assessments have been able to combine information on the response of marine ecosystem services to various drivers linked to changes in human or natural pressures. For example, spatial matrices of the sensitivity of broad sea bed habitats to disturbance from fishing gears were produced by Tillin *et al.* (2010), and Defra (2013b), and can be combined with maps of the spatial intensity of fishing activity to estimate changes in secondary productivity and its effect on harvestable fish production (see Dunstone, 2008; Finding Sanctuary, 2012; Vanstaen, 2010). However, the nature of the information available has meant that the relationships could not be mapped with a high degree of accuracy. The Defra and Marine Scotland *Business as Usual* Scenarios Project (ABPmer & eftec, 2012) also developed some additional pressure layers, including, for example, changes in sea bed sediment type associated with construction activity in the marine environment. Furthermore, Government Agencies such as JNCC and Cefas have an on-going programme of work to map human pressures, but currently few outputs are available.

Challenges therefore remain in estimating the relative importance of the factors controlling marine and coastal ecosystem services. For example, secondary productivity is likely to be particularly important for fish production. However, spawning and nursery areas also play a critical role. Thus judgements need to be made on how to combine contributing factors within a model, say, by using the relative contribution of different life stages to production.

Other previous studies have modelled future change in marine ecosystem services (e.g. ABPmer & eftec (2012), Tallis *et al.* (2013), Villa *et al.* (2009), Hull *et al*. *in press*); this includes work for the UK implementation of MSFD, based on the DPSIR framework (eftec & ABPmer*, in prep*). All of these methods require application of high level judgement. As a result, the translation of the UK NEA scenarios into spatial models of potential changes in marine ecosystem services delivery requires a number of assumptions to be made relating to locations and time periods over which change might occur, and how these changes might influence ES delivery.

#### 7.3.4.2 Conceptual modelling and mapping approaches

Changes in the ecosystem services of interest were modelled conceptually within the framework of the UK NEA scenarios. To do this we set out how the overall scenario assumptions would play out in detail in different coastal and marine futures, and developed maps to display the likely spatial changes that would result. Maps were therefore produced for time slices of 2015, 2030 and 2060 for a 2008 baseline for fish and shellfish (capture fisheries), fish and shellfish (aquaculture) and carbon sequestration. The study area was defined as the UK Continental Shelf (UKCS), modelled as a 2km x

2km km grid, using a British National Grid projection. We used UKCS wide spatial data for all three service types for each time slice. These maps were generated for the 2010 Baseline, *World Markets* (WM), *Nature@Work*, *National Security* (NS) and *Local Stewardship* (LS) scenarios. The subset was selected because it was felt that these were sufficiently diverse in relation to how the drivers of change would play out under different possible futures. These scenarios are also more closely aligned to those used in other marine work (see Hull *et al.,* in press). In the case of all three service types, we used the available information to derive estimates of the 2008 spatial baseline, and the drivers of temporal and spatial change.

For the fish and shellfish capture models, we used information on fisheries' catch value produced by Dunstone (2008) at 0.05º resolution, and reallocated this to a $2km^2$ grid. For aquaculture, the locations of fish and shellfish farms were taken from maps prepared for *Charting Progress 2* (UKMMAS, 2010). Analysis of fish farm production levels apportioned the total £147m GVA from aquaculture to approximately £134.5m for fin fish and £12.5m for shellfish. This equates to average revenue of approximately £520k per farm.

In the absence of any published overall value for carbon sequestration from UK seas, we used information from published sources (Thomas *et al*. 2005; Nelleman *et al.* 2009; IUCN, 2009) to estimate carbon sequestration from UK waters, including the influence of the North Sea carbon pump (Thomas *et al*. 2005) and the sequestration by saltmarsh. To prepare an economic valuation, quantities of carbon were converted to tonnes of $CO_2$ and then multiplied by the price of non-traded carbon (£52 per tonne, 2011 value).

To estimate how these services would change under the scenarios, a number of further assumptions were made about how UK waters would be managed under each of the scenarios (**Table 7.3**). Expert judgement was used to translate these qualitative descriptions into quantified changes over time (**Tables 7.4** and **7.5**). For fisheries, we took account of the fact that the spatial patterns may be influenced by changes to existing stocks, displacement in relation to some MPAs and offshore infrastructure developments (e.g. offshore wind farms) and climate change. MCCIP (2010) predicts, albeit with a low level of confidence, that the UK will benefit from climate change with slightly higher fishery yields by 2050 (i.e. + 1-2% compared to present), although the Irish Sea and English Channel may see a reduction. However, for the purposes of the spatial modelling, changes in the distribution of fishing activity were only considered in relation to potential displacement from MPAs (based on proposals for English MCZs), and from future offshore wind farm development. It has been assumed that fishermen will adapt their effort and methods to the inward and outward movement of stocks brought about by climate change, rather than by moving their activities elsewhere. It has also been assumed that all MPAs be would in place before 2018 and that under all four scenarios demersal fishing would be excluded from all MPAs and all offshore wind farms which are projected to be developed under the scenarios. Whilst both these assumptions may act to underestimate the spatial extent of fishery activity it should also be noted that proposals for MPAs in the devolved administrations are still being developed, potentially leading to higher levels of displacement in these regions.

**Table 7.3. Assumptions concerning three aspects of marine production use to inform the marine modelling work.**

| | Fisheries | Aquaculture | Carbon Sequestration |
|---|---|---|---|
| **WM** | Decline in Fish Stocks due to overexploitation. Increase in effort from trawl and dredge fleet. Increasing import of seafood, especially low-quality farmed seafood from Asia | Significant increases, focused on production volumes/value, for consumption and export. Production at expense of natural environment and wild fish stocks. Increasing use of non-native species. | High CO2 emissions lead to ocean acidification, reducing the ability of the ocean to take up atmospheric CO2 and resulting in a reduction in sequestration. |
| **N@W** | Fisheries more productive because better managed and mostly at Maximum Sustainable Yield. Reduction in effort from trawl and dredge fleet | Some increase. Better environmental stewardship and development of fish feeds from non-marine sources. Use of some non-native species. | Emphasis of sustainability prevents an increase in ocean acidification |
| **NS** | Fish stocks in UK waters are protected from foreign vessels and exploited sustainably by UK vessels. Fish stocks in non-UK and those that straddle UK waters not managed sustainably. Overall production declines slightly. | Increases to supplement wild fisheries production, within limits set by availability of finance. Environmental pollution and depletion of wild forage species – herring, mackerel and blue whiting fisheries used to support fish feed industry. | Some reduction in carbon sequestration because global climate targets are considered of secondary importance and medium-high GHG emissions lead to ocean acidification and a reduced ability of the oceans to absorb atmospheric CO2, again resulting in a reduction in sequestration. |
| **LS** | Initial slight decline due to loss of large-scale fleet but limited stock recovery leads to increase over time. Some localised stock overexploitation in coastal waters - Catch per Unit Effort increases in some cases, declines elsewhere | Greater emphasis on integrated farming-aquaculture practices and cultivation of herbivorous fish and shellfish at local level. | Emphasis of sustainability and relatively low growth prevents an increase in ocean acidification |

**Table 7.4. Assumptions on changes in fish and shellfish (capture fisheries) landings values (percentage of baseline value).**

| | Year | World Markets | Nature @ Work | National Security | Local Stewardship |
|---|---|---|---|---|---|
| **Capture Fisheries** | 2015 | 100% | 90% | 100% | 90% |
| | 2030 | 85% | 120% | 90% | 105% |
| | 2060 | 35% | 150% | 90% | 120% |
| **Aquaculture** | 2015 | 150% | 125% | 162% | 150% |
| | 2030 | 180% | 144% | 202% | 172% |
| | 2060 | 225% | 165% | 130% | 162% |
| **Carbon Sequestration** | 2015 | 100% | 100% | 100% | 100% |
| | 2030 | 95% | 100% | 95% | 100% |
| | 2060 | 85% | 100% | 90% | 100% |

For aquaculture, it has been assumed that there would be some growth due to improvements in aquaculture techniques (fish feed, fish health and farming methods) that would simply increase the output from existing farms rather than increase their spatial extent. The annual increased output due to technological improvements varied from 0.5% to 2% across the scenarios depending on availability of capital under each scenario. It is assumed that there would be a high level of capital available for investment in new technology, and therefore capacity is projected to increase by 2% annually for the first 20 years and then 1% annually as the market tapers off to 2060. Under *Nature@Work*, although there is capital available, it is assumed that there is less demand for farmed fisheries, therefore capacity increases start at 2% and taper off to 0.5% after 50 years. Under *National Security*, it is assumed that although there is high demand for farmed fish, there is less capital available compared to *World Markets*, therefore capacity increases start at 2% for the first ten years and then decreases to 0.5% annually. It is assumed that there is even less capital available under *Local Stewardship*, which starts off at annual increases of 1% and decrease to 0.5% per year.

For aquaculture, further growth was assumed to occur through the development of new farms and the farming of new species (see **Table 7.5**). Site selection of new fin-fish farms is assumed to be focused on sheltered areas in estuaries and areas of the Scottish coast where there are already existing markets and infrastructure (e.g. fish processing) to support the industry, but there could be a gradual increase in England and Wales as well, as the industry gathers momentum. Likewise, new shellfish farms are assumed to be developed within regions where there were existing farms, including England and Wales as well as Scotland. Fin-fish and shellfish farms are dependent on good water quality and suitable current flow. Therefore, a potentially important constraint is that shellfish farms and fin fish farms could not be close together and that all such farms need to avoid existing shipping routes and sewage disposal outfalls. Where it was estimated that no viable sites remained within existing areas, offshore farms were created, focussed on offshore wind farms as bases.

**Table 7.5. Assumptions on increases in aquaculture production from existing farms.**

| | Year | Total Value | Capacity Increase | New farms |
|---|---|---|---|---|
| **Baseline** | 0 | £147m | | |
| **World Markets** | 2015 | £221m | £29m | £44m |
| | 2030 | £265m | £36m | £53m |
| | 2060 | £331m | £63m | £56m |
| **Nature@Work** | 2015 | £184m | £29m | £7m |
| | 2030 | £211m | £18m | £17m |
| | 2060 | £243m | £29m | £20m |
| **National Security** | 2015 | £198m | £29m | £22m |
| | 2030 | £238m | £18m | £44m |
| | 2060 | £298m | £58m | £45m |
| **Local Stewardship** | 2015 | £191m | £15m | £29m |
| | 2030 | £220m | £16m | £42m |
| | 2060 | £253m | £53m | £21m |

It is difficult to project temporal changes in carbon sequestration over time, owing to the limited current understanding of the factors determining carbon sequestration in UK waters and uncertainties concerning how ocean acidification may influence it. Acidification caused by higher $CO_2$ emissions is known to reduce the capacity of the oceans to absorb $CO_2$ and so assumptions on temporal change were therefore made based on expected levels of atmospheric $CO_2$ under the scenarios (**Tables 7.3** and **7.4**). In the absence of detailed information on how the processes governing carbon sequestration might change in the future, it was not possible to identify how values for carbon sequestration might change spatially.

#### 7.3.4.3 Results

***Fish and shell fish capture***

The mapping exercise suggested that there were differences in the scale of potential total landings between scenarios, especially between *World Markets* and the other scenarios (for example, compare *World Markets* 2060 with *Nature@Work* 2060 (**Figure 7.9**). While the number of areas from which fisheries may be displaced varies between the scenarios (reflecting the extent to which offshore wind development might proceed), a striking feature is that most OWF development zones and proposed MPAs are located in areas of currently low fisheries value. These areas are shown as white blocks, indicating no fishing on the scenarios maps, but show fishing activity for the present baseline. Although the potential displacement areas are large, they do not appear to impact on the existing distribution of fisheries. It should be noted that, while the maps indicate locations of fish harvesting, this may be different from areas of fish production; the method used does not fully take account of spawning and nursery areas, but some harvesting does occur in areas where fish aggregate to spawn.

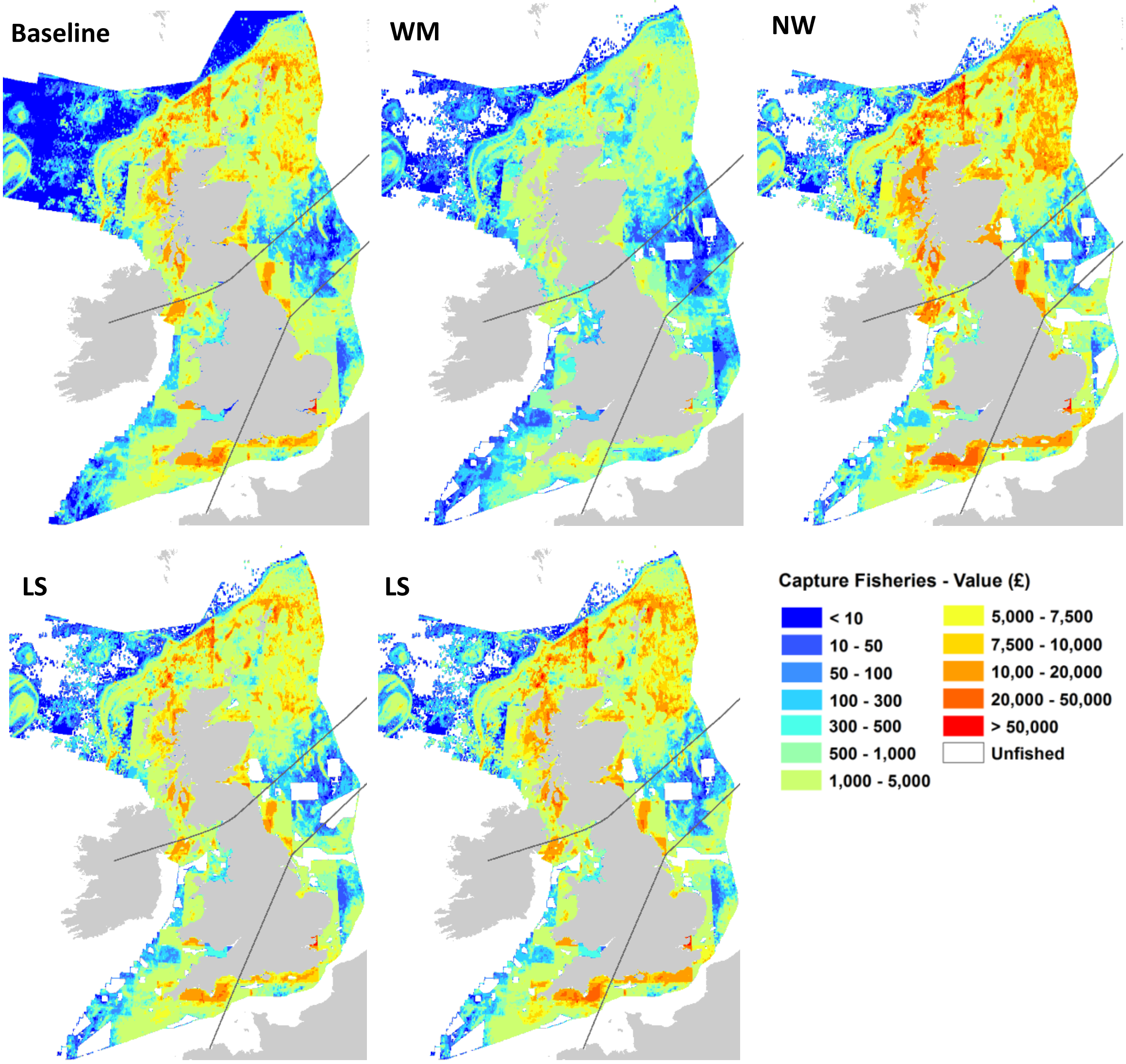


**Figure 7.9. Fish and shellfish landings values, for 2008 Baseline, and 2060 for *World Markets* (WM), Nature@Work (NW), *National Security* (NS) and *Local Stewardship* (LS) scenarios. The grey line indicates separation into North, South and Mid regions used in Figure 7.10.**

We looked for regional patterns in our projections by summarising the mapped data for capture fisheries according to the marine regions identified by WP4 (**Figure 7.10a**). It can be seen that although patterns are broadly similar across regions, northern areas were projected to show a particularly marked decline under *World Markets* between 2030 and 2060, with the equivalent data for southern areas showing the least dramatic declines.

***Aquaculture***

All scenarios were characterised by a projected expansion of aquaculture, and particularly under *World Markets*, where commercial fish landings are projected to the show strongest declines. An examination of regional patterns of the spatial data (**Figure 7.10**) showed sharp increases in GVA in the 'Mid' region for all scenarios except *Nature@Work*, and especially for *World Markets* (from £1.2m for the baseline to £103m at 2060). However, by 2060, even for *World Markets*, GVA in this region was at most only about half of that in the North, which had also increased in value, but less sharply. Southern areas showed very little increase in GVA from the baseline, with only *World Markets* (£ 7.9m) reaching values above £1.7m.

The coastline of the west of Scotland is currently responsible for a large amount of aquaculture production, and this level increases under all the scenarios, but less sharply for *World Markets* than for the other scenarios. The scenarios also suggest an expansion of aquaculture into offshore waters and south of the Scottish border, reflecting the strong growing demand for aquaculture products and the more limited scope for expansion within existing Scottish inshore sites due to environmental capacity constraints. This is especially noticeable for *World Markets* (**Figure 7.10**). Comparisons of the projected values for the different scenarios over time show the importance of capital investment in the development of this sector. Our analysis suggests that assumptions about differences in the availability of capital under the different scenarios have a greater influence on the predicted values than those made about changes driven by consumer demand or the price of wild-caught fish.

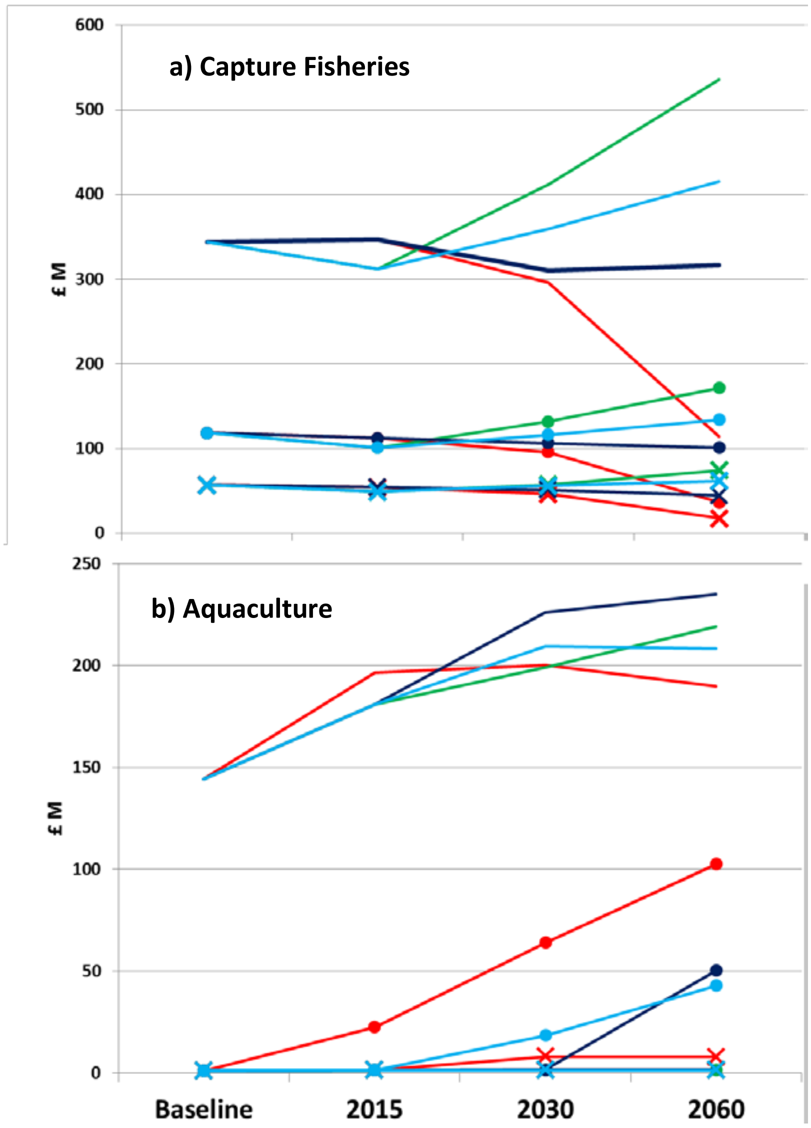


**Figure 7.10. GVA (£M) estimated for Capture Fisheries (a) and Aquaculture (b), for 2008 Baseline and each of four scenarios in 2015, 2030 and 2060. Data are broken up into 3 regions – North (N), South (S) and Mid (see Figure M3 for a map of the regions). Grey text in the legend indicates that data points may not be visible for Aquaculture as they are overlaid by other data at very low values throughout the series.**

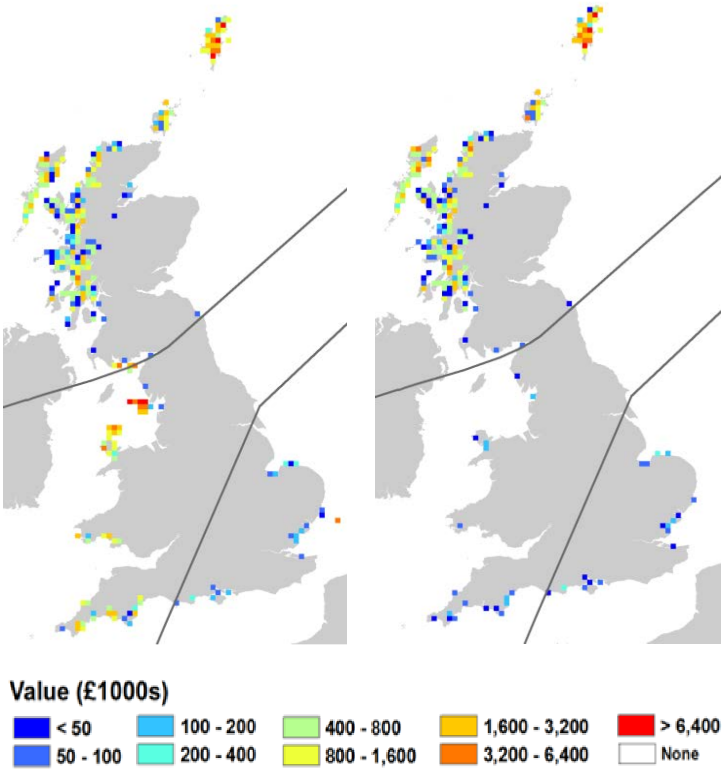


**Figure 7.11. GVA from Aquaculture, estimated for the 2008 baseline, and for 2060 for two of the UK NEA scenarios: *World Markets* (WM), and *Nature@Work* (NW). Data have been aggregated from a 2x2km to a 10x10 km grid.**

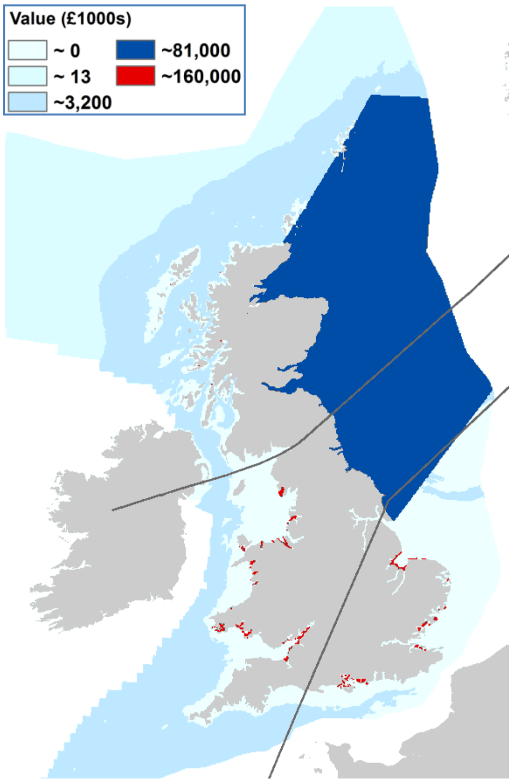


**Figure 7.12. Carbon Sequestration, by 2x2km grid square, for a 2008 baseline, estimated on the basis of the assumptions used in the marine modelling work.**

***Carbon sequestration***
The projections for the four scenarios suggest limited changes in the intensity of carbon sequestration. While changes may occur in the period to around 2060 (see **Table 7.4b**), the nature and scale of such changes are highly uncertain. The spatial baseline identified the relative contribution of the North Sea 'carbon pump' to overall carbon sequestration in UK waters (see **Figure 7.12**). While saltmarsh makes a significant contribution locally, its small extent means that it makes a minor contribution to that of UK waters as a whole. The work highlights the difficulty of mapping values for UK waters in relation to large scale processes operating at scales such as the North Sea as a whole.

#### 7.3.4.4 Discussion and conclusions

The study reported here continues to highlight the paucity of data and understanding of the drivers of change in the marine sector compared with terrestrial environments. Furthermore, the uncertainty means that the results of the modelling process must be interpreted with caution, especially in the regard to the magnitude and location of change. Nevertheless, although provisional, the results provide some insights that could form the focus of further work on marine ecosystem services.

First, under *Nature@Work*, *National Security* and *Local Stewardship*, the analysis suggests that around 2060 the value of fishery landings may be similar to, or higher than, under the current baseline, whereas they are markedly lower under *World Markets*. The latter assumes a free market approach to fisheries, with high levels of private investment. In the absence of quotas or other methods of fisheries management, one would expect stocks to decline to the point where they were no longer commercially viable. *Nature@Work* describes a world where ecosystem services are used intelligently for their contribution to human wellbeing, and so we might anticipate that steps would be taken to maintain stocks close to maximum sustainable yield. Under *National Security*, by contrast, although there is less commitment to the principle of sustainability, central government is assumed to be strong and there is relatively little private investment available. Protectionist policies would also likely to result in the exclusion of foreign fleets. These circumstances are more likely to lead to the protection of UK fish stocks. In *Local Stewardship*, most economic activity is done at a local level and relatively little capital investment is available to support large commercial fishing fleets. Thus overexploitation of stocks may be uncommon in 2060, although there may be some areas where it may occur locally.

A second finding of interest is that the values of aquaculture production appear to be driven more by the level of capital investment available than by consumer demand or the price of wild caught fish. This indicates that the availability of private capital and the level of public investment in the development of aquaculture are likely to be key factors in the development of this sector.

### 7.3.5 Cultural Ecosystem Services and the UK NEA Scenarios

#### 7.3.5.1 Introduction

The UK NEA made a significant theoretical contribution to our understanding of cultural ecosystem services and how to characterise them, by developing the notion of 'environmental settings' (Church *et al.* 2011), defined as the 'locations and places where humans interact with each other and nature that give rise to cultural goods and benefits that people obtain from ecosystems'. This conceptual framework has been further refined in UK NEAFO (see WP5 Report) by making a distinction between cultural *spaces* and cultural *practices*. While the former maintains the idea of a physical location in relation to cultural ecosystem services, the latter tries to explicitly recognise the expressive, symbolic and interpretive interactions between people and the natural environment. Cultural spaces and cultural practices can, according to this recent work, be considered as mutually reinforcing cultural services and it is primarily through them that a range of cultural benefits arise.

The UK NEA scenarios assume that the contributions that ecosystems will make to people's well-being will change as a result of differences in the capacity of the environment to supply these services and as a result of changes in people's demand for them. Changes in demand are assumed to reflect both change in tastes in these different futures as well as changes in economic circumstance, and the way society is organised and functions. The supply side will be partly determined by changes in land cover and use, and changes in land management, which will affect the stock and quality of the different types of setting. If cultural ecosystem services are to be modelled successfully under the different scenario assumptions, then both the demand and supply side have to be captured in some way. The aim of this work is therefore to explore how we can better understand the impacts of the different UK NEA scenarios by looking at each of these factors. It draws on a longer paper that brings together the work done on the scenarios and cultural services for UK NEAFO (see WP5 Report: Appendix 5.5).

### 7.3.6 Data and Methods

In the analysis described here, we examine these theoretical ideas about cultural ecosystem services empirically, using the Monitor of Engagement with the Natural Environment (MENE) data for England (Natural England, 2011, a & b)[6]. MENE is generated by a rolling, monthly survey. The information collected includes the types of destination (or setting) visited, the duration of the visit, mode of transport, distance travelled, spend, main activities and motivations for the visit. Significantly it records what people do when visiting the different type of place or setting, such as walking or watching wildlife. The respondents also provide information about themselves, so that they can be categorised in terms of their socio-demographic characteristics. The MENE data are collected as part of a larger omnibus survey of people in their homes and is restricted to the resident population of England. It began in 2009, and involves interviewing around 45,000 each year (roughly 800 per week).The MENE data is especially useful for understanding aspects of the demand for CES, at least in terms of the types of cultural spaces that the different socio-demographic groups visit for different cultural practices. In the analysis that follows we look at what these data can tell us about the present and how patterns of use and activity relate to indicators of access to 'green spaces' that have been developed in WP5. To do this we have used the MENE data for the years from 2009 through to 2012. From the 160,000 records a subset of roughly 50,000 has been extracted, covering those respondents who both made a visit of some kind, and who were interviewed in detail to find out what they did and where they went. In addition to the details of their trip, their home location and their socio-economic profile, the data provides a grid reference for the origin and destination of the trip, and whether it was a setting that was designated in some way.

The spatial reference for the visit destination has also enabled us to look at the character of the land cover in the neighbourhood of the sites visited. To do this we have used the 1km x 1km resolution land cover data for the present day and the scenario outcomes generated in the UK NEA. We have focussed on woodland and farmland in particular, as there are marked contrasts between the scenarios in terms of the way these two elements change over time. In terms of analysing present day patterns, we have investigated whether the land cover in the 1km x1km cell in which the visit occurred differed according to the characteristics of the visit (i.e. its duration, distance travelled and activity). For the analysis of the scenarios we have looked at how the characteristics of the land cover would change had the same visits occurred in these future worlds, to determine whether the

[6] http://www.naturalengland.org.uk/ourwork/evidence/mene.aspx

opportunity to access cultural ecosystem services is likely to improve or decline (assuming all other things are constant).

The analysis of the MENE data was initially undertaken using GIS techniques and spread sheet analysis of the spatially referenced subset of the MENE data. While these approaches have been useful in exploring the datasets, they are not easily made interactive. Thus to explore how the MENE data and the scenarios can be made more accessible, the work has also considered how some of the key theoretical relationships can be represented by means of a Bayesian Belief Network (BBN), using the HUGIN Expert software. The MENE data are well suited to analysis using a BBN, which typically estimate probabilities by segmenting the data into specific groups from which dependencies are estimated (see Kjærulff, U.B and Madsen, 2013); in MENE nearly all variables are categorical.

The work focussed on looking at how the socio-demographic characteristics of the respondents linked to the cultural practices they undertook and the cultural spaces they used. An initial step has therefore been to develop a BBN model based on the UK NEAFO conceptual framework for cultural ecosystem services. Such modelling approaches are now being used widely in the ecosystem service arena (Barton *et al.* 2012; Henriksen *et al.* 2011; Kuikka *et al*. 1999; Landuyt *et al*. 2013; McCann *et al.* 2006), and this work builds on that already undertaken in the UK NEA (Haines-Young, 2011). We have gone on to investigate the extent to which it could be used interactively to evaluate the impact of changes in the 'demand side' of cultural ecosystem services brought about through socio-demographic or environmental change under the scenarios.

### 7.3.6.1 Results

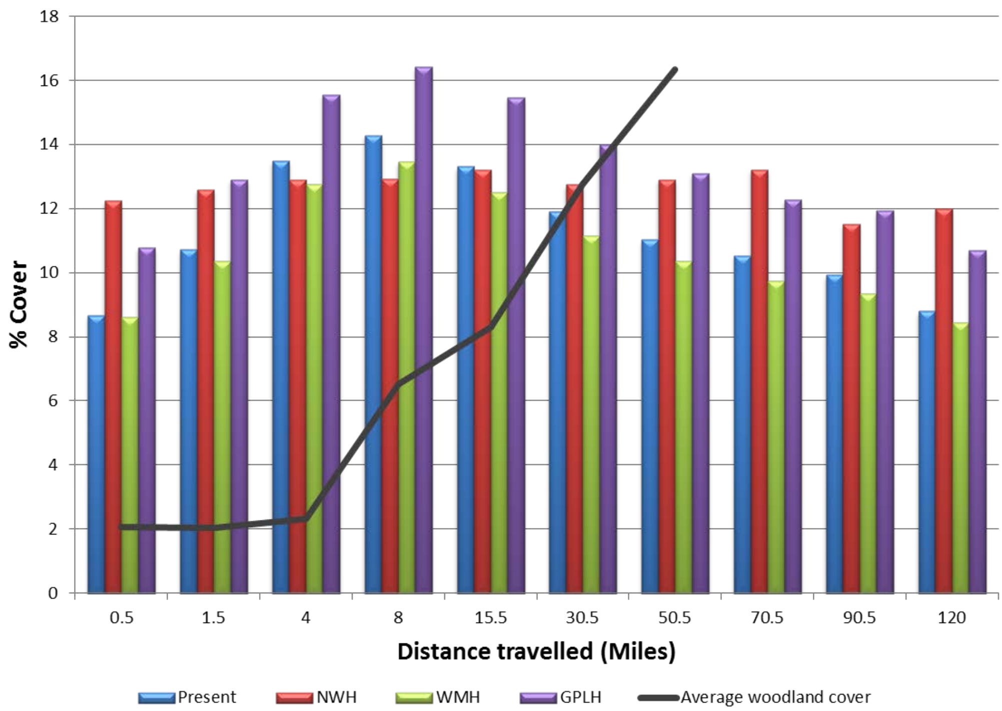


**Figure 7.13. Percentage land cover of woodland or farmland in 1km x 1km cells where MENE visits have been made between 2009-12(a, b), and as projected for selected UK NEA storylines (b-e). Average woodland cover for each distance is also shown (a).**

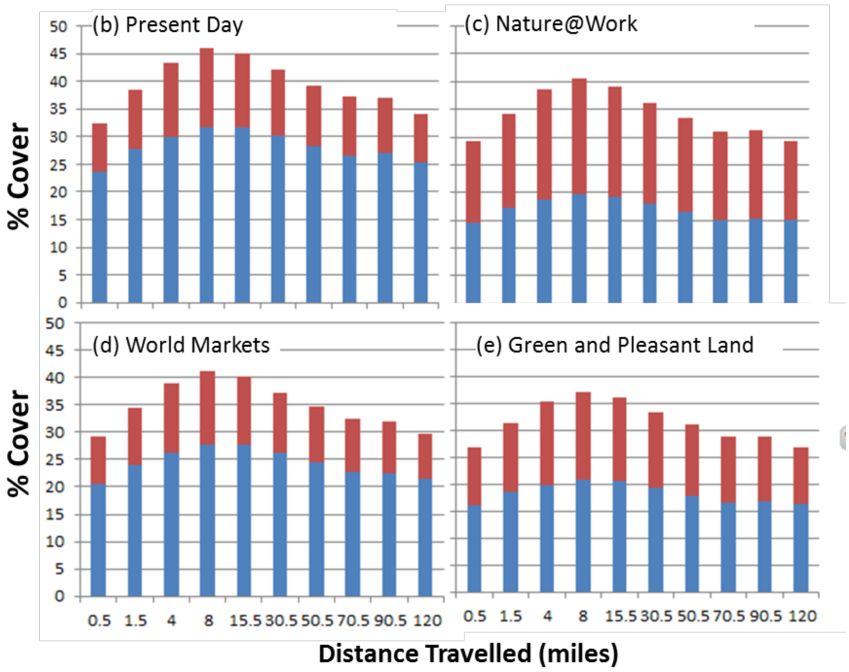


**Figure 7.13. Percentage land cover of woodland or farmland in 1km x 1km cells where MENE visits have been made between 2009-12(a, b), and as projected for selected UK NEA storylines (b-e).**

***Spatial patterns in MENE***

In our GIS analysis of the MENE data, we looked at the locations where present day visits have taken place, and investigated how they might change under the different UK NEA scenarios. **Figure 7.13a** shows how land cover consisting of woodland (broadleaved plus conifer) would change fewer than three of the UK NEA scenarios, in the 1km x 1km cells in which MENE visits to any setting were made between 2009 and 2012. Three scenarios are compared to the present: *Nature@Work*, *World Markets* and *Green and Pleasant Land*. The selection was based on the contrasts between the first two identified by Bateman *et al.* (2011, 2013), and because of the different approaches to biodiversity management between *Nature@Work* and *Green and Pleasant Land*. The MENE data have been partitioned by reported distance travelled.

At short to intermediate distances, people appear to choose locations where woodland and farmland cover are currently high compared to where they live or where they visit on longer journeys. The lower woodland and farmland cover at short distances is to be expected because the majority of people included in the MENE survey live in urban areas. At intermediate distances, however, the squares visited have woodland and farmland cover that is higher than average for these distances, suggesting that people select these types of location preferentially (average woodland cover for the whole landscape increases with increasing distance from the origins of visits). The preference for wooded areas tends to fall away after about 30km, suggesting longer visits take in other kinds of environment and hence different combinations of activity; there is, for example, evidence that the proportion of urban cover in the squares visited *increases* at longer distances. In terms of the supply of cultural benefits from woodland and farmed land, the conclusion to be drawn from the data shown in **Figure 7.13a** is that the woodland in the 'near countryside' is important to people. It is therefore interesting to see how this might change under the different UK NEA scenarios.

Change in relation to the three scenarios is also shown in **Figure 7.13**. Woodland cover is projected to double under *Nature@Work* and *Green and Pleasant Land.* However, in the former it is assumed to be planted close to where people live (to maximise recreational values) whereas under the latter it is planted where maximum biodiversity returns might be gained, e.g. in areas of high semi-natural ancient woodland cover or designated woodland sites. In both cases agricultural land is assumed to be the major source. Under *World Markets,* little woodland change is anticipated and agricultural land is more stable except where it is vulnerable to development such as around existing urban areas. These contrasting trajectories are reflected in the data shown in **Figure 7.13 b** to **e.** Thus under *Nature@Work*, compared to the present (**Figure 7.13b**), a much higher proportion of woodland in the landscape is located close to where people live, while at intermediate distances the two situations are comparable. If we assume that distance has a similar effect on propensity to travel as today, then clearly under this scenario there would be more opportunities to visit woodland close to where people live than at present. **Figure 7.13c** shows the cover of farmland and woodland across the same distance gradient and it is apparent that there is a more even balance between the extent of farmed land and woodland under this scenario than for the others. The change of woodland cover with distance under the *World Markets* scenario shows a similar pattern to that of today, except that there is a tendency to loose woodland at intermediate and longer potential journey distances (**Figure 7.13d**). Under this scenario there is a potential reduction in opportunities for realising the cultural ecosystem benefits associated with this cover type. As **Figure 7.13d** shows, this loss of opportunity is also associated with a loss of farmed land close to where people live, a tendency what would further erode the capacity to deliver cultural ecosystem services under this storyline.

The result for the *Green and Pleasant Land* scenario is perhaps the most interesting of those shown in **Figures 7.13a** and **e**. Under this scenario there would be major gains in woodland cover at the types of location currently visited by people across the entire gradient. This is especially marked for the short to intermediate distance classes, suggesting that a much greater assumed potential to supply cultural ecosystem services would be achieved under this scenario than even under *Nature@Work.* As with the latter there is some reduction in the area of farmland in areas close to where people live, but the key feature of this scenario is that given the present day geography of woodlands, and especially woodlands of higher ecological value, then a more substantial overall gain for biodiversity conservation and cultural ecosystem services might be realised under this kind of planting regime.

***Bayesian Network Model***

We used the HUGIN Expert BBN software to create a tool through which the MENE data can be explored interactively as a way of further investigating this important data resource. In particular the tool can be used to investigate how socio-demographic and location characteristics relate to the settings people visit and the activities they engage in, and can in turn be used to examine how future change might impact on behaviour and opportunities to benefit from CES. The HUGIN software enables users to visualise the relationships between the nodes using 'monitor windows' that show how the probabilities associated with them change as the inputs vary. The advantage of this approach in the context of using MENE is that it allows the data to be rapidly 'segmented' in different ways so that the patterns in the underlying data can be explored more easily.

**Figure 7.14** shows the status of the nodes for activities, settings and life stage after calibration of the network, and when we have chosen to examine the behaviour of a particular life stage (**Figure 7.14a**) or activity (**Figure 7.14b**). Note that this figure shows a much reduced list of the activities and settings represented in the BBN, for illustrative purposes. **Figure 7.14a** shows the BBN when we have chosen to look at people who are living in a family, and the network shows the probabilities of observing the activities undertaken and settings visited at this life stage. Walking with and without a dog, and playing with children, are the most likely activities, and parks in town, country parks and the beach are the most likely venues to be visited.

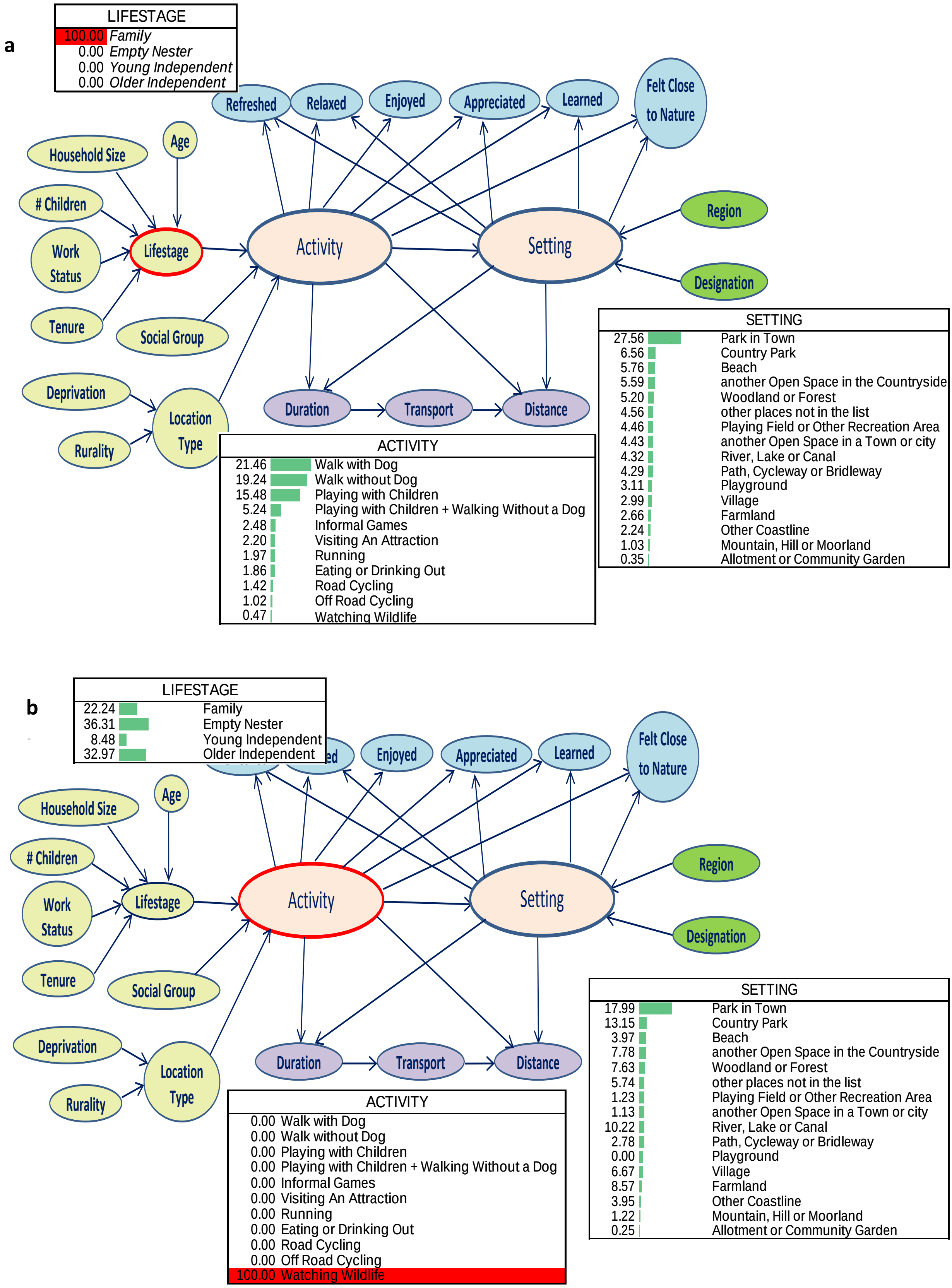


**Figure 7.14. The BBN developed for the MENE data, showing the effect of segmenting data by lifestage (a) and activity (b).**

If we now choose to explore how different activities are associated with different life stages, the tool shows us that watching wildlife should involve a relatively high proportion of 'empty nesters' (36%) and 'older independents' (33%) (**Figure 7.14b**); if we were to select all activities together, the network would should show us that the equivalent figures are 26% and 27% respectively. Moreover, the probability of a respondent using a park in a town declines, while there are increases in settings of a more rural character, such as farmland, woodland, country parks and fresh water. In contrast, when road cycling is selected, the probability of this being undertaken by an older independent increase substantially, and this is most likely to involve 'path' settings.

An important feature of any BBN is that as the probabilities at one node are changed the impacts are propagated across the network, as determined by the direction of the arrows in the influence diagram. Thus changing the category selected in the activity node shows that people tend to travel shorter distances to observe wildlife than to view scenery, and the duration of the visits are shorter. The nodes for distance and duration have states that are set to numerical ranges, and the software provides an estimate of the mean and variance of the resulting distribution. The mean distance travelled to observe wildlife is around 18 miles, whereas for scenery it is just over 22 miles. The average length of trip for scenery is about 3.3 hours compared to 2.7 for observing wildlife.

The network has also been used to investigate the data MENE provides for the strength of feelings they had about the visit (i.e. cultural benefits). The model suggests, for example, that people felt more strongly that they were 'close to nature' and had 'learned' from the experience when engaged in activities involving observing wildlife than when they were observing scenery. The BBN showed that a similar difference in response arose when comparing the experience of visiting woodland and farmland.

In order to make the network more easily accessible to users we have created a web-based version of the network that can be used interactively. This tool also allows exploration of the differences in patterns of behaviour in different areas across England.[7] It takes the socio-demographic characteristics of Local Authorities across England as recorded in the census of population for 2011, and uses these to 'instantiate' the network, which then shows the predicted pattern of activities and sites visited used for a population with those characteristics.

Although our BBN can be used to explore current preferences and behaviours, we have designed it primarily as a resource with which to explore issues of demand and supply of CES under a range of possible futures, such as those described by the UK NEA scenarios. For example, the ability to segment the data by region shows that the patterns of activity and setting used by people in London are different to those in the rest of the South East and in other parts of England. Most strikingly, people living in London make many more trips to parks (64% in London versus 18% elsewhere in the South East). Under the *World Markets* scenario the influence of London is assumed to strengthen, and the South East in particular is projected to experience marked development. If the South East becomes more like London, we would expect the importance of parks to increase, and planning for more urban green space in urban areas would seem to be an implication.

#### 7.3.6.2 Discussion and conclusions

The aim of the work described here was to better understand how cultural ecosystem services can be framed in the context of the UK NEA scenarios, and to develop the 'product base' around which discussion of these alternative futures might be conducted. Cultural ecosystem services are amongst

[7] http://nea-scenarios.hugin.com/

the most difficult to conceptualise operationally and so the availability of the MENE provides an important opportunity for those working in this area to examine some of the issues empirically.

The work involved in using a Bayesian Network model to capture the relationships in the MENE data suggests that it is possible to bring together this important information resource and the conceptual work on cultural ecosystem services undertaken in UK NEAFO. The BBN provides users with a way of rapidly exploring the MENE data and of understanding the dependencies between the key variables. The web-based version of this network that links to the 2011 census also demonstrates that it is possible to 'downscale' the findings, so that it can be used to inform analysis at more local scales. However, while the main contribution of this network is that it provides a new window on the current situation in relation to peoples cultural practices and use of cultural spaces, it also offers the potential for thinking about how these might change under different assumptions about the future.

The existing web-site that links the BBN for cultural ecosystem services to the geography of the 2011 census, for example, has the potential to be further developed to allow users to investigate the effect of changing the socio-demographic composition of the population in a selected area according to say, future ONS projections. Alternatively, it can also be used to explore some of the contrasts that might arise in relation to the demand for cultural ecosystem services based on the UK NEA scenarios. A key finding from the investigation of the MENE data using the BBN is the importance of urban green spaces in the highly populated areas such as London, in terms of the proportion of visits made. If development pressure in the South East and the West Midlands grows in a way anticipated under the *World Markets* scenario then the need to plan for additional areas of urban green space would seem essential. This type of application illustrates that by linking the UK NEA scenarios to the analysis of present day data sources, a richer conversation about the impacts of plausible changes on potential policy resources can be had.

The spatial analysis of the MENE data, and in particular the investigation of people's use of the landscape at short to intermediate distances from where they live has also contributed to a better understanding of the relationship between the supply of, and demand for, cultural ecosystem services. The work demonstrates the value of looking at existing patterns of behaviour through the lens of something like the UK NEA scenarios, in order to identify some of the implications of alternative land cover change trajectories. While many things might change in terms of people's behaviours and motivations in the context of the natural environment, the analysis has shown that the character of landscapes around our cities is an important issue to consider. A novel finding from the analysis was the preference people seem to show for wooded areas at intermediate distances from where they live. The work also suggests that while we might target these areas for planting to enhance their potential to deliver cultural ecosystem services, biodiversity gains might also be achieved by such a strategy.

The task of modelling cultural ecosystem services is a complex one because it involves an understanding of the biophysical characteristics and geography of the places people use, as well as people's motivations and practices. Thus the work reported here is of a preliminary nature and much remains to be done if we are to understand the relationships between the demand for and supply of cultural ecosystem services. Nevertheless, the study demonstrates that by looking at the development of such models and current data sources in the context of the UK NEA scenarios, new insights might be generated that can support the development of current thinking. The work also demonstrates the potential for developing interactive decision-support tools in this important area of debate.

### 7.3.7 Scenario-based models and analytical products

In previous sections (7.3.2 – 7.3.5) we have examined how a range of modelling and analytical approaches can be used to further develop an understanding of what the UK NEA scenarios imply. As we argued in the introduction, while modelling and techniques such as trend analysis can be used as an aid to scenario development, there is also a case for exploring how the assumptions of the different storylines can be used as the basis for targeted, scenario specific modelling or analytical studies. The resulting 'products' can then stimulate further debate about the plausibility of the scenarios themselves, as well as help us to better understand the capability of our present modelling and analytical tools to answer scientific or policy related questions. To draw the work described in Section 7.3 together, we now focus on the more generic aspects of the scenarios themselves by considering the four questions posed at the outset (see 7.3.1).

If the UK NEA scenarios are useful as an analytical framework, then they need to be sufficiently rich and well defined to allow meaningful analytical and modelling studies to be undertaken. The experience gained from the thematic work supports the case that they are. For example, the studies of catchment hydrology (Section 7.3.2), farmland birds (7.3.3) and cultural ecosystem services (7.3.5) all made use of the 1km x 1km resolution land cover maps produced by the original UK NEA scenario work. These data were appropriate for the scale at which catchment models operate, matched the 1km x 1km grids used for national bird survey data, and were able to capture important characteristics of the landscape that deliver cultural ecosystem services. All three of these studies went on to produce plausible results which offered new insights into what these contrasting futures might involve. In the marine context the claim that the UK NEA scenarios are sufficiently rich is, perhaps, more difficult to sustain. Many of the uncertainties which prevented the production of anything but tentative results in the original UK NEA work have persisted. Gaps in knowledge about the current marine environment and the processes operating appear still to limit the development of qualitative and quantitative projections about the future. Nevertheless, despite the preliminary nature of the work, the experience suggests that the UK NEA scenarios provide a relevant entry point for discussion and may help clarify important questions that we need to ask about potential future trends in the ecosystem services associated with this sector.

If scenarios are to support decision making then they clearly need to do more than merely stimulate academic debate. Thus a second issue that we might consider is the extent to which this additional analytical or modelling work based on the scenarios added significant value to what was achieved in the original assessment. In the context of the marine study it could be argued that the results largely confirm the findings of the first phase. However, the outputs are a step forward because they quantify the size and spatial configuration of change, and therefore allow a more informed comparison of the effect on marine ecosystem services under the scenarios. In this sense they do add something new to the debate. In contrast, given that hydrological changes were not explored in any depth in the original UK NEA scenario work, the catchment study reported represents a more significant advance in understanding. The finding that hydrological changes driven by modifications to land cover are likely to be catchment specific under *any* scenario has important implications for the design of future management or policy response options.

A further aspect of the value added by the kind of analytical and modelling work reported here comes from the new understandings of the differences between the scenarios that emerge. These differences are especially helpful in better understanding the kinds of trade-off that might be arise under the different futures. While the results of the analysis of changes in farmland bird populations largely matched the projections in the original assessment, the additional analysis reported here challenges the conclusions initially drawn about the synergies between improved service output and biodiversity gains in the *Nature@Work* scenario. By focussing on food availability and abundance of farmland birds rather than species number, the study found that biodiversity outcomes were more adversely affected by the scenarios with highest monetised value (cf. Bateman *et al.* 2012, 2013). The analysis of the spatial change in woodlands under the different scenarios also offered new insights into the benefits of the *Nature@Work* scenario for the supply of cultural ecosystem services compared to *Green and Pleasant Land.* The same general kind of conclusion also arises from the hydrological analysis, which indicates that 'greener' scenarios, such as *Nature@Work* and *Green and Pleasant Land*, may reduce the likelihood of flooding, whereas others, such as *World Markets*, may decrease the likelihood of drought, indicating that there may therefore be important trade-offs between flood prevention and water supply between scenarios.

The questions that arose around trade-offs in each of the thematic studies illustrate the value of undertaking modelling work within the framework provided by a suite of UK NEA scenarios, and their use as a tool to promote 'social learning'. For example, it was found that in the marine work, the scenario which results in lowest values for fisheries landings (*World Markets*) results in highest values for aquaculture production (due to the greater availability of capital investment). Overall, the scenario which appears to perform best was *Nature@Work*, which might be expected given that in general under this storyline ecosystem services are expected to be managed more sustainably. However, it is interesting that under the quite different *Local Stewardship* and *National Security* scenarios, fish landing in 2060 were projected to be almost as high as under *Nature@Work*, but for different reasons. While such projections need to be tested further, it is clear that context that the UK NEA scenarios provided for such work has stimulated the identification of new and relevant scientific questions. The marine study highlights a lack of understanding of marine drivers and the need for further work in this area, both in terms of data acquisition and more research to understand the processes. It also highlights the need to consider trade-offs between the possibility of higher capital investment under a free market environment and the higher levels of governance and state control needed to prevent fish catches declining to much lower than current levels.

The lesson from our hydrology study is that it is probably important to identify catchments which are especially sensitive to future land cover changes in terms of the impacts on flooding or drought. The implications of this study are that analysis should be extended to as wider a range of catchments as possible and that efforts should be made to further refine the land cover models produced by the scenarios for this purpose. Similarly the lesson from the farmland bird study is that a broader approach to analysing the effects of changes in biodiversity under different land use futures is needed. While land use changes that maximise the value of all monetized services may not have the same beneficial effects on biodiversity as originally anticipated, they may have important benefits for other components of biodiversity, such as birds associated with woodlands. Thus a more integrated and wider ranging analysis is required if questions about synergies and trade-offs in relation to biodiversity conservation are to be fully explored.

Although the range of ecosystem services considered in this 'analytical part' of our study is limited, the outcomes demonstrate that despite their qualitative character the UK NEA scenarios provide a relevant and challenging analytical framework. The analytical and modelling outcomes presented here illustrate how useful 'products' can be generated by using them and that these outcomes can potentially help people better understand the implications of different drivers of change. The examples presented here further demonstrate how the UK NEA scenarios can be used in a decision context, by supporting the kinds of deliberative processes needed for the design of robust management or policy responses.

## 7.4 Conclusions

Within the context of an ecosystem assessment, scenarios can be employed in a variety of ways. In this study we have examined two of them: scenarios as a framework for deliberation, and scenarios as analytical products. The outcomes of this work can help us answer the overarching question that has framed this study, namely: 'how can such possible futures help us to understand, manage and communicate the consequences of changes in ecosystem services?'

In this study we have sought to understand better how the UK NEA scenarios can be used to facilitate and stimulate discussion about the future. It has been argued that scenarios are not simply descriptions of some possible future, but devices that can be used to explore new ideas, challenge assumptions, and help generate new expectations and goals. The evidence that we have collected from our interaction with stakeholders suggests that the UK NEA scenarios are capable of doing this.

The results of the engagement with different stakeholder groups showed that the UK NEA scenarios were to be both plausible and relevant to their concerns. They also appeared to have significant potential as tools for developing dialogues between people with differing interests and perspectives. The work showed that these deliberative activities were two-way: the contributions of stakeholders enriched the scenarios and at the same time allowed us to see new perspectives and gain further insights from them. In fact, we found the UK NEA scenarios had already started to develop a 'life of their own', in that they were being used outside the UK NEA framework by Forest Research, The Defra Noise Futures Project and the Scottish Government as part of their work. However, whilst we found that they 'worked' when people were exposed to them, our findings suggest that more needs to be done to embed the UK NEA scenarios in the thinking of the broader stakeholder community if their full potential is to be realised.

Important barriers to be overcome involve finding ways to communicate the essential features of the scenarios to people so that they can use them actively in debates. This was especially apparent in the work we have done in conjunction with WP8 (see WP8 report) on policy response options. Their experience of using the scenarios to test the robustness of response options under different assumptions about the future will be a significant pointer to how the storylines can be used a decision support role. However, as the work of WP9 has shown (see WP9 Report), while ecosystem knowledge might be available, it may not always be used by policy customers. We have discovered that the time required to work with scenarios might be too long for many of those engaged in policy development in the current environment and so more indirect forms of engaging with this community may be required. Strategies include working with the kinds of people who advise them, and who act as knowledge brokers in the context of ecosystem services. Engagement might also depend on the preparation of relevant and accessible scenario analyses or products to inform and stimulate debate.

The follow-up work reported here has also sought to explore and expand the model base that can be used in the context of the UK NEA scenarios, and hence enrich them as a 'scenario product'. The focus has not so much been to use models to test or confirm the projections initially, that is to establish them more firmly as 'model-based scenarios', but rather to use them as a framework for additional modelling and analytical studies. Our investigation has demonstrated the value of reversing the logic that often surrounds models in the context of futures thinking, and has shown the merits of developing 'scenario-based models' rather than 'model-based scenarios'.

Four thematic areas have been targeted to examine how scenario-based models can enrich the debate surrounding ecosystem services under the different UK NEA storylines. We found that the scenarios are, for example, able to provide a framework in which established hydrological and ecological models can be used to extend the storylines. The results from this study posed some important and novel questions about the trade-offs between the capacity to reduce flooding or prevent drought under the different plausible futures. The richness of the analytical framework that the UK NEA scenarios provide was also demonstrated by the analysis of trade-offs and co-benefits between abundance of farmland birds and other ecosystem services, and between land cover and the supply of cultural ecosystem services around our cities. The study has also shown the potential for deepening the discussion around the scenarios in respect of the marine environment. This work has shown that of four scenarios considered only *World Markets* appears to result in a marked decline in fish stocks in the period up to 2060. These findings must now be looked at in the context of the marine valuation work that has been undertaken in UK NEAFO (see WP 4 Report).

The analytical and modelling work reported here has also demonstrated the potential for developing new tools to assist people in their thinking about the future. We have for example, developed a Bayesian Belief Network to provide rapid, interactive access to the data produced by the Monitor of Engagement with the Natural Environment (MENE). An internet version of this network is now available and this can be used to explore the conceptual framework for cultural ecosystem services that has been developed in WP5 (see WP5 Report). We have linked this to the geography of the 2011 census, and it now has the potential to model the effects of different assumptions about changes in socio-demographic makeup on the use of cultural spaces and the frequency of different cultural practices.

Thus in answer to the question of how the plausible future scenarios developed in the UK NEA can help us understand, manage and communicate the consequences of changes in ecosystem services across all scales, we suggest that it can be best achieved by recognising that scenarios must facilitate deliberative processes and support the development of analytical products. Both avenues must be pursued if the UK NEA scenarios are to be used effectively in a decision support role. Although we have found it useful to distinguish between these two dimensions, they are in fact mutually supporting and deserve equal attention. The UK NEA scenarios have been found to be sufficiently rich and comprehensive to support debate across a wide range of topics that are relevant to current policy concerns. It is also apparent that the scenarios can aid understanding by providing a framework in which current models can be applied. Such work has tested the plausibility of the scenarios themselves as well as extended the insights that can be derived from them.

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## 7.6 Appendix 1 List of Supplementary Material

WP7 Report: Supplementary Material 1. Leeds Questionaire
WP7 Report: Supplementary Material 2. Christie and McCabe (2013).
WP7 Report: Supplementary Material 3. Haines-Young (2011).
WP7 Report: Supplementary Material 4. Lum (2013). Supplemental Scenario Content for the UK National Ecosystem Assessment
WP7 Report: Supplementary Material 5. Gosling *et al.* (2013).
WP7 Report: Supplementary Material 6. Norris & Butler (2013).
WP7 Report: Supplementary Material 7. ABPMer (2013).