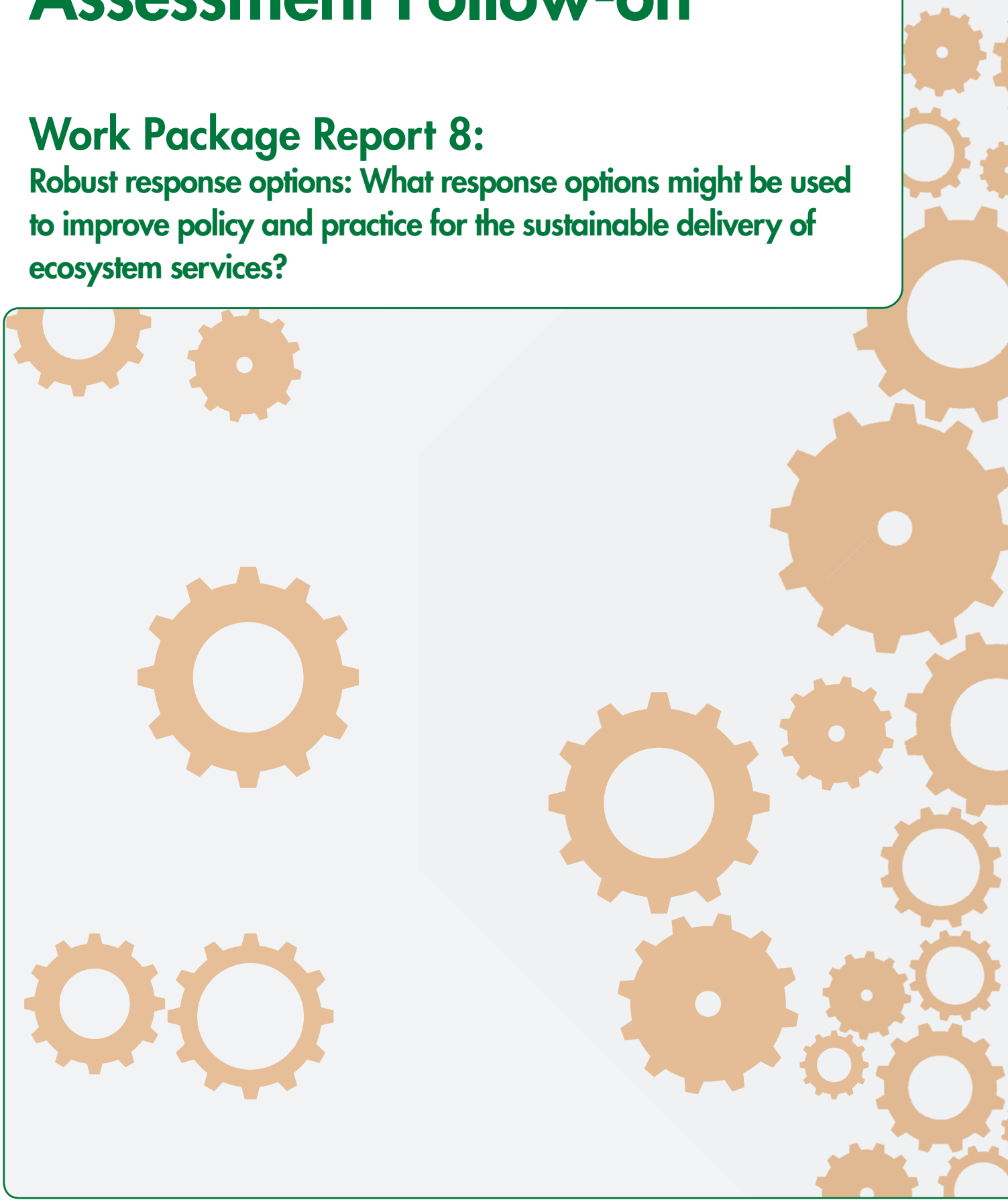
UK National Ecosystem Assessment Follow-on

Work Package Report 8:

Robust response options: What response options might be used to improve policy and practice for the sustainable delivery of ecosystem services?



Principal Investigators: Iain Brown[1]*, Paula Harrison[2]*

Authors: Iain Brown[1]*, Paula A. Harrison[2]*, Jayne Ashley[3], Pam M. Berry[2], Mark Everard[4], Les G. Firbank[5], Stephen Hull[6], Lian Lundy[7], Chris P. Quine[8], John S. Rowan[9], Rebecca Wade[10], Susannah Walmsley[6], Kevin Watts[8], Gary Kass[11]

Report Review Editor: Marion Potschin[12]

Affiliations:
[1] James Hutton Institute
[2] Environmental Change Institute, University of Oxford
[3] Spiral Delta
[4] Pundamilia Ltd
[5] Firbank Ecosystems Ltd
[6] ABP Marine Environmental Research
[7] Urban Pollution Research Centre, School of Science and Technology, Middlesex University
[8] Forest Research
[9] School of the Environment, University of Dundee
[10] Urban Water Technology Centre, University of Abertay
[11] Natural England
[12]University of Nottingham

*Correspondence to: Iain Brown, iain.brown@hutton.ac.uk and Paula Harrison, paula.harrison@ouce.ox.ac.uk

Suggested citation: Brown, I., Harrison, P., Ashley, J., Berry, P., Everard, M., Firbank, L., Hull, S., Lundy, L., Quine, C., Rowan, J., Wade, R., Walmsley, S., Watts, K., & Kass, G. (2014) UK National Ecosystem Assessment Follow-on. Work Package Report 8: Robust response options: What response options might be used to improve policy and practice for the sustainable delivery of ecosystem services? UNEP-WCMC, LWEC, UK.

Contents

Abbreviations and acronyms

AONB	Area of Outstanding Natural Beauty
BAP	UK Biodiversity Action Plan
CAP	Common Agricultural Policy
CBA	Cost-Benefit Analysis
CBD	Convention on Biological Diversity
EbA	Ecosystem-based Adaptation
ES	Ecosystem services
EU	European Union
FD	Floods Directive
GHG	Greenhouse Gas
GI	Green Infrastructure
ICM	Integrated Catchment Management
ICZM	Integrated Coastal Zone Management
ILM	Integrated Land Management
LCA	Life Cycle Assessment
MCA	Multi-Criteria Analysis
MSFD	Marine Strategy Framework Directive
NDBR	North Devon Biosphere Reserve
NFM	Natural Flood Management
NGO	Non-Governmental Organisation
PES	Payments for Ecosystem Services
RBMP	WFD's statutory river basin management plans
SA	Sustainability Appraisal
SEA	Strategic Environmental Assessment
SFM	Sustainable Forest Management
SUDS	Sustainable Urban Drainage Systems
UK NEA	United Kingdom National Ecosystem Assessment
UK NEAFO	United Kingdom National Ecosystem Assessment Follow-On
UKFS	United Kingdom Forestry Standard
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCC	UK Woodland Carbon Code
WFD	Water Framework Directive

Key Findings

Decision makers have alternative types of options for responding to environmental and societal change. Each option type has key requirements and interdependencies that translate into specific strengths, weaknesses and suitability for managing ecosystem services. This typically means that the sustainable delivery of ecosystem services cannot be guaranteed by individual response options in isolation, and is best addressed by combinations of options. Market-based schemes can leverage new investment in services and improve efficiency, but are exposed to market volatility; therefore, they are best accompanied by regulation, or other mechanisms to ensure minimum standards. Bottom-up initiatives can be valuable to engage and catalyse local action to manage change, but can result in missed synergies with related initiatives if wider planning to maximise coordination is not undertaken. Knowledge exchange systems can improve the uptake of scientific and technological innovation, including linking with good management practices. Investment in science and technology may provide possible 'low-regret' options which enhance other responses, regardless of the exact pathway of change.

Response options have strengths and weaknesses in terms of their flexibility to handle temporal change (including future uncertainty) and to match with different geographic contexts. Statutory top-down approaches, including protected areas, can define uniform minimum standards, but may be slow to adjust to changing circumstances. Innovative schemes with the potential to improve the delivery of ecosystem services, such as offsetting and incentive payments, may benefit some ecosystem services at the expense of others that provide less tangible benefits in market terms, or have a more localised value. Spatial targeting of response options may provide the best means to cope with the heterogeneity of ecosystem services. Further attention needs to be given to how future risk is factored into incentive schemes.

The evaluation of response options is currently constrained by a relative lack of knowledge about cultural ecosystem services and supporting ecosystem services. This constraint challenges approaches to identify a sustainable balance of ecosystem services. Cultural ecosystem services are particularly important in understanding the role of local identity as a key factor in managing terrestrial landscape or marine environment change. Supporting ecosystem services are crucial for enhancing ecosystem resilience and for buffering against abrupt change, including the loss of final ecosystem services. The inherent uncertainty of the future suggests that measures to enhance community cohesion and ecosystem resilience are a good strategy because they can provide a foundation for accommodating change management. The role of local identity in adapting to change has been understated in previous work on response options.

The robustness of response options when 'stress-tested' by the UK NEAFO under a range of UK NEA scenarios varies according to the differing influence of key factors, such as governance, market forces and the scale of decision-making. Thus, market-based options are most unconstrained within scenarios that emphasise free markets, such as the *World Markets* scenario. Similarly, national-scale interventions may be overridden by local priorities under the *Local Stewardship* scenario, while local initiatives may be subordinated by top-down priorities under *National Security*. Two UK NEA scenarios, *Nature@Work* and *Local Stewardship*, emerged as more receptive to the suite of response options, resulting in the most positive outcomes for all categories of ecosystem services (provisioning, regulating, cultural and supporting). In the *World Markets* and *National Security* scenarios, some responses are of low relevance, or may have negative effects on certain services, as they become overly focused on specific demands (often provisioning ecosystem services); cultural ecosystem services are identified to be particularly vulnerable when demand is focussed on individual services in isolation.

The UK NEAFO shows that the most effective response options in agriculture are those that develop and disseminate knowledge, technology and practice, because they support the delivery of ecosystem services under all scenarios, to a greater or lesser extent. The broadest range of response options is relevant to *Nature@Work*, with far fewer response options available for influencing outcomes under the *World Markets* and *National Security* scenarios. Very few response options give rise to negative impacts on ecosystem services, compared to the scenarios playing out without any interventions. This does not imply that ecosystem services on farmland will be maintained across all scenarios, rather that many individual interventions have a limited effect in modifying outcomes associated with the scenarios. The present situation in agriculture has elements of all scenarios. Designing robust response options that can work across the scenarios should build on cost-effective ecosystem service delivery as prioritised under the *National Security* and *World Markets* scenarios, while emphasising innovation and knowledge exchange using multiple platforms that embrace communities, policy and industry.

The forestry sector already incorporates features of adaptive management because of its long planning horizons. Therefore, response options that further develop adaptive knowledge-based initiatives, such as collaborative management groups, advisory services and visits, and community woodland groups, scored most highly in our assessment, particularly under the Nature@Work and Local Stewardship scenarios. These support structures operate through either national objectives (e.g. UK Forest Standard and grant aid), or local decision-making (e.g. community groups). Grant aid with specific spatial targeting is considered to be a relevant and robust response option across most scenarios, having a positive impact on the different groups of ecosystem services. However, it may become more unbalanced towards provisioning ecosystem services in *World Markets* and *National Security* if these scenarios become overly focused on material demands.

A key requirement for the biodiversity sector is to integrate its objectives with other sectors. In a changing world, the response options the UK NEAFO identifies as most viable in achieving this are greenspace and ecological networks, agri-environment schemes, and partnerships. However, the heterogeneity of biodiversity and ecosystems requires the recognition of spatial differentiation in responses, with protected areas continuing to be important in key locations. Most response options can actively contribute to the sustainable delivery of regulating, cultural and supporting ecosystem services, but with potential trade-offs against provisioning ecosystem services. Current protected areas could be made more robust to climate change through integration with ecological networks. The effectiveness of biodiversity offsetting and nature-based partnerships is notably reliant on other factors, especially the need for balanced regulation (offsetting) and support structures (partnerships). Voluntary quality-assurance and compulsory set-aside schemes are potentially weakened in futures dominated by free markets and increasing food production, but quality assurance and local provenance may become an asset in risk-averse conditions. There is currently limited evidence available to assess schemes like land-sparing and offsetting, which may be able to deliver provisioning services alongside other ecosystem services, but also involve balanced trade-offs that may not continue to hold in the future.

The response options that the UK NEAFO identifies as the most robust for the water sector are blue networks, River Trusts and Sustainable Urban Drainage Systems (SUDS). These can provide a range of ecosystem services and are sufficiently flexible to adapt to a variety of future conditions. The response options tested range from those which are short-term, local and relatively inexpensive, such as community-based urban stream restoration projects, to long-term, national-scale and hugely expensive infrastructure projects, including new reservoirs and desalinisation plants. The EU Water Framework Directive offers great potential to embed ecosystems thinking across the water sector with regards to sustainable ecosystem protection and enhancement, but this is dependent on strong governance, which may not occur under all scenarios. SUDS are designed to emulate natural

processes contributing to regulating, supporting and cultural ecosystem services, and offer many positive benefits to the built environment; they are the most robust of all the response options we considered. With regard to industry-based responses, a mix of measures for both supply and demand provides the greatest resilience to future economic and climate shocks.

The response options that are the most robust across all scenarios in urban areas are those relating to spatial and integrated planning, and science research and development that advance and communicate knowledge on the multiple benefits of urban ecosystems, including greenspace and blue and green networks. Of the eight response options the UK NEAFO tested, three were mainly positive for the delivery of all categories of ecosystem services: multi-functional green infrastructure, technology for water-saving and urban ecosystem assessments. These approaches have the capacity to deliver multiple ecosystem services and are adaptable enough to meet different challenges and drivers predominating in each of the scenarios. Some of the other response options tested were less likely to be robust for ecosystem services in all futures. For instance, energy-related EU legislation and national planning policy frameworks have less traction in scenarios where the role of legislation or international agreements declines (notably *World Markets*).

The most robust marine and coastal response options include 'no-take' zones and fisheries conservation measures because they can enhance market potential, as well as wider ecosystem integrity. A major challenge for the marine sector is the mobility and variability of stocks, especially with climate change, so the role of legally binding agreements is crucial to ensuring sustainability. Marine planning, certification of fisheries and environmental non-governmental organisations (NGOs) contribute significantly under the *Nature@Work* and *Local Stewardship* scenarios, but are less likely to have a major influence under *World Markets* and *National Security*, which have a stronger focus on economic objectives. The role of environmental NGOs, however, is particularly important in communicating the existence (non-use) value of marine ecosystems. Opportunities to strengthen the robustness of response options include a clearer articulation and application of the Ecosystem Approach within marine planning, defining legally binding management measures within no-take zones (especially nursery areas), and clear and enforceable fisheries conservation measures.

Stress-testing of response options collaboratively, or in workshops, enables greater discussion of the reasoning behind evaluation scores, is informed by a wider spectrum of knowledge, and enhances the institutional learning process. The impacts on ecosystem services of various response options were considered by the UK NEAFO in terms of the main categories (provisioning, regulating, cultural and supporting), all of which cover a wide diversity of individual ecosystem services which may not be affected in the same way. Further deliberation may refine our initial analysis, may result in different variants of a generic response option, and can help to distinguish the relative importance of different drivers of change, including the interaction of socio-economic factors and climate change. The definition of reference baseline conditions is an important precursor to assess change, particularly with regard to notions of sustainability; otherwise, there is a risk that progress is not effectively measured.

Effective implementation of a range of response options appropriate to achieving the best outcomes for ecosystem services in different situations entails institutional flexibility and close collaboration. Today, many institutions are bound by narrow interpretations of their responsibilities and have constraints on their response options, such as a subset of legislation, application of common law, or advice. These institutional constraints may inhibit realisation of joined-up outcomes across ecosystem services and opportunities for coordinated change management. The use of general behavioural frameworks to guide complementary responses, such as the 4Es (Enable, Encourage, Exemplify, Engage) or 4Is (Information, Institutions, Incentives, Identity) can provide a structure for more joined-up responses.

Summary

This study has analysed the suite of response options available to decision makers in terms of their robustness to present and future change. To achieve this it developed a stress-testing approach to assess the consequences for natural capital and resultant ecosystem services when response options are evaluated against major drivers of change. The UK NEA scenarios were used to contextualise future drivers of socioeconomic change, with additional compound effects due to climate change. After testing the current suite of response options, implications are considered for future policy design. The role of complementary initiatives can be enhanced by reference to conceptual frameworks (4Es; 4 Is) that link to human behaviours and motives for action.

The inherent uncertainty of the future implies that robust decisions on the sustainability of ecosystem services are best guaranteed by a mixture of response options. The analysis showed that several features should be considered when designing and evaluating this mixture. Firstly, a combination of top-down and bottom-up initiatives can act to balance their individual strengths and weaknesses. This particularly refers to trade-offs that emerge in schemes between large-scale efficiency and local-scale effectiveness, as for example is evident in the design of offsetting schemes. In this context, there is a risk that if large-scale efficiencies dominate then they will favour some types of ecosystem services (notably provisioning) at the expense of more local services (e.g. cultural). This may be important where ecosystem services are grouped together and where one service is used to 'piggy-back' others. If the chosen service operates at a large scale (e.g. carbon storage) it may not necessarily be representative of benefits at the more local level. Local bottom-up schemes can be particularly effective in delivering action on the ground based upon awareness of the local context, and therefore allow enhanced resilience and management of change with a minimum of externalities. However, localism can also produce very heterogeneous responses and outcomes, contingent on factors such as awareness and leadership, indicating that top-down guidance and minimum standards should continue to be important in managing change.

The role of market-based responses can be important for introducing new investment in maintaining ecosystem services, but markets can be volatile and exposed to changing drivers, implying that these risks need to be managed by appropriate regulation. This is particularly required because of the complexity of ecosystems and their services, with the need for safe margins to ensure future sustainability especially where demands are increasing. Some options are more flexible and adaptable than others, such as incentives (e.g. payments for ecosystem services), which can be locally tuned to deliver particular outcomes. Statutory top-down responses, such as protected areas or regulation, may be slower to respond to change because of the static planning system or challenges in defining minimum standards against a changing baseline, notably due to climate change. However, by comparison with some of the newer response options being trialled (e.g. market-based schemes) there is usually more evidence available of the efficacy of statutory interventions. Quality standards may be further supported through voluntary quality assurance schemes linked to environmental sustainability, such as branding and marques.

The study found that cross-sectoral initiatives, such as green (and blue) infrastructure, agri-environment schemes, strategic land-use planning, and local/regional partnerships, could be particularly useful in developing synergistic responses to change. A major barrier acting against the development of a robust mix of responses is often current institutional arrangements which often constrain organisations to implement a narrow range of pre-existing responses. However, positive examples of partnership working and integrated planning do exist at the local and regional level. Beyond this, the study suggests that the role of local identities and their relationship with the natural environment are underutilised levers in developing robust response options: they should be more influential in the design of innovative and flexible support schemes such as through incentives. The

importance of context in identifying the right mixture of response options also highlights a key role for spatial targeting.

Adaptive management will also be highly dependent on improved monitoring and information flows to better collectively interpret ecosystem dynamics and the effectiveness of response options in different contexts. This is particularly required for understanding basic ecosystem functioning ('supporting services') and social/cultural benefits, both of which are crucial for enhancing resilience and adaptability to change. Strategies that enhance ecosystem resilience and community cohesion are therefore identified as particularly useful in buffering against undesirable change. Amongst the different policy initiatives, the Water Framework Directive was highlighted as a notable exemplar as it is centred on concepts of 'good ecological status' and promotes cross-scale planning and sustainable long-term resource management. Other policies, such as the transition to the low carbon economy and the Common Agricultural Policy, have long-term objectives which could be better integrated with the ecosystem approach to enhance synergies with the natural environment.

8.1 Introduction

Decision-makers may use a diverse range of potential interventions (i.e. response options) when seeking to achieve objectives, and particularly so when challenged by changing circumstances. These response options include, for example, incentives, voluntary approaches, statutory legislation or regulation[1]. As shown by previous work in the UK National Ecosystem Assessment (UK NEA), current declines in ecosystem services (ES) suggest that there is considerable scope to improve the design of response options to better deliver multiple societal benefits from the natural environment. Such a reappraisal of options is particularly required when we are experiencing, and can further anticipate, the effects of climate change, population growth, societal change, and other broadscale influences on the sustainable delivery of ES. A key step in the decision-making process is to identify target outcomes and specific goals, including metrics appropriate for the measurement of progress. However, conflicts and inefficiencies are likely to result if these goals are set in isolation from other decisions, address narrow outcomes which overlook the potential for unintended consequences on non-focal ES, and are inadequately informed by changing biophysical and socio-economic context. Application of the Ecosystem Approach as a guiding protocol, setting a broader socio-economic and geographical context for management of ES outcomes, has the potential to provide a more 'joined-up' structure to decision-making, both across sectors and across scales.

Previous work in the UK NEA developed an ES conceptual framework to organise information on current trends in service delivery. This was complemented by an assessment of response options that investigated enablers and barriers for integrating this framework with current decision-making agendas (Vira *et al.* 2011). A key finding was that sectorally-focused approaches are unlikely to be effective by themselves, given the connectedness of ecosystems and their functions, and the consequent interdependence of multiple stakeholders. If the desired outcomes of decisions are reframed as maximising benefits across the full range of ES thereby achieving the greatest cumulative societal benefit (rather than simply maximising narrowly-framed outcomes), a broader mix of response options used in combination is required. This would also require support for collaboration and innovation by multiple stakeholders.

8.1.1 Robust decision-making strategies

Despite improved awareness of the societal benefits provided by ES, significant evidence gaps remain, which can constrain the appraisal of response options. This constraint is particularly apparent with regard to knowledge about the dynamic response of ecosystems to present and future change and the implications of this for the integrated delivery of ES at different scales. The twelve guiding Principles of the Ecosystem Approach (CBD, 2004) recognise explicitly that ecosystem management should be undertaken at appropriate spatial and temporal scales (Principle 7), with objectives set for the long term taking account of varying temporal scales and lag-effects (Principle 8) and recognising that change is inevitable (Principle 9). This implies a need to 'future-proof' current decision strategies in order that desired outcomes are robust against an inherently uncertain future, rather than assuming a single pathway to an 'optimal' decision (Lempert & Collins, 2007). The present study addresses this need by exploring the performance of different response options against a range of plausible future scenarios in addition to present conditions. This 'future-proofing' approach should be considered as a screening process to avoid 'lock-in' to unsustainable policies or management practices, both within and across sectors. It may also help identify actions that are

[1] In some situations, a 'do-nothing' decision can be characterised as a rational response option, such as for areas of coastline where 'no active intervention' is the preferred option in Shoreline Management Plans.

cost-effective to implement now, but that are likely to continue to return multiple societal benefits in the longer term (so-called 'no regret' or 'low regret' strategies).

8.1.2 Scenario analysis and stress-testing

This study builds upon the initial assessment of Vira *et al.* (2011) by developing and evaluating a future-proofing methodology which implements scenario analysis of response options through 'stress-testing'. In this procedure, policies or practices are evaluated against a series of changing socio-economic conditions exemplified by the UK NEA scenarios (Haines-Young *et al.* 2011) and also as influenced by climate change as projected by the UK Climate Projections 2009 (UKCP09; Murphy *et al.* 2009). These scenarios and climate projections provide multiple versions of an uncertain future against which we assess the robustness of response options. The inherent uncertainty of the future means multiple plausible interpretations are required although, by necessity, these future visions may be regarded as simplified by comparison with the complexities of the 'real-world'. This simplification is justified because the scenarios do not represent predictions, but rather collectively identify a range of future conditions against which the overall robustness of response options can be evaluated in the context of ES delivery.

Stress-testing is designed to be an iterative procedure: for some issues, once specific opportunities or vulnerabilities have been identified, more detailed investigation may then be required. The outputs of scenario analysis can therefore be improved when framed within a broader *learning* process that also investigates changes in co-dependencies of response options into the future, and also how response options can be modified to enhance their robustness. This learning process may be enhanced in a participatory group structure to help facilitate knowledge exchange and social/institutional learning. Individual studies can therefore only provide steps within this broader process. However, based upon user feedback we have aimed to reflect on the use of the stress-testing methodology as a 'future-proofing' tool for policy-makers and practitioners in environmental management with regard to improved understanding of systemic interdependencies between the natural and human environment.

8.1.3 Tools for options appraisal and integrated assessment

Options appraisal techniques to evaluate the relative merits of alternative response options are well-established, including standard government guidance in the UK (the 'Green Book') by HM Treasury (2011)[2]: this guidance emphasises the importance of understanding the capability of different options to withstand future uncertainty. Established appraisal tools include Cost-Benefit Analysis (CBA), Multi-Criteria Analysis (MCA), Life Cycle Assessment (LCA), Risk Assessment, Environmental Assessment[3] and Sustainability Appraisal (SA). Each of these differ in how they incorporate benefits/losses and stakeholder involvement, and whether they are primarily qualitative or quantitative and aim to achieve an evaluation based upon mixed or common units, or scoring against standard or varying criteria. Tools may be employed in an 'objectives-led' approach whereby the performance of a response option is gauged in relation to a series of aspirational objectives for

[2] In addition to guidance on key issues such as discount rates, valuation of non-market goods, and assessment of differential societal impacts based upon equity considerations, the 2011 edition of the Green Book also includes an explicit adjustment procedure to redress the systematic optimism ("optimism bias") that historically has afflicted the appraisal process with regard to expectations of final outcomes.

[3] Including Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA).

sustainable development, or alternatively a 'baseline-led' approach where potential impacts are assessed in relation to a reference baseline.

The stress-testing procedure developed in the present study is an extension of these techniques. It responds to demands for linked tools in integrated environmental decision-making (see also UK NEAFO WP10). The two-phase approach recommended by Eales *et al.* (2003) has been adopted: initial screening of response options followed by more detailed assessment, representing a pragmatic compromise between breadth and depth of analysis.

8.1.4 Synergies between response options

A particular aim of the research was to investigate whether a mix of different response options may lead to more robust and sustainable solutions compared to individual options. To achieve this, it is crucial to understand how each intervention is expected to change the current situation, or be used to manage external change to maintain the status quo. Understanding interventions as different levers in a systemic framework can then be used to establish complementarities between response options which may potentially deliver joined-up outcomes. At a strategic level, different *types* of response option can therefore be distinguished, each being associated with different forms of influence on human-environment interactions. Furthermore, complementarity can be informed by conceptual frameworks developed from research into the linkages between people's core motives[4] and their behaviour. One such framework used in this study to consider generic response options is the '4 Es' model to promote pro-environment behaviour in the context of sustainable development policy (HM Government, 2005):

- enabling - i.e. making it easier by removing barriers and developing capacity;
- encouraging - i.e. sending the right (economic) signals through policy interventions;
- exemplifying - i.e. Government leading by example; and
- engaging - i.e. involving those Government is seeking to influence.

This has been complemented by another framework that specifically links responses to individual/group core motives as defined by van Vugt (2009) through the '4 Is':

- information - associated with a motivation to improve *understanding* and help show how individual actions can make a difference;
- incentives - linked to *self-enhancing* motives that are seen to reward responsible actions;
- institutions - crucial to motives based upon *trust* and the need for common rules that seem fair and transparent; and
- identity - based upon the high social value that most people place upon their recognition in *belonging* to peer groups or local communities.

These frameworks further highlight that individual response options are unlikely to be effective without considering other *types* of options. For example, there is considerable evidence to show that simply providing people with information is unlikely to lead to successful appreciation or behaviour change (the failed 'deficit model' of communication) unless enabling frameworks that engage and build capacity to use that information (such as targeted training and appropriate institutions) are also promoted in order to make the information relevant to different users (Farrell *et al.* 2001; Sarewitz & Pielke 2007). This is particularly important when planning for change, as it is unlikely that information alone will be able to reduce uncertainty in decision-making. Similarly, incentive schemes

[4] Core motives are fundamental psychological processes influencing thoughts, emotions and behaviour in situations involving other people.

that are not in sympathy with local identities are unlikely to receive a large uptake, as exemplified by the resistance in some farming communities to agri-environment schemes if they do not acknowledge the primary cultural identity of farmers as food producers (Burton *et al.* 2008). Knowledge systems that combine scientific with other forms of knowledge can therefore provide one mechanism for stimulating both improved awareness of change and appropriate local action, consistent with the intention of Principle 11 of the Ecosystem Approach (CBD, 2004).

Interventions that address multiple core motives simultaneously have been identified as most likely to be successful (van Vugt, 2009). Whilst economic factors are part of this mix of motives, not all people are primarily motivated by economic self-interest, reinforcing the importance of being aware of shared, social and cultural benefits provided by ES (see UK NEAFO WP5 and WP6). Formal (top-down) intervention schemes may work in some contexts, but in other circumstances they may be unnecessary due to strong community identity or local trust in common institutions (Ostrom, 2009). In the latter case, government may be most effective when positioning itself as an enabler of local innovation, or by providing incentives sympathetic with existing institutions, constructive identities or social norms.

The '4 Es' and '4 Is' conceptual frameworks have been used to draw general inferences for synergistic policy design based upon the stress-testing of specific response options. To help explore links between the suite of response options and the challenges of 'joined-up' policy, we have made reference to the current and future development of major policy topic areas. These include not just current policy developments (and by implication legacies from previous policy), but also future policy cycles and the role of an ES framework in delivering their long-term objectives. Policy topics include ongoing reform of the EU Common Agricultural Policy, integrated water resource management (including EU Water Framework Directive, Floods Directive and Marine Directive), Green Infrastructure, and the transition to the Low Carbon Economy (stimulated by the UK Government commitment for an 80% reduction in greenhouse gas emissions by 2050).

8.1.5 Generic response options

It was not feasible in the present study to investigate all sectoral response options in detail. Rather, an indicative sample of different response types was selected with reference to a generic typology. The UK NEA had previously developed a model structure for response options based upon their role as foundational, enabling or instrumental types (Vira *et al.*, 2011). These response types were linked in a series of steps through which knowledge ('foundational' level) creates the context for governments and other institutions to develop policy-based interventions that provide 'enabling' conditions for actors to undertake specific 'instrumental' actions. This top-down model of response options provided a standard structure for understanding the diversity and differences in priorities between sectors. However, factors such as legacy, the role of institutions (public and private), and scale effects (including local/regional as well as national/international context) mean that most situations are more complex in practice. For instance, policy aspirations are sometimes developed ahead of the knowledge required for their delivery, acting as a stimulant to knowledge-based innovation, as shown by the challenge inherent in the UK policy commitment for a 80% reduction in greenhouse gas emissions by 2050. Another counter-example is where responses arise from bottom-up processes, with local knowledge providing the stimulus for local action, such as through community partnerships, trusts, or similar initiatives[5]. The primary role of policy may sometimes

[5] Numerous examples of such bottom-up initiatives exist, including community woodlands, farming groups, nature partnerships, river trusts, and coastal partnerships, as referred to in the sectoral analysis in section 8.3.

therefore be reframed as providing the space (intentionally or otherwise) for such local initiatives to flourish, rather than imposing prescriptive guidance (Ostrom, 2009). Bottom-up initiatives also specifically address guiding principles of the Ecosystem Approach including: the need for local management (Principle 2); integration of scientific with local knowledge (Principle 11); and the participation of multiple stakeholders in decision-making (Principle 12).

The original categorisation of response options proposed by Vira *et al.* (2011) has therefore been modified to incorporate a broader cross-scale perspective (**Figure 8.1**) and to allow cross-referencing against frameworks for policy interventions ('4 Es'/'4 Is'). This modified framework includes 13 different response types, and allows the relative balance of top-down and bottom-up responses, such as statutory against voluntary measures, to vary based upon different scenario assumptions.

It should be noted that existing schemes sometimes aim to combine different types of responses together, formally or informally (e.g. regulation and levies). Furthermore, response options often evolve over time and may morph into each other. For example, precedents established under Common Law may inform new economic valuation and market approaches and in time become cemented in statutory legislation. This is often particularly apparent at the local level where context can strongly influence the shaping of combined response options. It is also apparent in the need for key actors to work together including: government (national and local); business and industry; land managers; marine resource users; civil society (including NGOs); research organisations; citizens and communities.

The generic responses options were categorised as follows:

- statutory protected / designated areas;
- statutory regulation and quality standards;
- levies;
- direct economic incentives;
- market-based schemes;
- spatial and integrated planning;
- good management practices;
- voluntary standards and quality assurance;
- social and cultural networks, partnerships and community schemes;
- education and knowledge exchange;
- technological innovation;
- scientific research & development; and
- common law.

A summary of the generic response option types, including governance arrangements, key requirements, scales, and challenges associated with their implementation is provided in **Appendix 8.1**.

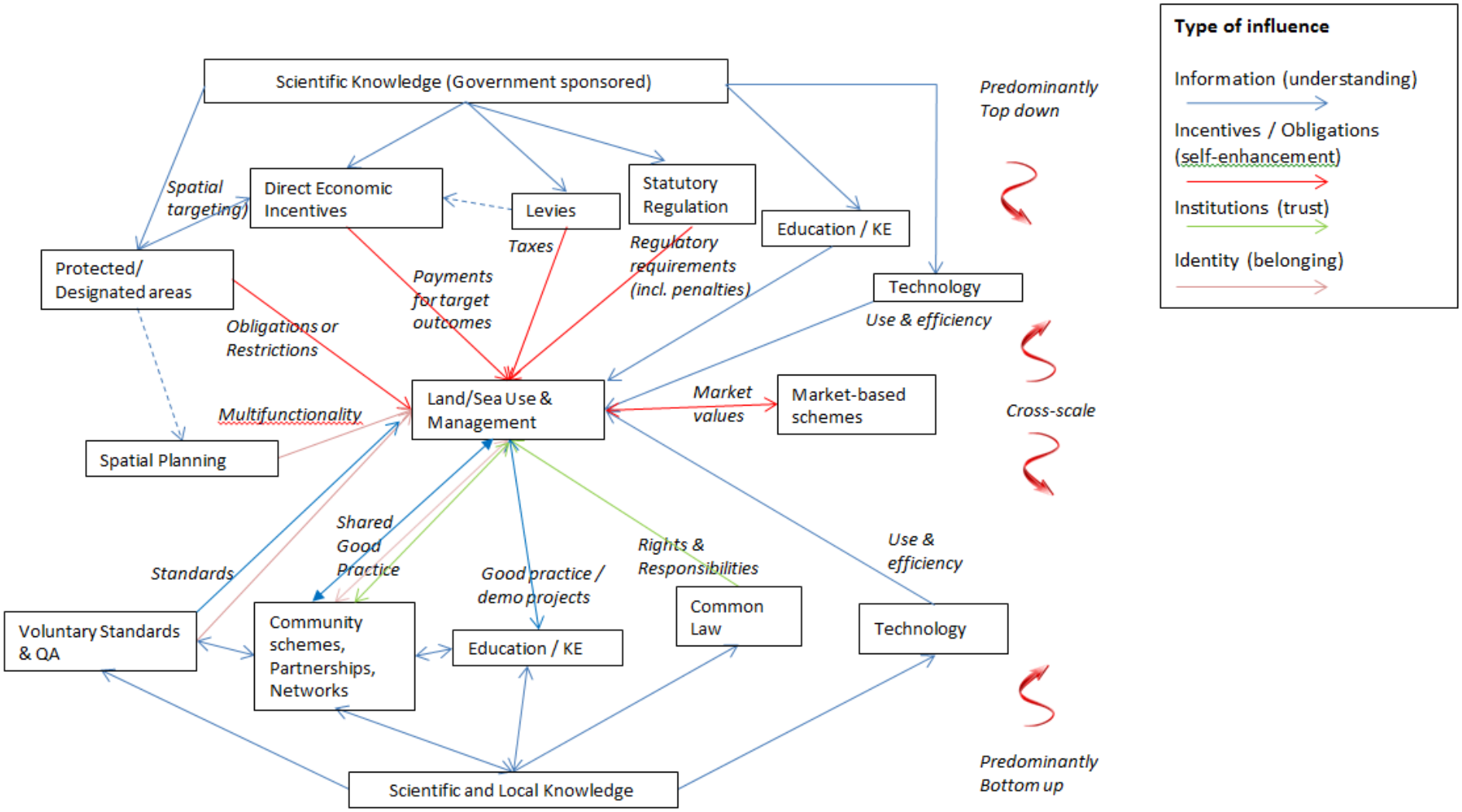


Figure 8.1. Schematic relationships between the generic response option categories.

8.2 Method

The stress-testing approach implements a structured process of testing response options against possible scenarios, where each scenario is a plausible version of the future. The method is flexible and can be adjusted to meet different requirements, with a specific implementation outlined here based upon the steps depicted in **Figure 8.2**.

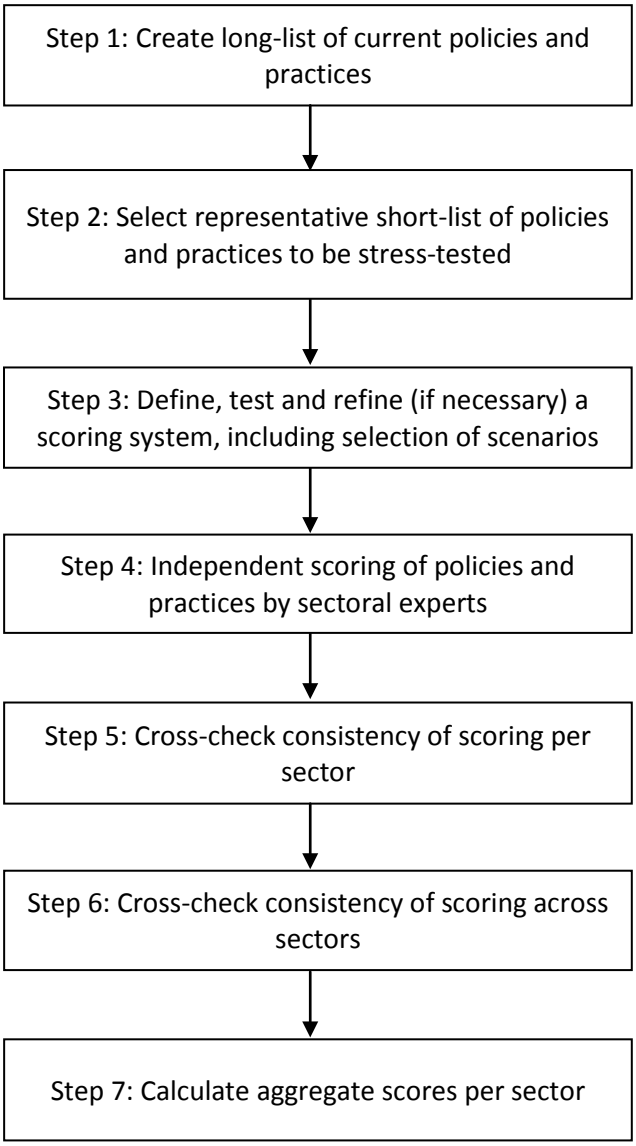


Figure 8.2. Basic steps involved in the stress-testing exercise.

Step 1: Create long-list of current policies and practices. A long-list of response options provides a quick broad-based summary of topical issues that helps to identify the range of alternative responses. In this study, information on their type, current status, relevant governance arrangements, the time horizons associated with policy objectives, and the key scales associated with implementation for each option was documented (see **Appendix 8.2**).

Step 2: Select representative short-list of policies and practices to be stress-tested. A screening process can be used to allow identification of a representative subset of response options for more detailed evaluation. For the present study, the screening was based upon the different categories of

the generic typology (**Figure 8.1**) with options that varied in terms of the following criteria: stages of implementation (established or early stages); spatial scale (including top-down and bottom-up); key actors; and flexibility. Some of the short-listed response options are sector-specific (highlighted in red in **Appendix 8.2**) and some are cross-sectoral (highlighted in blue in **Appendix 8.2**). 48 response options were short-listed which are listed in **Table 8.2** in relation to the generic response option categories. Response options were related to a primary generic response option category, but can involve elements of other categories as indicated in **Table 8.2**. The short-list was then reviewed with key stakeholders (listed in Section 8.9), to ensure it had a reasonably representative set of response options for stress-testing.

Table 8.2. Short-list of response options to be stress-tested against the UK NEA scenarios. Dark green indicates the primary generic category associated with each response option and light green secondary categories.

Response option	Generic categories												
	Protected areas	Statutory regulation	Levies	Direct economic incentives	Market-based schemes	Spatial & integrated planning	Management practices	Voluntary standards	Networks, & partnerships	Education & KE	Technology	Science R&D	Common law
Agriculture:													
Payments for ecosystem services													
Mitigation of diffuse pollution and emissions													
Indicators for sustainable agriculture													
Agricultural networks, associations & initiatives													
Urban food production													
Food labelling to encourage healthy diets													
High frequency/resolution sensing (precision farming)													
Research on spatial 'optimisation'													
Research on climate change adaptation													
Forestry:													
UK Forestry Standard													
Woodland Carbon code (credit system)													
Grant aid with spatial targeting													
Collaborative management groups													
Certification													
Community woodland groups													
Advisory services and visits													
Biodiversity:													
Protected areas													
Ecological networks													
Compulsory set-aside													
Incentive-based agri-environment schemes													
Biodiversity offsetting													
Land sparing													
Voluntary quality assurance schemes													
Nature-based partnerships													

Response option	Generic categories												
	Protected areas	Statutory regulation	Levies	Direct economic incentives	Market-based schemes	Spatial & integrated planning	Management practices	Voluntary standards	Networks, & partnerships	Education & KE	Technology	Science R&D	Common law
Water:													
Health and well-being (blue networks)													
Water Framework Directive													
Natural flood management													
Water industry (public supply measures)													
Water industry (demand-side management)													
Integrated catchment management													
Sustainable urban drainage systems													
River Trusts													
Urban, energy and transport:													
National Planning Policy Framework													
Energy-related EU legislation													
Multi-functional green infrastructure													
Art, humanities and culture projects													
Urban ecosystem assessments													
Sustainable modes of transport													
Technology to deliver energy and water saving													
Research on climate change adaptation													
Marine and coasts:													
No take zones													
Conservation measures in fisheries													
Marine Plans													
Managed realignment													
Beach nourishment													
Certification (fisheries and aquaculture)													
Coastal partnerships													
Marine monitoring													
Environmental NGOs (marine)													

Step 3: Define, test and refine (if necessary) a scoring system, including selection of scenarios.
Quantitative scoring can be very useful to evaluate and communicate the performance of response options using an ES framework. However, design of an appropriate scoring system should balance the need to be comprehensive against the problems of over-complexity, particularly if used in a participatory setting. Similarly, although multiple scenarios are required to identify different pathways of change, the choice of number of scenarios (and time periods) needs to be based upon decision-making priorities and associated practicalities (e.g. time/resources available). For the stress-testing methodology, a stakeholder workshop was used to test the scoring system and based upon feedback the method was subsequently simplified to three criteria:

- Relevance (or priority) of the response option within the future scenario where the categories are low relevance, medium relevance and high relevance.
- Effect of the response option on provisioning, regulating, cultural and supporting services where the categories are -- (very negative effect), - (slight negative effect), 0 (neutral effect), + (slight

positive effect) and ++ (very positive effect). These scores express the relative effect of each response in the changed conditions provided by each scenario (i.e. relative to a non-intervention situation, not with the present day which is provided by a baseline assessment: see below). It can sometimes be difficult to evaluate impacts on ESS categories because they cover a wide diversity of individual (or interlinked) services which may not be affected in the same way. This categorisation was a necessary simplification for undertaking the stress-testing in the time available, but uncertainties should be borne in mind when interpreting the results in different situations. If these issues are important for a decision, further analysis should investigate individual services.

- Overall uncertainty where the categories are low uncertainty, medium uncertainty and high uncertainty. Levels of uncertainty associated with allocated scores can be based on uncertainty due to limitations in the scenario description (this was particularly noted for 2030 compared to 2060), uncertainty due to the relevance of the option within that future, or uncertainty due to the effect of a response option on ES related to lack of scientific knowledge.

In addition to evaluating future change, scoring of relevance and effect on ES for response options was conducted for the baseline situation to highlight their current priority (relevance) and performance (i.e. positive, negative, no change). The baseline assessment therefore provides a link with the existing evidence base (UK NEA, 2011) by confirming the current status of ES. This enables the future robustness of the response options to be also assessed in relative terms against this baseline, taking account of the scenario assumptions and available evidence. It is important to note that the response options are framed as they exist at present. An outcome of the stress-testing exercise was identification of the strengths and weaknesses of each response option, and hence implications for future policy design.

From the original 6 UK NEA scenarios (Haines-Young *et al.,* 2011), a subset 4 were used in this study due to time constraints; this selection was considered to provide the most divergent examples. The 'Go with the Flow' scenario which represents business-as-usual was considered to be less useful for the longer time horizon (2060) compared to the shorter term.

Step 4: Independent scoring of policies and practices by sectoral experts. The scoring process can be accomplished in various ways, either individually or in groups. For the present study, a combined approach was used (steps 4-6). Each response option was first scored independently by a sectoral expert (i.e. one of the co-authors of this report). The scoring was based on multiple forms of knowledge (data/evidence where available, stakeholder interviews and expert opinion) following Principle 11 of the Ecosystem Approach. Guidelines for applying the method were created to ensure it was implemented in a consistent manner across the policy sectors. This involved providing summary descriptions of the four UK NEA scenarios and two timeslices considered in the study and ratings of important drivers within each scenario for testing the performance of each response option (see **Appendix 8.3**). The guidelines used in our study also stated that the scoring should be at the UK scale (or equivalent for marine). Furthermore, climate change implications were considered during each stress-test in terms of whether the response option has the flexibility to adapt to climate change based on the UKCP09 central estimate (50% level) for medium emissions.

Step 5: Cross-check consistency of scoring per sector. The individually scoring of response options was then compared with at least one other expert per sector. The reasoning and justification for the scores were discussed and a consensus reached.

Step 6: Cross-check consistency of scoring across sectors. Finally, the scoring was compared across sectors in a 2-day meeting where the scoring for each sector was presented and discussed to ensure that the method had been applied consistently across policy areas.

Step 7: Calculate aggregate scores per sector. To aid the synthesis of the results, the scores for relevance and effect on ES were aggregated in two ways: (i) across response options for each UK NEA scenario to give an indication of which scenarios resulted in the most beneficial impacts on ES; and (ii) across scenarios for each response option to give an indication of the robustness of options across different futures. The aggregate scores are presented as x/y where x is the actual aggregate score based on "high" relevance equating to a value of 3, "medium" to a value of 2 and "low" to a value of 1, and y is the maximum possible score[6]. The effect scores were aggregated assuming "- -" equates to a value of -2, "-" to -1, "+"to +1 and "++"to +2. However, this should be viewed alongside the results for the individual service categories to ensure that large service benefits in one category (i.e. intensive farming for food) do not result in excessive trade-offs on other crucial services (e.g. landscape amenity, soil carbon storage, water quality).

To summarise, the specific future-proofing methodology implemented here was designed to be broadly-based and cover a wide range of response options across multiple sectors. Individual scoring was cross-checked in a group setting for consistency. This type of implementation may be most suitable for cross-sectoral assessments, including formal options appraisals such as strategic environmental assessment (SEA) and sustainability appraisal (SA). However, the methodology can easily be refined for more detailed evaluation of response options for particular decisions, in which case it may be useful to score individual ES to investigate potential trade-offs. The scoring presented here has also assumed equal weighting of response options for transparency, but it can also be useful to investigate weighting of different response options (e.g. based upon their relevance in each scenario).

[6] The maximum value depends on the number of response options and time-periods stress-tested for the sector: i.e. y would equal 48 for a sector where eight response options were stress-tested over the two timeslices.

8.3 Results

8.3.1 Cross-sectoral overview

A primary objective of this study was to identify response options that can enhance sustainability by building synergies across multiple sectors. Consequently, a cross-sectoral overview is presented first, with more detailed sector-specific[7] considerations addressed in the following sections, including the results of the stress-testing analysis.

The overview is guided by **Table 8.3** which summarises the assessment by grouping sectoral response options according to generic types, based upon results for the 2060 timeslice. Information is provided on:

- whether or not a response option is considered likely to remain important and be supported within the background condition of that future scenario (i.e. of medium/high relevance); and
- relative robustness of a response option across the four scenarios in delivering a positive net effect for the different categories of ES (maximum score of 4 for a positive effect in all 4 scenarios).

Table 8.3 can be interpreted in two different but compatible ways:

- by reading down the columns, the types of response option that would be likely to be effective in a particular future scenario can be identified; similarly, for each category of ES reading down a column identifies which response options can enhance that category in multiple scenarios; and
- by reading across a row of response options (grouped by generic type), the relative robustness of different response types for delivering balanced outcomes across ES categories can be ascertained, including whether it is likely to continue to have a high profile in different future scenarios (hence a 'yes' for relevance in all 4 scenarios and a net positive effect score of 4 for each ES category would imply a very robust option).

This cross-sectoral overview should be seen as indicative based upon the necessary level of generalisation, and the details may be queried through the sectoral results. Variations of the response option may be identified that differ from the general pattern, and an understanding of these specific differences can subsequently be used to fine-tune responses to a particular decision context.

It is evident that although statutory and regulatory responses are effective in some scenarios (Nature@Work and National Security), they would be less effective in futures where markets dominate more than today (World Markets) or possibly where they are overtaken by a localism agenda (Local Stewardship). By contrast, economic incentives and market-based schemes, that are inferred to have greater support and ES delivery potential in the World Markets scenario, may be less successful within the National Security or Local Stewardship scenarios unless they complement national or local priorities, respectively. Again, this may be compared with the effectiveness of local/community partnership-type schemes which appear more effective in delivering ES under the Local Stewardship scenario (and Nature@Work and National Security scenarios), but with less support in the World Markets scenario. This observation suggests that a combination of each of these three types of response options (regulation, market schemes, partnerships) may collectively produce a more robust design for policy development, especially if the design could be adapted

[7] To maintain consistency we have used the same 6 socioeconomic sectors previously employed in the UK NEA.

across scales as, for example, when local partnerships have a role in shaping objectives. This combination could also address some of the issues relating to uncertainty of long-term outcomes for market-based schemes by using regulation to identify necessary minimum standards, but encouraging innovation through incentives or other schemes to reward benefits that go beyond these minimum standards.

Table 8.3. Cross-sectoral assessment of response options. Key to scenarios: N@W = Nature@Work; WM = World Markets; NS = National Security; LS = Local Stewardship. Key to ES: P = provisioning services; R = regulating services; C = cultural services; S = supporting services. Positive net effect on ES calculated as the number of scenarios have a + or ++ score. Colours in cells are only used to help visualise the patterns in the results.

Generic option categories	Medium or high relevance in scenarios = Y; low relevance = N				Positive net effect on ES			
	N@W	WM	NS	LS	P	R	C	S
Statutory protected/designated areas:								
Protected areas	Y	N	Y	Y	0	3	2	3
No take zones	Y	N	N	Y	4	2	0	4
Statutory / regulation and quality standards:								
UK Forestry Standard	Y	N	Y	N	2	1	1	1
Water Framework Directive	Y	N	Y	N	1	2	2	2
Compulsory set-aside	Y	N	N	Y	0	2	0	2
EU energy legislation	Y	N	N	N	1	1	1	1
Conservation measures in fisheries	Y	Y	N	Y	4	2	0	4
Direct economic incentives/ Market-based schemes:								
Payments for ecosystem services	Y	Y	N	N	0	2	1	0
Grant aid for spatial woodland targeting	Y	N	Y	N	3	1	1	1
Biodiversity offsetting (national)	Y	Y	Y	N	3	2	0	1
Agri-environment schemes	Y	Y	Y	Y	2	4	2	3
Water industry (demand-side measures e.g. leakage, metering)	Y	Y	Y	Y	1	3	2	2
Integrated catchment management	Y	Y	N	Y	2	2	2	2
Spatial and integrated planning:								
Forestry – jigsaw scheme	Y	N	Y	N	3	1	1	1
Land sparing	Y	N	N	N	3	1	0	0
Sustainable urban drainage systems	Y	N	Y	Y	0	3	2	2
Ecological networks	Y		Y	Y	0	3	3	3
Multi-functional green infrastructure	Y	N	Y	Y	3	3	3	3
National Planning Policy Framework	Y	N	Y	Y	4	2	2	1
Blue networks	N	N	Y	Y	1	2	4	3
Marine Plans	Y	Y	Y	Y	2	2	2	2
Management practices:								
Mitigation and management of pollution from agriculture	Y	N	N	Y	0	2	2	2
Collaborative forestry management groups	Y	N	N	Y	2	2	2	2
Natural flood management	Y	N	Y	Y	1	2	2	2
Managed realignment (small-scale)	Y	N	N	Y	2	2	1	2
Beach nourishment	N	N	Y	N	0	2	0	0
Voluntary standards and quality assurance:								

Generic option categories	Medium or high relevance in scenarios = Y; low relevance = N				Positive net effect on ES			
	N@W	WM	NS	LS	P	R	C	S
Indicators of sustainable agriculture	Y	N	N	Y	1	2	1	1
Voluntary quality assurance (biodiversity)	Y	N	N	Y	1	2	1	2
Woodland carbon code	Y	Y	N	N	2	2	0	0
Certification - UK Woodland Assurance Standard	N	N	N	N	2	2	2	2
Fisheries certification	Y	Y	N	Y	3	2	2	0
Social and cultural networks, partnerships and community schemes:								
Urban food production	Y	Y	Y	Y	4	3	2	2
Agricultural networks, associations and initiatives	Y	N	Y	Y	3	3	3	3
Community woodland groups	Y	N	N	Y	2	2	2	2
Nature-based partnerships	Y	N	Y	Y	0	3	3	3
River Trusts	Y	N	N	Y	2	2	2	2
Coastal partnerships	Y	N	N	Y	2	2	2	1
Education and knowledge exchange:								
Food labelling for healthy diets	Y	N	N	Y	0	2	0	2
Forestry advisory visits	Y	N	N	Y	3	2	2	2
Arts, humanities and culture projects	Y	N	Y	Y	2	2	4	2
Urban Ecosystem Assessments	Y	N	N	Y	2	2	2	2
Marine monitoring	Y	N	N	Y	3	3	1	2
Marine environmental NGOs	Y	N	N	Y	2	2	2	2
Technological innovation:								
High frequency sensing (precision farming)	Y	Y	Y	Y	4	3	2	1
Water industry (national water supply infrastructure)	Y	Y	Y	N	3	2	0	2
Sustainable modes of transport	Y	Y	Y	Y	4	2	3	3
On-site greywater re-use	Y	Y	Y	Y	3	3	3	3
Scientific research & development:								
Research into spatial optimisation of agriculture	Y	N	Y	Y	2	3	2	1
Research into climate change adaptation for agriculture	Y	N	Y	Y	3	3	1	3
Research into climate change adaptation in urban areas	Y	N	Y	Y	3	3	2	3

The basic differences assumed by the UK NEA scenarios imply that provisioning ES would tend to have a greater emphasis than other ES in World Markets (due to market value) and National Security (due to food/energy policy) compared to the more balanced profile of services in the other two scenarios explored here. However, an important distinction may be apparent between land-based sectors and the marine sector with regard to protected areas and statutory interventions. The assessment is based upon an assumption of good practice; hence if these types of intervention are used to protect crucial nursery areas in marine areas, then it is possible that due to their mobility, stocks of fisheries could be enhanced elsewhere. These interventions could therefore help to enhance marine provisioning services in all scenarios through an emphasis on maintaining habitat quality (i.e. supporting ES). By contrast, protected areas and statutory interventions on land typically aim to maintain or enhance regulating or supporting ES (and to a lesser extent cultural ES) and it is

more difficult to envisage circumstances where these could also enhance food production, although improved supply of potable water and timber production may be possible.

Similarly, although **Table 8.3** suggests that technological and scientific innovation would provide reasonably robust response options in most scenarios (often depending on the type and scale of innovation), a leap of faith is required that these innovations would automatically be widely adopted and therefore result in positive net enhancement across all ES categories. For example, technology in isolation can often result in over-exploitation of a narrow subset of ES at net cost to other services and overall system resilience. Therefore, in order to deliver on sustainability objectives, these types of responses would need to be combined with either knowledge exchange through education, networks or partnerships, or top-down regulation to protect vulnerable ES.

Another issue summarised by **Table 8.3** is that different response option types can vary in their potential to enhance different categories of ES. As highlighted above, statutory-based interventions are particularly designed to enhance regulating services (and by association, supporting services, and possibly cultural services), with potential trade-offs for provisioning services. Market-based schemes and related incentives would offer good potential to enhance provisioning and regulating services, they would seem to be less effective in enhancing cultural and supporting services; this is at least partly due to the difficulty in defining the benefits from cultural and supporting services as tangible commodities or direct outcomes. Similarly, technological innovation is identified to be a more relevant response option for provisioning and regulating services rather than cultural services. A notable exception to this general pattern is sustainable modes of transport where associated reduction in levels of air pollution could also enhance cultural benefits delivered across a range of contexts. Some types of responses, notably integrated planning and good management practices, supported by knowledge development and exchange, have the potential (often unrealised at present) to provide a balance across the full range of ES. Spatial and integrated planning, and partnerships and networks, or community-based initiatives, would seem to be particularly important types of measures in ensuring that cultural services are adequately maintained or enhanced when designing an appropriate mix of responses.

Geographical variations in the performance of different response options for ensuring continued ecosystem resilience and the sustainable supply of ES are masked by the overall picture. This is most strongly exemplified by protected areas, which are very likely to deliver positive results in their designated areas (assuming that the same legal framework is enforced), but which may have no effect or even a negative effect (due to constraints on institutional resources) for unprotected areas in the wider landscape. This would suggest that response options that have a specific geographic focus, such as protected areas, need to be considered alongside other response options to ensure that the integrity of the wider landscape or seascape and the resilience of ecosystems is central to planning considerations.

The analysis in **Table 8.3** is based upon the supply of different categories of ES and, therefore, probably undervalues the importance of good management practice and appropriate governance for matching supply with demand. Again, there are important scale issues here which need to be considered in the design of integrated response options. If supply and demand are grossly-mismatched in scale, their combined pressure can result in the short-term over-supply of some ES beyond their sustainable limits; the complexity of ecosystem dynamics mean that often these limits are difficult to define before they are reached and/or exceeded. Therefore, both statutory and market-based schemes, and the uptake of new innovations, need to maintain a connection to local-level management practices, underpinned by improved knowledge on the sustainable limits of different types of ES. This requires these relationships to be reflexive and adaptive, and this may require revised approaches to existing schemes, some of which may be challenging to modify quickly

at present, especially if associated with a legislative procedure. This challenge would include the setting of regulatory limits or the cost-benefit ratios of market incentives against a background of dynamic ecosystem processes (e.g. due to climate change). Proactive spatial planning can play a key role in facilitating these multi-scale cross-sectoral connections, though as yet it has generally failed to deliver these synergies, an outcome often attributed to legacy challenges of linking fragmented initiatives and overcoming institutional barriers which can act against proactive planning approaches and favour a more reactive mode of working (Hurliman & March, 2012).

8.3.2 Agriculture

The UK NEA showed that, in very general terms, agricultural policy and practices boosted national food production during the mid-20th Century, with declines in other ES (Firbank *et al.*, 2011). Since around 1980, public and policy concerns have sought to improve the environmental footprint of agriculture, with the result that diffuse pollution to water courses and emissions to the atmosphere have fallen in recent decades (Firbank *et al.*, 2011). This has been achieved through a combination of regulation, financial support, new practices and sharing of information. Consumer concerns about the safety of food, animal welfare and environment have given rise to various accreditation and assurance schemes, whilst the increased use of the Ecosystem Approach by policy-makers is stimulating a range of initiatives to support the delivery of ES from farmland, for example, the Cambrian Mountains Initiative[8]. However, concerns about food security have been growing in the UK in recent years, prompted by doubts that global food supply will fail to keep up with demand that is rising swiftly because of increasing population, a shift towards more meat-rich diets and the pressures of climate change (Foresight, 2011).

There are many possible interventions to enhance the delivery of ES, including food production, from the farming sector. A subset of nine current response options was selected for detailed assessment (**Table 8.4**); some options relevant to agriculture (notably set-aside, agri-environment schemes and Water Framework Directive) are considered under other sectors. Major differences in impacts from the general pattern were considered unlikely at sub-UK level. All scenarios assumed an increasing tightening of global food supply due to rising global demand not being easily met by supply, and increased variability of agricultural production because of climate change (Foresight, 2011). The results of the stress-testing of the responses are shown in **Table 8.5** and **Figure 8.3.**

The relevance of the response options varies greatly between scenarios. They are most relevant to Nature@Work (score = 48/54), with its top-down yet integrated approach to delivering ES that allows for regulation, research knowledge exchange and financial instruments. The Local Stewardship scenario (score 38/54) is seen to be less favourable to market-based and top-down instruments, while World Markets (score of 28/54) is seen to favour market instruments above all others. National Security (score of 34/54) favours a top-down, technology-based approach to securing national food supplies. The differences are most pronounced for the regulating services (which ranged from a score across all options of 4 under National Security to 30 under Nature@Work) and cultural services (that ranged from -5 under National Security to 16 under Nature@Work) (out of a maximum of 36). Few differences between 2030 and 2060 are noted, because it is assumed that those interventions currently in development will be having an impact by 2030, and this impact is largely expected to continue into the future, even though the effects of climate change on overall ES delivery are expected to be more severe over time.

[8] http://cambrianmountains.co.uk/

Table 8.4. Agricultural response options included in the stress-testing study.

Response Option	Type	Status	Reason for short-listing
Payments for Ecosystem Services	Market-based mechanisms	Early stages	A much-touted response to declines in delivery of ES
Methods for mitigation and management of diffuse pollution and GHG emissions	Management practice	Well established	A tested approach that often relies on regulation and support
Indicators of sustainable intensification	Voluntary standards	Early stages	A topical response that supports the concept of sustainable intensification
Agricultural networks, associations and initiatives	Networks and partnerships	Well established	They have a strong cultural and KE role
Urban food production	Networks and partnerships	Long tradition, but developing rapidly	An intervention to support cultural ES in particular
Food labelling to encourage healthy diets	Education and KE	Early stages	To address the need to improve awareness of diet and nutrition
High frequency and high resolution agro-environmental sensing (for precision farming)	Technology	Early stages	An application of new technologies to food production and nutrient input
Research into improved spatial 'optimisation' of land use	Science R & D	Early stages	A topical response to concerns over natural capital and ES
Research into climate change adaptation in agriculture	Science R & D	Early stages	A topical response to climate change

The uncertainties vary between scenarios; the findings are least certain for Local Stewardship because it is not clear to what extent technologies and regulation will be taken up at a local level. The major uncertainty about the World Markets scenario is the extent to which businesses adopt what are now largely seen as public goods (healthy food, indicators of sustainable intensification) as marketing strategies, and the degree to which markets take over the current role of the state in developing and managing interventions. The current emphasis on joint state-industry funding for research (e.g. through the Technology Strategy Board) and engagement with industry at a policy level (e.g. the Green Food Project (Defra 2012)) is enhancing the role of industry in shaping a wide range of interventions; it remains to be seen how well this may work if the state were to largely withdraw from being responsible for developing and managing interventions as assumed under this scenario.

There are also considerable uncertainties about effects of interventions on supporting services. This is partly because our current knowledge makes it hard to forecast the effects of current interventions on many of them (e.g. due to time lags), and partly because they may become a much greater focus of research, innovation and interventions over time. Likewise, the role of cultural services from agricultural land may become rather different from present in the World Markets and National Security scenarios.

Most of the interventions are not seen to have a negative effect on ES; the exceptions are Payments for Ecosystem Services under Nature@Work, where regulating services are assumed to be promoted at the expense of provisioning services, and optimising land use and urban food production under National Security, in which cultural services are sacrificed for increased food production. However, this level of analysis disguises important trade-offs between provisioning of food and clean water that may require more detailed spatial evaluation.

The most robust response options are those that develop and disseminate knowledge, technology and practice, because these apply to greater or lesser extents to support the delivery of ES in a

changing world under all 4 scenarios. The analysis suggests that the most effective of all is "Agricultural networks, associations and initiatives," including public and private sector networks, which were inferred to have an important role in spreading best practice in all scenarios except for World Markets (this role is expected to be taken over by major food suppliers and retailers in this scenario). Less formal networks are also likely to underpin urban food production, with its support for all forms of ES, except under National Security, which envisages the loss of much public amenity as land is taken over for food production; perhaps multifunctional green infrastructure could enhance food production in this scenario (see Urban section; **Table 8.13**). Methods to manage diffuse pollution will prove most relevant to Nature@Work and Local Stewardship, as will the Water Framework Directive and integrated catchment management (see Water section; **Table 8.11**).

The scientific and technological developments of research into climate change adaption and agri-environment sensing also scored highly, given their relevance to food production under most scenarios (the assumed lack of relevance to World Markets assumes that companies do not take over the state role for funding such research). Research on spatial 'optimisation' of agricultural land is relevant to all scenarios except for World Markets, and would be needed to enhance interventions intended to manage the trade-offs between provisioning and other ES. However, there are inherent challenges in implementing such research which would require a level of top-down planned cross-sectoral integration that does not exist at present. This could be made through links to spatially-targeted grant aid, (see Forestry sector; **Table 8.7b**), biodiversity offsetting and land sparing (see Biodiversity sector; **Table 8.9**); and blue networks (see Water sector; **Table 8.11**. Alternatively, it could be argued that in a World Markets future, where markets dominate and state intervention is very limited, then a form of 'optimisation' would occur as only the more profitable land uses would be able to compete globally. A key challenge to notions of large-scale spatial 'optimisation' is provided by the sensitivity of agriculture to weather, and the likelihood that future patterns of climate change and variability will shift agro-climatic regions in the UK, with implications for presumed optimal land use arrangements (e.g. Brown *et al*., 2011). Nevertheless, at farm and field scale, innovations such as high resolution and high frequency sensing for precision farming could allow better management of soils and other resources to adapt to changing conditions from year to year.

The present situation in agriculture has elements of all scenarios. The continued development of the Common Agricultural Policy and rural development programmes is partly consistent with Nature@Work; the importance of global cereal, protein and energy prices on agriculture reflects World Markets; the new emphasis on food security has elements of National Security, while the growth of urban and peri-urban farming is consistent with Local Stewardship. The new emphasis on developing and disseminating technology and practice (BIS, 2013) is therefore highly appropriate to this analysis. However, advisory services may need to be supplemented by the much wider range of policy options available under Nature@Work and Local Stewardship in order to maintain the delivery of non-provisioning ES. In institutional terms, developing partnerships between industry, research and government may enhance the effectiveness of flexible interventions based on technology, practice and voluntary standards. In addition to the opportunities for cost-effective ES delivery, this may help to emphasise innovation and knowledge exchange using multiple platforms that embrace communities, policy and industry.

Table 8.5. Results of the stress-testing exercise for the agriculture sector: (a) Present relevance and performance of response options; and (b) Future relevance and performance of response options. Rel = Relevance of the response option within the UK NEA scenario (categorised as high (H), medium (M) or low (L)). Effect on ES = Effect of the response option on ES (P = provisioning services; R = regulating services; C = cultural services; S = supporting services) within the UK NEA scenario (categorised as very negative (- -), slightly negative (-), neutral (0), slightly positive (+) or very positive (++)). These are all given in comparison with the scenario in the absence of the intervention. Note that options covered by other sectors are also relevant to agriculture.

(a)

Response option	Rel	Effect on ES			
		P	R	C	S
Payments for ecosystem services	L	0	+	+	0
Methods for mitigation and management of diffuse pollution and GHG emissions	H	–	++	+	0
Indicators of sustainable intensification	M	0	+	+	0
Agricultural networks, associations and initiatives	H	++	+	+	+
Urban food production	L	0	0	++	0
Food labelling to encourage healthy diets	L	0	0	0	0
High frequency and resolution agro-environmental sensing	L	+	+	0	0
Research on spatial optimisation of agricultural land use	L	0	0	0	0
Research on climate change adaptation in agriculture	L	0	0	0	0
Aggregate score	***14***	***2***	***6***	***6***	***1***

(b)	Nature@Work					World Markets					National Security					Local Stewardship					Aggregate score
	Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				
		P	R	C	S		P	R	C	S		P	R	C	S		P	R	C	S	
Payments for ecosystem services:																					
2030	M	–	+	0	+	H	++	+	+	0	L	0	0	0	0	L	0	0	0	0	**5**
2060	M	–	+	0	+	H	++	+	+	0	L	0	0	0	0	L	0	0	0	0	**5**
Methods for mitigation and management of diffuse pollution and GHG emissions:																					
2030	H	0	++	+	+	L	0	0	0	0	L	0	0	0	0	H	0	++	+	+	**8**
2060	H	0	++	+	++	L	0	0	0	0	L	0	0	0	0	H	0	++	+	+	**9**
Indicators of sustainable intensification:																					
2030	H	+	++	++	+	L	0	0	0	0	L	0	0	0	0	M	0	+	0	0	**7**
2060	H	++	++	++	++	L	0	0	0	0	L	0	0	0	0	M	0	+	0	0	**9**
Agricultural networks, associations and initiatives:																					
2030	H	+	++	++	++	L	0	0	0	0	M	0	+	+	+	H	++	++	++	++	**18**
2060	H	+	++	++	++	L	0	0	0	0	M	0	+	+	+	H	++	++	++	++	**18**
Urban food production:																					
2030	M	+	+	++	+	L	+	+	0	0	M	++	–	– –	0	M	+	+	++	+	**11**
2060	M	+	+	+	+	M	++	+	0	0	M	++	–	– –	0	M	+	+	++	+	**11**
Food labelling to encourage healthy diets:																					
2030	M	0	+	0	0	L	0	0	0	0	L	0	0	0	0	M	0	+	0	0	**2**
2060	M	0	+	0	0	L	0	0	0	0	L	0	0	0	0	M	0	+	0	0	**2**
High frequency and resolution agro-environmental sensing (precision farming):																					
2030	H	++	++	0	+	H	++	+	+	0	H	++	0	0	0	M	+	+	0	0	**13**
2060	H	++	++	0	+	H	++	+	+	0	H	++	0	0	0	M	+	+	0	0	**13**
Research on spatial optimisation of agricultural land use:																					
2030	H	0	++	+	0	L	0	0	0	0	H	+	+	–	0	M	+	+	+	+	**8**
2060	H	0	++	+	0	L	0	0	0	0	H	++	+	– –	0	M	+	+	+	+	**8**
Research on climate change adaptation in agriculture:																					
2030	H	++	++	0	+	L	0	0	0	0	H	+	+	0	+	M	+	+	0	0	**10**
2060	H	++	++	+	++	L	0	0	0	0	H	++	+	0	+	M	+	++	0	+	**15**
Aggregate	**48**	**13**	**30**	**16**	**19**	**27**	**11**	**6**	**4**	**0**	**34**	**14**	**4**	**-5**	**4**	**38**	**12**	**21**	**12**	**11**	

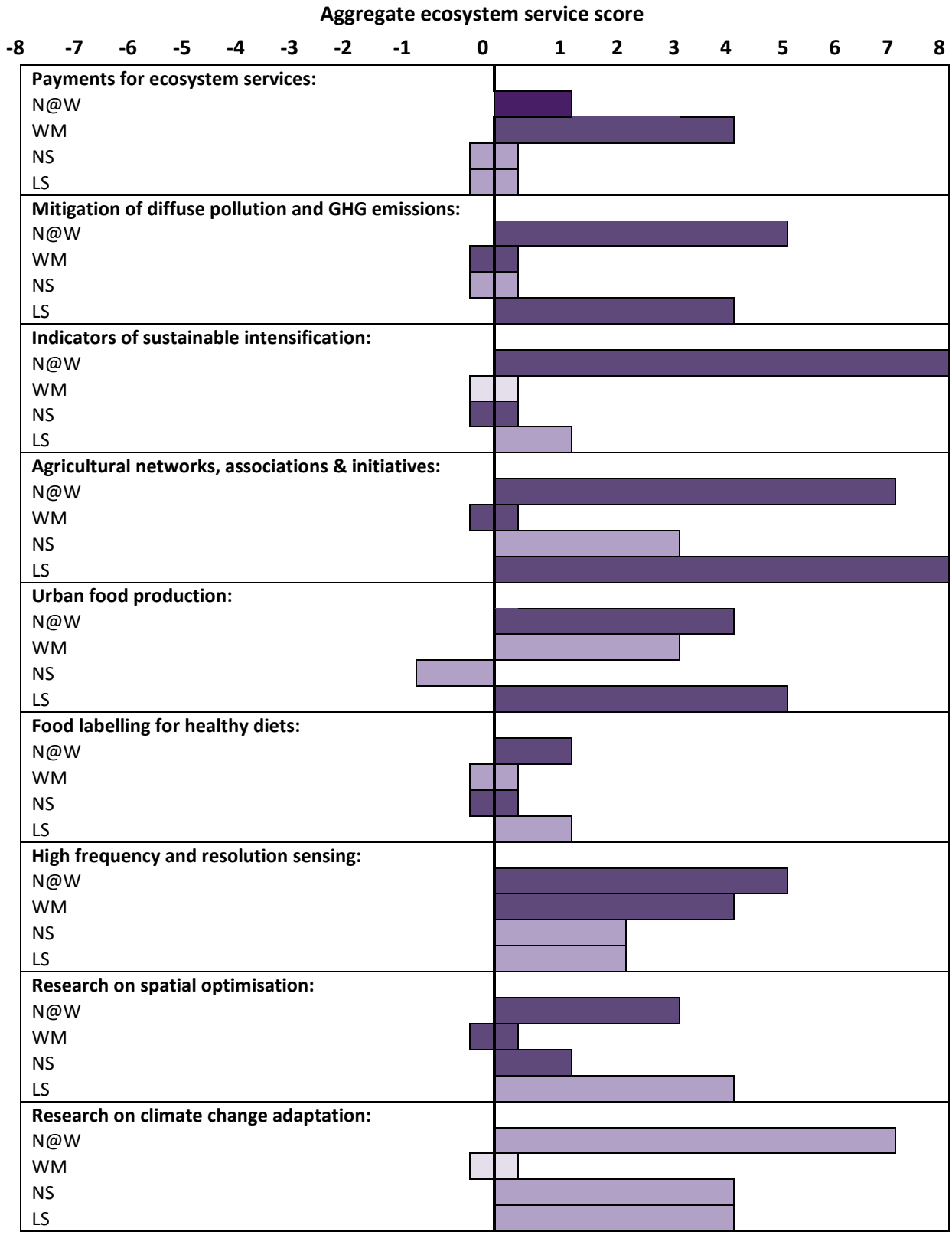


Figure 8.3. Graphical summary showing how the agricultural response options fare under the UK NEA scenarios in 2060. The bars show the aggregate score across the provisioning, regulating, cultural and supporting ES classes. The bars are colour-coded according to the uncertainty related to the score (dark purple = low uncertainty; mid purple = medium uncertainty; light purple = high uncertainty). The figure should be viewed alongside Table 8.5 which shows the results for the individual service categories as gains and losses in different service categories can counteract each other.

8.3.3 Forestry

Forestry has been a focus for policy for the past century. Only 5% of woodland cover remained in the UK in the early 20th Century, and the lack of timber supply during wartime created a policy imperative to build a strategic reserve. This resulted in the establishment of the Forestry Commission in 1919, and the initiation of a substantial afforestation programme through state and private planting which was maintained over most of the 20th century. UK woodland cover has increased from 5% in 1924 to 9% by 1980 and is now 13% (Quine *et al.* 2011). During the latter half of the 20th century, a series of legislative and policy changes shifted the goal for forestry away from simply provisioning of timber towards multi-purpose forestry. This involved the use of various regulations and incentive schemes to increase the broadleaved component, restrict expansion in valued landscapes (e.g. in upland England and the Flow Country), and enhancing protection afforded to the remnants of ancient woodland. The Convention on Biological Diversity (and the expression of the Ecosystem Approach) stimulated the emergence of 'sustainable forest management' (SFM) and multi-purpose forestry was further modified to require explicit consideration of environmental, economic and social objectives. Policy development for SFM now aims to reflect these three pillars of sustainability (Quine *et al*., 2013), as well as to respond to the threat of climate change through mitigation and adaptation (Read *et al.* 2010). Most recently, with the arrival in the UK of a number of new pests and pathogens, tree health has become a focus of policy concern (Defra 2011).

By comparison with some other sectors (e.g. agriculture), the forestry sector necessarily has longer-term horizons for decision making. A variety of mechanisms have been developed to support the implementation of SFM, including knowledge-based initiatives, such as through a strategy and funding for applied research, provision of advice, professional bodies and societies; 'enabling' frameworks such as legislation (including restrictions on tree-felling and conversion of forest land), forest policies, and the UK Forestry Standard; and 'instrumental' measures such as a variety of financial incentives (both tax and grant aid, evolved with different targeting over the past decades), the development of voluntary certification schemes, and early steps to develop voluntary carbon markets (through derivation of a code of practice). A subset of seven current forestry responses options, across a range of types, response maturity and geographic focus, was selected for stress-testing (**Table 8.6**), with the results of the stress-testing shown in **Table 8.7** and **Figure 8.4.**

Table 8.6. Forestry response options included in the stress-testing study.

Response Option	Type	Status	Reason for short-listing
United Kingdom Forestry Standard (UKFS)	Statutory regulation	Well-established	Sector approach to describe standards to deliver sustainable forest management (i.e. multiple ecosystem services)
UK Woodland Carbon Code (WCC) – credit system	Voluntary standards	New	An early attempt to underpin voluntary markets in ES with a focus on a quantifiable good
Grant aid with spatial targeting	Spatial & integrated planning	Well-established	Mechanism used to bring about benefits in specific locations (e.g. for habitat connectivity or to benefit disadvantaged communities)
Collaborative management groups	Management practices	Mix of new and well-established	An approach to coordinating management across ownerships of relevance to delivery of landscape-scale ecosystem services
Voluntary certification	Voluntary standards	Established	National variant of international schemes providing quality assurance and potential access to markets
Community woodland groups	Networks & partnerships	Mix of new and established	Involvement of local people in ownership or management of resources
Advisory services and visits	Education & knowledge exchange	Well-established	A way of mobilising land managers and promoting both regulations and incentives

Comparison of how the seven response options perform across the scenarios shows that they have highest relevance overall to Nature@Work (aggregate relevance score of 26/42) and Local Stewardship (23/42) and less of a place in National Security (20/42) and World Markets (19/42). This reflects their fit to worlds which emphasise co-production of multiple services and collective effort (consistent with SFM), but their limited scope in worlds in which there is either strong central control, leading to direction of land use via regulation, or the global market is powerful, leading to loss of power for local and voluntary initiatives.

Relevance of the set of responses showed modest increase over time in Nature@Work, Local Stewardship and National Security, but a slight decline for World Markets; the changes in part reflect the scenarios strengthening in character over time. However, it should be noted that only in Nature@Work in 2060 was the aggregate score higher than the baseline situation. The aggregate scores across all categories of ES from this indicative suite of responses identifies a clear hierarchy of scenarios in which it would be most effective – from Nature@Work (66/112), Local Stewardship (34/112), World Markets (10/112) and National Security (3/112) against a baseline equivalent of 54[9].

Uncertainty associated with the interpretations was highest for World Markets and National Security compared to Nature@Work and Local Stewardship. The variation across scenarios is partly related to the scale and nature of governance structures implied and their difference from the current position – for example, whether national-level schemes which are currently important in the forestry sector would be maintained or have traction within a global market or in circumstances whether other quality standards or priorities (e.g. food security) would predominate.

No single response was robust across all scenarios and both time steps, and indeed responses that were most effective in 2030 did not maintain this in 2060. In 2030, the responses with greatest

[9] The baseline score is doubled in this case as the scenario scoring has aggregated the 2030 and 2060 results.

applicability were the United Kingdom Forestry Standard (UKFS), grant aid with spatial targeting, and voluntary certification. By comparison, in 2060 the responses with greatest applicability were identified as adaptive knowledge-based initiatives such as collaborative management groups, advisory services and visits, and community woodland groups. These aggregate scores are sensitive to whether responses are deemed to have only positive and neutral effects on ES delivery or whether some might incur trade-offs by having negative effects (for example by focussing on the delivery of provisioning services at the expense of cultural services). For example, the UKFS option was associated with a positive effect on each group of services in Nature@Work and Local Stewardship, but within National Security the primary focus is on provisioning services at the expense of cultural and supporting services; in contrast certification was associated with positive or neutral effects on ES across the scenarios.

In general, the assumed decreasing relevance of responses which operate at the national level (e.g. UKFS) in the Nature@Work and Local Stewardship scenarios was based upon changes in the scale of decision-making, extent of private ownership and development of local economies. By contrast, voluntary measures were less suited to scenarios with strong central control or local stewardship. Grant aid with spatial targeting was most relevant to National Security by providing a means to direct and control land use. Both collaborative management groups and community woodland groups appeared to have most relevance within the Nature@Work and Local Stewardship scenarios with positive effects across each group of services. These responses fitted with the emphasis on local collaborative management, evaluation and decision-making to meet local needs. The advisory services and visits (education & knowledge exchange) option also appeared to be most relevant within the Nature@Work and Local Stewardship scenarios where it would inform community evaluation of ES and underpin local decision-making.

Overall, the effect on provisioning services was positive or neutral for all combinations of response options and scenarios, but there were potentially negative effects on regulating and particularly cultural services from some response options. These were most marked in World Markets (and to a lesser extent) National Security, and particularly in connection with the application of voluntary markets, statutory regulation, grant aid and knowledge exchange; this partly reflects assumptions around the targets to which these measures would be applied in these worlds and that these would be based upon focal ES rather than balanced across a range of categories.

The scope for adaptive management of woodlands and evolution of goals is especially important in a time of rapid climate change (Read *et al*., 2010), and when there is a considerable lag time between establishment of a resource (e.g. planting of woodland) and the flow of subsequent ES (e.g. time to become a carbon sink, a feature in a landscape or a habitat for woodland biodiversity). The reliance on voluntary markets to manage (or provide for) a wide range of ES is a high risk strategy, as such mechanisms may focus on easily quantifiable services which are readily monetised, while neglecting others (harder to measure, or whose occurrence is in the distant future). These markets may also be highly volatile and lack the long-term and adaptable vision deemed necessary for robust and resilient future forest systems. On the other hand, national Forest Standards and grant schemes, supported by decades of research and consultation, may be a less risky long-term solution to delivering multiple benefits, but are constrained by availability of public funds and the acceptance amongst land owners of the accompanying regulation.

There are also substantial knowledge gaps around some of the supporting and cultural services; how to measure and value them; how much delivery of services changes with breadth of management objective (e.g. explicitly multi-objective versus single objective with indirect by-products); the role of biodiversity in supporting other services; the breadth of ownership objectives and how these, and societal demands, change over time. Improved understanding will be necessary to pick the right

options and evolve the current set of responses into the future. The key to a less risky future will be to integrate national standards, regulations and grant schemes with voluntary markets, to bring in additional new money, and local-decision making to ensure an appropriate balance of multiple benefits. However, institutional and governance issues in the sector will depend on the changing relative profile of the state (or local communities) against the private sector in managing woodlands and the role of coordinating agencies such as the Forestry Commission.

Table 8.7. Results of the stress-testing exercise for the forestry sector: (a) Present relevance and performance of response options; and (b) Future relevance and performance of response options. Rel = Relevance of the response option within the UK NEA scenario (categorised as high (H), medium (M) or low (L)). Effect on ES = Effect of the response option on ES (P = provisioning services; R = regulating services; C = cultural services; S = supporting services) within the UK NEA scenario (categorised as very negative (- -), slightly negative (-), neutral (0), slightly positive (+) or very positive (++)).These are all given in comparison with the scenario in the absence of the intervention. Note that options covered by other sectors are also relevant to forestry.

(a)

Response option	Rel	Effect on ES			
		P	R	C	S
UK Forestry Standard	H	++	++	++	++
Woodland Carbon Code	L	+	++	0	0
Grant aid with specific spatial targeting	M	+	+	+	+
Collaborative management groups	L	+	0	+	0
Certification	M	+	+	+	+
Community woodland groups and community forests	L	0	0	+	+
Knowledge exchange (advisory services and visits)	M	+	+	+	+
Aggregate scores	***12***	***7***	***7***	***7***	***6***

(b)	Nature @ Work					World Markets					National Security					Local Stewardship					Aggregate scores
	Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				
		P	R	C	S		P	R	C	S		P	R	C	S		P	R	C	S	
UK forestry standard:																					
2030	H	++	++	++	++	L	0	+	0	+	M	+	0	–	0	M	+	+	+	+	**14**
2060	M	+	+	+	+	L	0	0	–	0	H	++	–	–	–	L	0	0	0	0	**2**
Woodland Carbon code (credit system)																					
2030	M	++	++	–	0	M	++	+	– –	– –	L	0	0	0	0	L	0	0	0	0	**2**
2060	M	++	++	–	0	H	++	+	– –	– –	L	0	0	0	0	L	0	0	0	0	**2**
Grant aid with specific spatial targeting:																					
2030	M	+	+	+	+	M	+	+	0	+	M	+	+	0	+	M	+	+	+	+	**14**
2060	M	+	+	+	+	L	+	0	–	0	H	++	0	–	0	L	0	0	0	0	**5**
Collaborative management groups:																					
2030	L	+	+	+	+	L	0	0	0	0	L	0	0	0	0	L	+	+	0	0	**6**
2060	M	++	++	++	++	L	0	0	0	0	L	0	0	0	0	M	++	++	+	+	**14**
Certification:																					
2030	L	+	+	+	+	M	+	++	+	++	L	0	0	0	0	L	0	0	0	0	**10**
2060	L	+	+	+	+	L	+	++	+	++	L	0	0	0	0	L	0	0	0	0	**10**
Community woodland groups and community forests:																					
2030	L	+	+	+	+	L	0	0	0	0	L	0	0	0	0	M	+	+	+	+	**8**
2060	M	+	+	+	+	L	0	0	0	0	L	0	0	0	0	H	++	+	+	+	**9**
Knowledge exchange (advisory services and visits):																					
2030	M	+	+	+	+	L	+	–	–	–	L	0	0	0	0	M	+	+	+	+	**6**
2060	H	++	++	++	++	L	+	–	–	–	L	0	0	0	0	H	++	+	+	+	**11**
Aggregate scores	**26**	**19**	**19**	**13**	**15**	**19**	**10**	**4**	**-4**	**0**	**20**	**6**	**0**	**-3**	**0**	**23**	**11**	**9**	**7**	**7**	

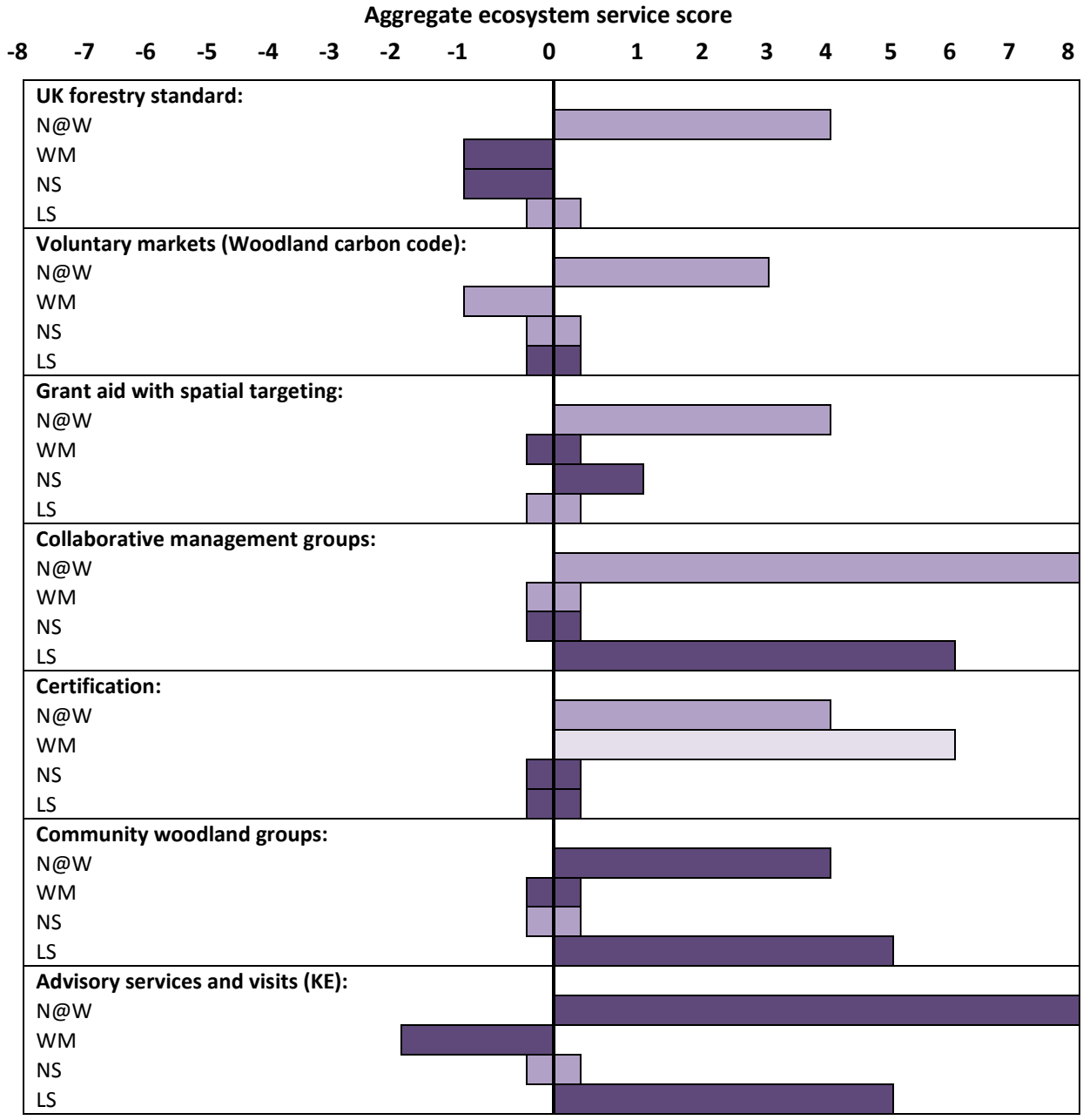


Figure 8.4. Graphical summary showing how the forestry response options fare under the UK NEA scenarios in 2060. The bars show the aggregate score across the provisioning, regulating, cultural and supporting ES classes. The bars are colour-coded according to the uncertainty related to the score (dark purple = low uncertainty; mid purple = medium uncertainty; light purple = high uncertainty). The figure should be viewed alongside **Table 8.7** which shows the results for the individual service categories as gains and losses in different service categories can counteract each other.

8.3.4 Biodiversity

Traditionally, policy initiatives in the biodiversity sector have focused on protected areas (e.g. Natura2000, SSSI, etc.) to conserve key locations with high biodiversity value. Although this importance continues, the agenda has broadened to place more emphasis on the wider landscape (or seascape), with increased recognition of the significant biodiversity value outside of protected areas, including the presence of UK Biodiversity Action Plan (BAP) and EU Habitats Directive[10] priority species and habitats. Furthermore, as highlighted by the recent Lawton Review in England (Lawton *et al*. 2010), the current protected area network may not be sufficiently coherent for species movements in response to climate change, due to habitat degradation and fragmentation in the wider landscape. Current climate change impacts are expected to substantially increase in the future, particularly in combination with other pressures, such as land use change and pollution (Brown *et al*. 2012; Morecroft & Speakman, 2013).

This broadening of the policy agenda has led to a greater emphasis on initiatives that can enhance biodiversity by improving ecological integrity, functioning and connectivity in the wider landscape. This shift also acknowledges the fundamental interdependencies of biodiversity with other sectors, particularly agriculture in the UK as the dominant land use. Incentive schemes, such as agri-environment schemes, have therefore become increasingly important for enhancing biodiversity and ES (Whittingham, 2011). More recent cross-sectoral initiatives include Nature Improvement Areas (Warren, 2012); the role of green and blue infrastructure (Natural England, 2009), particularly in peri-urban areas; and explicit characterisation of the additional benefits provided by biodiversity through ES. These latter initiatives remain in the early stages, therefore limited evidence is currently available on whether implementation has been successful in addressing current declines in biodiversity and ES. The institutional setting for biodiversity policy and its implementation is complex, with multiple organisations involved depending on their statutory role or other responsibilities. NGOs have a prominent role in recent developments, such as Futurescapes (RSPB) and Living Landscapes (Wildlife Trusts), and industry-led initiatives have also increased, notably the Campaign for the Farmed Environment[11]. In addition, there is increased policy support for initiatives to raise awareness of direct and indirect benefits from biodiversity, including via Local Nature Partnerships. At the international level, these developments are mirrored by the shift in emphasis provided by new agreements from the UN Convention on Biological Diversity, notably the framework established to redress past biodiversity loss by 2020 ('Aichi Targets')[12], which explicitly includes the wider benefits of biodiversity for human well-being.

A subset of the current biodiversity responses, which cover a range of types, response maturity and scales, was selected for stress-testing (**Table 8.8**). All of the selected options have medium or high priority at present with the possible exception of land sparing which is included because it represents a radical alternative to achieve biodiversity objectives (Balmford *et al*., 2005). With regard to their influence on different types of ES at present (**Table 8.9a**), a broad distinction may be made between responses which:

- tend to result in trade-offs between provisioning and other types of ES as land is taken out of production or has a less intensified management regime (protected areas, ecological networks, set-aside, agri-environment schemes);

[10] The Habitats Directive now also requires status reporting of priority habitats from non-protected areas
[11] http://www.cfeonline.org.uk/home/

[12] http://www.cbd.int/sp/targets/

- adjust trade-offs between provisioning and other types of ES on a spatial basis with the rationale that this produces no net loss and potentially a net gain (offsetting, land sparing); and
- aim to provide a balanced range of ES, but with emphasis on enhancing regulating, cultural or supporting ES; by contrast to (i) and (ii) these tend to be bottom-up schemes (voluntary standards, nature-based partnerships).

These are of course large-scale generalisations and important local variations also occur, but they help to contextualise an assessment of the robustness of these responses against future changes.

Table 8.8. Biodiversity response options included in the stress-testing study.

Response Option	Type	Status	Reason for short-listing
Protected/designated areas	Protected areas	Well established	Conventional approach to biodiversity protection
Ecological networks	Spatial and integrated planning	Preliminary planning stages	Ecological approach to restoring functional connectivity of landscapes to enhance integrity and resilience
Compulsory set-aside	Statutory regulation; Incentive-based schemes	Established	Links incentives to compulsory land use requirements for land managers. Also exemplified by possible use of Ecological Focus Areas in CAP
Agri-environment schemes (local)	Incentive-based schemes	Established/early stages	Links incentives to land management on a voluntary basis; increasingly associated with ES
Biodiversity offsetting (national scale)	Market-based incentives*	Early stages (in UK)	Strong stakeholder interest (e.g. Ecosystem Markets Task Force)
Land sparing	Spatial and integrated planning	Early stages	Concentrates/intensifies agriculture in selected areas to make space for nature
Voluntary standards and certification (e.g. LEAF)	Voluntary quality-assurance schemes	Established	Associated with good environmental stewardship; can be independent of government
Nature-based partnerships	Networks, partnerships & community schemes	Well established	Acts as basis for local grassroots action

* Other types of offsetting scheme also exist but the assessment is based upon this specific type.

The response options tested here have the greatest relevance under Nature@Work (aggregate relevance score of 36/48) and Local Stewardship (35/48), as these scenarios are more cognisant of biodiversity and environmental issues (**Table 8.9b**). All response options produced either neutral or positive aggregate ES scores across the range of scenarios (**Figure 8.5**) indicating that they each have potential to enhance ES delivery or at least to maintain the status quo. However, there are important differences between scenarios, with most responses performing best across the full range of ES under the coordinated knowledge-based green economy of the Nature@Work scenario. A measure of the robustness of the response options in delivering balanced ES is given by its aggregate score (final column: **Table 8.8b**): on this basis the most robust schemes by 2060 are identified to be agri-environment schemes, ecological networks and nature-based partnerships. These schemes all have a higher degree of adaptability and flexibility to adjust to changing circumstances, either from a top-down or bottom-up perspective, building on the dynamic links between biodiversity and ES. Other response options may be constrained because (in their current version) they have less flexibility (e.g. protected areas) or because they are based upon land use zones that attempt to balance trade-offs spatially (land sparing, offsetting, set-aside) but which may not hold for the future due to either changing biophysical or socio-economic conditions. Other types of response option

may be particularly valuable in some scenario conditions, but may only have a limited role in other circumstances, therefore may be vulnerable to loss of future traction or support for continued delivery of ES (notably voluntary quality-assurance schemes).

These general findings mask important differences between the biodiversity response options in terms of how trade-offs between different categories of ES are resolved. As highlighted above, this is most apparent in achieving a balance between provisioning and other ES. Future conditions, as represented by the different scenarios, therefore interact with the response options depending on: (i) the priority given to the need to balance provisioning with other ES; and (ii) the relative influence of government, markets or local communities in supporting responses. Based upon the effect on ES of the combined selected response options (assuming they are equally weighted: final row **Table 8.9b**) then it is inferred that two of the scenarios (Nature@Work; Local Stewardship) would see an increase in other ES at the expense of a relative decrease in provisioning ES. By contrast, maintaining provisioning ES is assumed as a priority in the other two scenarios (World Markets; National Security) and the lower scoring suggests that the balance between ES remains similar to present, with the exception that the importance of regulating/supporting ES in maintaining food security (e.g. via pollination or pest/disease control) may result in gains for these services in National Security.

Hence, some current response options are not identified as leading to significant changes in ES in some scenarios because they involve taking land out of production (e.g. set-aside) which would not be favoured for policy purposes (National Security) or market forces (World Markets). By contrast, incentive or market-based schemes would be favoured in such scenarios, and could potentially be designed to integrate with other initiatives that retain support in the other two scenarios (Nature@Work, Local Stewardship). Enhanced benefits through cultural ES seem to be under-represented in the scoring of the chosen response options (although this may be partly a consequence of their strong context dependence and a limited knowledge base): nevertheless, nature-based partnerships would seem particularly important in delivering the cultural benefits associated with biodiversity.

There are also important scale issues to consider. The current evidence base would suggest that trade-offs can be best managed in changing circumstances through coordinated landscape-scale initiatives (e.g. ecological networks) rather than piecemeal schemes at local level that do not enhance overall ecosystem integrity (e.g. Lawton *et al*., 2010). Scale issues are also evident in market-based schemes (e.g. offsetting) that can potentially use the large-scale efficiency of markets to invest in enhanced biodiversity and ES. This may also allow the spatial targeting of these measures in specific zones that can enhance other response options (e.g. ecological networks). However, these scale efficiencies may act against benefits that accrue at the local level, notably through cultural ES. For example, if offsetting was implemented over large distances to redress biodiversity losses, it may produce a positive gain for ES that deliver their benefit at a larger scale (e.g. carbon storage for climate regulation). However, it would be likely to reduce the cultural benefits that local people previously experienced at the original sites and which are not as easily transferrable to the offset site, particularly if it required travel over larger distances. This implies a need to also incorporate local-level benefits into the design of larger-scale initiatives.

The evidence base for most of these response options has been classed as low to medium uncertainty (**Figure 5**), with only two newer options (biodiversity offsetting and land sparing) given high uncertainty due to limitations on current evidence. However, knowledge and information flow of the links between biodiversity and ES delivery remains a significant constraint on inferences of future change. This is particularly apparent for initiatives such as biodiversity offsetting and land sparing, which are based upon the assumption that trade-offs can be successfully balanced in a spatial context. Particularly due to climate change, these spatial relationships may change and there

is no guarantee of successful ecological restoration at new locations. A fundamental issue for offsetting is how this risk is handled, and the institutional framework in which it is managed (McKenny and Kiesecker, 2010; POST, 2011). Similarly, although market-based schemes can fund incentives that enhance biodiversity and ES, they are also a risky strategy as markets are volatile and support may be transient. In scenarios where government-funded support is maintained or enhanced (Nature@Work, National Security) then the risks from market volatility to incentive-based schemes could be reduced, making them potentially more robust. Other initiatives, such as the tried-and-tested option of protected areas, may be considered less risky but they require ongoing investment (which may be reduced in some scenarios) and concerns exist about their flexibility to meet the challenge of climate change (Wilson and Piper, 2008).

The current debate over land sparing versus land sharing initiatives for biodiversity conservation (cf. Ewers *et al*., 2009) is particularly pertinent in terms of robust future proofing. Land sparing, which makes long-term decisions on land use trade-offs based upon an identification of 'optimum' spatial patterns, may become less robust as the capability of the land changes, and land use options and priorities change in the future (Gimona *et al*., 2012). By comparison, land sharing, which assumes a co-existence of food production with other ES in the same dynamic landscape, may not have the same large-scale efficiencies of land use, but by incorporating flexible local schemes (e.g. agri-environment schemes) may be more adaptable to changing circumstances. Further work on the implications of these changing spatial and temporal trade-offs would therefore be useful.

All response options had some relevance in the range of scenarios, suggesting that they can form a basis for selection of appropriate responses, with further tailoring as required to enhance robustness. For example, as biodiversity and ES are distributed rather heterogeneously in the UK, spatial targeting of different response options may deliver a more robust mix. It would seem likely that the most effective strategy in areas of high biodiversity (and ES) value, where losses would have very negative consequences, is to follow a low-risk strategy and maintain these as protected areas. This would imply that innovation in response options, such as agri-environment schemes and offsetting, may better operate in parallel in targeted areas where ecological restoration and enhancement is prioritised to produce sustainable delivery of ES, particularly if enhanced through ecological networks. The influence of nature-based partnerships and voluntary quality assurance is likely to vary strongly depending on changing attitudes to biodiversity; their role in raising awareness of the social and cultural benefits from biodiversity will extend from local to national influence if attitudes are supportive. Shared knowledge-based systems will be particularly important to address current information deficits and to facilitate adaptation to change, particularly climate change.

As biodiversity underpins the delivery of ES, potentially competes with other land uses and is affected by other land uses, there is a high level of interdependency with other sectors. The interaction is best seen in the case of agri-environment schemes and similar initiatives (e.g. in forestry, freshwater and marine habitats) which aim to deliver both biodiversity and balanced ES through cross-sectoral collaboration. Currently, funding for these schemes is mainly linked to top-down routes and international agreements (e.g. Common Agricultural Policy) which mean that flexibility and efficiency to meet changing local needs can be compromised, hence the added value of bottom-up initiatives such as local quality assurance in providing a more robust mix of responses.

Table 8.9. Results of the stress-testing exercise for the biodiversity sector: (a) Present relevance and performance of response options; and (b) Future relevance and performance of response options. Rel = Relevance of the response option within the UK NEA scenario (categorised as high (H), medium (M) or low (L)). Effect on ES = Effect of the response option on ES (P = provisioning services; R = regulating services; C = cultural services; S = supporting services) within the UK NEA scenario (categorised as very negative (- -), slightly negative (-), neutral (0), slightly positive (+) or very positive

(++)). These are all given in comparison with the scenario in the absence of the intervention. Note that options covered by other sectors are also relevant to biodiversity.

(a)

Response option	Rel	Effect on ES			
		P	R	C	S
Protected areas	H	–	+	0	+
Ecological networks	H	–	+	+	+
Compulsory set-aside	M	–	+	0	+
Agri-environment schemes	H	–	+	+	+
Biodiversity offsetting	H	0	0	0	0
Land sparing	L	0	0	0	0
Voluntary quality-assurance schemes	M	0	+	+	+
Nature-based partnerships	M	0	+	+	+
Aggregate scores	**19**	**-4**	**6**	**4**	**6**

(b)	Nature@Work					World Markets					National Security					Local Stewardship					Aggregate scores
	Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				
		P	R	C	S		P	R	C	S		P	R	C	S		P	R	C	S	
Protected areas:																					
2030	M	–	+	0	+	L	0	0	0	0	M	–	+	0	+	H	–	+	+	+	**4**
2060	M	–	+	0	++	L	0	0	0	0	M	–	+	0	+	H	–	+	+	+	**5**
Ecological networks:																					
2030	M	–	+	+	+	L	0	+	0	+	M	0	+	+	+	L	–	+	+	+	**8**
2060	H	–	++	++	++	L	0	+	0	+	M	0	+	+	+	M	–	+	+	+	**11**
Compulsory set-aside:																					
2030	M	–	+	0	+	L	0	0	0	0	L	0	0	0	0	M	–	+	0	+	**2**
2060	M	–	+	0	+	L	0	0	0	0	L	0	0	0	0	M	–	+	0	+	**2**
Agri-environment schemes:																					
2030	H	–	+	+	+	M	+	+	0	0	M	+	+	0	+	H	–	+	+	+	**9**
2060	H	–	++	+	++	M	+	+	0	0	M	+	+	0	+	H	–	++	+	+	**12**
Biodiversity offsetting:																					
2030	M	+	+	–	+	H	+	0	–	0	M	+	+	–	0	L	0	0	0	0	**3**
2060	M	+	+	–	+	H	++	0	– –	0	M	+	+	–	0	L	0	0	0	0	**3**
Land sparing:																					
2030	M	+	+	0	0	L	+	0	–	0	L	+	0	–	0	L	0	0	0	0	**2**
2060	H	+	+	0	0	L	+	0	–	0	L	+	0	–	0	L	0	0	0	0	**2**
Voluntary quality-assurance schemes:																					
2030	M	0	+	0	+	L	0	0	0	0	L	+	0	0	0	H	0	+	+	+	**6**
2060	M	0	++	0	++	L	0	0	0	0	L	+	0	0	0	H	0	+	+	+	**8**
Nature-based partnerships:																					
2030	M	0	+	+	+	L	0	0	0	0	M	0	+	+	+	H	0	+	++	+	**10**
2060	M	0	+	++	+	L	0	0	0	0	M	0	+	+	+	H	0	+	++	+	**11**
Aggregate scores	**36**	**-4**	**19**	**6**	**18**	**22**	**5**	**4**	**-5**	**2**	**26**	**6**	**10**	**0**	**8**	**35**	**-8**	**13**	**12**	**12**	

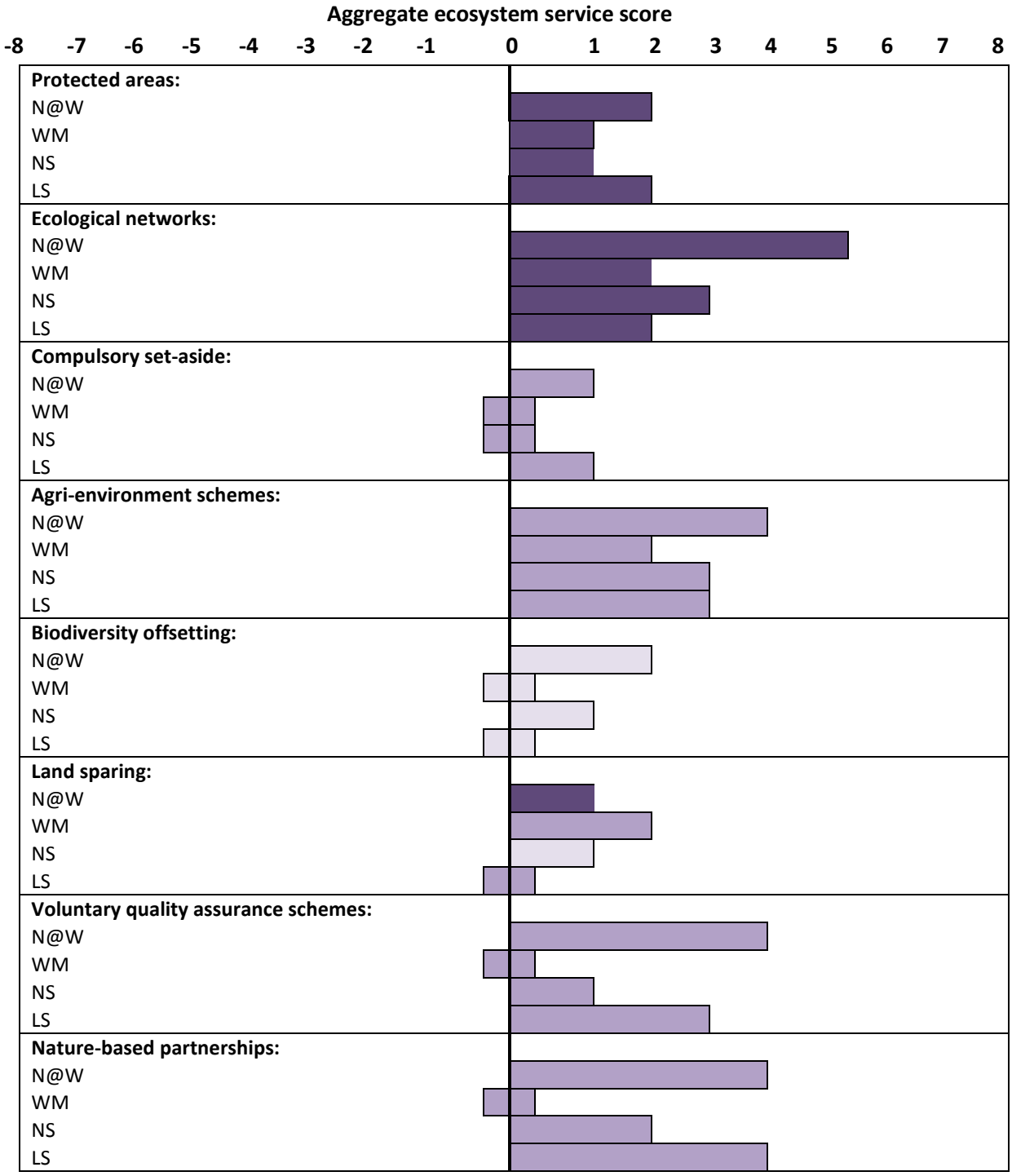


Figure 8.5. Graphical summary showing how the biodiversity response options fare under the UK NEA scenarios in 2060. The bars show the aggregate score across the provisioning, regulating, cultural and supporting ES classes. The bars are colour-coded according to the uncertainty related to the score (dark purple = low uncertainty; mid purple = medium uncertainty; light purple = high uncertainty). The figure should be viewed alongside **Table 8.9** which shows the results for the individual service categories as gains and losses in different service categories can counteract each other.

8.3.5 Water

Freshwaters are among the UK's most productive and naturally diverse ecosystems. Water supply is the most obvious form of provisioning service derived from freshwater ecosystems in order to support domestic, agricultural, industrial and power generation needs. Widely distributed ecosystems, such as wetlands, rivers, floodplains and lakes, provide multiple additional benefits including the regulation of floods and detoxification of polluted water. Enjoyed by millions, freshwaters are also a major source of cultural services because of their landscape value and significance in terms of biodiversity, amenity and recreation. However, despite their central role, the integrity of freshwater systems has been neglected, one consequence of which is that formerly highly interconnected habitats are now widely fragmented and functionally compromised. This long-term decline has been explained with respect to weak governance, systemic undervaluation of natural capital and piecemeal regulatory practices, with an over-reliance on water quality as a management objective (Maltby *et al.,* 2011),.

With a strong European impetus, as well as a range of international initiatives, the water sector has witnessed a policy revolution in recent decades, not least with the introduction of the hugely ambitious EU Water Framework Directive (2000). This enabling legislation, along with the later Floods Directive (2007), is doing much to promote long-term 'systems-thinking' and greater appreciation of the underpinning role of ecosystem services within catchments. This has meant that more attention is now being paid to water flow, the physical structure of habitats and measures of ecosystem integrity as overall system indicators. It is now widely recognised that restoring historically damaged habitats, controlling pernicious problems including diffuse pollution from agriculture, and restoring the natural flood buffering capacity of wetlands and floodplains can yield multiple win-win benefits to society and promote greater resilience in relation to the negative impacts of climate change (e.g. Maltby *et al*., 2011). The introduction of the WFD has redefined attitudes (statutory and voluntary) in relation to more integrated land and water management. In addition to regulation, promotion of catchment-based water resource protection programmes such as 'Upstream Thinking'[13] in SW England has linked ecological restoration and sympathetic land management with incentives through payments for ecosystem services. In relation simply to water supply, this can provide a highly cost-effective means to improve raw water quality and the consequent minimisation of treatment costs once water is abstracted, certainly compared to treatment of more contaminated water. Opportunities are now being explored to extend these initiatives to enhance other water-related services.

From the long-list of nearly 30 response options (see **Appendix 8.2**), a subset of eight was selected for the stress-testing exercise (**Table 8.10**). Some options, such as major capital investment in large-scale water supply infrastructure, have decadal time-scales for implementation associated with the design, consent and construction phases. By comparison bottom-up approaches, such as River Trusts or community-based Sustainable Urban Drainage Systems (SUDS), may involve more limited capital investment but can potentially provide a wide range of co-benefits at local level.

An evaluation of the present relevance and performance of the subset of response options for the water sector is presented in **Table 8.11a**. Most, with the exception of Blue Networks and Integrated Catchment Management (ICM), are currently well-established as mechanisms to achieve the long-term goal of a secure, accessible and sustainable water sector. Considered individually the different response options can produce both positive and negative impacts on ES. Some options, particularly

[13] http://www.upstreamthinking.org/

those founded on ecosystem principles (Natural Flood Management (NFM), SUDS, River Trusts, ICM and Blue Networks), generate entirely positive or at least neutral behaviour in terms of the ES provided. Others, such as those favoured by the water industry, still show that managing the system for increased supply through infrastructure investments (e.g. new reservoirs or inter-basin water transfers) will increase a subset of target provisioning services, but generally at the expense of supporting services (natural water cycle and environmental flows). When taken together this subset of response options delivers positive benefits, with the highest aggregate scores in relation to cultural services (notably amenity and biodiversity gains), followed by regulating and supporting services. Whilst still overwhelmingly positive, the smallest aggregate benefit accrues in relation to provisioning services (supply of drinking water, hydropower and food). Such an outcome is not unexpected, particularly in consideration of the cross-cutting nature of the water sector and its interdependence with other sectors and in particular agriculture, forestry and coastal fisheries.

Table 8.10. Water sector response options included in the stress-testing study.

Response Option	Type	Status	Reason for short-listing
Health and well-being (Blue Networks)	Knowledge, networks and partnerships	Early stages	Strong social dimensions and links to greater urban resilience
Water Framework Directive (WFD)	Statutory regulation	Established	Key legislative pillar for delivering sustainable water environment
Natural Flood Management (NFM) reducing flood risk	Statutory regulation	Early stages	Important cross-sectoral connections (biodiversity, agriculture, forestry)
Water industry services (public water supply measures)	Markets; technology; regulation	Established	Strategic infrastructure challenges with strong geographical variations
Water industry services (demand-side measures)	Incentives; markets; statutory regulation; technology	Established	Strategic issue with strong geographical variations in practice
Integrated catchment management (ICM)	Integrated spatial planning	Early stages	Strong cross-sectoral connections
Sustainable urban drainage systems (SUDS)	Integrated spatial planning; management practices	Established	Established for new development and scope for retrofits
River Trusts and voluntary activity	Networks & partnerships; knowledge exchange	Established	Some world leading exemplars e.g. West Country Rivers Trust

Comparison of performance across the UK NEA scenarios shows that the subset of response options are likely to have greatest relevance within Nature@Work (aggregate relevance score of 40/48) and Local Stewardship (36/48), slightly lower relevance within National security (31/48) and lowest relevance in World Markets (25/48) (**Table 8.11b; Figure 8.6**). The selected options show a clear division between those scenarios with relatively high positive aggregate scores for effects on ES (all ES categories and both time slices), which included Nature@Work (79) and Local Stewardship (64), and those scenarios showing an overall negative effect on ES, National Security (-5) and World Markets (-13). The response options mainly had a neutral to positive effect on provisioning services, but the effects on regulating, cultural and supporting services differed greatly between the Nature@Work / Local Stewardship scenarios and the World Markets / National Security scenarios, with strongly positive effects in the former and generally neutral to negative effects in the latter.

The assessment suggests that the more robust response options (**Table 8.11b**: last column) are blue networks, river trusts and SUDS because these can provide a range of ES and are flexible enough to adapt to different conditions implied by the scenarios. The response options based upon WFD and ICM also score as moderately robust, but as these require co-ordination of smaller-scale activities it

is possible that they may not be able to meet all their objectives because other priorities dominate (e.g. food or energy security). Similarly, demand-side measures that reduce pressure on water resources in water-stressed areas, although beneficial for ecosystem health, may be de-prioritised compared to supply-side measures in some scenarios (notably World Markets). Large-scale water supply infrastructure (for provision of water and hydropower) was identified as the least effective option at providing a robust and balanced range of ES because of the potential loss of regulating, supporting and cultural services through ecosystem modification (e.g. hydromorphology). Similarly, natural flood management approaches are likely to be less favoured in futures where security and protection of conventional capital assets dominate (National Security, World Markets), but receive a higher priority when natural capital is more highly valued (Local Stewardship, Nature@Work) because of their association with other benefits in addition to flood risk reduction (Iacob *et al*., 2013).

It was also inferred that a number of bottom-up or voluntary options (such as Blue Networks, ICM and River Trusts) become more effective over time as restorative measures take effect through regeneration of natural processes, augmented through top-down support through the WFD's statutory river basin management plans (RBMPs). Furthermore, the overall amount of land subject to such management regimes would be expected to expand (especially under Nature@Work and Local Stewardship). These findings strongly echo results from the biodiversity sector. By contrast, regulatory measures (WFD, NFM and ICM) do relatively poorly under World Markets and National Security. These findings demonstrate how different option and scenario combinations can result in strongly differentiated environmental outcomes.

Medium levels of uncertainty were highlighted for most of the response options because of the reasonably long timescale and limitations on the current evidence base. In particular, climate change is likely to significantly affect the water sector, notably due to shifting geographical and seasonal patterns of precipitation. Together with changing patterns of water demand and land use, this could pose particular risks to ambitions for integrated delivery of water services based upon healthy functioning ecosystems, as identified by the aims of the WFD (Wilby *et al*., 2006). It is likely that reference conditions for defining ecosystem health will be modified by climate change, which will require difficult decisions in defining key indicators and regulatory limits (e.g. environmental flow) based upon distinctions between biophysical influences and socioeconomic factors.

Despite these risks, the WFD could provide a key link between new policy and participative mechanisms (being established for the River Basin Management Plans) to accommodate change. Ecosystem-based Adaptation (EbA) is an emerging paradigm for managing natural resources under increasingly variable and perturbed climatic conditions. It embraces integrated catchment management (ICM), emphasising partnership and cooperation across whole catchments, with targeted restoration to promote the resilient qualities of complex natural ecosystems. Key to this is identifying and characterising high-risk areas and tailoring management plans to remove sources and disconnect pathways of pollution, yielding the win-win of improved water quality and financial savings to both landowners and downstream water treatment costs. EbA accepts that the future is intrinsically uncertain, meaning that the most effective strategies to reduce risk are measures to improve system resilience (i.e. supporting ES) rather than managing for any particular environment good or service such as raw water quality in isolation. This risk-based approach is particularly important regarding the design of regulatory limits that are robust to climate change and other drivers of change.

The current trajectory in the water sector, strongly influenced by the WFD, is perhaps most closest to the Nature@Work scenario, with elements of Local Stewardship represented by the strong role of local partnerships in some (but not all) locations. Nevertheless, pressures to reduce flood risk and

the commoditisation of water resources also show elements of the other two UK NEA scenarios explored here. The response options range from those which are short-term, local and relatively inexpensive, such as community-based urban stream restoration projects, to long-term, national-scale and hugely expensive infrastructure projects, such as new reservoirs or desalinisation plants. The WFD has the potential to significantly promote a greater level of systems thinking across the water sector, and in terms of links to other sectors (notably agriculture and forestry), with regard to sustainable ecosystem protection and enhancement. This includes improved integration with measures investigated in other sectors, including agri-environment schemes (see Biodiversity sector) and Payments for Ecosystem Services (see Agriculture sector). However, this is dependent on strong governance, which may not occur under all scenarios. SUDS and NFM schemes designed explicitly to realise a greater range of the regulating, supporting and cultural benefits provided by ecosystems can have an important role in some locations, particularly where co-ordinated through ICM planning. Often this requires clearer linkages to be established between upstream services (e.g. floodwater storage, source protection) and downstream beneficiaries. With regard to industry-based responses, a mix of both supply-side and demand-side measures would seem to provide the greatest resilience to future economic and climate shocks.

Important knowledge gaps remain which, if tackled, could help to develop improved responses. These include a more complete valuation of the full range of benefits obtained from water, including cultural benefits, as a precursor to the design of more comprehensive incentive schemes to maintain or enhance these benefits. Another key issue is to improve understanding of the dynamic links between changing hydromorphology and ecosystem processes, which in turn will affect the range of water-related ES (Wilby *et al.,* 2006). This will help in the evaluation and better design of schemes such as SUDS and NFM, which have a range of variants that respond to change through different processes, and may therefore be more flexibly adapted to local contexts depending on their priorities.

Table 8.11. Results of the stress-testing exercise for the water sector: (a) Present relevance and performance of response options; and (b) Future relevance and performance of response options. Rel = Relevance of the response option within the UK NEA scenario (categorised as high (H), medium (M) or low (L)). Effect on ES = Effect of the response option on ES (P = provisioning services; R = regulating services; C = cultural services; S = supporting services) within the UK NEA scenario (categorised as very negative (- -), slightly negative (-), neutral (0), slightly positive (+) or very positive (++)). These are all given in comparison with the scenario in the absence of the intervention. Note that options covered by other sectors are also relevant to water.

(a)

Response option	Rel	Effect on ES			
		P	R	C	S
Health and well-being (blue networks)	M	0	+	++	+
Water framework directive (WFD)	H	0	+	+	+
Managing flood risk (natural flood management)	H	+	++	+	+
Water industry services (public water supply measures)	H	++	–	0	– –
Water industry services (demand-side measures)	H	–	+	+	+
Integrated catchment management (ICM)	M	0	+	+	+
Sustainable urban drainage systems (SUDS)	H	0	++	++	+
River trusts and voluntary activity	H	+	+	++	+
Aggregate scores	***22***	***3***	***8***	***10***	***5***

(b)	Nature@Work					World Markets					National Security					Local Stewardship					Aggregate scores
	Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				
		P	R	C	S		P	R	C	S		P	R	C	S		P	R	C	S	
Health & well-being (blue networks):																					
2030	L	0	+	++	0	L	0	0	0	0	M	0	0	+	0	H	0	+	++	+	**8**
2060	L	0	++	++	+	L	0	0	+	+	M	+	0	+	0	H	0	+	++	+	**13**
Water framework directive:																					
2030	H	0	++	++	++	L	0	0	0	–	M	+	–	–	–	L	0	+	+	+	**6**
2060	H	0	++	++	++	L	0	–	–	–	M	+	–	–	–	L	0	+	++	+	**5**
Managing flood risk (natural flood management):																					
2030	H	+	++	+	+	L	0	0	0	–	M	0	0	–	–	M	0	+	+	+	**5**
2060	H	+	++	+	++	L	0	0	0	–	M	0	–	–	–	M	0	++	++	++	**8**
Water industry services (public water supply measures):																					
2030	M	+	+	0	+	H	++	–	–	–	H	+	0	–	–	L	0	0	0	0	**1**
2060	M	+	+	0	+	H	++	– –	– –	– –	H	++	+	–	–	L	0	0	0	+	**1**
Water industry services (demand-side measures):																					
2030	H	0	+	+	+	H	0	0	0	0	M	+	+	0	0	H	0	+	+	+	**8**
2060	H	0	+	+	+	H	0	0	0	0	H	+	+	0	0	H	–	+	+	+	**7**
Integrated catchment management:																					
2030	H	+	+	+	+	L	0	0	–	–	L	0	0	0	0	H	+	+	+	+	**6**
2060	H	+	++	++	++	M	0	0	–	–	L	–	–	0	–	H	+	++	++	++	**9**
Sustainable urban drainage systems (SUDS):																					
2030	H	0	++	++	++	L	0	0	0	0	M	0	+	0	0	M	0	++	++	+	**12**
2060	H	0	++	++	++	L	0	0	0	0	M	0	+	0	0	M	0	++	++	+	**12**
River trusts:																					
2030	M	+	+	+	++	L	0	0	0	0	L	0	0	–	0	H	+	+	++	+	**10**
2060	M	++	++	++	++	L	0	0	0	0	L	0	0	–	0	H	++	++	++	++	**15**
Aggregate scores	**40**	**9**	**25**	**22**	**23**	**25**	**4**	**-4**	**-5**	**-8**	**31**	**7**	**1**	**-6**	**-7**	**36**	**4**	**19**	**23**	**18**	

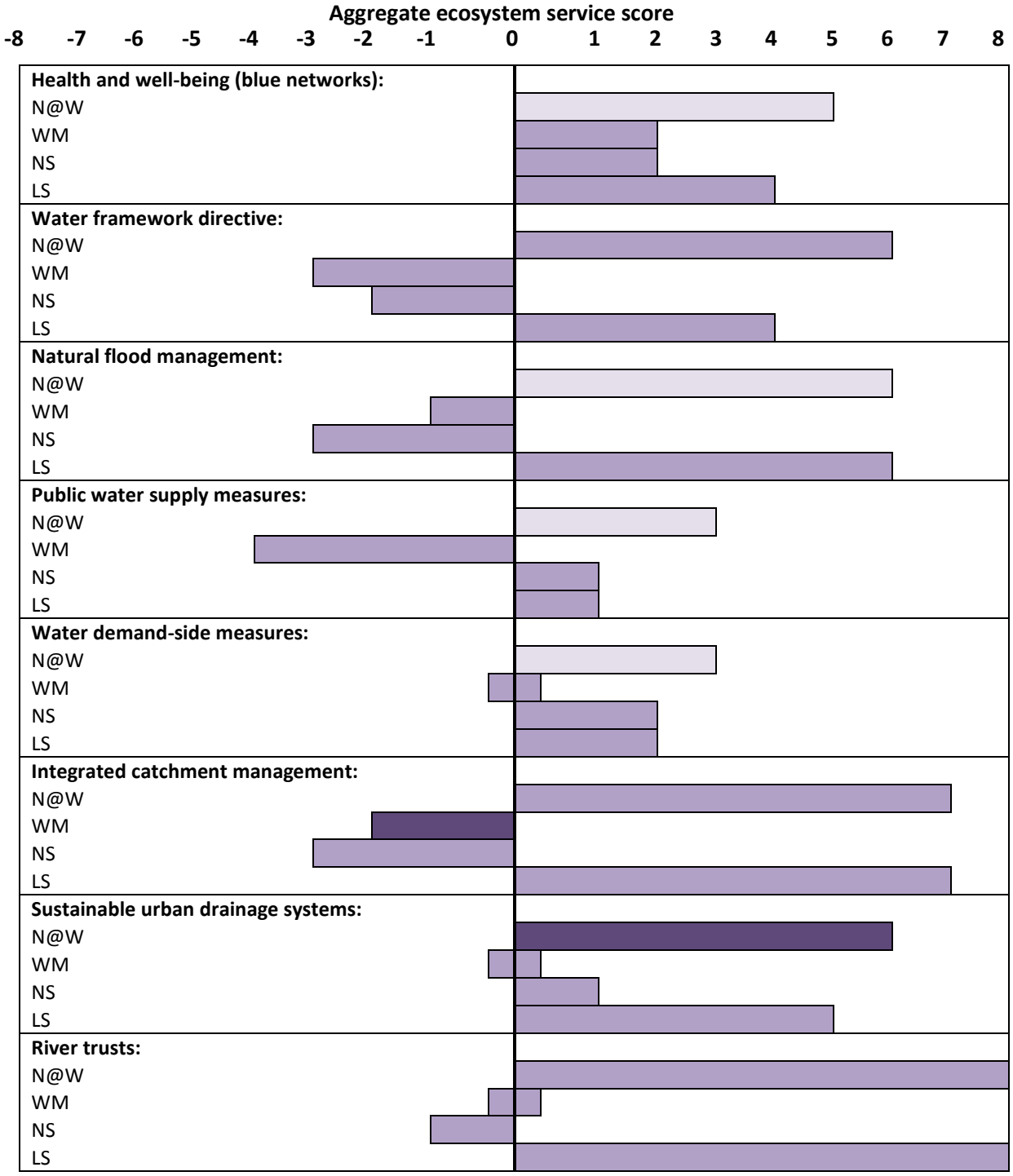


Figure 8.6. Graphical summary showing how the water response options fare under the UK NEA scenarios in 2060. The bars show the aggregate score across the provisioning, regulating, cultural and supporting ES classes. The bars are colour-coded according to the uncertainty related to the score (dark purple = low uncertainty; mid purple = medium uncertainty; light purple = high uncertainty). The figure should be viewed alongside **Table 8.11** which shows the results for the individual service categories as gains and losses in different service categories can counteract each other.

8.3.6 Urban, including energy and transport

In urban areas, current drivers of policy include: reducing energy, water and transportation footprints; providing jobs, houses and associated infrastructure; enhancing the quality of both the mental and physical health of expanding urban populations. The diversity of needs that urban areas are required to meet is recognised as placing huge demands on both in situ and distant ecosystems as lifestyles and life choices are met by businesses and industries which work at local to global scales. As a consequence decisions taken in the urban sector can have profound impacts on all other sectors, particularly agriculture, water and biodiversity. Established measures to tackle urban challenges as diverse as population growth, urban sprawl, and social and environmental justice include redevelopment of the planning system and greater requirements for stakeholder participation in a range of policy and practice developments (e.g. implementation of the EU Water Framework Directive (2000) and Floods Directive (2007)). This legal requirement for stakeholder engagement presents an obvious opportunity for cross-sectoral linking of response options through integration of networks, partnerships and community schemes.

A strong preference for multi-functional or multi-benefit responses is emerging within national and international urban development agendas as so called 'smart solutions' to enhancing human and environmental health in high-density living spaces. Currently, the planning system is the point of intersection at which many of these urban demands meet. Whilst inherently less ecosystem-centric in its outlook, the obvious complementarities between an ES approach and the urban planning process (e.g. public consultation, the need for trade-offs and to take into account environmental impacts) are increasingly recognised.

Of the many established and emerging response options considered (long list is given in **Appendix 8.2**), a short-list of eight response options were selected for a more in-depth evaluation (see **Table 8.12**). These included the representation of legislative (two options) and non-legislative (six options) approaches, whilst also including options that are implemented through greater use of technological practices (two options), market incentives (one option) and social attitudes (one option). Many of the response options can combine different types of intervention. For example, the use of water and energy saving technologies could be cited as examples of technology and practice, or market incentives, or social awareness categories, depending on the wider socio-economic and environmental context and scale (e.g. household vs. national level) at which decision-making takes place. Several possible options such as the use of SUDS (water sector) and urban food production (agricultural sector) were addressed elsewhere. This identification of cross-linkages between sectors is highlighted as a key opportunity for strengthening integrated management of ES across sectors (see Section 8.3.1)

Table 8.12. Urban response options included in the stress-testing study.

Response Option	Type	Status	Reason for short-listing
National planning policy framework	Integrated spatial planning	Proposed/Planned	Planning legislation influences the provision and quality of ES in urban areas
Energy related EU legislation	Statutory regulation	Established	Energy use, and energy policies, are a key factor underpinning policy-making in urban areas
Multi-functional green infrastructure	Integrated spatial planning	Early	Cross-sectoral mechanism for delivering multiple ES benefits in urban areas
Art, humanities and culture projects	Knowledge exchange; networks and partnerships	Proposed/Planned	Example of bottom-up response in which localism / community action are pivotal
Urban ecosystem assessments	Science; Knowledge exchange	Proposed/Planned	Combination of top-down scientific rational implemented through bottom-up knowledge
Improving sustainable modes of transport	Technology; Science (behavioural issues)	Early	Transport is a key factor for policy-making in urban areas
Technology for water and energy saving (domestic & industry (on-site greywater re-use)	Technology; Incentives; Knowledge exchange/education	Early	Innovation to meet national and international objectives (e.g. EU directives)
Research on planned adaptation to climate change in urban areas	Science	Early	To inform biophysical, and socio-economic adaptation of urban environments

Under present conditions (**Table 8.13a**), most response options are scored as having an overall positive effect on the delivery of ES categories. Whilst no response option leads to an aggregated reduction in the delivery of ES under any of the future scenarios, there is considerable variation in the magnitude of the aggregated effect of the different response options on ES delivery. These range from a minimum aggregate score of 2/32 (energy related EU policy) to a maximum aggregate score of 26/32 (multi-functional green infrastructure). Research on adaptation to climate change (25/32) and national planning policy framework (22/32) are also comparatively highly performing response options, further supporting the earlier suggestion that synergies between planning and ES delivery mechanisms should be identified and exploited.

Evaluation of the aggregate scores per scenario indicates that the relevance of response options varies under the four scenarios evaluated, with greatest relevance reported for Nature@Work (40/48), lower but similar levels of relevance under the National Security and Local Stewardship scenarios (33/48 and 34/48, respectively), and least relevance under World Markets (27/48) (**Table 8.13** and **Figure 8.7**). This comparatively lower relevance of this subset of options under World Markets is associated with the inclusion of community/local initiatives and government-driven responses as such measures would have less pertinence in a free-markets future with weak governance.

Examination of the relevance scores per response option suggests certain options are more relevant under all scenarios (e.g. research on adaptation to climate change and sustainable transport) indicating a greater degree of robustness. A factor in this could be that these options can be driven and implemented at multiple levels with potential to achieve social, economic and environmental objectives, and hence can deliver benefits under a range of possible futures. In contrast, the

implementation of national or European policies/legislation (e.g. national planning policy framework and energy-related EU legislation) is interpreted to fare less well under World Markets (weak governance and enforcement of regulations) and Local Stewardship (greater local self-sufficiency, such as through the use of local renewable resources).

Examining the effect scores across all categories of ES showed little variation between the 2030-2060 timeslices. Where impacts on the delivery of ES over time were noted, these typically indicated a neutral to positive or positive to very positive effect on ES delivery over time. An exception to this trend is for the national planning policy framework and energy-related EU legislation under the World Markets scenario which indicates negative impacts on the delivery of provisioning and supporting services and all categories (except supporting services) between 2030 and 2060, respectively. These negative effects are linked to an assumption of reduced environmental awareness and associated intensity of resource exploitation which characterises the World Markets scenario and is therefore likely to be associated with further degradation of ES (Piracha and Marcotullio, 2003).

Within-scenario effects on the delivery of the different ES categories show that the response options are most beneficial for cultural (highest score in 3 scenarios) and regulating (highest score under one scenario) services. Typically the response options under all scenarios show the least positive effect on the delivery of supporting services, associated with factors such as comparatively lower levels of vegetation and soils, limiting their contribution to nutrient, oxygen and water cycling. The baseline assessment had suggested that this suite of responses would have a lower impact on the delivery of supporting and provisioning services. In contrast, the impact on the delivery of regulating and cultural services is more evident. A factor in this could be the increasing evidence base and associated policy push on the value of urban green space in contributing to a number of topical issues from enhancing mental and physical human health to providing cost-effective flood risk mitigation, highlighting cross-sectoral synergies with response options evaluated in the water, biodiversity and forestry sectors (Vira *et al.*, 2011). These preliminary findings also suggest that the delivery of supporting and provisioning services is currently under exploited and opportunities to enhance local delivery of these crucial services should be actively sought. With strong links to the agricultural sector, a pertinent example would be supporting initiatives to enhance urban food production as a way to provide fresh local food sources (see Agriculture sector; **Table 8.5**).

Comparison of the trajectory of current response options within the four scenarios evaluated suggests that the use of water saving technologies, research in adaptation to climate change in urban areas and improving sustainable modes of transport will remain key initiatives under a wide range of future conditions. The potential economic returns from these responses suggest that they could also provide benefits in World Markets, a scenario under which legislative options in particular fare less well. This evaluation also indicates that any response options adopted, irrespective of scenario, should be developed and implemented in relation to the delivery of multiple objectives, enabling the delivery of certain benefits in contrast to others to be enhanced (as appropriate) as the future becomes more certain with the progression of time. By implication, this application should begin with current policy development based upon multiple benefits as a way to both meet current needs and open opportunities to enable the ongoing revision (or tailoring) of options to ensure their relevance under uncertain future conditions. For example, the results of this study suggest that options which offer scope for technological applications and climate change research opportunities would be key elements in a robust mix of urban response options.

Table 8.13. Results of the stress-testing exercise for the urban (including energy and transport) sector: (a) Present relevance and performance of response options; and (b) Future relevance and performance of response options. Rel = Relevance of the response option within the UK NEA

scenario (categorised as high (H), medium (M) or low (L)). Effect on ES = Effect of the response option on ES (P = provisioning services; R = regulating services; C = cultural services; S = supporting services) within the UK NEA scenario (categorised as very negative (- -), slightly negative (-), neutral (0), slightly positive (+) or very positive (++)). These are all given in comparison with the scenario in the absence of the intervention. Note that options covered by other sectors are also relevant to urban, energy and transport.

(a)

Response option	Rel	Effect on ES			
		P	R	C	S
National policy planning framework	M	+	+	+	+
Energy related EU legislation	L	0	0	0	0
Multi-functional green infrastructure	M	0	+	++	+
Art, humanities and culture projects	M	0	0	+	0
Ecosystem assessments	M	+	+	+	0
Improving sustainable modes of transport	M	0	+	+	0
Technology for water saving in urban dwellings and industry (on-site greywater re-use)	H	+	+	0	+
Research on adaptation to climate change in urban areas	H	+	++	++	+
Aggregate scores	***17***	***4***	***7***	***8***	***5***

(b)	Nature@Work					World Markets					National Security					Local Stewardship					Aggregate scores
	Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				
		P	R	C	S		P	R	C	S		P	R	C	S		P	R	C	S	
National policy planning framework:																					
2030	M	++	++	++	+	L	0	+	+	0	M	++	++	+	+	L	++	++	++	+	**22**
2060	M	++	++	++	++	L	–	+	+	–	M	++	++	++	+	L	++	++	++	+	**22**
Energy related EU legislation																					
2030	M	+	+	+	0	L	–	–	0	0	L	0	0	0	0	L	+	+	0	0	**3**
2060	M	++	+	+	+	L	– –	– –	–	0	L	0	0	0	0	L	+	+	0	0	**2**
Multi-functional green infrastructure																					
2030	H	+	++	++	++	L	+	+	+	0	M	++	++	+	++	H	++	++	++	++	**25**
2060	H	++	++	++	++	L	+	+	+	0	M	++	++	+	++	H	++	++	++	++	**26**
Art, humanities and culture projects																					
2030	M	0	0	++	0	L	0	0	++	0	M	0	0	+	0	H	0	0	++	0	**7**
2060	M	+	+	++	0	L	0	0	++	0	M	0	0	++	0	H	+	+	++	+	**13**
Ecosystem assessments																					
20030	M	++	++	++	+	M	+	+	0	+	M	+	+	0	0	M	++	++	++	+	**19**
2060	M	++	++	++	+	L	+	+	0	+	M	++	++	0	0	M	++	++	++	+	**21**
Improving sustainable modes of transport																					
2030	H	+	+	++	0	H	0	0	+	0	M	0	+	+	0	M	+	+	++	0	**11**
2060	H	+	+	++	0	H	0	0	+	0	M	0	0	+	0	M	+	+	++	0	**10**
Technology for water saving in urban dwellings and industry (on-site greywater re-use):																					
2030	H	+	+	0	+	H	+	+	0	+	H	++	++	0	0	H	+	+	0	+	**13**
2060	H	+	+	0	+	H	+	+	0	+	H	++	++	0	0	H	+	+	0	+	**13**
Research on adaptation to climate change in urban areas:																					
2030	H	+	++	++	+	M	0	0	0	0	M	++	++	+	+	M	++	++	++	+	**19**
2060	H	++	++	++	++	M	+	+	0	+	H	++	++	++	+	M	++	++	++	+	**25**
Aggregate scores	**40**	**22**	**23**	**26**	**15**	**27**	**3**	**6**	**9**	**4**	**33**	**19**	**20**	**13**	**8**	**34**	**23**	**23**	**24**	**13**	

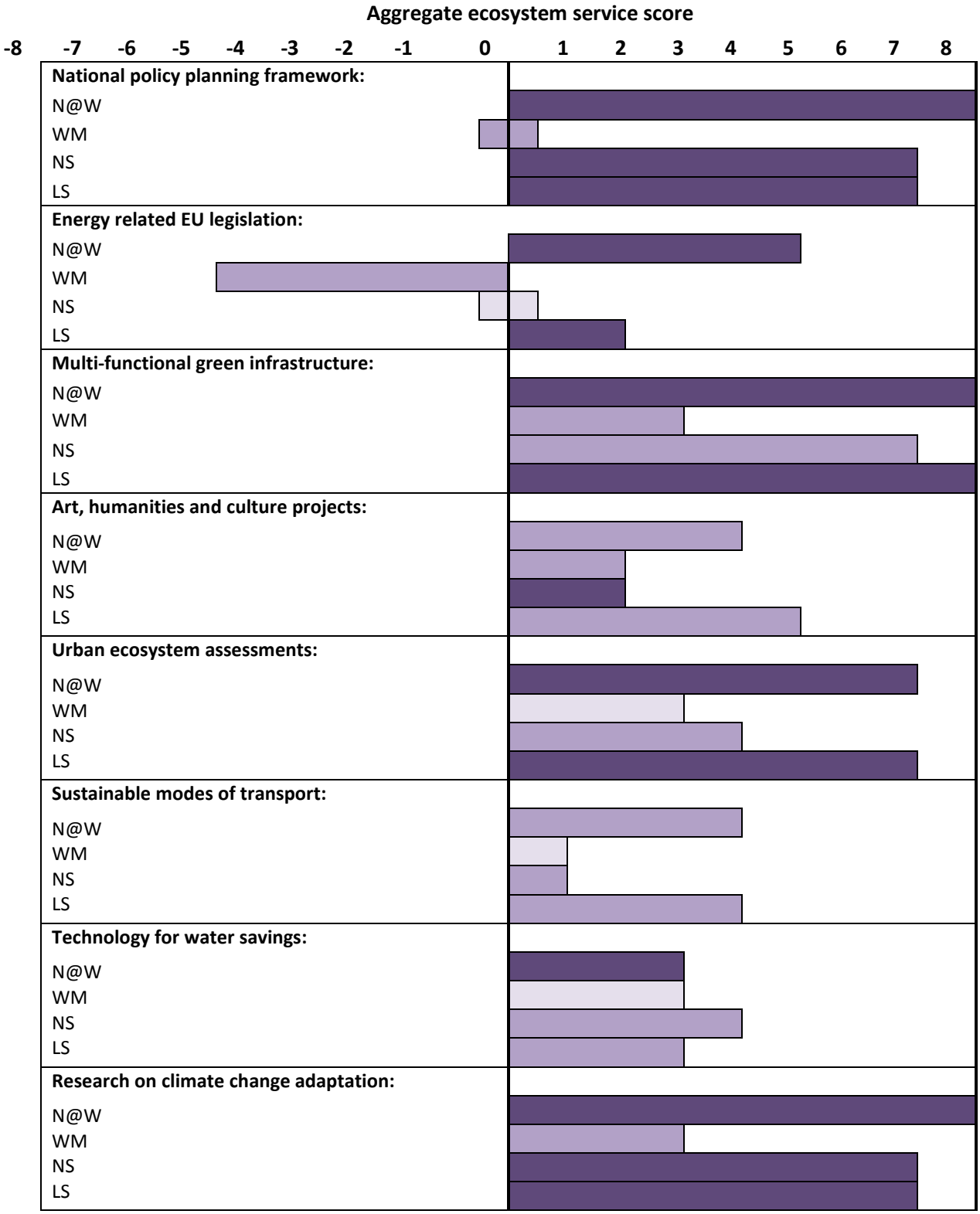


Figure 8.7. Graphical summary showing how the urban, energy and transport response options fare under the UK NEA scenarios in 2060. The bars show the aggregate score across the provisioning, regulating, cultural and supporting ES classes. The bars are colour-coded according to the uncertainty related to the score (dark purple = low uncertainty; mid purple = medium uncertainty; light purple = high uncertainty). The figure should be viewed alongside Table 8.13 which shows the results for the individual service categories as gains and losses in different service categories can counteract each other.

8.3.7 Marine and coasts, including fisheries

Within marine and coastal environments although a range of response options exist, the management of UK seas has lagged behind land management and many of these options are only in the early stages of implementation. For example, while there have been established programmes of fish stock monitoring to inform fisheries management for many years, ecological monitoring in the marine environment has been more limited, highlighted by the difficulties in preparing meaningful reports on the state of UK seas (UKMMAS, 2010).

In recognition of the need to improve management of the marine environment (Defra, 2003), new legislation and supporting policy has been developed over the past decade including European legislation such as the Water Framework Directive, Marine Strategy Framework Directive and reform of the Common Fisheries Policy and national legislation under the UK Marine Acts[14]. Together this legislation provides clear objectives for the management of the marine environment and establishes new institutional arrangements and delivery mechanisms to support their achievement, including statutory systems of marine spatial planning, improved marine licensing arrangements and the establishment of a network of Marine Protected Areas.

Historically there has been limited use of tailored actions in the marine environment and most existing initiatives relate to aspects of fisheries management, for example, certification schemes. However, various incentive schemes are now being trialled, for example, the Scottish Conservation Credit Scheme to support improved fisheries management. There is also increasing use of managed realignment as a measure to recreate intertidal habitats lost as a result of past development and ongoing sea-level rise. The last decade has also seen a major expansion of the use of the marine environment for renewable energy projects, particularly offshore wind. This trend is likely to accelerate over the next decade, together with initial commercial scale deployments of tidal stream and wave arrays.

A subset of nine current response options was selected for detailed consideration of their potential impacts on different ES under the UK NEA scenarios (**Table 8.14**). The baseline assessment highlights that these still tend to remain of low or medium priority which may be compared with the higher priority of response options tested in other sectors. In addition, these response options tend to target provisioning or regulating services with a lesser emphasis placed on cultural and supporting services.

[14] The UK Marine & Coastal Access Act 2009; Marine (Scotland) Act 2010; impending Northern Ireland Marine Act.

Table 8.14. Marine and coastal (including fisheries) response options included in the stress-testing study.

Response Option	Type	Status	Reason for short-listing
No take zones	Protected areas	Early stages	Major pillar for delivering Ecosystem Approach
Conservation measures in fisheries	Statutory regulation	Early stages	Sector specific response option in early stages of implementation
Marine Plans	Spatial and integrated planning	Early stages	Major cross-sectoral pillar for delivering sustainable development
Managed realignment (small scale)	Management practices	Established	Well established response option focused on intertidal areas
Beach nourishment	Management practices	Established	Well established response option focused on intertidal areas
Certification (fisheries and aquaculture)	Voluntary standards and quality assurance	Established	Well established response option for fisheries
Coastal partnerships	Networks, partnerships and community schemes	Established	Well established, operating at local scale
Marine monitoring	Education and knowledge exchange	Early implementation to established	Example of a knowledge-based response with varying degrees of implementation
Marine Environmental NGOs	Networks, partnerships and community schemes	Established	Well established, operating at local to national scale

The performance of the response options across the scenarios is variable (**Table 8.15** and **Figure 8.8**). The relevance of the response options was greatest under Local Stewardship (44/54) and Nature@Work (38/54) with lower relevance under World Markets (22/54) and National Security (26/54). The higher scores for Local Stewardship and Nature@Work reflect the greater relevance of most response options under these scenarios, and particularly so in relation to the role of networks and partnerships which are especially relevant to Local Stewardship. Relevance was assessed as being relatively constant at the time steps 2030 and 2060 – in part this reflects the relatively long time period to 2030 during which policies might become embedded.

Uncertainty scores (**Figure 8.8**) were generally high across all scenarios, reflecting the relatively greater uncertainty and more limited scientific understanding of marine and coastal systems and that many of the response options are new and untested. Aggregate uncertainty scores were slightly higher in Nature@Work (41/54) and Local Stewardship (38/54) compared to World Markets (31/54) and National Security (32/54). This largely reflected the greater confidence that some response options would be of limited effectiveness under the latter two scenarios.

Under Nature@Work and Local Stewardship, effects of response options on all types of ES were generally positive, particularly for provisioning and regulating services; this would continue the gains in the latter type of services evident in the baseline assessment. Under World Markets and National Security, many of the response options were of little or no benefit to ES and in a number of instances were potentially detrimental. This included marine planning, which it was considered could be used to prosecute unsustainable objectives in these scenarios. Similarly, continued use of high levels of beach nourishment to maintain natural hazard protection could over time give rise to negative impacts on provisioning and cultural services by modifying coastal ecosystems (particularly if local material is not used) (Nordstrom, 2006).

The main impacts of the response options are generally assessed to be on provisioning and regulating services with combined scores across scenarios of 60/144 and 39/144 (**Table 8.15b**). Lower scores were obtained for cultural and supporting services across the scenarios (19/144 and 23/144, respectively). This may, in part, reflect limited understanding of cultural and supporting services in the marine environment and the lack of response options directly targeting them. The aggregate effect scores across all ES categories (both time slices combined) of the selected response options shows marked differences between scenarios. Under Nature@Work and Local Stewardship, large positive scores were obtained (72 and 65). However, for World Markets a slight negative score was obtained (-6) and for National Security a minor positive score was recorded (4). This highlights that the response options evaluated here are unlikely to be effective in futures shaped by narrow short-term economic or political objectives.

There are pronounced differences in the assessments of the effectiveness of response options for different types of ES under the four scenarios. For example the aggregate scores for provisioning and regulating services ranged from 24/36 and 21/36 (Nature@Work) to 5/36 and -2/36 (World Markets), respectively (**Table 8.15b**). This reflects the assumption that under World Markets, the response options will do little if anything to support regulating services and that only statutory measures will provide long-term sustainability of provisioning services (notably fisheries).

Given the risks that short-term economic objectives might prevail under some scenarios, the most effective response options are likely to be those that are specific and prescriptive and which have strong legal underpinning. Indeed, this is a lesson that can be learned from past failures in marine policy. In particular, given that commercial fishing pressures give rise to the largest impacts on marine ecosystems, effective response options to address these risks are likely to be beneficial across all scenarios. Measures that protect crucial nursery areas for fisheries (notably 'no-take zones') may have cost-effective benefits in all scenarios by improving fisheries stocks in addition to habitat quality.

Marine and coastal response options which appeared most robust across all options include 'no-take' zones (10/32 in 2030 and 2060) and fisheries conservation measures (5/32 in 2030 rising to 10/32 in 2060) (**Table 8.15b**) because these can also enhance market potential as well as wider ecosystem integrity. Marine planning and environmental NGOs contributed significantly under Nature@Work and Local Stewardship, but were less effective under the other two scenarios which had a stronger focus on economic or political objectives. Opportunities to strengthen the robustness of response options might include a clearer articulation and application of the Ecosystem Approach within marine planning, legally binding management measures within no-take zones and clear and enforceable fisheries conservation measures. NGOs may have a particularly important role in articulating benefits from the marine environment because most people are probably unaware of their full range of services due to their remoteness (i.e. being on land). In addition, the marine environment is generally assumed to have a significant non-use (existence) value (Tinch and Mathieu, 2011) but awareness of this in decision making is currently limited.

The least robust response options were assessed to be beach nourishment, small-scale managed realignment, and coastal partnerships. Beach nourishment is generally envisaged as a shorter term solution to problems of coastal erosion, rather than representing a sustainable long term strategy, particularly with rising sea levels. For managed realignment the low scores were largely a function of the limited spatial scale over which the options were likely to be applied. Achieving multiple benefits from managed realignment would be constrained by small-scale schemes and there is evidence to suggest that greater benefits would be achieved at a larger scale (e.g. Brown, 2009), although

further work is required on this topic[15]. The low scores for coastal partnerships reflected the assessment of their limited effectiveness under World Markets and National Security.

The main cross-sectoral linkages inevitably occur at the coast where land meets sea. Managed realignment of former farmland may provide opportunities for Payments for Ecosystem Services (PES) (see Agriculture section 8.3.2), linked to biodiversity offsetting (see Biodiversity section 8.3.4). Managed realignment may also support the establishment of ecological networks and nature-based partnerships (see Biodiversity section 8.3.4). Both managed realignment and beach nourishment link to natural flood management and integrated catchment management within the wider water environment (see Water section 8.3.5). Where such response options provide multiple benefits (multifunctional green infrastructure) they are likely to be more robust across scenarios (see Urban including Energy and Transport section 8.3.6). Marine planning has an important role to play in developing synergies across the land sea interface through engagement with the terrestrial planning system and taking account of existing Shoreline Management Plans.

There are significant knowledge gaps concerning the effectiveness of many of the response options because of the limited evidence base. Many of the response options are relatively new or novel. The difficulties of monitoring in the marine environment also make data collection expensive. The impacts of climate change on the marine environment are uncertain and thus the influence of climate change on the response options is also uncertain. While climate change is already leading to alterations in the structure of some marine ecosystems, response options that effectively manage human pressures will help to promote resilience, to increase the potential for adaptation and reduce risks of ecosystem collapse.

Table 8.15. Results of the stress-testing exercise for the marine and coasts sector: (a) Present relevance and performance of response options; and (b) Future relevance and performance of response options. Rel = Relevance of the response option within the UK NEA scenario (categorised as high (H), medium (M) or low (L)). Effect on ES = Effect of the response option on ES (P = provisioning services; R = regulating services; C = cultural services; S = supporting services) within the UK NEA scenario (categorised as very negative (- -), slightly negative (-), neutral (0), slightly positive (+) or very positive (++)). These are all given in comparison with the scenario in the absence of the intervention.

(a)

Response option	Rel	Effect on ES			
		P	R	C	S
No take zones	L	0	0	0	+
Conservation measures in fisheries	M	+	0	0	0
Marine Plans	L	0	0	0	0
Managed realignment	L	0	+	0	0
Beach nourishment	L	0	+	0	0
Certification (fisheries and aquaculture)	M	+	0	0	0
Coastal partnerships	L	0	0	+	0
Marine monitoring	M	+	+	0	0
Environmental NGOs	M	+	+	+	0
Aggregate scores	***13***	***4***	***4***	***2***	***0***

[15] The evidence base for managed realignment is limited because such schemes have (to-date) been small-scale, have only been implemented for a short time, and from difficulties of generalisation due to the influence of different local factors.

(b)	Nature@Work					World Markets					National Security					Local Stewardship					Aggregate scores
	Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				Rel	Effect on ES				
		P	R	C	S		P	R	C	S		P	R	C	S		P	R	C	S	
No take zones:																					
2030	M	++	+	0	+	L	+	0	0	+	L	+	0	0	+	H	++	+	0	+	**11**
2060	M	++	+	0	+	L	+	0	0	+	L	+	0	0	+	H	++	+	0	+	**11**
Conservation measures in fisheries:																					
2030	H	++	0	0	0	L	+	0	0	0	M	+	0	0	0	M	+	0	0	0	**5**
2060	H	++	+	0	+	L	+	0	0	+	M	+	0	0	+	M	++	+	0	+	**12**
Marine Plans:																					
2030	H	++	++	++	++	M	+	–	–	–	H	0	0	0	0	H	++	++	++	+	**13**
2060	H	++	++	++	++	M	+	–	–	–	H	+	–	–	–	H	++	++	++	+	**11**
Managed realignment (small-scale):																					
2030	M	+	+	0	+	L	0	0	0	0	L	0	0	0	0	M	+	+	+	+	**7**
2060	M	+	+	0	+	L	0	0	0	0	L	0	0	0	0	M	+	+	+	+	**7**
Beach nourishment:																					
2030	L	0	+	0	0	L	0	0	0	0	M	0	0	0	0	L	0	+	0	0	**2**
2060	L	0	+	0	0	L	–	0	–	0	M	–	0	–	0	L	0	+	0	0	**-2**
Certification (fisheries and aquaculture):																					
2030	M	+	+	+	0	M	0	0	0	0	L	+	0	0	0	H	++	+	+	0	**8**
2060	M	+	+	+	0	M	0	0	0	0	L	+	0	0	0	H	++	+	+	0	**8**
Coastal partnerships:																					
2030	M	+	+	+	+	L	0	0	0	0	L	0	0	0	0	H	+	+	+	0	**7**
2060	M	+	+	+	+	L	0	0	0	0	L	0	0	0	0	H	+	+	+	0	**7**
Marine monitoring:																					
2030	M	+	+	+	+	L	0	0	0	0	L	+	+	0	0	M	+	+	0	+	**9**
2060	M	+	+	+	+	L	0	0	0	0	L	+	+	0	0	M	+	+	0	+	**9**
Environmental NGOs:																					
2030	M	++	++	+	+	L	0	0	0	0	L	0	0	0	0	H	+	+	+	+	**10**
2060	M	++	++	+	+	L	0	0	0	0	L	0	0	0	0	H	+	+	+	+	**10**
Aggregate	**38**	**24**	**21**	**12**	**15**	**22**	**5**	**-2**	**-3**	**1**	**26**	**8**	**1**	**-2**	**2**	**44**	**23**	**19**	**12**	**11**	

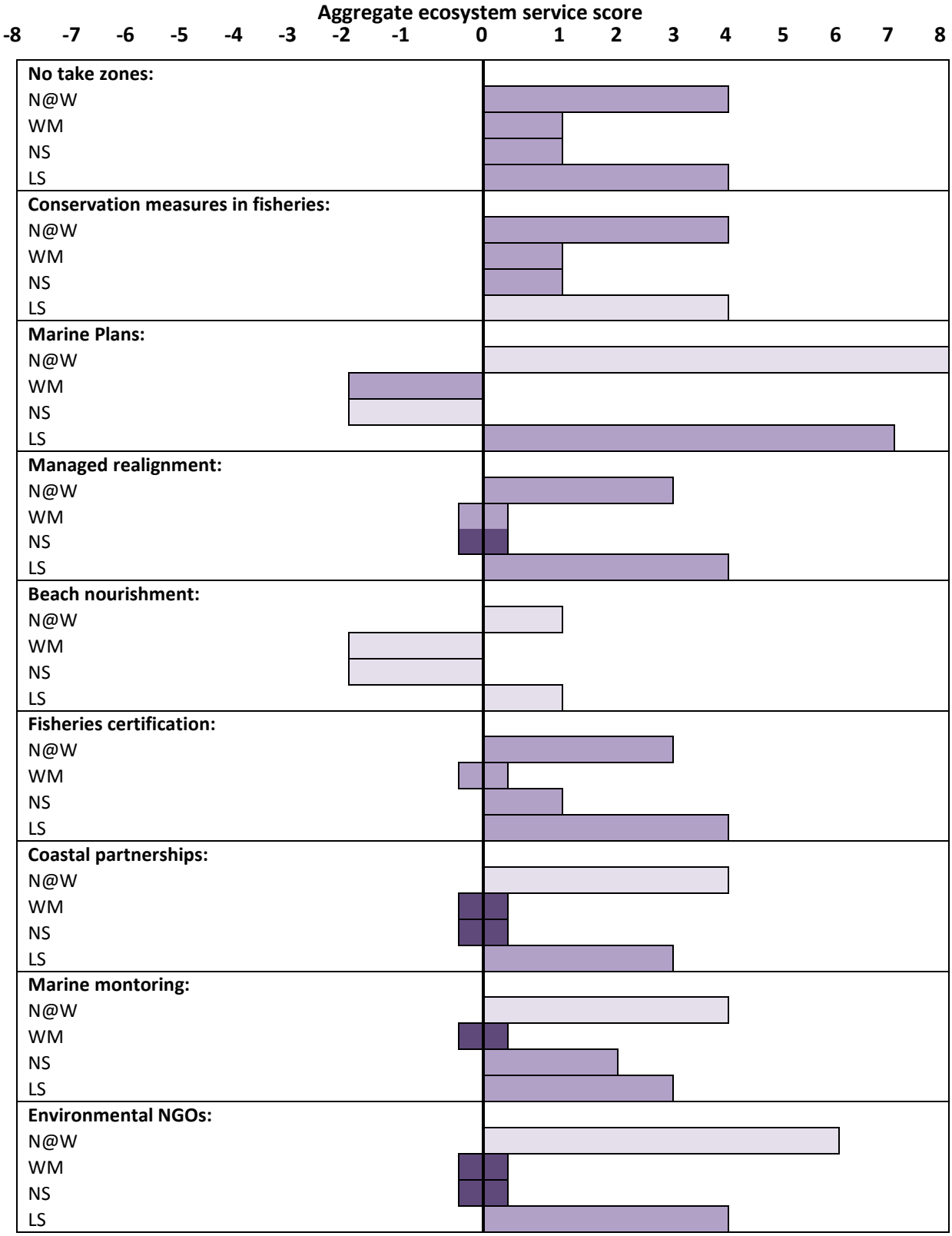


Figure 8.8. Graphical summary showing how the marine and coastal response options fare under the UK NEA scenarios in 2060. The bars show the aggregate score across the provisioning, regulating, cultural and supporting ES classes. The bars are colour-coded according to the uncertainty related to the score (dark purple = low uncertainty; mid purple = medium uncertainty; light purple = high uncertainty). The figure should be viewed alongside **Table 8.15** which shows the results for the individual service categories as gains and losses in different service categories can counteract each other.

8.3.8 Strategic policy issues

In order to highlight the relevance of an integrated future-proofing approach to strategic decision-making, reference is made to a series of topical cross-sectoral policy issues. To allow generalisation of findings in this context, reference is made not only to types of response option, but also to general frameworks for rationalising policy interventions (based on the '4 Es' and '4 Is'; see Section 8.1). Related factors which can identify suitable combinations of responses include: associated inter-dependencies; understanding stakeholder behaviours; spatial and temporal scales; and flexibility to adapt to present/future change.

Common Agricultural Policy (CAP) reform

CAP provides the framework for agricultural policy in the European Union (EU) and has important interactions with other land-based sectors, including biodiversity, forestry and water resources. Since 2000, the CAP has comprised two Pillars: Pillar 1 was intended to maintain food production through output support payments, whereas Pillar 2 was more targeted at enhancing biodiversity, landscape amenity and rural development, as well as controlling pollution to air, water and soil (i.e. cultural and regulating services). However, subsequent reforms mean Pillar 1 support for farmers is now conditional on a broad cross-compliance requirement to maintain good environmental as well as agricultural condition. CAP has an implementation/review cycle of 6 years: the current round of CAP reform is scheduled to be confirmed by 2014, including a significant reduction in the budget (CAP currently accounts for 32% of the EU budget). Reform also includes specific reference to the wider benefits of ES from agricultural land, although the current round (2014-2020) of proposed measures for 'greening' of Pillar 1 support actually specifies land use allocations, rather than a focus on specific ecosystem outcomes, as land use allocation is considered easier to audit.

A key issue for the future trajectory of CAP is addressing prospects for food security through 'sustainable intensification' to meet the twin challenges of increased global demand for food and a healthy environment (Garnett *et al*., 2013). The structure of CAP and its implementation at farm level mean that its use of land resources is consistent with a 'land sharing' rather than a 'land sparing' approach, with the provision of multiple services from the same area of land rather than different geographic locations. As identified in the Biodiversity sector analysis, 'land sharing' may be more inefficient (and many would argue that the current implementation of CAP is particularly inefficient) but it may also be more flexible and adaptable to change than notions of 'optimisation' as encouraged by 'land sparing'. An intermediate sharing/sparing path may be characterised by the incorporation of farm-level options within broader landscape-scale (or catchment-scale) initiatives through targeted incentives that encourage farmer co-operation. This may facilitate the further development of ecological networks and green infrastructure that provide enhanced ecological resilience whilst maintaining local links which may be particularly important for cultural services.

Good land management practices are obviously crucial to ensuring a balanced delivery of ES, and the CAP currently aims to encourage this using direct payments, additional economic incentives, and regulation (cross-compliance). This mix of response options is most consistent with the priorities of the Nature@Work and National Security scenarios, with a strong top-down influence on setting a policy agenda to deliver those priorities (focused on environmental sustainability and food/energy security, respectively). Nevertheless, there are significant challenges in modifying this suite of response options to a changing world, exemplified by global shifts in commodity prices and the effects of climate change and variability (notably extreme events). Direct payments, incentives and regulation can potentially be adapted to these changing circumstances but this requires the ongoing incorporation of appropriate information to fine-tune administration systems based upon suitable

reference standards. This in turn highlights the role of research and knowledge exchange in providing this information.

By reference to the broader range of response options, including results from the stress-testing, possible avenues may be identified for developing a more robust approach to change management. Measures to encourage the increased uptake of science and technology would be a notable example where further opportunities exist to balance provisioning services (notably food and fibre production) against other ES. Technology-based measures, such as those incorporated into precision farming (e.g. high resolution sensing), performed well when tested under most scenario conditions suggesting that they might represent low-regret options, particularly with the increased availability of sensing data. Technology transfer may therefore be encouraged through rural development measures, supported by institutional initiatives to further develop skills and knowledge exchange, similar to the uptake of other ICT developments.

Similarly, another avenue is provided by improved and more systematic use of scientific knowledge to explicate ecosystem-based approaches that enhance the resilience of provisioning services against extreme weather or pests and diseases, notably through the maintenance of crop yields by regulating and supporting services (e.g. pollination, pest/disease control, soil organic matter). The link between science/technology and management-level responses could be further encouraged through increased support for voluntary QA schemes, community partnerships and other knowledge exchange schemes that encourage rapid uptake of new innovations contingent on their suitability for local contexts (e.g. through demonstration projects). The latter type of scheme is particularly consistent with the Local Stewardship scenario, but with associated engagement and networking activities can have a national outreach (akin to 'National Stewardship').

As funding for conventional agri-environment schemes may be constrained by CAP budget cuts, further innovation in response options may be trialled through Payments for ES (PES) type schemes; although a basic challenge here is to design schemes that can deliver ES whilst meeting the audit requirements of CAP. Payment by results or outcomes would allow for land managers to develop appropriate service delivery skills and encourage market efficiencies (as prioritised by the World Markets scenario), but would potentially be more complex to validate and administer than the current CAP system (although there may be further scope to devolve the identification of priority services to local/regional level).

In particular, there is increased scope to use CAP to establish more of an enabling framework for delivering multiple benefits by building schemes around the core motives of land managers. Hence, economic incentives will continue to be important, but the targeting of incentives needs to take account of the importance that land managers place upon their identity linked to both the local community and the local landscape. Information on environmental change and on managing change could be better communicated through peer networks and the translation of scientific knowledge into information that is resonant with its target audience. Further support for innovative schemes that build upon local identity, such as through PES or quality assurance branding, may be particularly beneficial. In some cases, this may require institutional reform to build trust across previously disparate 'sectors' (e.g. agriculture and forestry) based upon successful exemplars, including advisory services and knowledge brokers. Demonstration studies may therefore have a key role to play in building peer-to-peer learning and confidence.

REQUIREMENTS FOR ADAPTIVE MANAGEMENT

Institutions – cross-sectoral linkages and information sharing, particularly between agriculture, forestry and biodiversity; support for technology transfer and industry-led initiatives
Information – research on seasonal variability / change and its implications for productivity and ecosystem services; building resilience to extremes and pests/diseases; reducing soil nutrient loss
Incentives – trialling of targeted schemes, such as PES, linked to defined outcomes; links to new opportunities (e.g. low carbon economy)
Identity – encourage and enable initiatives that recognise skills of land managers as stewards of change for their local landscape

EU Water Framework Directive, Floods Directive and Marine Strategy Framework Directive

The EU Water Framework Directive (WFD), Floods Directive (FD) and Marine Strategy Framework Directive (MSFD) have specific objectives regarding freshwater, coastal and marine water bodies, but also potential synergies that could be realised through coordinated responses for water quality, flood risk reduction and healthy ecosystem functioning . Each directive also acknowledges the need for greater citizen involvement in their implementation. At the national level these issues are compounded by boundaries between devolved administrations such as the Solway-Tweed and across borders exemplified by the Neagh-Bann International River Basin District (Northern Ireland and Republic of Ireland). Multinational maritime jurisdictions add further complexities as represented by the OSPAR Convention, which binds 15 Governments together with the European Community to protect the North-East Atlantic. Whilst considerable progress has been made in terms of defining common objectives in terms of sustainable management, achieving political consensus backed up by the necessary financial resources remain the key barriers to implementing successful response options.

Individually and collectively, effective implementation of these Directives requires integrated approaches. Everard (2012) highlighted that early implementation of the WFD in the UK has prioritised classification and development of environmental standards, often leading to fragmented identification of issues and localised 'programmes of measures' to address them. This risks overlooking the primary purpose of the WFD, which encapsulates most of the key principles of the Ecosystem Approach (economic context, balancing exploitation with conservation, a living resource underpinning future human well-being, etc.), and requires a more systemic foundation to coordinate actions. The importance of measures introduced by the MSFD are highlighted by a recent assessment of how the state of the UK's marine environment was likely to change based on current drivers and response options (best estimate using expert judgement) (ABPmer & eftec, 2012). This analysis suggested that under this 'Business-as-Usual' scenario, key targets and indicators to deliver 'good environmental status' would be unlikely to be met, particularly associated with biodiversity, food webs, sea floor integrity and commercially exploited fisheries.

The stress-testing exercise for both water and marine sectors indicated that major policy instruments such as the WFD and Marine Plans are likely to deliver significant benefits across the range of ES under Nature@Work and Local Stewardship. By contrast they will be much less effective, and indeed generate negative outcomes, under the World Markets scenario, where high consumer demand and low production costs are the main determinants of decision-making, and regulatory controls, particularly those dependent on international agreement, are weaker. Similarly, in the National Security scenario, if water security is not prioritised as highly as food or energy security, then negative consequences for non-provisioning ES are likely. Under Nature@Work and Local Stewardship response options based around integrated catchment management and 'catchment-to-

coast' upstream thinking will see contributions from NGOs, such as River Trusts and Coastal Partnerships, delivering positive outcomes.

The stress-testing also suggested that technological innovation could enhance the mix of robust response options, particularly if this was industry-led, or otherwise linked to incentives that encourage inward investment in new technology that could help restore or maintain healthy ecosystems. Innovation can therefore include measures that both address supply-side and demand-side issues of water availability, which may be particularly important with climate change projections suggesting warmer, drier summers. Technological innovation may also be linked to the development of improved management practices, such as the use of artificial offshore reefs in maintaining sediment supply for coastal ecosystems to provide natural flood and erosion protection.

Together WFD, FD and MSFD provide a comprehensive adaptive management framework in place for managing freshwater and marine systems. Adaptation to change will require not only coordination of institutional activities, but improved sharing of information, particularly with regard to the monitoring of change and the implications that these will have for setting appropriate standards (e.g. levels for environmental flow in rivers). The complexity and transboundary nature of the marine environment highlights the need for this to incorporate international standards and to include all relevant organisations, notably NGOs.

REQUIREMENTS FOR ADAPTIVE MANAGEMENT

Institutions – better alignment of responsibilities and regulatory requirements based upon systemic frameworks, common objectives and shared knowledge.
Information – knowledge of hydrological-related variability and change; valuation of multiple benefits from water.
Incentives – encouragement for measures that enhance source protection and water security.
Identity – support for initiatives that develop actions based upon local benefits from water.

Green infrastructure and ecological networks

Green Infrastructure (GI) can have a strategic role in delivering multiple societal benefits: storm and surface water management, improvement of air and water quality, energy demand reduction, recreation, sustainable transport, health and amenity - as well as supporting biodiverse habitats (Lafortezza *et al.,* 2013). Stress-testing analysis in the urban sector affirmed that it could have the potential to be robust and adaptable to the changing conditions implied by the scenarios. However, there are also important co-dependencies and further potential synergies with other types of response options that could help remove existing barriers and enhance a strategic-level response. For example, a closer incorporation of business opportunities and market-based schemes into GI (e.g. PES, offsetting) could allow a more robust strategy in the event that the free-market economic conditions exemplified by the World Markets scenarios prevail more in the future.

Ecological networks were specifically addressed in the biodiversity sector analysis and like GI emerged as a relatively robust strategy, with similar issues regarding the potential to enhance their robustness through the strategic use of market-based schemes. In the past in the UK, GI has tended to be more associated with urban settings, and ecological networks with rural settings, but efforts are now being made to bridge the urban-rural divide; this integration could also help to provide a more integrated response to change as flows of ES are modified by changing patterns of demand. Crucial to the delivery of GI and ecological networks is spatial/integrated planning which provides a coordinated larger-scale vision for the spatial targeting of local initiatives that can enhance both local benefits and the overall network (Lafortezza *et al.,* 2013). Planning-related response options

fared reasonably well in the stress-testing (**Table 8.3**) and were recognised as key mechanisms to achieve balanced ES and to integrate other responses (particularly bottom-up and top-down initiatives), with the important proviso that planning tools need to be flexible and adaptable.

A significant constraint for both GI and ecological networks is that they are currently delivered through a planning process with a significant information deficit in ecosystem-based knowledge and capacity. This has tended to result in piecemeal implementation and a failure to robustly defend spatial decisions at the Inquiry stage (Roe and Mell, 2012). Therefore improved availability and access to both scientific and local knowledge of ES-related benefits could facilitate further development and the implementation of strategies. The stress-testing suggests that knowledge from urban ecosystem assessments (including parks, gardens and smallholdings), and of the role of GI and ecological networks in adapting to climate change could be particularly useful in developing robust approaches (e.g. through enhanced resilience to ecosystem shocks, and the moderation of extreme events such as heatwaves or intense rainfall). This could also extend to improved integration with other forms of infrastructure (e.g. transport, renewable energy), including the use of new technology and the development of 'green corridors'.

There are significant opportunities for specific sectoral initiatives to also contribute to GI and ecological networks, including the further integration of green and blue (water-based) networks. Hence, schemes that deliver natural flood management, enhanced water quality, or sustainable drainage could also contribute to larger-scale benefits (e.g. landscape amenity) if coordinated together. Similarly, spatial targeting of new woodland or other habitats, including appropriate incentive schemes (e.g. offsetting; PES), can contribute to larger-scale networks and their benefits (e.g. carbon storage; biodiversity), whilst also potentially have the flexibility to deliver local outcomes and to respond to changing circumstances.

Although, national and regional initiatives, including institutional collaboration, can provide an enabling framework for GI and ecological networks, they are unlikely to develop into robust cross-sectoral responses without strong engagement and action at the local level. This is particularly exemplified by the Local Stewardship scenario, which has a stronger emphasis on bottom-up initiatives than the other scenarios. Robust strategies therefore need to combine an enabling framework and business opportunities with support for partnerships, networks and community-based responses in grounding large-scale strategies in local identities. Complementary local initiatives that can establish local benefits and stimulate action may include *inter alia:* community woodland groups, local biodiversity partnerships, local food initiatives, river trusts and coastal partnerships. As identified in the urban sector analysis, interaction between these local groups based upon their distinctive place-based identities can provide a strong foundation for cross-sectoral action (see also section 8.3.9).

REQUIREMENTS FOR ADAPTIVE MANAGEMENT

Institutions – need for a common framework for cross-sectoral and cross-boundary collaboration
Information – improved knowledge of ecosystem services at multiple scales, including mapping of service flows, and integration into common planning agendas
Incentives – innovation in schemes (e.g. PES) to build and consolidate networks
Identity – support for community-based initiatives that provide a platform for local actions and that record local aspects of change

Transition to the Low Carbon Economy

The UK Climate Change Act 2008 established the world's first long-term legally binding framework to tackle the risks of climate change, committing the UK to meeting its 80% greenhouse gas reduction targets by 2050[16]. In its contribution to the Europe 2020 commitment, the UK is focusing on reducing greenhouse gas emissions by 34% compared to 1990 levels. The natural environment has an important role in the delivering these objectives, notably through ES provided by carbon storage and sequestration, but also through other contributions such as renewable energy sources. Scenario analysis has already been employed through the 2050s Pathways (HM Government, 2010) to explore with stakeholders and the public the different choices and trade-offs involved in meeting these emissions targets. However, to-date there has been limited analysis of how these pathways may interact with other drivers, using a wider array of future-proofing techniques.

Adoption of the Ecosystem Approach could potentially enable more holistic and systemic decision-making strategies for emissions reduction, including decisions in rural, urban and marine settings. This includes economies of scale through coordinated local initiatives at the regional scale, such as also exist with planning for GI. Although the stress-testing was not specifically directed at the low carbon economy, some of the analysis can be used to make preliminary suggestion as to how the transition could be made more robustly and efficiently. More detailed analysis would require integration of the stress testing with the 2050s Pathways and IPCC projections rather than to use the exploratory UK NEA scenarios in isolation.

The stress-testing (**Table 8.3**) suggests that technology could make further contributions towards emissions reduction from land uses, notably through the use of precision farming to reduce N_2O emissions from fertiliser application, when used in combination with good management (e.g. low tillage) and information-based awareness schemes (e.g. woodland carbon code). Investment in science and technology emerged as a reasonably robust response because it was seen to have a role in all scenarios. However, engagement events suggest that land managers and the wider public often remain uncertain on which land uses, management practices, and general behaviours contribute most to GHG emissions. A robust mix of responses options would therefore complement technological innovation with exemplar demonstration projects to encourage knowledge exchange and support peer-to-peer networks to share new skills. In conjunction with spatially targeted incentive schemes this could reward low emission behaviours and encourage scale efficiencies through networks and improved cooperation, including improved communication to the general public through quality assurance and accreditation schemes.

The importance of increasing awareness of GHG emissions is recognised by information-based tools, such as carbon accounting, footprinting and certification standards, for which the Carbon Trust currently acts as a knowledge broker. These tools are currently complemented by progressive market-based incentive schemes, such as offsetting and trading, which recognise that carbon storage benefits for climate regulation accrue at the global scale, and can therefore be transferred at that scale. However, carbon offsetting and trading schemes also modify other ES by changing ecosystem processes at source and destination sites; benefits from these other ES may accrue at the local/regional level and may not necessarily be consistent with the maximum returns determined from carbon storage value only. As the development of carbon markets has been limited to-date, this suggests that a greater uptake of low-carbon schemes may be encouraged by also incorporating and communicating the co-benefits that are provided at the local/regional level, including ES such as flood hazard regulation or landscape amenity, and the association with complementary initiatives such as GI or wetland restoration.

[16] Targets have also been set by the devolved administrations of the UK.

REQUIREMENTS FOR ADAPTIVE MANAGEMENT

Institutions – collaborative frameworks and knowledge sharing based upon integrated long-term strategies
Information – improved knowledge of emissions from different uses in rural and urban settings and their synergies with other ecosystem services in the long term
Incentives – targeted schemes to reward emissions reduction and co-benefits for other ecosystem services
Identity – support for local actions to reduce carbon and environmental footprints

8.3.9 Place-based implementation

Stress-testing analysis at the national scale can mask important geographic differences in the UK at local/regional scales. Two contrasting case studies were explored to complement the national level analysis and to highlight additional information requirements and tools that may be required at this level of implementation.

North Devon Biosphere Reserve (NDBR)

The UNESCO concept for a Biosphere emphasises the role of all three pillars of sustainability (social, economic, environmental) in an adaptive learning-based setting. North Devon has a distinctive identity or 'sense of place' based upon both its natural and cultural heritage, and this has further moulded the general Biosphere vision to match with local circumstances, facilitated by active management and an inclusive Partnership. The NDBR has been defined to include terrestrial, freshwater, coastal and marine environments: a particular objective is to develop the green economy of the area based upon its unique landscape attributes and to, therefore, ensure ongoing investment in enhancing its natural capital.

The NDBR Partnership recognises that meeting their sustainability objectives could be challenged by changing circumstances (external and internal): the current Action Plan identifies that planning for future change could be further enabled by scenario analysis. Drivers of change that have been specifically identified include: demographic change and migration; employment and international dependencies (e.g. market prices); renewable energy[17]; and climate change. Planning for sustainability is also identified as being constrained by the high uncertainty of future land use patterns due to issues such as food security, climate change and bio-fuels.

The NDBR has developed synergies with other initiatives including:

- Catchment Sensitive Farming which has targeted soil and water quality improvements based upon poorly-performing areas.
- A Nature Improvement Area (NIA: based on the larger Torridge Catchment) which links biodiversity enhancement, water quality/quantity and community engagement, particularly through new woodlands.
- The Taw River Improvement Project which is primarily driven by the Water Framework Directive and aims to enhance both aquatic and terrestrial ecosystems through wetland and woodland creation and buffer area management.

[17] Renewable energy issues are highlighted at present by the proposed Atlantic Array (large-scale wind farm) in the offshore area of the NDBR.

- The North Devon Area of Outstanding Natural Beauty (AONB) which aims to conserve and promote the area of high landscape quality adjacent to the north coast.

With regard to the generic response types, the NDBR area includes national-level initiatives (e.g. regulatory standards; designated areas), but also features the following local initiatives:

- Integrated spatial planning is emphasised to enhance synergies across multiple initiatives; NDBR is recognised as a key driver in the spatial vision for the Local Plan. Planning for, and demonstration of, integrated land management (ILM) is identified as a key strategic planning objective, but also the development of integrated coastal zone management (ICZM), including the Taw Torridge estuary management plan, and marine planning. The spatial strategy also aims to recognise the synergies provided by GI to provide ES at multiple scales.
- Locally designated protected sites, including local nature reserves.
- The design of ecological networks based upon local BAP habitat plans and implementing the principles affirmed by the Lawton report (larger sites, better quality, more connected: Lawton *et al.* 2010). Culm grassland habitats are identified as of specific high priority: this habitat has become fragmented through past agricultural improvements and the BAP identifies the main threats as a cessation of traditional farming practices, land use change (due to changing markets), inadequate enforcement of environmental regulation, discontinuation of agri-environment schemes, and long-term climate change .
- The development of ecosystem markets based upon 'credits' for water, biodiversity, carbon, and related services (currently in early stages of development).
- Maintenance of natural capital through compensatory schemes associated with biodiversity offsetting and land-banks. However, the policy of the NDBR is that offsetting should be seen as a 'last resort' option to be used only when biodiversity cannot be retained at the same level on-site.
- Procurement and quality assurance schemes based upon local identity and its association with high landscape quality, including Biosphere Business accreditation.
- Community schemes, including integration with the local authority community strategy. Stakeholder and public engagement aims to empower local decision-making to deliver the strategic aims of the NDBR (e.g. by recognition of local champions).
- Education and informal knowledge exchange schemes: the NDBR has an education strategy and associated arts strategy to celebrate the local heritage. The recent development of the NIA includes an advisory information service to land managers based upon environmental improvements for multiple benefits.

It is evident from these initiatives that the distinctive identity and social capital of North Devon, combined with existing institutional synergies that have been further reinforced by the NDBR, have led to innovation across a suite of response options to match the local context. In some cases, these are local-level modifications of national initiatives, but most represent genuine bottom-up responses that are based upon an identification of local needs. The NDBR provides a strategic enabling and encouraging framework to provide coherence between these local-level responses. Some of these initiatives remain in the early stages, such as the development of ecosystem markets and associated incentives, but they are embedded within a philosophy of 'learning by doing' that is entirely consistent with the concept of Biosphere Reserves as 'living laboratories'.

There is recognition of the drivers and pressures of change in the NDBR action plan. The existing suite of initiatives would appear collectively to provide a robust response to these changes (**Table 8.16**), grounded in the principles of adaptive management, community engagement and the design of suitable incentives for land managers. A more detailed case study is required based upon local versions of the UK NEA scenarios and climate change projections to stress-test these responses. In some futures (e.g. World Markets scenario), the strong local identity that has provided a foundation

for existing actions may be eroded, unless momentum is maintained or further responses are developed. For example, Adger *et al.* (2009) have highlighted that the undervaluing of places and culture in general society may limit local adaptation to climate change (or other drivers of change). It is very likely that cultural identities will evolve as local landscapes change through time, and external relationships also change, therefore formal and informal initiatives that build upon and help to shape evolving identities are most likely to be robust to change. The Biosphere concept is one example that deserves further examination as a potential 'enabler' in strengthening the links between local identity, adaptive management and the Ecosystem Approach.

Table 8.16. Preliminary testing of response options for NDBR up to 2060.

	N@W	WM	NS	LS
Integrated/spatial planning; ecological networks and GI	***	*	**	**
Designated sites	***	*	*	**
Regulation	**	*	**	**
Ecosystem markets & offsetting	**	***	*	*
Local branding & procurement	**	*	**	***
Community schemes	**	*	*	***
Education & knowledge exchange	***	**	**	**

*** Strong support and likely to deliver balanced ES
** Moderate support or less likely to deliver balanced ES
* Weak support and unlikely to deliver balanced ES

Staffordshire

The Staffordshire case study area (including Stoke-on-Trent) is based upon a diverse rural and urban landscape that is also adjacent to the major conurbations of Greater Manchester and Birmingham. A focal issue was provided by the long-term development of minerals planning for the area. Staffordshire is relatively rich in mineral resources and its adjacency to major conurbations implies that demand is likely to continue into the future. When exploitation of a mineral resource has been completed, the emphasis is placed upon effective ecological restoration. Therefore with advanced planning, opportunities exist to link this issue with other long-term objectives, such as the enhancement of ecological networks and floodplain restoration.

Planning regulations require local authorities in England to prepare Minerals Local Plans based upon strategic objectives for the resource base. By EU Directive, plans are required to be screened for environmental criteria through Strategic Environmental Assessment (SEA), but UK regulations also require socio-economic evaluation. Hence, recent practice has shifted towards using Sustainability Appraisal (SA) as the key tool in this process (also incorporating SEA reporting obligations) using a broader objectives-led approach. However, although SA and SEA have been linked for minerals planning (e.g. James, 2001), the assessment process has not yet fully utilised an ES framework to evaluate sustainability issues and the scope for subsequent restoration and enhancement.

Currently, Staffordshire are developing a new Minerals Plan with an associated SA/SEA to evaluate its viability against other long-term objectives. Based upon the 2008 SA/SEA, sustainability objectives are listed in **Table 8.17** and identified against relevant ecosystem services and response options, with an indication of the sensitivity of these interactions against drivers of change. This listing highlights that many of the objectives can be associated with an ES framework and that these relationships are sensitive to change. Hence, some change from the baseline would be expected

regardless of the proposed minerals strategy and the assessment of the impact of the minerals strategy should take this into account[18]. Scenario analysis and stress-testing of the minerals strategy against the core SA/SEA framework could therefore help to provide future proofing and screening with regard to it meeting its long-term objectives, using suitable indicators. This should also include post-extraction remedial work that may be used to further develop opportunities for ecosystem restoration, such as through ecological networks and GI. Further work to develop customised scenarios to test the sustainability of the minerals strategy would therefore also help to develop a common toolkit for development of SA/SEA.

Table 8.17. SA/SEA objectives (2008) and their association with ecosystem services and response options for the Staffordshire case study.

SEA/SA objective	Associated ecosystem services	Potential Response Options	Sensitivity to change
Avoid loss of tranquil areas	Noise reduction / screening	Integrated/spatial planning; Protected areas; GI	Low
Reduce transportation impacts	Noise reduction/screening	Sustainable transport; Regulation	Low
Reduce GHG emissions	Carbon storage	Regulation; Incentives (eg. offsetting); Levies	Medium
Contribute to flood risk management	Flow regulation	NFM, SUDS	Medium
Protect/enhance biodiversity	Wild species diversity	Protected areas; Ecological networks; Offsetting;	High
Protect water resources	Water quality regulation/purification	Regulation; SUDS; Integrated/spatial planning; Levies	Medium
Protect soil resources	Soil quality regulation	Regulation; Levies	Medium
Maintain air quality	Air quality regulation	Regulation; Levies	Low
Protect historic/cultural heritage	N/A	Protected areas	Low
Maintain local building supply	N/A	N/A	Low
Maintain landscape quality	Sense of place / environmental settings	Protected areas; Integrated/spatial planning; GI	High
Protect/enhance recreation	Cultural services	Integrated spatial planning; GI	Medium
Protect health/amenity/well-being	All	All	High
Recycling of alternative aggregate	N/A	Technology etc	Medium
Safeguard important geological sites	N/A	Protected areas	Low
Ensure long-term mineral supply	N/A	Regulation	Low
Protection from short term demands	N/A	Regulation	Medium

[18] The SEA Directive requires an analysis of "the relevant aspects of the current state of the environment and the likely evolution thereof without implementation of the plan or programme.

8.4 Discussion and Conclusions

This study explored the robustness of a range of response options that may provide mechanisms to integrate the ecosystem approach into decision-making. Emphasis was placed on the sustainability of ES to enhance long-term multiple benefits for society. The current implementation of most of these response options does not automatically address ES either explicitly or on an integrated and interdependent basis. Many organisations today remain committed to particular responses, rather than considering the full range of options, including further potential innovation. Analysis of the strengths and weaknesses of the response options highlights that no response options emerged as a 'magic bullet' that directly addresses all ES, drivers of change and local contexts. Rather, each is best suited to specific sets of issues, generally within specific societal contexts, and should ideally be used in combination with other response options to deliver sustainable outcomes. This analysis challenges implicit assumptions that legacy practices and tools are automatically fit-for-purpose simply because they have been part of established practices and assumptions.

In the following sub-sections, concluding remarks are referenced against key components of the study in order to highlight progress and opportunities for further development.

8.4.1 Methodology (and application to SEA/SA)

The appraisal process addressed a nested set of challenges including: (1) characterising a diversity of response options; (2) means to embed the ES framework within response options; (3) 'stress-testing' to determine the robustness of response options under different plausible scenarios; and (4) establishing the potential contribution of each to implementing the Ecosystem Approach in the context of strategic policy issues.

Pervading the principles of the Ecosystem Approach is that participation of multiple stakeholders better addresses inherent uncertainties and evidence gaps. This was affirmed by the appraisal and stress-testing of response options against the different scenarios, which is best achieved by combining multiple perspectives and forms of knowledge. This can also help establish the analysis as a two-way communication 'process' of knowledge exchange including mediation, translation, feedback and trust building (Cash *et al*. 2003). Nevertheless, resources typically dictate the level of participation that can be employed in the analysis, and the present study was no exception in this regard. Limits to participation and the full development of deliberative processes are also evident in the challenges involved in bringing all stakeholders together and requirements to make 'timely' decisions.

Inclusive deliberative processes need to pay particular regard to cultural services which were identified as inherently uncertain, commonly overlooked today, yet frequently pivotal to the successful *implementation* of different response options. Cultural benefits have often been neglected or discounted given significant uncertainties about how to value them and also a less-than-inclusive historic approach to decision-making. However, these benefits are crucial in terms of the ways that people identify with the places in which they live and how they perceive their future aspirations. Selection of the most efficacious response options can only be achieved with an increased awareness of this varying local context, including the full range of benefits (tangible and intangible) that people receive through ES.

The current methodology may be criticised for its explicit inclusion (and scoring) of supporting services, as some may regard this as double counting of services which are assumed to be fully expressed through final delivery of regulating, cultural or provisioning services. However, as with

cultural services, the assessment found major uncertainties with regard to supporting services and also that many response options did not explicitly consider them. This is particularly important when planning for change, as supporting services such as water or nutrient cycling, or the availability of soil organic matter, are key components of ecosystem resilience. Degradation of these services therefore could risk a step change in the delivery of final ecosystem services because of the myriad interconnections within ecosystems. It is therefore suggested that the design of robust response options requires improved knowledge and awareness of the key role of supporting services in maintaining healthy ecosystems.

The main emphasis of the present study was broad-based evaluation of response options at UK scale, but the methodology has scope to be applied for more localised assessments (as highlighted in section 8.3.9). In particular, the development of systematic scenario analysis based upon an ES framework has close links to the appraisal requirements of SEA and SA. The current methodology has elements of both baseline-led appraisal procedures (based upon characterising the current status of ES) and objectives-led appraisal (where the different categories of ES provide indicators to measure the relative efficacy of different response options). Further work to establish integration of stress-testing within formal SEA and SA frameworks could therefore be beneficial to further embed the ecosystem approach. This may include the assessment of specific key services (e.g. soil/water/air quality, landscape amenity, crop production) rather than general categories. It may also include weighting of different indicators rather than assume they all have equal value, as employed by multi-criteria assessment.

Reference to baseline or past conditions was found essential to support decision-making, and to provide a reference frame for the analysis of scenarios (which otherwise may appear too abstract). This is also important with regard to notions of sustainability as this can only be defined relative to a temporal baseline, otherwise there is a risk that the baseline keeps shifting downwards, since society is unaware of or simply accepts what it has lost.

8.4.2 Response options: Synergies and trade-offs

The matrix-based approach adopted for stress-testing can provide a systematic procedure from which to select appropriate response options. The matrix can also facilitate identification of a mix of response options that may work best to address multiple policy issues simultaneously, and which offer the prospect of maximising outcomes across the full range of ES categories (see **Table 8.3**).

The following attributes of different response options may be highlighted: (i) protected areas may be the most effective approach for the management of areas identified as important for the supply of single or multiple ES of high importance; (ii) regulation for minimum standards are a response option that has more generic applicability; (iii) voluntary schemes may be particularly effective where services are of high local or niche importance; (iv) market-based schemes (such as PES, agri-environment schemes or offsetting) may provide tools promoting innovative approaches to service enhancement in well-defined spatial areas; (v) spatial planning enables coordination across scales; and (vi) improved knowledge exchange is fundamental to develop generic applicability and to enable people to make better-informed choices.

Each sector has historically tended to focus on its own suite of response options but the availability of an integrated ES framework now provides the prospect for increased collaboration. To achieve this also requires a common strategy for co-ordinated interventions to maximise joined-up outcomes. Reference to the response options in the context of the ‘4 Is’ framework (van Vugt, 2009) can identify both barriers and enablers to developing cross-sectoral responses.

as the economy and technology[19]. Communication of ES as benefits, described in accessible and socially resonant terms, is essential to connect with the perspectives and priorities of business, policy, ecosystem management and other diverse sectors of society, and thus tailored communication may of itself represent a key additional response option to promote engagement with the Ecosystem Approach.

Incentives can be a particularly useful lever in encouraging sustainable behaviours and recent innovation in schemes has begun to explicitly address types of ES (e.g. PES, offsetting). However, the analysis in the present study has highlighted the risks of both short-term responses and potential distortion towards some ES which are more easily defined and quantified as metrics. This may be particularly apposite for market-based schemes if they are not complemented by suitable regulation to ensure minimum standards or they result in large-scale transfer of ecosystem services which disbenefits local beneficiaries. The analysis suggested that cultural services may be particularly disadvantaged in this regard. Therefore caution is required to ensure that efficiency gains and additional investment that may be generated through 'trading' of ecosystem services does not occur at the expense of those services that particularly provide local or less tangible benefits.

The institutional setting for sustainable delivery of ES is complex. For example, different institutions may currently be tasked with implementing a subset of statutory regulations or incentives, or using common law solutions. To achieve greater co-ordination will require much greater institutional flexibility and collaboration if the synergies from co-ordinated responses are to be realised. This aspect of cultural challenge is far from insignificant, warranting greater attention and leadership.

With regard to information for change management, knowledge gaps have already been highlighted (notably cultural and supporting ES). However, amongst the key challenges entailed in embedding an Ecosystem Approach is to communicate its core principles and the means for their implementation in terms that are meaningful for different stakeholder groups. A common critique of ES and the Ecosystem Approach is that the language is too technical. Indeed, they do comprise complex concepts for audiences tasked with day-to-day decision-making, the vast majority of whom will not be ecosystems specialists. This complexity is further compounded by inherent uncertainties. Some degree of generalisation is therefore required both to simplify implementation and also to enable decision-making to continue even where evidence may be lacking, contradictory or contested. In practice, this observation about ES is as relevant to many other complex aspects of modern life such

Perhaps the most underutilised of the '4 Is' in the current suite of responses is 'identity' which also utilises the value of peer groups and communities to stimulate action. In each of the future scenarios, these identities will continue to evolve and are likely to be highly influential in determining responses to change. They are particularly strongly linked with notions of cultural services and concepts of 'sense of place' (Church *et al.,* 2011), which our analysis suggests remain at the fringes of knowledge and decision-making.

As the '4 Is' are interdependent, they require an equal emphasis in decision making. A role for government and its agencies in co-ordinating responses is highlighted by the '4 Es', and in particular to create an enabling framework to implement the ecosystem approach by removing institutional

[19] Mander *et al*. (2011) highlight that a successful sales pitch for a car does not focus on technical minutiae, but rather on the services and benefits of the assembled whole relevant to the needs of prospective customers. Relevance of ES to audience needs and perspectives is of central importance, including the diverse needs of decision makers. In theory, the 'sales pitch' for ES is simple, as they define the diverse benefits that the natural world confers upon different groups of people.

barriers and supporting efforts to build capacity to adapt to change (**Figure 8.9**). This may provide a further role for exemplar projects that have used incentives or have engaged with local community identity to enhance service delivery. As robust responses to change require a flexible combination of top-down encouragement and bottom-up actions, then mechanisms for shared information based upon 'learning by doing' seems to be a crucial requirement.

An important issue to address is the role of government with regard to incentive schemes, such as PES. Two contrasting approaches to PES can be recognised (Schomers and Matzdorf, 2013) based either upon market economics (Coasian approach[20]) or the role of government as administrator (Pigouvian approach[21]) and these distinctions can also be distinguished in the UK NEA scenarios. There are important issues to address here in terms of risks to ES and how losses are compensated. The role of independent brokers (or regulators) may provide a third variant of such schemes **(Figure 8.9**), with the broker being responsible for negotiating ongoing service delivery between providers and beneficiaries.

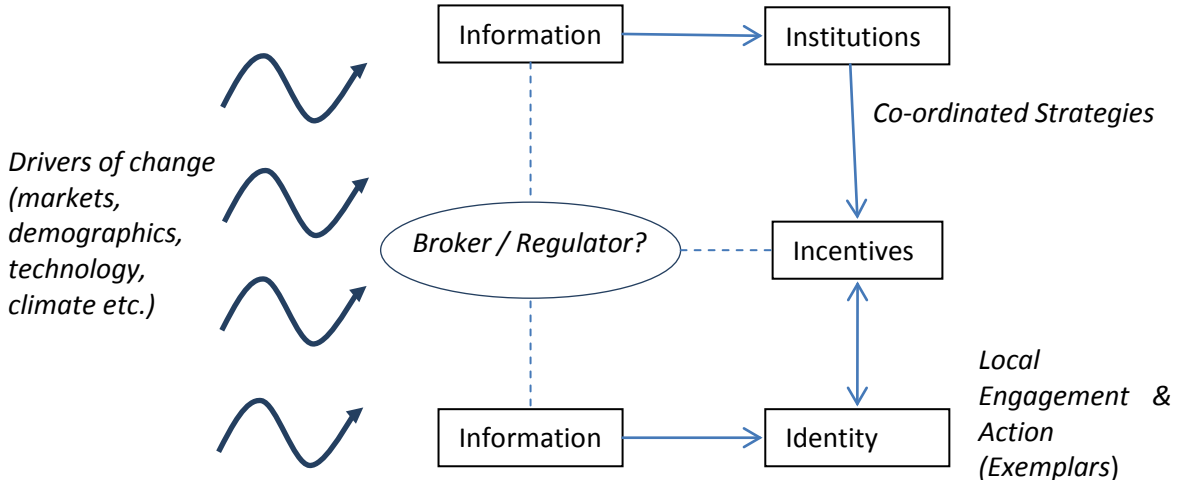


Figure 8.9. A potential enabling framework for co-ordinated interventions, including a possible broker or regulator.

The relative influence of different factors of change between sectors can act as a barrier for cross-sectoral actions. This is particularly exemplified in differing time horizons for decision making between sectors: for example, agriculture operates on shorter-term horizons than does forestry or water resources. Differences are also apparent between land-based sectors and the marine sector on several important topics including: the relevance of property rights in management; relationship between ES and their beneficiaries; information on spatial and temporal variability of ecosystem processes. These differences have historically tended to reinforce sectoral approaches to decision making and therefore act as barriers to co-ordinated strategies.

Climate change adds an extra level of complexity in combination with socio-economic changes. It is important to recognise the relative importance of both types of change on different types of responses, and on different sectoral interests. For example, climate change was recognised as a particularly important driver for the biodiversity and water sectors, whereas for agricultural shorter-

[20] The Coase Theorem argues that, given low transaction costs and clearly defined and enforce-able property rights, no governmental authority is needed to overcome the problem of internalizing external effects.
[21] The Pigouvian approach is based upon a philosophy of taxing negative or subsidizing positive externalities within existing product markets

term socio-economic factors appeared to dominate (although shorter-term climate variability is also a key factor).

8.4.3 Adaptive management

All response options have to function in the face of significant uncertainty. Some of this uncertainty is exposed by stress-testing options against a subset of scenarios, but no scenario is a prediction, rather they are a means to explore the 'possibility space' of potential futures. Further uncertainty is introduced by 'tipping points' in environmental and economic systems, societal attitudes and/or the consequences of extreme event. This implies that taking an adaptive approach to the selection and use of response options will be essential for making a major contribution to managing for future uncertainty. This in turn may require evolution of governance systems determining selection of response options and iterative review cycles of their outcomes. Furthermore, an acceptance of the need for adaptive approaches also challenges some response optimisations that are currently framed around concepts of large-scale 'optimisation' as it is very likely that so-called optimal arrangements will vary both temporally and spatially, and also probably with regard to the priorities of stakeholders and society.

Change is always a difficult and contentious process. Adaptive management requires effective monitoring of outcomes and commitment to social learning, including sufficiently reflexive governance arrangements such that management response is steered by outcome rather than pre-determined execution of a particular chosen set of response options. Furthermore, although some response options are perceived as being more risky due to greater uncertainty, they may remain valid for achieving change when incorporated as part of a locally adapted 'bundle' of response options. This requires additional technical as well as management skills, including devolved empowerment of management and information products to support flexible decision-making incorporating novel approaches within the day-to-day work priorities of multiple organisations. Transition from established to systemic practice can be facilitated by focusing on ES that are already acknowledged as being of high priority, such as protection of water quality or wildlife. It can also draw upon 'success stories' highlighting win-win outcomes or explicit incorporation of the ES framework as a logical, 'value-added' evolution of pre-existing schemes, such as Environmental Stewardship, SEA or SA to emphasise the full range of public benefits being sought as return on public investment.

To conclude, potential robust interventions across sectors that may provide 'low-regret' options are those that are flexible and adaptable, and that help enhance ecosystem resilience to inevitable but uncertain change. These include investment in science and technology that can assist in managing change regardless of its specific pathway. The flexible coupling of economic incentives, that encourage new investment in enhancing ES, with suitable regulation and planning, provides another avenue for innovation. Finally, support for those bottom-up schemes that build social capital and are being successful in managing change can provide important exemplars for similar actions elsewhere.

8.4.4 Recommendations for next steps

In addition to key knowledge gaps identified (notably on cultural and supporting services) and the need for better integration of socio-economic and climate change scenarios, the following recommendations are made:

- Undertake a comprehensive cross-sectoral mapping to show where ES approaches and current planning processes do (and do not) overlap. This could provide be a starting point for making the concepts more tangible in the minds of many practitioners and policy-makers.

- To further develop scenario analysis and stress-testing in an outcome-based framework (i.e. a normative approach) to identify how current and future barriers may be tackled for meeting sustainability objectives. The 2050 Pathways for the low carbon economy represent one possible blueprint for how this may be achieved.
- Further exploration of individual and group core motives with regard to attitudes to change and the influence of different ecosystem services. This should also evaluate the role of property rights, common law and social norms with regard to service delivery across different beneficiaries.
- Place-based case studies that integrate scenario analysis and multi-criteria assessment with other components of the UK NEA toolkit to evaluate their role in specific decision contexts.

8.5 Links to other Work Packages

The response options Work Package is integrally linked to all other strands of the National Ecosystem Assessment Follow-on programme. For example, more detailed valuation of ecosystems and their services under Work Packages 1-4 will support the extent to which these services are internalised into regulatory, common law, market, stakeholder, levies, stimulation of new technologies and most other response options. Equally, stronger appreciation of cultural services (WP5) and of shared and plural values (WP6) will support the 'mainstreaming' of these values into the breadth of response options.

As described above, these response options are linked directly to the scenarios Work Package of the UK NEAFO programme as scenarios from WP7 were used in stress-testing under this Work Package. A robust understanding of institutional cultural and behavioural barriers (WP9) will be important in selecting and further developing response options.

There are particularly strong synergies between consideration of response options within this Work Package and the consideration of tools under the WP10 TABLES programme, which has a particular focus on the spatial planning process. Indeed, many approaches addressed here as response options also constitute tools under the TABLES programme. A logical further piece of work is to further integrate learning under these Work Packages (WP8 and 10), moving from analysis of tools and response options, including their potential development, into practical case study work in specific settings (local authority decision-making, implementation of specific regulations, etc.). Ideally, this would identify means to achieve optimal outcomes across ES, in turn leading to practical guidance attuned to different decision-making situations and needs.

8.6 Acknowledgments

We are grateful for the time and advice from the UK NEA Stakeholder Group and the stakeholders that we interviewed in reviewing our short-list of response options and suggesting key strategic policy issues that could be related to the stress-testing results. The stakeholders interviewed were: Andrew Robinson (Defra), Jonathan Tillson (Defra), Lee Davies (Defra), Dave Waterman (Defra), Sarah Andrews (Defra), Dagma Droogsma (Defra), Paul Bradley (Defra), Dominic Rowland (Defra), Chris de Grouchy (Defra), Arik Dondi (Defra), Geoff Richards (Defra), Panayiota Apostolaki (Defra), David Cooper (Defra), Paul Morling (RSPB), Tony Whitbread (Sussex Wildlife Trust), Ruth Waters (Natural England), Sallie Bailey (Forestry Commission), Nick Blyth (IEMA), Ian Smith (UEA), Barbara Illsley (University of Dundee), Neil McLean (MWH environmental consultants), Robert Crow (ERDF project LoCalNet, The University of Abertay Dundee). We thank the following for their comments on the analysis: Adriana Kiss and colleagues at the Welsh Government; Diane Mitchell of the NFU; Brian Pawson on Natural Resources Wales; Cécile Smith and Maria dela Torre of SNH and Tim Benton, Champion of the UK's Global Food Security programme. We are also grateful to all the stakeholders who attended the workshop to trial the stress-testing methodology in Leeds in January 2013 and to the reviewers of the zero-order draft of the report.

8.7 References

ABPmer & eftec (2012). Business as Usual projections of the marine environment to inform the UK implementation of the Marine Strategy Framework Directive. October, 2012.

Adaptation Sub-Committee (2012). Climate change – is the UK preparing for flooding and water scarcity? Available from: http://www.theccc.org.uk/publication/climate-change-is-the-uk-preparing-for-flooding-and-water-scarcity-3rd-progress-report-2012/ **.**

Adaptation Sub-Committee (2013). Managing the land in a changing climate. Adaptation Sub-Committee Progress Report 2013. Available from: http://www.theccc.org.uk/publication/managing-the-land-in-a-changing-climate/.

Balmford, A., Green, R.E. & Scharlemann, J.P.W. (2005). Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production. *Global Change Biology,* **11(10),** 1594-1605.

BIS (2013). A UK Strategy for Agricultural Technologies. Deparment for Business Innovation and Skills. HM Government, London**.**

Brown, I (2009). Multi-functional assessment of coastal landscapes with climate change. In Green, D.R. (ed) *Coastal and Marine Spatial Technologies*.pp335-346. Springer-Verlag.

Brown, I, Poggio, L, Gimona, A & Castellazzi, M (2011) Climate change, drought risk and land capability for agriculture: implications for land use in Scotland. *Regional Environmental Change,* **11,** 503-518.

Brown, I. *et al.* (2012). UK Climate Change Risk Assessment: Biodiversity and ecosystem services. Sector report.

Burton, R; Kuczera, C & Schwarz, G (2008) Exploring Farmers' Cultural Resistance to Voluntary Agri-environmental Schemes. *Sociologia Ruralis*, **48**, 16-37.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jager, J. & Mitchell, R.B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Science USA*, **100**, 8086–8091.

CBD (2004). Principles of the Ecosystem Approach. 7th Conference of Parties to the UN Convention on Biological Diversity.

Defra (2003). Safeguarding our Seas: A strategy for the conservation and sustainable development of our marine environment.

Defra (2012). Green Food Project conclusions. Defra, London.

Defra (2013) Government Forestry and Woodlands Policy Statement: Incorporating the Government's Response to the Independent Panel on Forestry's Final Report. Defra, London.

Eales, R. *et al.* (2003). Integrated appraisal methods. Environment Agency R&D Technical Report E2-044/TR.

Ecosystem Markets Task Force (2013). Realising nature's value. Final Report.

Everard, M. (2012). Why does 'good ecological status' matter? *Water and Environment Journal*, 26(2), 165-174.

Ewers, R.M., Scharlemann, J.P.W., Balmford, A. & Green, R.E. (2009). Do increases in agricultural yield spare land for nature? *Global Change Biology,* **15,** 1716-1726.

Farrell, A., Van Deveer, S.D. & Jager, J. (2001). Environmental assessments: four under-appreciated elements of design. *Global Environmental Change,* **11**, 311-333.

Firbank, L., Bradbury, R. McCraken, E. & Stoate, C (2011). Enclosed Farmland. In: UK National Ecosystem Assessment Technical Report. UNEP - WCMC, Cambridge, pp. 197-240.

Foresight (2011). The Future of Food and Farming: Challenges and choices for global sustainability. The Government Office for Science, London.

Forestry Commission (2007). Strategy for England's Woods Trees and Forests. Forestry Commission England, Cambridge.

Forestry Commission (2009). Woodlands for Wales: The Welsh Assembly Government's Strategy for Woodlands and Trees. Forestry Commission Wales, Aberystwyth.

Forestry Commission (2011). *The UK Forestry Standard*. Forestry Commission, Edinburgh.

Garnett T, Appleby M C, Balmford A, Bateman I J, Benton T G, Bloomer P, Burlingame B, Dawkins M, Dolan L, Fraser D, Herrero M, Hoffman I, Smith P, Thornton P K, Toulmin C, Vermeulen S J & Godfray H C J (2013). Sustainable Intensification in Agriculture: Premises and Policies. *Science,* **341,** DOI: 10.1126/science.1234485

Gimona, A., Poggio, L., Brown, I. & Castellazzi, M.S. (2012). Woodland networks in a changing climate: threats from land use change. *Biological Conservation,* **149**, 93-102.

Haines-Young, R., Paterson, J., Potschin, M., Wilson, A. & Kass, G. (2011). The UK NEA scenarios: Development of storylines and analysis of outcomes (Chapter 25). UK National Ecosystem Assessment: Technical Report. UNEP-WCMC, Cambridge, pp. 1195-1264.

HM Government (2005). Securing the Future. **The UK Government Sustainable Development Strategy.**

HM Government (2010)**.** 2050 Pathways Analysis

HM Treasury (2011). The Green Book**:** Appraisal and evaluation in central Government.

Hurlimann, A. & March, A. 2012. The role of spatial planning in adapting to climate change. WIREs Climate Change 3 477-488.

Iacob, O., Rowan, J.S., Brown, I. & Ellis, C. (2013). Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. *Hydrological Research* (in press).

IPF (2012) Independent Panel on Forestry (2012) Independent Panel on Forestry: Final report. Defra, London.

James, E. (2001). Assessing the sustainability of minerals development in Devon, UK: evolution of appraisal methods. *Impact Assessment and Project Appraisal,* **19(2),** 153-160.

Lafortezza, R., Davies, C., Sanesi, G. & Konijnendijk, C.C. (2013). Green Infrastructure as a tool to support spatial planning in European urban regions. iForest (early view): e1-e7 [online 2013-03-05] URL: http://www.sisef.it/iforest/contents/?id=ifor0723-006 .

Lawton, J.H. *et al.* (2010) Making space for nature: a review of England's wildlife sites and ecological network. Report to Defra.

Lempert, R.J. & Collins, M.T. (2007). Managing the risk of uncertain threshold responses: Comparison of robust, optimum, and precautionary approaches. *Risk Analysis,* **27,** 1009-1026.

Maltby, E., Ormerod S. *et al.* (2011) Freshwaters – Openwaters, Wetlands and Floodplains. In: Watson, R.T. and Albon, S. (Eds). The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge, pp. 295-360.

Mander, M., Roberts, D. & Diederichs, N. (2011). What car salesmen can teach environmentalists. *Solutions*, **2(6)**, 24-27.

McKenney, B.A. & Kiesecker, J.M. (2010). Policy Development for biodiversity offsets: A review of offset frameworks. *Environmental Management*, **45**, 165-176.

Morecroft, M. & Speakman, L. (2013). Terrestrial biodiversity report climate change impacts report card 2012-13. LWEC.

Murphy, J. *et al.* (2009). UK Climate Projections 2009. Science Report.

Natural England (2009). Green Infrastructure Guidance. Natural England Report NE176.

Nordstrom, K. (2005). Beach nourishment and coastal habitats: research needs to improve compatibility. *Restoration Ecology, **13*****(1),*** 215-222

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science,* **325**, 419-421.

Phalan, B., Onial, M., Balmford, A. & Green, R. (2011). Reconciling food production and biodiversity conservation: Land sharing and land sparing compared*. Science,* **333**, 1289-1291.

Piracha, AL & Marcotullio PJ (2003). UNU/IAS Report Urban Ecosystem Analysis:Identifying Tools and Methods. United Nations University Institute of Advanced Studies (UNU/IAS) 5–53–67 Jingumae, Shibuya–ku, Tokyo, 150–8304, Japan.

POST (2011). Biodiversity offsetting. POST NOTE 369, Houses of Parliament - Parliamentary Office of Science & Technology.

Quine, C.P., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A. & Valatin, G. (2011). Chapter 8 Woodlands. *In: UK National Ecosystem Assessment Technical Report*. UNEP-WCMC, Cambridge.

Quine, C.P., Bailey, S.E. & Watts, K. (2013). Sustainable forest management in a time of ecosystem services frameworks: common ground and consequences. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.12068.

Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, CC. & Snowdon, P.R. eds. (2010). *Combating climate change – a role for UK forests*. The Stationery Office, Edinburgh.

Regulatory Task Force (2011*). Forestry Regulation Task Force (2011) Challenging Assumptions, Changing Perceptions*. Defra, London.

Roe, M. & Mell, I (2012). Negotiating value and priorities: evaluating the demands of green infrastructure development. *Journal of Environmental Planning and Management,* **56**(5), 650-673.

Sarewitz, D. & Pielke, R.A. Jr. (2007). The neglected heart of science policy: Reconciling supply of and demand for science. *Environmental Science & Policy*, **10**, 5-16.

Schomers, S. & Matzdorf, B. (2013). Payments for ecosystem services: A review and comparison of developing and industrialized countries. *Ecosystem Services* (in press)

UK NEA (2011). *United Kingdom National Ecosystem Assessment: Technical Report*. UNEP-WCMC, Cambridge.

UKMMAS (UK Marine Monitoring and Assessment Strategy) (2010). *Charting Progress 2. The state of the UK seas*. TSO, London.

Van Vugt, M. (2009). Averting the Tragedy of the Commons: using social psychological science to protect the environment. *Current Directions in Psychological Science*, **18**, 169-173.

Vira, B., Elliott, L.C., Fortnam, M. & Wilks, S. (2011). Response Options (Chapter 27). *UK National Ecosystem Assessment: Technical Report*. UNEP-WCMC, Cambridge, pp. 1309-1451.

Warren, L.M. (2012). Legislation and Policy: New approaches to nature conservation in the UK. *Environmental Law Review,* **14**(1), 44-52.

Wilby, RL *et al*. (2006). Risks posed by climate change to the delivery of Water Framework Directive objectives in the UK. *Environment International* **32,** 1043–1055

Wilson, E. & Piper, J. (2008). Spatial planning for biodiversity in Europe's changing climate. *European Environment,* **18**(3), 135-151.

Whittingham, M.J. (2011). The future of agri-environment schemes: biodiversity gains and ecosystem service delivery? *Journal of Applied Ecology*, **48**(3), 509-513.

8.8 Appendices

Appendix 8.1: Descriptions of the generic response options

Appendix 8.1 and Table 8.A1 provides a high-level summary of governance arrangements, key requirements, scales and challenges associated with implementation of each of the generic response options.

8.A1.1 Statutory protected / designated areas

These responses define particular geographic areas of high acknowledged importance for a variety of reasons (typically one or a combination of nature conservation, landscape aesthetics, water catchment and/or heritage), generally imposing restrictions on the use of land or sea (either implicitly or explicitly) to meet specific objectives. These measures are primarily underpinned by statutory law, including often under EU Directives and corresponding domestic implementing legislation. A hierarchy of different levels of designated protection may exist: for example, in nature conservation, Natura 2000 areas (EU Directives) and other international obligations (Ramsar, OSPAR, World Heritage Sites) are found at the highest level, followed by national designations (e.g. SSSIs), then local designations (such as Local Wildlife Sites).

8.A1.2 Statutory regulation and quality standards

Interventions in this category are top-down responses that aim to define minimum acceptable standards, underpinned by statutory regulation (including both EU and national legislation). The regulating authority has the power to monitor, ensure compliance and enforce penalties if required. For example, in new developments, planning and permitting approvals are required from the regulator to ensure that relevant standards will be met. Regulation is a particularly important component of environmental protection for water quality and air quality and also (to a lesser extent) for soil quality and landscape amenity value. Ideally, science informs the evidence base adding to the credibility and defensibility of statutory regulations, although the regulations themselves result from political processes. Factors such as natural variability[22] can mean that this underpinning evidence, as well as the specifics of implementation of regulations, may be challenged. The portfolio of regulation comprises a spectrum from instruments with a narrow focus, for example, addressing a particular metric or outcome (such as reaching a target chemical standard), towards more progressive regulations adopting a whole-systems approach (such as the EU Water Framework Directive for which 'good ecological status' is a key requirement). The current regulatory portfolio contains many 'legacy' instruments with a narrower focus, with associated issues of 'siloed' thinking and 'ring-

[22] If the science evidence base is lacking, other influences can dominate as with the failure of the EU to require Maximum Sustainable Yield to directly inform fishery limits under the 2013 Common Fisheries Policy negotiations.

fenced' budgets. The ways in which legacy regulations are interpreted and implemented in the light of emerging knowledge and strategic policy goals can, therefore, represent a significant 'enabling' modification (generally in the form of government guidance) to deliver a joined-up ES agenda (Everard 2010, Everard & McInnes 2013).

8.A1.3 Levies

Levy schemes require licensees to make a financial contribution to a central fund that supports good practice, pays for remedial work and environmental improvements, or acts to mitigate damages. The tax may be recovered either as a proportion of profits or as a fixed levy related to the scale of the activity or development. Levies may also be used to send signals aimed at achieving widespread changes in business behaviour, as for example in the case of the Landfill Tax or Aggregates Levy. They can be designed to be revenue-neutral for the government; for example, revenues can be hypothecated to support specific environmental objectives, such as investment in cleaner technologies (e.g. Clean Development Initiative) or to reward better performers. A disadvantage of these schemes is that transaction costs to ensure transparent implementation may be significant.

8.A1.4 Direct economic incentives

These schemes make direct payments to land managers or marine resource users to modify their management practices for a specific area of land, water or sea; eligibility can be passed to others under the same conditions. Payments are generally defined as compensation for 'income foregone' (to satisfy World Trade Organisation rules) resulting from the proscribed change, and may be arbitrated centrally or subject to local negotiation; in the latter case, this may introduce more local adaptability and flexibility. This category includes forestry grants and direct payments to farmers in the EU CAP (subject to cross-compliance requirements), together with voluntary agri-environment schemes, or those which aim to compensate by taking land out of production (set-aside type schemes).

Payment for Ecosystem Services (PES) is an emerging and increasingly common approach that develops voluntary markets to incentivise measures to enhance ES based upon the value of those assets to defined beneficiaries, rather than depending upon income foregone. PES is paid directly by the beneficiary of the ES, although most often through some form of intermediary 'broker' linking the supplier to the beneficiary. Schemes can be either directly related to the delivery of specific ES outcomes, or to measures which are agreed to be likely to protect or enhance service delivery (e.g. wetland restoration to enhance flood alleviation, sequester carbon, support biodiversity, etc.). PES may relate to single or multiple services, with 'buyers' either combining their payments for multi-benefit outcomes, operating parallel markets for desired services, or where a dominant market produces co-benefits that are not paid for (as in the case of a water company investing in catchment-based water management from which non-excludable fishery, biodiversity and aesthetic co-benefits are provided 'for free'). PES are regulated by agreements which may vary typically from short-term commitments to multi-decade convenants.

8.A1.5 Market-based schemes

A diversity of market-based instruments currently exist. (PES is a form of market-based instrument, but is considered above in the context of economic incentives, reflecting their role in creating markets where none may have existed previously for the desired services.) At the simplest level, these include long-established markets for food, energy and water-based services. These schemes differ from direct economic incentives in that the environmental benefits are defined as tradable goods justifying that changes in one location can be compensated for, or used to, subsidise changes in different locations. The rationale is that the use of markets as a 'regulator' is more efficient than if this role is provided by government or another third party, particularly as it can be a spur for innovation rather than mere compliance. A good example of this is tradable emissions permits such as carbon trading, which create an incentive for businesses to reduce emissions and profit from the sale of permits. Some authorities advocate an increasing role for markets in biodiversity and ES offsetting schemes (Ecosystem Markets Task Force, 2013) which aim to compensate for unavoidable adverse development impacts based upon a rationale of "no net loss and preferably a net gain of biodiversity with respect to species composition, habitat structure and ecosystem services" (Defra, 2011). There are risks involved because processes of ecological restoration or carbon sequestration inevitably include elements of outcome uncertainty which are not factored into the market price. This uncertainty is likely to be further exacerbated by climate change, suggesting that market-based schemes may need to be supported by regulation or insurance.

8.A1.6 Spatial and integrated planning

Spatial planning aims to integrate land use and development policy with other policies to positively influence places and how they function. This coordination role can facilitate synergies between different sectoral plans whilst facilitating consistent cross-scale translation of national frameworks into regional and local planning structures. Spatial planning is also intended to have a visionary role in shaping places and landscapes, including public participation, and it therefore has the potential to be flexible, dynamic and forward looking, although this flexibility may be difficult to implement within current systems. Other examples of integrated approaches include river basin management planning (based upon catchments), shoreline management plans (based upon littoral cells) and marine planning. Recent developments include the integration of green and blue infrastructure to maximise the use of space in urban or peri-urban areas, and the formation of multi-functional spaces including sustainable transport, recreation and quiet areas. Spatial planning may therefore be used to design and manage target zones for the supply of multiple ES outcomes which, by harnessing natural processes, may also be low-input solutions that maximise public value across services (defined as 'systemic solutions' by Everard & McInnes 2013).

8.A1.7 Good management practices

Evolving best practice in the management of ecosystems is encouraged by 'best management practice' response options. These can inform or encourage more sustainable practices or multi-functional uses. Published best practice standards can also discourage practices known to be damaging when forming qualifying criteria for subsidies (as in the case of cross-compliance for agricultural land use) or as a basis for supporting enforcement actions (as in the case of justifying

pollution control enforcement in Codes of Good Agricultural Practice). In these two examples, as in other cases, best management practices may reinforce other response types (e.g. economic incentives, knowledge exchange, seeking compliance with regulation). Management objectives may also require co-operation between land managers (e.g. at the catchment level) or marine resource users. Management systems that increase efficiency and reduce waste (e.g. by recycling) may be particularly beneficial. There is also a significant need to maintain flexibility to adapt to changing conditions (e.g. natural ecosystem variability and climate change), in conjunction with evolving knowledge. This may include 'softer' schemes as an alternative to hard engineered schemes, including natural flood management and sustainable urban drainage systems; these include ecosystem-based management schemes with the potential to optimise outcomes and net benefit across a range of services, rather than maximising a single focal service with associated externalities for other ES and their associated beneficiaries.

8.A1.8 Voluntary standards and quality assurance

Voluntary standards provide an alternative (or complement) to statutory approaches through schemes that emphasise the use of a certificated brand or marque to provide quality assurance to customers. Businesses subscribe to a general set of published quality assurance standards that are enforced by an audit of practice and funded by participating businesses, or which are self-certifying. In return, they receive the value-added benefits of being associated with a brand that has built a strong reputation and consumer trust. Schemes, such as Red Tractor, also often aim to ensure quality through the supply chain, which is seen as increasingly important as globalisation expands these chains. In some cases, consumers will pay a premium for such branded products because of their quality assurance and businesses may gain a competitive advantage. A further use of voluntary standards, where transparently reported, is for self-certification of compliance with regulatory obligations, a cost-effective approach favoured by the US Environment Protection Agency that is finding favour elsewhere.

8.A1.9 Social and cultural networks, partnerships and community schemes

These are usually bottom-up volunteer-based initiatives (e.g. communities, trusts or co-operatives) stimulated to take action by a local or wider awareness of the value of the environment. If the issue or area is of high profile, the outreach of the network can be national (as in the RSPB) or international (such as India's 'Save Ganga Movement'). Conversely, a local community woodland, urban garden area or local nature reserve may be maintained by a few dedicated individuals. Some networks and partnerships, such as the UK Rivers Trust, coastal partnerships or biodiversity partnerships, have a role in connecting diverse stakeholder groups around a common interest which can harness a range of other response options (grants, subsidies, legislation, good management practices, etc.) to achieve strategic goals. There may also be some form of reward from association with a local or other 'brand' (e.g. 'Produce of the New Forest') which also links with quality assurance schemes (A1.8).

8.A1.10 Education and knowledge exchange

Knowledge exchange activities between key actors, such as land managers, regulatory agencies and planners, are increasingly associated with actions to positively change attitudes and behaviours. A wide variety of media and fora have been developed to facilitate this, including awareness-raising campaigns, good practice guidance and practitioner workshops. There is also an important link with education at multiple levels. The role of 'citizen' science initiatives to stimulate and develop knowledge exchange, particularly at a local level, is a specific example of these initiatives.

8.A1.11 Technological innovation

Technological developments can lead to rapid advances in the efficient use and management of natural resources, but can also cause significant negative impacts when used without awareness of environmental limits or when outcomes are not assessed in terms of the full suite of ES. Rapidly-advancing technologies include the use of biotechnology (e.g. GMOs), nanotechnology, satellite-based remote sensing and automated monitoring. These developments can be further incentivised by increased investment in technology and by government or businesses providing enabling infrastructure (e.g. broadband and other ICT initiatives). However, uptake of technology may also require investment in associated knowledge schemes, such as education and skills. A notable development is the Smart Cities Agenda, which aims to harness a range of technologies to deliver a low carbon future and reduction in exposure to natural hazards through efficient use of water and energy resources, whilst also maximising synergies through spatial planning.

8.A1.12 Scientific research & development

Investment in science can develop the knowledge base from which improved management of resources can occur, including regulatory limits. It also provides the foundation for improving knowledge of ecosystem functioning and services. Increasingly, this requires interdisciplinary collaboration within and between the natural sciences, economics and social sciences. Funding mechanisms may be an enabler of scientific enquiry into priority areas. Scientific research outputs also need to be integrated with other types of response options to facilitate the effective communication and subsequent use of evolving knowledge in delivering policy and management goals.

8.A1.13 Common Law

Common law, also known as case law or precedent, constitutes an incrementally evolving body of case law formed by judicial decisions relating to rights, by contrast to the statutory and regulatory procedures established by the legislative and parliamentary process. Hence, common law can evolve rapidly in accord with evolving knowledge and public expectations in order to put in place injunctions or recover damages from activities that damage individual property, rights or the common good. An important link therefore exists with the many public goods produced by ES (particularly sporting rights and cultural benefits, as well as the enjoyment of water and other environmental media of undiminished quality), and protection of these *rights* of access to these services against infringement by others. Common law has thereby been evolving for a wide variety

of ES where these constitute 'property' to which a quantum of damage can be quantified, though expression of common law in explicit terms of ES is in an early stage of evolution as indeed are legal remedies to address damage to commonly-held interests. There are complex interactions between common law and statutory law, the former often informing development of the latter. Nevertheless, the principle of *stare decisis* states that similar cases should be decided according to consistent principled rules so that they will reach similar results.

Table 8.A1. Key requirements, scales and challenges associated with the categories of generic response options.

Protected / designated areas (enabling):	
Actors/governance	Lead responsibility with government agency. Local land managers have to comply with restrictions.
Key requirements	• Knowledge to define appropriate areas. • Funding for monitoring and, if necessary, enforcement of restrictions.
Scale	From a few m^2 to 10-100km^2.
Key challenges	Although the network of protected areas should in principle be dynamic (e.g. as defined by the EU Habitats Directive), in practice it is sometimes seen as over-rigid and unable to adapt to change due to the inflexibility of the planning system. This has been identified as a particular challenge for nature conservation by the Lawton Review (Lawton *et al.* 2010) due to the effects of climate change on the movement of species and habitats.
Examples	Natura2000, Sites of Special Scientific Interest, Nitrate Vulnerable Zones, Marine Conservation Zones.
Statutory regulation (enabling):	
Actors/governance	Statutory regulator has lead responsibility. All have to comply.
Key requirements	• Knowledge to define regulatory limits. • Funding for surveillance, monitoring and enforcement.
Scale	National level
Key challenges	Regulation can be expensive and requires active inspection, either on the ground or increasingly by technology (e.g. remote sensing). It is sometimes criticised because once penalties have been enforced the damage to the environment has already occurred and in extreme cases may be irreparable. However, regulation also gives businesses confidence to invest, and establishes a 'level playing field' that allows sector leaders to compete on a more even basis with less progressive players. Defining minimum standards requires good scientific data and at a time of major change these standards may require regular updating to ensure ecosystem resilience.
Examples	Food Safety & Hygiene, Drinking Water, Bathing Water, Fisheries Quotas, Air Quality Standards, Environmental Impact Assessment/Strategic Environmental Assessment.
Levies (enabling):	
Actors/governance	A levy authority has responsibility, with a board to administer funding.
Key requirements	Setting an appropriate levy rate, establishing a market-based brokerage for hypothecated levies.
Scale	National to local level.
Key challenges	Taxes can be unpopular and subject to avoidance. Environmental improvements may not necessarily compensate for the original loss of function and service. Levies must also be set at a level that provides a sufficiently

	significant incentive to induce behaviour change.
Examples	Aggregate Levy Fund, Landfill Tax, Climate Change (Fossil Fuel) Levy, Dairy Co (dairy farming levy board).
Direct payments and incentives (enabling):	
Actors/governance	Payments are either (a) controlled by a government agency who is responsible for monitoring compliance with the schemes and removing payments as penalties or (b) in payments for ecosystem service schemes based upon direct transactions between service provider and beneficiary.
Key requirements	Establishing compliance with the scheme requirements can be difficult, though is easier if based on measures required to deliver an outcomes rather than tied to the outcome itself. The rules to administer the scheme need to be simple enough to allow cost-effective monitoring. Drafting of flexible yet binding contracts are required to formalise financial agreements.
Scale	Local level through to global level .
Key challenges	Defining rules that meet good practice for environmental objectives, but are simple enough to administer (e.g. standards for Good Agricultural and Environmental Condition (GAEC)), especially with external changes. Payments for Ecosystem Services schemes based on target service outcomes may be compromised by confounding factors, such as weather patterns, affecting service delivery.
Examples	Agri-environment schemes, woodland grants, catchment-scale payment for ecosystem service water quality schemes.
Market-based schemes (enabling):	
Actors/governance	Market-based but within a legal framework. Often includes a broker as intermediary.
Key requirements	Metrics to define tradable units.
Scale	Usually small-scale changes, but may be spatially separated over larger spatial scales. Multiple time periods.
Key challenges	Defining appropriate metrics for trading and offsetting that include spatial and temporal variations in the natural environment, including the time taken to restore habitats and the uncertainties involved. The uncertainties involved suggest insurance may be necessary (e.g. as habitat banking or financial bonds).
Examples	Carbon trading, offsetting schemes, 'ecosystem markets'.
Spatial and integrated planning (enabling):	
Actors/governance	Planning authorities working in collaboration with regulators and developers to optimise ecosystem service provision across their collective fields of interest.
Key requirements	Co-ordination activities. Availability of spatially explicit knowledge. Flexibility of regulatory and budgetary application to maximise across ecosystem services, including those beyond the narrow remits of participant organisations.
Scale	Cross-scale.
Key challenges	Incorporating flexibility and adaptability to change.
Examples	Green infrastructure, River Basin Management Plans, Integrated Coastal Zone Management, marine spatial planning, shoreline management plans.

Good management practice (instrumental):	
Actors/governance	Management decisions are made at the local level by managers based upon their local knowledge, networks, etc. Some management decisions require landscape-scale co-operation.
Key requirements	Identifying, encouraging and disseminating good practice. Practitioner networks can be very important.
Scale	Local level, but may require landscape-scale co-ordination.
Key challenges	Integrating local with scientific knowledge. Overcoming existing barriers. Landscape-scale co-operation may be difficult even with suitable incentives.
Examples	Integrated farm management, flexible cropping systems (e.g. cover crops, intercropping, rotations), low tillage systems, coppicing, natural flood management, beach nourishment, habitat management, buffer zones.
Voluntary standards & quality assurance (enabling / instrumental):	
Actors/governance	A governing authority with members and board of directors; independent from government and often not-for-profit (may be also an international NGO). In some cases, certification may be by a third party (e.g. Marine Stewardship Council).
Key requirements	Needs a meaningful set of standards of practice. Requires an active audit system and a critical mass of committed members.
Scale	At all levels (some schemes are a global standard, others national or local).
Key challenges	Needs to be recognised by consumers for added value. Reputation takes some time to establish, but can be eroded very quickly. Requires reliable and trusted independent auditors. Complex supply chains may be difficult to fully monitor.
Examples	Forest Stewardship Council, The Assured Foods Standards' Red Tractor scheme, Marine Stewardship Council, Organic food, VinylPlus.
Networks, partnerships and community schemes (enabling /instrumental):	
Actors/governance	Local level, both formal (e.g. trusts) and informal. National/international networks, formal and informal.
Key requirements	Often depend on key individuals to stimulate action because of their voluntary basis.
Scale	Local to national/international level.
Key challenges	Integrating local with scientific knowledge. Overcoming existing barriers. Landscape-scale co-operation may be difficult even with suitable incentives.
Examples	Coastal partnerships, catchment partnerships, community woodlands, Local Biodiversity Action Plan partnerships, local food markets, co-operatives, Rivers Trusts, national / international NGOs.
Education and knowledge exchange (foundational):	
Actors/governance	Varied - Government, NGOs, local authorities, universities and research institutes; professional bodies, etc.
Key requirements	Requires ongoing funding and/or committed individuals to establish a long-term legacy from knowledge exchange activities.
Scale	National to local.
Key challenges	Communicating complex messages, such as on environmental change and climate change; ensuring that knowledge exchange is linked to practical actions.

Examples	Campaigns, good practice guidance, professional development, demonstration projects, citizen science, eco-schools (e.g. forest schools), environmental footprinting, LEAF (Linking Environment and Farming) farms.
Technological innovation (foundational):	
Actors/governance	Business and markets (venture capital); Universities; Government incentives.
Key requirements	Investment in new technology and associated infrastructure.
Scale	Multiple scales.
Key challenges	Investment may not necessarily produce large technological advances. Uptake may be limited by access to capital, skills or cultural barriers (e.g. GM crops).
Examples	Precision farming, renewable energy, water treatment, irrigation systems, crop & livestock breeding, recycling and waste reduction, demountable flood defences, blue-green algae.
Scientific research and development (foundational):	
Actors/governance	Universities and research institutes; Government; Industry.
Key requirements	Funding; skills; capacity; infrastructure; interdisciplinary cooperation.
Scale	Multiple scales.
Key challenges	Scientific knowledge of some key topics remains limited, particularly in understanding the full implications of present and future change. 'No regrets' decision-making processes are also required to make use of imperfect knowledge or to address knowledge gaps.
Examples	Better understanding of the links between biodiversity, ecosystem function and ecosystem services, and also the interactions between different ecosystem services (such as the balance of food, biodiversity, water).
Common law (enabling):	
Actors/governance	Judiciary.
Key requirements	Established precedents.
Scale	Multiple scales.
Key challenges	Current systems of property rights and land tenure.
Examples	Scallop fishery in Lyme Bay (see Everard & Appleby, 2008).

References

Everard, M. (2011). Why does 'good ecological status' matter? Water and Environment Journal, 26(2): 165-174. DOI:10.1111/j.1747-6593.2011.00273.x.

Everard, M. and McInnes, R.J. (2013). Systemic solutions for multi-benefit water and environmental management. The Science of the Total Environment, 461-62: 170-179.

Appendix 8.2: Long-lists of response options for the six policy sectors

Note that the response options which were short-listed are highlighted in red within the Appendix.

8.A2.1 Response options for the agricultural sector (long-list).

Options in red are included in the agriculture short-list used for stress-testing (underlined words give the short title of the option); options in blue are covered in the short-lists of other sectors.

Response Option	Type (based on UK NEA 2011; Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Awareness raising, campaigns and advice on healthy and sustainable diets and food waste	Enabling - Changing social attitudes	Established responses	National	Ongoing	Industry, private individuals	Food production, pollution control
Collaboration between researchers, industry and the farming community	Enabling - Changing social attitudes	Early implementation plans	Catchment / landscape to national	Ongoing	Research, Industry	Food production, regulatory services
Food certification and labelling to encourage healthy diets	Enabling - Changing social attitudes	Established responses	National and global	Ongoing	Industry	Food production
Raising public awareness of risks and benefits to health & environment	Enabling - Changing social attitudes	Early implementation plans	Local to national	10 years	Research, policy, industry, media, private individuals	All
Climate Change Act	Enabling - Legislation	Established responses	Farm scale and above	Ongoing	Policy	Climate regulation
Nitrates, Birds, Habitats and related Directives	Enabling - Legislation	Established responses	Farm scale and above	Ongoing	Policy	Pollution control
Water Framework Directive	Enabling - Legislation	Established responses	Catchment / landscape	Ongoing	Policy	Pollution control

Response Option	Type (based on UK NEA 2011; Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Agri-environment schemes (AES)	Enabling - Policies, institutions and governance	Established responses	European	Ongoing	Policy	All
Agri-environment schemes (AES) applied at multiple spatial and temporal scales	Enabling - Policies, institutions and governance	Proposed, under development	Farm scale and above	5 years	Policy, Research	All
Compulsory set-aside	Enabling - Policies, institutions and governance	Established responses	European	5 years	Policy	Regulating services
Cross compliance under CAP	Enabling - Policies, institutions and governance	Established responses	Farm scale and above	Ongoing	Policy	Food production, landscape, pollution control
Governance of delivery of ES (including valuation)	Enabling - Policies, institutions and governance	Proposed, under development	National	10 years	Policy, Research	All
High Nature Value farming concept	Enabling - Policies, institutions and governance	Proposed, under development	Farm scale and above	Ongoing	Policy	Landscape
Integrated Catchment Management	Enabling - Policies, institutions and governance	Established responses	Field - catchment	Ongoing	Research, policy, industry	Pollution control
Integrated map-based targeting of ecosystem services delivery by AES	Enabling - Policies, institutions and governance	Proposed, under development	Field scale and above	10 years	Research, policy, industry	Regulating, provisioning services
Land planning guidance	Enabling - Policies, institutions and governance	Established responses	Farm scale and above	Ongoing	Policy	Landscape
Land use strategies to optimise delivery of ES	Enabling - Policies, institutions and governance	Proposed, under development	National	5 years	Policy, Research	All

Response Option	Type (based on UK NEA 2011; Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
UK Food and Agri-Tech Strategies	Enabling - Policies, institutions and governance	Early implementation plans	National	Ongoing	Policy, Industry, Research	Food production
Agricultural census and farm business surveys	Foundational - Knowledge	Established responses	National	Ongoing	Policy	Food production
Balancing land sharing and land sparing	Foundational - Knowledge	Proposed, under development	Global	10 years	Research	Food production, landscape
Interactions among ecosystem services at multiple scales	Foundational - Knowledge	Proposed, under development	National	10 years	Research	Food production, regulating services, landscape
Landscapes that enhance biodiversity during climate change	Foundational - Knowledge	Proposed, under development	Catchment / landscape	10 years	Research, Policy	Supporting, regulating, cultural
Long-term monitoring of ES over multiple scales	Foundational - Knowledge	Proposed, under development	National	10 years	Research, Policy	All
Methods for mitigation and management of diffuse pollution and GHG emissions	Foundational - Knowledge	Early implementation plans	Catchment / landscape	5 years	Research, Industry, Policy	Pollution control
Research into climate change adaptations for agriculture	Foundational - Knowledge	Early implementation plans	European	Ongoing	Research, Industry, Policy	Food production, Regulating services
Research into spatial optimisation of agricultural land use	Foundational - Knowledge	Proposed, under development	Catchment / landscape	15 years	Research	All
Agricultural networks, associations and initiatives	Instrumental – Voluntary actions	Established responses	Farm scale and above	Ongoing	Industry	Food production, pollution control

Response Option	Type (based on UK NEA 2011; Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Industry engagement with ecosystem services, e.g. through Green Food project	Instrumental – Voluntary actions	Early implementation plans	National	Ongoing	Industry	All
AES adjusted to reward ES delivery and fit rural priorities	Instrumental - Markets and incentives	Proposed, under development	National / European	10 years	Policy , Research	All
Food production from semi-natural habitats	Instrumental - Markets and incentives	Established responses	Farm scale and above	Ongoing	Research, Industry	Food production
On-farm tourism & leisure	Instrumental - Markets and incentives	Established responses	Farm scale and above	Ongoing	Industry	Cultural services
Payments for Ecosystem Services	Instrumental - Markets and incentives	Proposed, under development	Farm scale and above	15 years	Policy, research, industry	All
Prices of land, inputs and commodities	Instrumental - Markets and incentives	Established responses	Farm scale and above	Ongoing	Industry	All
Purchase of land by ES suppliers, e.g. water companies	Instrumental - Markets and incentives	Established responses	Farm scale and above	Ongoing	Industry	Provisioning services
Removal of production-based incentives	Instrumental - Markets and incentives	Established responses	European	10 years	Policy	
Valuing natural capital	Instrumental - Markets and incentives	Proposed, under development	National	10 years	Policy , Research	Regulating services
Voluntary quality assurance schemes (Red Tractor, Organic etc)	Instrumental - Markets and incentives	Established responses	Farm scale and above	Ongoing	Industry	Food production
Company 'sustainability' schemes and labels	Instrumental - Markets and Incentives; Enabling - Changing social attitudes	Early implementation plans	National and global	Ongoing	Industry	Food production, Pollution control

Response Option	Type (based on UK NEA 2011; Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Farmers and internet markets	Instrumental - Markets and Incentives; Enabling - Changing social attitudes	Established responses	Farm scale and above	Ongoing	Industry	Food production, cultural services
Anaerobic digestion	Instrumental - Technologies and practice	Established responses	Farm scale and above	Ongoing	Policy, industry	Climate regulation, energy production, pollution control
Animal feeds for increased efficiency of production	Instrumental - Technologies and practice	Established responses	Field scale and above	Ongoing	Research, industry	Food production, pollution control, climate regulation
Ecosystem and environmental monitoring	Instrumental - Technologies and practice	Established responses	National	Ongoing	Policy, Research	All
Genomics in support of enhanced productivity	Instrumental - Technologies and practice	Proposed, under development	Global	Ongoing	Research	Food production
High frequency and resolution agro-environmental sensing	Instrumental - Technologies and practice	Early implementation plans	Point scale and above	10 years	Research	Food production, pollution control
Improved housed food production (livestock, horticulture)	Instrumental - Technologies and practice	Early implementation plans	Farm scale and above	Ongoing	Research, industry	Food production, climate regulation, pollution control
Improved management of soil biology and function for large-scale farming	Instrumental - Technologies and practice	Proposed, under development	Field scale and above	10 years	Research, policy, industry	Food production, regulating services
Indicators of sustainable intensification	Instrumental - Technologies and practice	Early implementation plans	Farm scale and above	5 years	Industry, Policy, Research	Food production, pollution control, regulatory services

Response Option	Type (based on UK NEA 2011; Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Integrated Farm Management / Energy and resource-efficient farming	Instrumental - Technologies and practice	Established responses	Field scale and above	Ongoing	Industry	Food production, climate regulation, pollution control
Intensification of food / biomass production	Instrumental - Technologies and practice	Established responses	Field scale and above	Ongoing	Research, policy, industry	Food and energy production
Investment in resilient, low input breeds and crop varieties	Instrumental - Technologies and practice	Early implementation plans	Global	15 years	Research, Industry	Food production
Joint delivery of food and other ecosystem services	Instrumental - Technologies and practice	Proposed, under development	Catchment / landscape	10 years	Research, policy, industry	All
Land sparing from agriculture	Instrumental - Technologies and practice	Early implementation plans	Catchment / landscape	Ongoing	Research, NGOs	Regulatory and cultural services
Precision application and utilisation of inputs (nutrients, feeds, energy)	Instrumental - Technologies and practice	Established responses	Point scale and above	Ongoing	Research, industry, policy	Food production, pollution control
Urban food production	Instrumental - Technologies and practice	Early implementation plans	Building /street / town	15 years	Citizen groups, planners, architects, policy and research	Food production, social capital

8.A2.2 Response options for the forestry sector (long-list)

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Underpinning sciences on ecosystem services and human well-being	Foundational – Knowledge generating	Early stages e.g. LWEC Tree Health, BESS late call for woodland inclusion (though established in some disciplines e.g. Climate change mitigation)	National - international	Long-term	Research organisations, research funders (domestic and international)	Many
Applied research	Foundational – Knowledge generating	Established but limited (compared to e.g. agriculture)	National	Ongoing	Forestry Commission (Science and Innovation Strategy), research funders, research organisations	Many
Knowledge exchange (information sources)	Foundational – Knowledge sharing	Established	Regional to National	Ongoing	Forestry Commission and Forest Research (e.g. FC and FR publications, websites, seminars), NGOs, land managers	Many
Knowledge exchange (advisory services and visits)	Foundational – Knowledge sharing	Established	Local to regional	Ongoing	Forestry Commission woodland officers, advisers of other agencies and NGOs	Context-specific
Knowledge exchange (societies and professional networks)	Foundational – Knowledge sharing	Established	Local to national	Ongoing	Forestry Societies (RFS, RSFS), Institute of Chartered Foresters (ICF), and other membership bodies, woodland owners groups and charities.	Organisation - specific

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Knowledge exchange (international networks) e.g. International Union of Forest Research Organisations (IUFRO) and Global Partnership for Forest Landscape Restoration (GPFLR)	Foundational – Knowledge sharing	Established	International to national	Ongoing	Scientists and practitioners	Wide-ranging
Legislation – direct (e.g. Forestry Act 1967, Wildlife and Countryside Act) and indirect (e.g. Renewables Obligation Orders)	Enabling – Legal framework	Established	National, UK and European	Ongoing (some long established)	Government at national and UK levels (and implementation of European directives, etc)	Provisioning and regulating (as well as biodiversity)
Legal protection (e.g. Tree preservation orders)	Enabling – Legal framework	Established	Local (in implementation)	Long-term	Local authorities	Focus on cultural though with other services accruing
Policy statements (e.g. national forest policies/strategies, specific e.g. biomass, woodfuel, ancient woodland)	Enabling – Policy framework	Established /under development (e.g. England where previous Govt's policy has not been adopted and response to Independent Forest Panel is being formulated)	National	Typically last <10 years	National bodies	Wide-ranging

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
UK Forestry Standard (a reference standard for sustainable forest management including legal and best practice requirements) and detailed guidance	Enabling – Instrumental framework	Established	UK	First edition produced in 1998	National and UK bodies (with wide consultation)	Wide-ranging; specific guidelines published for Biodiversity, Climate Change, Historic Environment, Landscape, People, Soil, Water. See http://www.forestry.gov.uk/forestry/INFD–8BVECX
Forest design plans and coupe plans (an established framework for incorporating multiple objectives into management of woodlands and forests)	Enabling – Instrumental framework	Established	Local (in implementation)	Ongoing	Forest managers (and consultation with stakeholders)	Wide-ranging
Wardens and rangers (through patrols, guided visits, educational activities incl. Forest School)	Enabling – influencing social behaviours	Established	Local	Ongoing	Employees of national (e.g. Forestry Commission) and local bodies (e.g. Local authorities)	Wide-ranging

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Community woodland groups and community forests	Enabling – influencing social behaviours	Established	Local	Ongoing	Voluntary bodies (sometimes with support from national (e.g. Forestry Commission) and local bodies (e.g. Local authorities)	Wide-ranging
Voluntary markets - Woodland Carbon Code; voluntary carbon markets	Instrumental – changing markets	Early stages	National - local	Long-term	Code established by Government body after broad consultation. For implementation by Forest managers and those interested in investing in the carbon market	Focussed on regulating
Favourable tax regimes	Instrumental – incentives	Established (though some elements removed in 1988 as a result of concerns over incentivisation of inappropriate afforestation)	National	Long-term	UK Government	Not specific
Grant aid with specific theme targeting e.g. England Woodland Grant Scheme - for planting, replanting, species diversification e.g. broadleaves, public access, nature conservation meas, management plans	Instrumental – incentives	Established (though interest in innovative methods of encouraging new behaviours)	National - regional	Ongoing (though subject to change in emphasis due to shifts in policy)	National governments and their delivery bodies	Wide-ranging (though historically focussed on provisioning and biodiversity; also recreation)

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Grant aid with specific spatial targeting e.g. Highland Woodland Locational Premium Scheme and JIGSAW – premiums paid to encourage woodland creation adjacent to existing woodland thereby reducing habitat fragmentation. e.g. WIAT – grants for woodland creation adjacent to population centres	Instrumental – incentives	Established (though interest in innovative methods of encouraging new behaviours)	Regional	Ongoing (though subject to change in emphasis due to shifts in policy)	National governments and their delivery bodies	Wide-ranging (though historically focussed on provisioning and biodiversity; also recreation)
Grant aid to achieve specific aims of NGOs (e.g. MOREWOODS of Woodland Trust)	Instrumental – incentives	Early trials	National - local	Long-term	NGOs	Context-specific
Technological development and innovation (e.g. mechanisation, reduction in chemicals, tree-breeding)	Instrumental – technologies and practices	Established/under development	National - local	Long-term	Research and development bodies, industries, co-operatives	Context-specific

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Collaborative management groups (e.g. Deer Initiative; squirrel control groups)	Instrumental – technologies and practices	Established/under development	National - local	Long-term?	Specific bodies funded through government support and voluntary contributions	Preventing damage to broad range of services
Certification e.g. UK Woodland Assurance Standard (UKWAS), Programme for the Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC)	Instrumental – certification	Established	International - National - local	Long-term	Certification bodies and forest managers	Wide-ranging
Specific campaigns (e.g. Big Tree plant campaign)	Instrumental – Voluntary actions	Sporadic	National - local	Time-bound	Partnerships involving NGOs and government support	Context-specific
Land owning by Conservation NGOs (via membership)	Instrumental – Voluntary actions	Established	Local	Long-term?	NGOs (e.g. Woodland Trust, RSPB, Carrifran Wildwoods)	Context-specific
Land owning by state on behalf of public (via public forest estate) and associated provision of e.g. recreational facilities, and demonstration of best practice	Instrumental – Direct actions	Established	National - local	Long-term?	Government agencies	Context-specific

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Repositioning of public forest estate e.g. reinvestment following sale of FC woodlands in Scotland into new woodlands close to urban areas	Instrumental – ?Direct actions	Established	National - local	Long-term?	Government agencies	Context-specific

8.A2.3 Response options for the biodiversity sector (long-list)

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Knowledge exchange (e.g. FWAG, Campaign for Farmed Environment)	Foundational - Knowledge	Established	Regional to National	Ongoing	NGOs, land managers	Context-specific
Improved ecosystem science (biodiversity, soils, ecosystem functioning), e.g. NEA1	Foundational - Knowledge	Early stages	Translation across scale is a key issues	Long-term	Research organisations, research funders	Potentially all (but biases towards some)
Protected site network	Enabling - Legislation (EU and national)	Established (flexibility to modify but may be difficulties with planning system)	Local-National International	Long-term	Statutory agencies. Land managers	Context-specific
Protected species and habitats /species conservation via BAP	Enabling - Legislation (International agreements + national targets)	Established (but often limited data outside protected areas)	Local-National International	10+ years	BAP partnerships, LBAP partnerships (e.g. local authorities), land managers Local Nature Partnerships http://www.defra.gov.uk/environment/natural/whitepaper/local-nature-partnerships/ Many conservation NGOs	Context-specific

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
					also contribute to the response	
Access to the countryside	Enabling - Legislation (supported by policies e.g. Countryside Recreation Network, Tourism Alliance , The Countryside Access and Activities Network in Northern Ireland	Established	Local	Long-term	Statutory agencies, land managers	Cultural
Green accounting (natural capital assets)	Enabling - Institutions & Policy (International agreements [Aichi] and national policy)	Early stages (e.g. National Capital Initiative)	National	Annual?	Government, business	All
Biodiversity offsetting	Enabling - Institutions & Policy, Markets / regulation	Early stages (testing local-pilots)	Local	10+ years	Developers/ statutory agencies Local planning authorities, land owners, businesses and the public	Context-specific
Ecological networks and landscape-scale initiatives for enhanced connectivity [NB linked to protected sites]	Enabling - Institutions & Policy (e.g. Scotland – national ecological network in Land Use Strategy; England -White Paper Making Space for Nature))	Proposed	National (possibly international e.g. Ireland)	Long-term	Government, statutory agencies, NGOS Local nature Partnerships	Context-specific

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Agri-environment schemes – incentive based (e.g. RDP, HLS; HNV farming; Payments for ecosystem services)	Enabling - Institutions & Policy (via CAP) and incentives	Established / early stages	Local (often not co-ordinated at higher level)	5 years+	Government (funders), land managers, statutory agencies	Context-specific
Agri-environment schemes – compulsory (e.g. setaside, cross-compliance)	Enabling - Institutions & Policy (via CAP)	Established	Local	5 years+	Government, statutory agencies, land managers	Context-specific
Regulatory limits based upon ecological thresholds (e.g. 'environmental flows' and water body status to maintain GES in WFD)	Enabling - Institutions & Policy / Regulatory	Established	Local to regional	5 years+	Statutory agencies, land managers, businesses	Regulating services quality (water quantity/quality and to a lesser extent soil)
Nature Improvement Areas	Instrumental - Incentives	Early stages		?	Business, statutory agencies, local authorities	Context-specific
Wild-space schemes (rewilding)	Instrumental – Markets and incentives (also voluntary actions)	Established	Local (England)	?	Local authorities; NGOs; local volunteers	Primarily cultural (support LBAPs)

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Restoration of ecological function (e.g. wetlands, peatlands, coastal realignment)	Instrumental - Voluntary actions, incentives	Established	Local	Long-term	Statutory agencies, NGOs, land managers	Particularly regulating (carbon storage, water, soils, etc.) and cultural services
Agri-environment schemes – voluntary or quality-based (e.g. LEAF)	Instrumental - Voluntary actions	Established	Local	5 years+	NGOs, land managers	Context-specific
Land owning by Conservation NGOs (via membership)	Instrumental - Voluntary actions	Established		Long-term	NGOs	Context-specific
Biodiversity partnerships and Community-based conservation (e.g. local nature reserves)	Instrumental - Voluntary actions	Established	Local	Long-term	Communities	Cultural services
Countryside Codes	Instrumental – Voluntary actions	Established	National	Long-term	Statutory agencies (e.g. Blue flag); land managers (e.g. Country Parks accreditation) communities and volunteers (e.g. Green Flag awards)	Primarily cultural

Response Option	Type (based on NEA1 Chapter 27)	Status	Scale	Timescale	Actors / Governance	Ecosystem services (in addition to biodiversity)
Adaptive site management (to handle uncertainty)	Instrumental - Voluntary actions (also Knowledge)	Early stages	Local	Reviewed on regular cycle (e.g. 5 years). Long term strategy for forestry?	Land managers, NGOs, statutory agencies	Context-specific
Precision farming / Land sparing	Instrumental – Technology and practices	Early stages	Local	Annual	Land managers	Carbon storage, soil quality, water quality

8.A2.4 Response options for the water sector (long-list)

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Improved catchment science (water quantity & quality, ecosystem functions & integrity)	Foundational - Knowledge	Established	Local, National International	On-going, some long established	Statutory Authorities; Academia; Water companies (inc Scot & NI Water); NGOs	Regulating, Supporting, Provisioning, Cultural
Better flood prediction (forecasting and mitigation)	Foundational - Knowledge	Established	Local, National	On-going	Env Agencies; Gov. & Local Authorities; Business; Academia	Regulating, Cultural
Blue Networks (health and well-being)	Foundational – Knowledge Enabling - planning	Early	Local, National	On-going	Local & Regional Planning Authorities.; Green networks; NGOs	Regulating, Cultural
Integrated catchment management (ICM)	Foundational - Knowledge (and Instrumental – Technology)	Early	Local, National	5-10 years	Statutory Authorities; DEFRA; RESAS etc.	Provisioning, Regulating, Supporting
Water Framework Directive	Enabling - Legislation	Established	National	On-going, 6 year River Basin Management Planning cycles	Statutory Authorities; Consultancy; Academia	Supporting, Provisioning
Regulatory limits based upon ecological thresholds (e.g. 'environ. flows' WFD-context)	Enabling - Legislation	Established	Local, National	On-going	Statutory Authorities; Consultancy; Academia	Provisioning, Regulating, Supporting
Water Protection Zones	Enabling - Legislation	Established	Local, National	On-going	DEFRA, Welsh Assembly	Regulating, Supporting

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Sustainable Urban Drainage (SUDS)	Enabling – Legislation, Instrumental-Technology)	Early	Local, National	5 years	Local Gov, Housing Authorities	Regulating, Supporting
Sectoral water management	Enabling - Policy	Established	Local, National	On-going	Government; Water companies; Stat. Authorities	Provisioning, Regulating, Supporting, Cultural
River basin management plans (RBMPs)	Enabling - Policy	Early	National	On-going, up dated on 6 yearly cycles	Statutory Authorities; Agric; Water Companies; Energy;	Provisioning, Regulating, Cultural
Integrated Water Resources Management – agric., healthy ecosystems & livelihoods	Enabling - Policy	Early	Local, National	On-going	Multiple stakeholders uniting to set policy and actions	Provisioning, Regulating
Engineered flood defences, including pluvial in urban areas	Enabling – Policy (and Instrumental - Technology)	Established	National	On-going	Statutory Authorities; Planning; Housing sector	Regulating, Cultural
Water industry services (public water supply measures)	Enabling - Policy Instrumental – Markets and Technology	Established	Local, National	Long-term > 10-15 year planning cycles	Water and Energy companies, Stat. Authorities; DEFRA; DECC	Provisioning, Cultural
Water industry services (demand-side measures)	Instrumental – Markets and Technology Enabling - Policy Knowledge	Established	Local, National	Long-term	Water and Energy companies, Stat. Authorities; DEFRA; DECC	Provisioning, Cultural
Land use on floodplains	Enabling – Policy (and Instrumental - Markets)	Early	Local, Regional	On-going	Planning Agencies; Local Authorities; Insurance Sector	Cultural

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Flood risk management including raising awareness and ecosystem-based approaches	Enabling - Policy Knowledge	Early	Local, National	On-going	Stat Authorities; Local Authorities; Flood Forums	Cultural, Regulating
Water saving conservation	Enabling - Attitudes	Established	Local, National	On-going	Water companies, Business, Housing sector	Cultural, Provisioning
Land manager (catchment) education & awareness raising	Enabling - Attitudes	Early	Local, National	On-going	Land Owners/Farming Orgs., NGOs,	Cultural, Provisioning
Water valuation (natural capital assets)	Instrumental – Markets	Early	National	On-going, 5-10 years	Water companies, Env Agencies,	Cultural, Provisioning, Supporting
Agri-environment schemes – PES improve water quality and reduce flood risk –	Instrumental – Markets and Technology	Established	Local	Typically 5-10 years	Water companies, River Trust partnerships, Env Agencies	Provisioning, Regulating, Cultural, Supporting
Water metering	Instrumental - Markets	Early	Local, National	On-going	Water companies; Local Authorities; Housing sector	Cultural, Provisioning
Abstraction licence trading	Instrumental - Markets	Early	Local, National	On-going	Water companies; Statutory Authorities	Cultural, Provisioning
Wastewater treatment & water use	Instrumental - Technology	Established	Local, National	Long-term	Water companies; Statutory Authorities	Cultural, Provisioning, Supporting
Development of new engineering solutions e.g., high-tech demountable defences	Instrumental - Technology	Established	Local	On-going	Business, Flood Forums; NGOs, Local Authorities	Cultural, Regulating
Restoration of ecological function (e.g. wetlands, peatlands, coastal realignment)	Instrumental - Voluntary Action and Technology	Early to NFM	Local, National	On-going	NGOs, Public, Land owners, Stat Authorities	Cultural

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
River Trusts and local community-based actions (e.g. river restoration)	Instrumental – Voluntary Action	Established	Local	On-going, 5-10 years	NGOs, Public, Land owners, Stat Authorities	Regulating, Cultural, Supporting, Provisioning
Adaptive site management (to handle uncertainty)	Instrumental - Voluntary Knowledge	Early	Local	On-going	Statutory Authorities; Government	Cultural

8.A2.5 Response options for the urban sector (long-list)

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Mapping of public green space	Foundational – Knowledge	Established	Local, National	On-going	Selected local authorities; NGOs; academia	Regulating, Cultural, Provisioning
Collaborative interdisciplinary research centres and programmes e.g. EPSRC SUE	Foundational - Knowledge	Established	Local, National, International	On-going	Academia; environmental protection agencies; environmental and engineering consultants; NGOs; policy advisors; local authorities	Regulating, Cultural, Supporting, Provisioning
Strategic Environmental Assessments	Foundational - Knowledge	Established	Local	Fixed	Planners; local authorities; environmental and engineering consultants	Regulating, Cultural, Supporting, Provisioning
Research on adaptation to climate change in urban areas	Foundational - Knowledge	Early	Local, National, International	On-going	Academia; environmental protection agencies; Gvt research groups; NGOs;	Regulating
Integrated urban infrastructure plan	Foundational - Knowledge	Early	Local	Fixed	Academia; local authorities	Regulating, Cultural
Urban Ecosystem Services mapping (e.g. Kent Thames-side Green Grid)	Foundational - Knowledge	Early	Local	Fixed	Academia; environmental and engineering consultants; NGOs	Regulating, Cultural, Supporting, Provisioning
National database on green spaces	Foundational - Knowledge	Proposed/ planned	Local, National	On-going	NGOs (e.g. Grenspace Scotland)	Regulating, Cultural, Supporting, Provisioning
Urban ecosystem assessments	Foundational - Knowledge	Proposed/ planned	Local, National, International	6 years	Academia; Gvt research groups; environmental and engineering consultants; NGOs	Regulating, Cultural, Supporting, Provisioning

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Research on impact of transport systems and energy technologies on ecosystems	Foundational - Knowledge	Proposed/ planned	Local, National, International	On-going	Academia; environmental and engineering consultants	Regulating
Enhancing effective communication of science to policy makers	Foundational - Knowledge	Proposed/ planned	Local, National, International	On-going	Academia; environmental protection agencies; NGOs; policy advisors;	Cultural
Flood risk assessment & Surface Water Management Plans (identification of critical drainage areas)	Foundational - Knowledge	Established	Local	Fixed	environmental and engineering consultants Academia; local authorities	Regulating
Environmental Impact Assessment Directives	Enabling - Legislation	Established	Local, National, International	On-going	Planners; local authorities; environmental and engineering consultants	Regulating, Supporting, Provisioning
Environmental Noise Directive	Enabling - Legislation	Established	Local, National, International	On-going	Local authorities - Environmental Health departments;	Regulating, Cultural
Energy related EU legislation (e.g. Combustion Plant Directive)	Enabling - Legislation	Established	Local, National, International	On-going	Local authorities; industry; environmental protection agencies; Government departments; water companies; environmental & engineering consultants	Regulating, Cultural, Supporting
Water related EU legislation e.g. WFD, Floods Directive, UWWT Directive, IPPC Directive; Biodiversity (LBAPS)	Enabling - Legislation	Established	Local, National, International	On-going	Academia; environmental protection agencies; Gvt research groups; industry; water companies; environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural, Supporting

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
EU Climate Change policies: http://europa.eu/legislation_summaries/environment/tackling_climate_change/index_en.htm	Enabling - Policies, institutions & governance	Established	Local, National, International	On-going	EU and National and Local Government	Regulating, Cultural, Supporting, Provisioning
EU Transport policies: http://europa.eu/legislation_summaries/transport/index_en.htm	Enabling - Policies, institutions & governance	Established	Local, National, International	On-going	EU and National and Local Government	Cultural
Waste Framework Directive 2008/98/EC	Enabling - Policies, institutions & governance	Established	Local, National, International	On-going	Environmental protection agencies; Gvt departments; local authorities; NGOs.	Regulating
UK Energy Act 2011	Enabling - Policies, institutions & governance	Established	National	On-going	National and Local Government	Cultural, Provisioning
Designation of 'Quiet Areas'	Enabling - Legislation	Early	Local	On-going	LAs, NGOs and others?	Regulating, Cultural
Climate change and energy legislation e.g. Climate Change Act 2008	Enabling - Legislation	Early	Local, National, International	On-going	National and Local Government	Regulating, Cultural, Supporting, Provisioning
Renewable Energy Directive (2009)	Enabling - Legislation	Early	Local, National, International	On-going	National and Local Government	Regulating, Cultural, Supporting, Provisioning

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Natural environment White Paper 2012	Enabling - Legislation	Early	Local, National	Fixed	Gvt research groups and departments; Environmental protection agencies; NGOs	Regulating, Supporting, Provisioning
National Planning Policy Framework	Enabling - Legislation	Proposed/ Proposed/ planned	National	On-going	Planners; local authorities; property developers; Gvt departments	Regulating, Cultural
Planning Policy Statements	Enabling - Policies, institutions & governance	Established	Local, National	On-going	Gvt departments; policy advisors	Regulating, Cultural,
Decentralisation and Localism Bill (2011)	Enabling - Legislation	Proposed/ planned	Local, National	On-going	National and Local Government	Cultural
Green networks; migratory corridors,	Enabling - Legislation	Proposed/ planned	Local, National	On-going	NGOs; environmental and engineering consultants; local authorities; academia	Regulating, Supporting
Catchment management partnerships (RBMPs)	Enabling - Legislation	Proposed/ planned	Local, National	6 year	Academia; environmental protection agencies; Gvt research groups; industry; water companies; environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural, Supporting, Provisioning
UK Sustainable Development Strategy	Enabling - Policies, institutions & governance	Established	Local, National	On-going	National and Local Government	Regulating, Cultural, Provisioning

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
SUDS legislation and standards. All new and redevelopments must consider use of SUDS (England and Wales); use of SUDS in Scottish developments mandatory – support for this from proposed SABs (SUDS Approval Bodies) and SUDS standards.	Enabling - Policies, institutions & governance	Established	Local, National	On-going	Planners; Environmental protection agencies; Gvt research groups and departments; water companies; environmental and engineering consultants; local authorities; academia	Regulating, Cultural
Renewables Obligation e.g. Renewable Heat Incentive http://www.dft.gov.uk/topics/sustainable/	Enabling - Policies, institutions & governance	Established	National	On-going	National and Local Government	Cultural, Provisioning
Renewable Transport Fuels Obligation	Enabling - Policies, institutions & governance	Established	National	On-going	National and Local Government	Cultural, Provisioning
Climate Change (Scotland) Act 2009	Enabling - Policies, institutions & governance	Established	National	On-going	National and Local Government	Regulating, Cultural, Supporting, Provisioning
Waste (Scotland) Regulations 2012	Enabling - Policies, institutions & governance	Established	National	On-going	Environmental protection agencies; Gvt departments; local authorities; NGOs.	Cultural, Provisioning
Low Carbon Economic Strategy 2010	Enabling - Policies, institutions & governance	Established	National	On-going	National and Local Government	Cultural, Supporting Provisioning

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Energy Efficiency Action Plan 2010	Enabling - Policies, institutions & governance	Established	National	On-going	National and Local Government	Cultural, Provisioning
Operationalising the concept of environmental limits in spatial plans	Enabling - Policies, institutions & governance	Early	Local, National, International	On-going	Planners; local authorities; NGOs; environmental and engineering consultants.	Regulating, Supporting, Provisioning
Management and ownership of green space by local communities	Enabling - Policies, institutions & governance	Early	Local,	On-going	Local communities; local authorities; NGOs	Cultural, Supporting, Provisioning
Improving sustainable modes of transport	Enabling - Policies, institutions & governance	Early	Local, National, International	On-going	Local authorities; local communities; NGOs	Cultural, Provisioning
Low Carbon Transition Plan	Enabling - Policies, institutions & governance	Early	Local, National, International	On-going	EU, National and Local Government	Regulating
Renewable energy developments designed to also benefit biodiversity	Enabling - Policies, institutions & governance	Early	Local, National, International	On-going	?	Regulating, Provisioning
Stakeholder engagement to identify and deliver WFD PoMs.	Enabling - Policies, institutions & governance	Early	Local, National, International	6 years	Academia; environmental protection agencies; Gvt research groups; industry; water companies; environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural, Supporting

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Ecosystem services approach and Green Infrastructure in development planning	Enabling - Policies, institutions & governance	Proposed/ planned	Local, National,	On-going	Academia; planners; environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural, Supporting, Provisioning
Integrate transport and spatial planning to minimise car use and improve public transport	Enabling - Policies, institutions & governance	Proposed/ planned	Local, National,	On-going	Planners; Gvt department; NGOs; local authorise	Regulating, Cultural
Local Transport White Paper	Enabling - Policies, institutions & governance	Proposed/ planned	Local	On-going	National and Local Government	Regulating, Cultural, Supporting, Provisioning
Organisational guidance – Natural England and SNH (urban area agendas), water authorities (sustainable water management), local authorities (SUDS guidance)	Enabling - Policies, institutions & governance	Proposed/ planned	National	On-going	Academia; environmental protection agencies; Gvt research groups; environmental and engineering consultants; NGOs	Regulating
Use of Learning Alliances as a mechanism to deliver sustainable urban water management	Enabling - Policies, institutions & governance	Proposed/ planned	Local, National, International	On-going	Academia; environmental protection agencies; Gvt research groups and departments ; industry; water companies; environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural
Energy Saving Trust	Enabling - Social attitudes	Established	Local, National	On-going	NGOs?	Regulating, Provisioning

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
National Environmental campaigns: e.g. SEPA – Yellow Fish and oil care campaigns, WWF - Watersense, Defra - 'love your river'	Enabling - Social attitudes And Legislation	Mix - Early & Established	Local, National	On-going	Local authorities; local community; NGOs; media	Regulating, cultural
Local authority campaigns e.g. reducing use of washing powders containing phosphate	Enabling - Social attitudes	Established	Local	On-going	Local authorities; local community; NGOs; media	Regulating, Cultural
Volunteer opportunities to manage urban green space	Enabling - Social attitudes	Early	Local,	On-going	Local authorities; local community; NGOs; media	Regulating, Cultural
Improve appeal of sustainable travel modes to change attitudes towards travel	Enabling - Social attitudes	Early	Local, national	On-going	Local authorities; local community; NGOs; media	Cultural, Provisioning
Targeted Environmental initiatives: e.g. WWT 'SUDS in schools' project; 'Love the Lee' and Brent catchment partnership – clean up rivers etc	Enabling - Social attitudes	Early	Local	On-going	Local authorities; local community; NGOs	Regulating, Cultural
Training of planners to consider ecosystem services	Enabling - Social attitudes	Proposed/ planned	Local, National	On-going	Planners; academics; environmental consultants	Cultural

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Public participation in the delivery and ownership of renewable energy	Enabling -Social attitudes	Proposed/ planned	Local, National	On-going	Community Groups, NGOs,	Regulating, Cultural
Requirement for public participation in WFD (Water framework Directive) Programme of Measures	Enabling -Social attitudes	Proposed/ planned	Local, National, International	On-going	All	Regulating, Cultural
Art, humanities and culture projects	Enabling -Social attitudes	Proposed/ planned	Local	On-going	All	Cultural
Urban gardens, orchards, commons	Enabling -Social attitudes	Early	Local	On-going	Local communities, Local authorities	Cultural, provisioning, regulating
Technology for water and energy saving in urban dwellings and industry (on-site greywater re-use).	Instrumental - Markets & incentives Technologies and Practice	Early	Local, National	On-going	Academia; water companies; environmental and engineering consultants; industries; NGOs; local authorities; planners; property developers	Regulating, Cultural, Provisioning
EU Emissions Trading System	Instrumental - Markets & incentives	Established	Local, National, International	On-going	EU, National and Local Government, Industry	Regulating
Road pricing, congestion charging	Instrumental - Markets & incentives	Established	Local, National, International	On-going	National and Local Government, Highways Agency, Transport Scotland	Regulating
Water and sewerage billing	Instrumental - Markets & incentives	Established	Local, National, International	On-going	Water companies; Gvt departments/'watch dogs'; NGOs	Regulating, Cultural

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Feed-in-tariffs (energy)	Instrumental - Markets & incentives	Early	Local, National, International	On-going	National and Local Government, Industry	Regulating, Provisioning
Reform of electricity market to favour low-carbon energy	Instrumental - Markets & incentives	Proposed/ planned	Local, National, International	On-going	EU, National and Local Government, Industry (energy suppliers)	Cultural, Provisioning
Measures to minimise impacts of energy installations and energy crops	Instrumental - Technologies & practices	Established	Local, National, International	On-going	EU, National and Local Government, Industry (energy suppliers, land managers/farmers)	Regulating, Provisioning
Multi-functional Green Infrastructure	Instrumental - Technologies & practices	Early	Local, National, International	On-going	Academia; environmental protection agencies; Gvt research groups and departments ; industry; water companies; environmental and engineering consultants; NGOs; local authorities; local communities	Regulating, Cultural, (Supporting, Provisioning)
New renewable energy technologies, carbon capture and storage	Instrumental - Technologies & practices	Early	Local, National, International	On-going	EU, National and Local Government, Industry (energy suppliers, innovators), academia	Regulating, Provisioning
SuDS new and retro fit schemes e.g. DEX, Upton, Lambs Drove, Ashby Grove rain garden, Counters creeks, Hackney rain garden	Instrumental - Technologies & practices	Early Proposed/ planned	Local	On-going	Academia; environmental protection agencies; water companies; environmental and engineering consultants; local authorities	Regulating, Cultural

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Leapfrogging concept – transitioning to water sensitive cities (e.g. SWITCH)	Instrumental - Technologies & practices	Proposed/ planned	Local, National, International	On-going	Academia; environmental protection agencies; Gvt research groups and departments ; industry; water companies; environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural, Provisioning
Coventry – Edible Campus	Instrumental - Technologies & practices	Proposed/ planned	Local	On-going	Academia	Cultural, Provisioning
Green roofs and other urban retrofit options for transitioning cities.	Instrumental - Technologies & practices	Proposed/ planned	Local	On-going	Academia; environmental protection agencies; Gvt research groups and departments ; property developers; planners environmental and engineering consultants; NGOs; local authorities	Regulating, Cultural

8.A2.6 Response options for the marine and coastal sector (long-list)

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Marine monitoring, GIS, Charting Progress 2, KnowSeas, UK Seamap	Foundational - Knowledge. Gradually improving knowledge base on marine environment increasing spatialisation of data with GIS. MSFD requires establishment of monitoring programme	Early implementation / Established	National - UK seas	MSFD monitoring programme must be established by 2014. Include monitoring of progress towards GES	Defra, MMO, Cefas, Marine Scotland, Natural England, JNCC, UKMMAS, industry, researchers, consultants	Education, knowledge
Ecosystem approach applied to fisheries management	Foundational - Knowledge. Integrate ecosystem aspects into fisheries management – food web interactions, bycatch, multispecies fisheries.	Early stages	Regional Sea scale and EU-scale (through CFP)	Further research needed; potential for increasing and incremental implementation to 2060	EU: European Commission, Council and Parliament, International Council for the Exploration of the Seas (ICES), 27 Member States, UK: Defra, Marine Scotland, MMO; researchers/ universities	Provisioning (food-fisheries); biodiversity
Fisheries data collection (fish stock assessment, monitoring landings, logbook schemes)	Foundational - Knowledge	Established responses	EU water and national	Ongoing, annual assessments	Fishers, Defra, MMO, IFCAs, Marine Scotland, ICES	Provisioning (food-fisheries); biodiversity
CCTV monitoring onboard fishing vessels for fully documented fisheries	Foundational – Knowledge (and Instrumental – Technologies and Practice)	Early stages, (successful pilots)	Local – used in some pilot studies but could be rolled out across EU	5-10+ years	Fishers and fisher associations, producer organisations, Defra, MMO, Marine Scotland, European Commission, Council & Parliament,	Provisioning (food-fisheries), biodiversity, regulating, knowledge

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Aquaculture practices with lower environmental impacts (e.g. reduce waste, increase conversion ratios, prevent escapes)	Foundational - Knowledge, practice	Early stages	Local – national	5-10 years	Aquaculture businesses, supermarkets (sourcing demands), certification bodies, Defra, MMO, Marine Scotland	Provisioning (food-aquaculture), biodiversity,
Tourism surveys	Foundational - Knowledge. Few specifically marine/coastal surveys available. Existing information does not always differentiate coastal/marine from terrestrial. E.g. GB Tourism Survey since 2011 (Previously UK Tourism Survey) includes 'Seaside' as a category of 'Type of place visited'. Data available on number of trips, number of nights, expenditure; A Review of Marine and Coastal Recreation in Scotland.	Established / Early stages	National	Annual	Tourism authorities	Cultural/aesthetic, recreation

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Marine and Coastal Access Act (MCAA) 2009 (relevant to marine plans, MPAs) (NB secondary legislation for Wales and NI)	Enabling - Legislative (national). Aims to ensure clean healthy, safe, productive and biologically diverse oceans and seas. Introduces marine planning system and provision to establish network of MPAs	Early stages / Established (legislation in place, initial phase of implementation)	England and Wales; Regions (north-east, east, south-east, south, south-west, Cumbria)	10+ years (establish MPA network 1st tranche 2013, 1st Marine Plan (East Coast) 2012/2013, full set from early 2020 (England)	National (England & Wales): Defra, MMO, Natural England, JNCC; Regional: Local Councils, planning authorities	All – biodiversity, cultural/ aesthetic, tourism through MCZs, provisioning (food/fisheries/ aquaculture, non-food e.g. renewable energy, aggregates), regulating
Marine Strategy Framework Directive	Enabling - Legislation	Early stages	EU	Good Environmental Status to be achieved by 2020	EU: European Commission, Council, Parliament, European Environment Agency, 27 Member States; UK: Defra, MMO, JNCC, Natural England	All esp. biodiversity, provisioning (food), hazard protection, regulating, pollution control, aesthetic values
Draft Scottish Technical Standard for Scottish Aquaculture Farms (Feb 2012)	Enabling - Legislation (draft) – would be applied universally through legislation	Proposed, under development	National (Scotland)	Short term 1-5 years	Marine Scotland, Aquaculture farms	Provisioning (food – aquaculture and fisheries due to reduction of impacts on wild stocks)
Marine licensing	Enabling - Legislation. Licence required for range of marine activities. EIA must be carried out.	Early stages	National	Short term 1-5 years. Licensing system is already in place, over next few years exempt activities will also need licence	MMO, individual developers	All. Biodiversity, provisioning, hazard protection, flood control, navigation, aesthetic values

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Strategic Environmental Assessment (applied to fisheries)	Enabling - Legislation/ Policy/ Practice. SEA Directive includes fisheries plans. Not compulsory but starting to be used	Proposed, under development	So far, used to assess inshore (<6nm) shellfish management regimes. Could be used at local, regional, international level	First SEA for fisheries in UK implemented 2008.	Local and national authorities, consultancies, NGOs	Provisioning (food-fisheries), biodiversity
Reform of Common Fisheries Policy	Enabling - Policy/Legislation. Established in 1983 for management of European fish stocks. Applies beyond 12nm. Implemented through TACs and quotas for certain stocks; technical measures to limit effort; fleet capacity limits; enforcement. Undergoing reform. Expected to increase use of multi-annual management plans, implement discard reduction/ban	Proposed, under development (but also existing policy is established)	EU waters, with regional focus through (Regional) Advisory Councils ((R)ACs).	Reform due 2013 but likely only in 2014/2015. Revised every 10 years	EU: European Commission, Council and Parliament, 27 Member States; UK: Defra, Marine Scotland, MMO; Local: Inshore Fisheries and Conservation Authorities (IFCAs), fishers	Predominantly provisioning (food-fisheries), but linked to/impacts on other services e.g. biodiversity (impacts on target stocks and bycatch of non-target species), in turn impacts on tourism, aesthetic benefits

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Shoreline Management Plans	Enabling - Policy. Strategy and long-term framework for coastal flood and erosion risk management in England and Wales (22 areas). Some also exist in Scotland	Established	Regional	First SMPs produced in mid-1990s. Updated every 5 years. 2nd generation plans outline risks in short (0-20), medium (20-50) and long term (50-100) timescales.	Coastal groups (local authorities, Environment Agency)	Hazard protection (coastal and flood defence)
European Fisheries Fund / European Maritime and Fisheries Fund	Enabling - Financial support to the fisheries/maritime sector from the EU. EMFF has 4 main areas: adaptation of EU fleet (capacity); aquaculture, inland fishing, processing, marketing; collective action; diversifying and sustainable development of fishery-dependant areas. EMFF will also focus on implementing the IMP.	EFF: Established; EMFF: Proposed, under development	European waters	EFF from 2007-2013; EMFF from 2014-2020	European Union/ Commission/ Parliament/ Council; Member States (Defra for UK); within UK - devolved administrations; local-level Fisheries Local Action Groups (FLAGs), Producer Organisations	All, esp. provisioning (food-fisheries) wrt EFF; EMFF also includes coastal protection in face of climate change, green energy, C-sequestration.
Greater involvement of fishermen in decision-making	Enabling - Policies, institutions and governance	Early stages, Proposed	National, local	10 years	Defra, MMO, Marine Scotland, IFCAs, Fisher Associations, Producer Organisations, NGOs	Provisioning (food-fisheries), biodiversity

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Plan of Action for Seabirds	Enabling - Policies, institutions and governance	Proposed, under development	National, EU	Short term 5-10 years. EU is preparing a Plan of Action to reduce seabird bycatch, and UK expected to do the same	European Commission, Defra, MMO, fishers	Biodiversity, aesthetic values
Marine Plans	Enabling - Policies, institutions and governance	Early stages	Regional, national (marine plans being developed for NE, E, SE, S, SW, Cumbria, Scotland, Wales, NI)	10+ years 1st Marine Plan (E) by 2013? Full set (England) by 2020	MMO, Defra, Local authorities, various marine and inshore stakeholders	All: Biodiversity, provisioning (food – fisheries, aquaculture; biofuel, pharmaceuticals), navigation, regulating, coastal defence, aesthetic values, cultural heritage, employment
Media - documentaries, raising awareness	Enabling - Changing social attitudes	Established	National, regional, local	Short-term	NGOs, media and production companies	Biodiversity, aesthetic values, cultural heritage, education
Educational programmes (in National curriculum and by NGOs)	Enabling - Changing social attitudes	Established	National, regional	Medium-term	NGOs, local education authorities, Department for Education, schools	All
Coastal Partnerships (bottom-up approach to integ. & man. of coastal actions and activities)	Enabling - Changing social attitudes	Established	National, Regional, local	Short-medium term	Coastal Partnerships, Coastal Partnership Network, MMO, European Marine Site management groups, AONB, ICZM, coastal and estuary stakeholders	All

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
Environmental NGOs	Enabling - Changing social attitudes/awareness	Established	National, local (and links to European and global-level initiatives)	Generally 5-year planning horizon, but NGOs likely to be around and evolve their remit to 2060	WWF, MCS, Greenpeace, RSPB et al. Mainly national-level, often linked to global NGOs	Main focus on wild species diversity, associated with public use of coast/marine e.g. tourism, leisure
Conservation measures in fisheries e.g. Scottish Conservation Credits Scheme	Instrumental - Markets and incentives (and Instrumental - technologies and practices) (technical measures e.g. real-time closures, square mesh panels, ban on discards, in return for extra days at sea)	Early stages (successful in Scotland, could be applied more widely)	Regional, National, EU	Medium term	Defra, Marine Scotland, European Commission, ICES, fishermen, fishing associations, producer organisations	Provisioning (food – fisheries), biodiversity, regulating
Certification (fisheries and aquaculture) – voluntary schemes (also market-based)	Instrumental - Markets & Incentives / Voluntary actions. Certification of fisheries/aquaculture facilities as sustainable against set criteria. Voluntary, market-based schemes	Established	Local (individual aquaculture farm or inshore shellfish fishery) to regional (North Sea / North East Atlantic fishery with multiple stakeholders involved)	Ongoing. Expected increase in demand	Fishers, Certification bodies, certification organisations (e.g. MSC, ASC), retailers (to stock product), consumers (to provide market demand)	Provisioning (food-fisheries); biodiversity

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
No take zones / MCZs	Instrumental – Technology & Practice. Network of MPAs to be established in English waters under MCAA 2009 (MCZs), similar in Scottish inshore and offshore zone. Other no-take reserves	Early implementation plans / Proposed	National - UK seas (local areas for MCZs)	1st tranche MCZs by 2013. Recommendations for Scottish MPAs expected 2012/2013.	Defra, MCZ projects, JNCC, Natural England, local stakeholders (fishery, industry, recreation). SACs and SPAs established under Habitats and Birds Directives	Tourism, cultural/aesthetic, provisioning (negative, or indirect positive)
Managed realignment	Instrumental – Technology & Practice. Technology/practice. Allow sea to breach flood defences to enable intertidal habitats to be recreated	Established	Local	First sites established in 1991; over 50 sites currently exist. Implementation is expected to increase.	Local and national authorities, land owners, local people, NGOs, wildlife trusts, National Trust, and businesses	Various ecosystem services created inc. C-sequestration, flood protection, biodiversity, recreation/tourism.
Participation of fishermen in developing more selective gear (Project 50%)	Instrumental – Technologies and practices	Early stages (successfully applied in pilot projects)	Local, regional	Short-medium term	Defra, MMO, Marine Scotland, fishermen, fishing associations, producer organisations	Provisioning (food-fisheries), biodiversity, regulating, knowledge, aesthetic value
New renewable energy technologies, carbon capture and storage	Instrumental – Technologies and practices	Early stages	National	Medium term	MMO, Oil & Gas companies	Climate regulation, air quality regulation
Beach nourishment	Instrumental – Technologies and practices	Established	Local	Short-term	Local authorities, Environment Agency, dredging companies, Crown Estate	Coastal protection, tourism and recreation

Response Option	Type	Status	Scale	Timescale	Actors / Governance	Ecosystem services
VMS technology	Instrumental – Technologies and practices. Vessel Monitoring System used to track location of fishing vessels; fishing activity can be inferred from speed.	Established (vessels >15m); Early stages (vessels 12-15m); and Proposed, under development (vessels <12m)	Local (UK fisheries) and EU, also UK/EU vessels fishing worldwide	Mandatory on all vessels >15m, being brought in for all vessels >12m (2012), could be extended to <12m	Fishers, MMO, Marine Scotland, Defra, European Commission	Indirectly, Provisioning (food-fisheries); biodiversity, through better management/more sustainable exploitation of fish stocks
Voluntary codes of conduct	Instrumental – Voluntary actions (e.g. Responsible Fishing Scheme, Code of Good Practice for Scottish Finfish Aquaculture 2006)	Established	Regional, national	Short-term, medium-term	Fishers, fisher associations, producer organisations, aquaculture facilities, industry bodies	Food (provisioning – fisheries and aquaculture), biodiversity, aesthetic value, regulating
Blue Flag eco-label for beaches	Instrumental – Voluntary actions	Established	Local, national	Short-term	Blue Flag scheme, local authorities	Recreation, aesthetic value
Voluntary action groups e.g. Surfers against sewage, beach clean-ups	Instrumental – Voluntary actions	Established	Local	Short-term	Local groups, communities, NGOs	Recreation, aesthetic value, biodiversity

Appendix 8.3: Summary descriptions of the NEA scenarios used in the stress-testing (provided by WP7)

8.A3.1 Short narratives of the scenarios for two timeslices

Nature@Work

2030: There is an increasing understanding of the importance of ecosystem services, especially in the face of climate change. Decision-making is balanced between local and national and although much economic activity is in private hands the government sector plays an important role in managing and regulating economic activity to ensure efficiency in the use of resources and the minimisation of environmental externalities. Renewables cover an increasingly large proportion of energy generation.

2060: 'Balanced service provision' is key and many ecosystem services are the result of careful evaluation of the trade-offs through scientific and community review. Maintaining and enhancing the output of ecosystem services in response to climate change is a key priority and society accepts that trade-offs are necessary to achieve it. 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. Decision-making is balanced between local and national and although most economic activity is in private hands the government sector plays an important role in managing and regulating economic activity to ensure efficiency in the use of resources and the minimisation of environmental externalities. Renewables cover a large proportion of energy generation.

World Markets

2030: Trade liberalisation and economic growth combined with a predominately materialistic attitude within a fragmented society means that free market capitalism becomes the dominant ideology. Government is relatively weak and the economy is increasingly dominated by big business. Public decision-making is done at both the national and local level, but does not have much control over private business. More energy comes from nuclear and renewables than currently, but gas and oil are still used where cost-effective.

2060: Economic growth is prioritised 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 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. Fish stocks have plummeted and some species have become locally extinct; most fish eaten in the UK is imported from Asia now. The UK's coastal areas

are changing in response to the increasing demand for ecosystem services. The east coast is the prime location of the desalination plants that have been built to meet the high demand for water. Coastal areas elsewhere accommodate the network of power plants and gas pipeline stations that are required now that domestic fossil fuel energy production is declining and imports of gas have increased. The UK's expanded nuclear industry is financed by the private sector and supplies of other ecosystem services are increasingly being privatised as well.

National Security

2030: An increasingly uncompetitive UK economy is finding it hard to compete internationally and living standards are declining. Fossil fuels are becoming increasingly scarce and expensive, with negative impacts on the UK economy. Government is becoming increasingly centralised at a national level and the state sector is strong. A large proportion of the UK's energy needs are still being met by traditional fuels, although alternative energy sources are seen as increasingly attractive if they can be accessed more cheaply.

2060: In the face of an increasingly uncompetitive UK economy, 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 rather than a source of conflict between nations, and 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. This has led to the reopening of many coalmines, greater protection of the UK's fisheries and the conversion of previously non-productive land to farming. Resource consumption is curbed and society is less profligate and more sustainable—though perhaps out of economic necessity as much as environmental concern.

Local Stewardship

2030: Society is beginning to respond to poor UK economic performance and lower living standards by seeking greater local self-sufficiency. Things are increasingly done at a local level, and local government is relatively strong, although much activity is conducted by private individuals in small local businesses. Energy is increasingly generated from local renewable resources.

2060: 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, such as 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. Alternative

economies such as LETS (Local Exchange Trading Systems) schemes are popular. 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.

8.A3.2 Changes in key drivers for the NEA scenarios

Table 8.A3 Strength and direction of changes in key drivers in the NEA scenarios provided by WP7. N@W = Nature@Work; WM = World Markets; NS = National Security; LS = Local Stewardship.

Driver	Scenario / timeslice							
	N@W		WM		NS		LS	
	2030	2060	2030	2060	2030	2060	2030	2060
SOCIAL								
Population	0	+	++	++	+	+	0	+
Social cohesion	+	+	-	--	+	++	+	++
Tertiary education	+	++	-	--	-	-	-	-
Level of social activism	+	+	-	+	-	-	+	+
Respect for the environment	+	++	--	-	-	--	++	++
Preference for urban living (as opposed to rural)	0	0	+	++	+	++	--	--
Preference for living at the coast	0	0	-	-	0	**0**	-	-
Demand for provisioning services (consumerism)	-	-	+	++	-	--	--	--
Demand for regulating services	++	++	-	--	-	-	++	++
Demand for cultural services	+	+	-	--	--	--	+	+
TECHNOLOGY								
Innovation (techno-centric)	+	+	++	++	-	-	--	--
Innovation (eco-centric)	++	++	-	--	-	-	++	++
Innovation (hybrid, appropriate mix of technology)	++	++	0	+	0	0	0	0
Level of mechanisation	+	+	++	++	-	-	-	-
ICT	++	++	++	++	0	0	-	-
ECONOMIC								
Magnitude of economic development	+	+	++	++	-	--	-	-
Stability of economic development	+	+	--	--	+	+	++	++
Equity/distribution of wealth	+	+	--	--	+	+	++	++
Energy prices	+	+	++	++	++	++	+	+
Food prices	+	+	++	++	++	++	+	+
Water prices	+	+	++	++	+	+	++	++
Globalisation	+	+	++	++	--	--	--	--
Reliance on imports	0	0	+	++	--	--	--	--

Driver	Scenario / timeslice							
	N@W		WM		NS		LS	
	2030	2060	2030	2060	2030	2060	2030	2060
ENVIRONMENTAL								
Sustainable resource management	+	++	-	--	++	++	++	++
POLICY								
Strength of governance	++	++	--	--	++	++	+	+
Strength of spatial planning regulations	++	++	--	--	+	+	++	++
Strength of international cooperation	+	+	-	-	--	--	-	-
Geo-political stability	+	+	-	--	--	--	--	--

-

Appendix 8.4: Detailed descriptions of stress-testing results per response option

Appendix 4 reports the detailed analysis of the stress-testing study in which the impacts of a representative set of response options per sector were assessed against the NEA scenarios. This supports Section 3 of this report which provides a synthesis of the main findings per sector. The scenarios encompass Nature@Work, in which decision-making is integrated between local and national, and ES are highly valued; World Markets, in which decisions are driven by the encouragement of economic growth through trade liberalisation; National Security, in which policy has a strongly centralised and protectionist slant in the face of declining living standards and an uncompetitive economy, and Local Stewardship which assumes greater self-sufficiency and sustainable resource use at local levels (see Appendix 3 for details). Expert opinion, supported by data/evidence where available and stakeholder interviews, was used to forecast the potential impacts of each response option on each class of ES under each scenario by 2030 and 2060 using a simple five point scale, from large negative impact through to large positive impact. We used the UKNEA analysis of ES delivery under each scenario as our point of comparison for each option; thus an intervention may be scored as '+' if it is judged that ES delivery would be improved compared with the situation without the intervention, but this may still mean a decline compared with the present. Inevitably, the responses are indicative only and are sensitive to assumptions about how the scenarios would unfold.

8.A4.1 Agriculture

The UKNEA showed that, in very general terms, agricultural policy and practices boosted national food production during the mid-20th Century, with declines in other ES (Firbank *et al.*, 2011). Since around 1980, public and policy concerns have sought to improve the environmental footprint of agriculture, rather than increasing provisioning, with the result that diffuse pollution to water courses and emissions to the atmosphere have fallen in recent decades (Firbank *et al.*, 2011). This has been achieved through a combination of regulation, financial support, new practices and sharing of information. Consumer concerns about the safety of food, animal welfare and environment have given rise to various accreditation and assurance schemes, whilst the increased use of the Ecosystem Approach by policy-makers is stimulating a range of initiatives to support the delivery of ES from farmland, for example, the Cambrian Mountains Initiative[23].

However, concerns about food security have been growing in the UK in recent years, prompted by doubts that global food supply will fail to keep up with demand that is rising swiftly because of increasing population and a shift towards more meat-rich diets (Foresight, 2011). The new paradigm is 'sustainable intensification', in which food production per unit area is increased without negative impacts on other ES (Foresight, 2011). This is most likely to be driven by markets, policy, research, technology and knowledge exchange (Department for Business, 2013). The early indications suggest that this process will prove easier through the control of pollution at the farm scale (because

[23] http://cambrianmountains.co.uk/

pollution is inherently wasteful of nutrients, water and/or energy, and is therefore a cost to the farm) than through the management of biodiversity and cultural assets (Firbank *et al.*, 2013). Moreover, the British weather has recently demonstrated extremes of cold, drought and rainfall that could be part of an overall change in climate (Francis & Vavrus, 2012). Thus, the policy, trade and environmental contexts are all changing rapidly for UK farming.

As there are many possible interventions to enhance the delivery of ES, including food production, from agriculture, it is therefore not easy to identify ones that may prove to be sound investments looking ahead. It depends on their sensitivity to how the future unfolds, and their potential impacts on different ES[24]. A broad group of potential interventions, or response options, was identified to cover a range of research, policy, and community-led actions (see Appendix 8.2). From this list, a subset of nine current response options was selected for detailed consideration of their potential impacts on different ES under the NEA scenarios. These nine were chosen to provide a range of the types of responses in terms of their maturity, who is responsible for delivering them and their potential scale of impact (see **Table 8.4**). Some options relevant to agriculture (notably set-aside, agri-environment schemes and the Water Framework Directive) are considered under other sectors. The responses chosen in this section are addressed at the UK scale, as they were not considered likely to generate different impacts in the devolved administrations. They are assumed to be applied widely. The ES are grouped into provisioning services (food production, addressing both quantity and nutritional quality, as well as bioenergy, timber and the supply of fresh water), regulatory services (encompassing control of flood risk, GHG emissions and diffuse pollution to water courses), cultural services (including sports, recreation, a sense of place and the spiritual value of nature) and supporting services (addressing the slower and less obvious services that underpin the others, such as soil formation and photosynthesis). Where this grouping disguised important trade-offs, these are noted in the text. The results of this stress-testing of the responses are shown in **Table 8.5** and **Figure 8.3**.

Payments for ecosystem services

There have been many examples of payments to farmers and landowners to provide what are now thought of as ES, ranging from support for habitat enhancement through quasi-markets such as agri-environment schemes to true markets, such as the purchase of upland areas by water companies to manage water regulation, to direct payments for on-farm holiday accommodation and game shooting. Payments for the provisioning service of food and bioenergy production have been the major driver of agricultural production, although they are not normally included within the Payments for Ecosystem Service (PES) paradigm and so are not considered here. The increasing awareness of the potential financial value of ES has not, however, been widely backed up by the finances to pay for non-provisioning forms of ES, and so while this intervention is highly relevant to agriculture, its impact thus far has not been great beyond well establish market and support mechanisms.

[24] It also depends, of course, on their cost-effectiveness, but this analysis is beyond the scope of this report.

There is considerable uncertainty about the role of PES under the different scenarios. Direct payments for ES may prove most relevant to the market-driven World Markets scenario. Here, they may prove most effective for provisioning services and certain regulating services where PES is cost-effective, e.g. reducing diffuse pollution into watercourses. PES may be the only way of ensuring the supply of cultural services in this scenario through the creation of privately-funded parks and nature reserves; this would alleviate the otherwise large scale decline of cultural services in this scenario (**Table 8.5**). Supporting services are unlikely to be commoditised in this way. There may be a role for such schemes in the Nature@Work scenario to supplement the delivery of ES using regulatory mechanisms, possibly reducing the area used mainly for food production for leisure and regulatory services. By contrast, under National Security, the provision of ES may be dictated by government, rather than through markets. Under Local Stewardship, the value of different ES are accepted by society in an informal way, delivered though consent and dialogue, rather than through financially-driven contracts. Payments for ES are unlikely to play a major role in this scenario, except perhaps at a very local level.

Methods for mitigation and management of diffuse pollution and GHG emissions

This intervention focuses on improving the regulation of water quality in landscapes and catchments, though it will also improve cultural services such as fishing and the supporting service of nutrient cycling over time, as well as controlling soil losses. At present, such methods may be accompanied by slightly reduced food production (e.g. by the creation of buffer areas), but this effect may reduce over time as new techniques appear (e.g. the use of buffer areas for bioenergy production or nutrient harvesting). The development and dissemination of methods to reduce pollution and emissions have been an important aspect of policy and practice in recent years in order to improve water quality and reduce GHG emissions (Collins & McGonigle, 2008). These methods have reduced pollution loads from agriculture in recent decades, and are the focus of interventions by policy, the industry and researchers (e.g. Water Framework Directive, catchment management initiatives, the Defra Demonstration Test Catchment programme) (McGonigle *et al.*, 2012).

The Nature@Work scenario involves the improvement of water and air quality, so the continued development of practical methods to achieve these ends from farmland is important (**Table 8.4**). These could involve a planned reduction of livestock numbers to reduce GHG emissions. There is a potential trade-off between food production on the one hand, and policies that support increased water quality and provision, along with biodiversity and enjoyment of nature. Practical methods for pollution control will also be very important under the Local Stewardship scenario; again, there is a potential for a trade-off between food production and water quantity and quality. This intervention may prove relevant to the World Markets and National Security scenarios only if economic incentives are present to reduce pollution, perhaps through high costs of nutrients or carbon trading payments to reduce GHG emissions.

Indicators of sustainable intensification

Several companies are setting indicators and targets of sustainable agriculture for the farms that supply them, using metrics for food production and environmental quality, in a drive to demonstrate

to consumers that their supply chain is becoming more sustainable (e.g. the Sustainable Agriculture Platform[25]). The initial work has focussed on enhancing biodiversity on farmland as a cultural service, and on regulating services through the carbon footprinting of farms (e.g. the Cool Farm Tool; Hillier *et al.*, 2011), with water and nutrient footprinting are not far behind. Holistic indicator sets are appearing (Firbank *et al.* 2013). The new UK Agri-Tech Strategy (Department for Business, 2013) proposes a new UK Centre to address indicators of sustainable intensification (i.e. the increase of food production without additional environmental harm, and ideally with environmental improvements), capable of tracking enhancements to food production and other ES.

A key feature of the Nature@Work scenario is 'balanced service provision'. The development of evidence-based indicators of sustainable intensification for farms is a valuable way of delivering this outcome, as it provides clear targets and metrics for the delivery of appropriate services, including enhanced food production. Such targets could become mandatory under this scenario. They will have a very large effect on provisioning services and support for biodiversity, as they could encapsulate how different ES should be balanced at the farm level. Indicators for supporting services might also be possible (**Table 8.5**).

Formal indicators of sustainability are likely to be less relevant to the Local Stewardship scenario compared with Nature@Work due to a less centralised approach to food production. Such indicators would not feature in the remaining scenarios. The World Markets scenario promotes quantity and price and not quality; it is hard to see any commercial justification for the implementation of indicators of sustainability. The focus of the National Security scenario is on provisioning services, whether or not these can be sustained. Therefore, indicators of sustainable land management are unlikely to be appropriate.

Agricultural networks, associations and initiatives

There are many local and national networks, associations and initiatives, independent from government or the larger companies in the food supply chain, that facilitate sharing knowledge, ideas and experiences among farmers and land managers, thereby developing and disseminating good practice. For example, LEAF (Linking Environment and Farming)[26] is a charity that supports a network of farmers that promotes sustainable food and farming, through knowledge exchange, self-assessment and independent audits of farms and outreach events. The UK's Farmers Unions support farm businesses and advance their interests, while regional and national agricultural societies support technology transfer and sharing of best practice. Some initiatives involve marketing, e.g. emphasising local provenance. It is not possible to evaluate the impacts of all of these organisations, they are too diverse; but it is safe to assume they are considerable, delivering benefits to all ES, especially food production.

The Nature@Work scenario envisages a more resource-efficient and multi-functional agriculture than at present (**Table 8.5**). A key delivery of such changes is now, and will continue to be, through

[25] http://www.saiplatform.org/
[26] http://www.leafuk.org/leaf/home.eb

formal and informal agricultural networks. Their current emphasis is on enhancing environmental management and resource utilisation efficiency rather than maximising food production, benefitting regulatory services and biodiversity conservation especially, though under this scenario food provisioning could increase through knowledge exchange within the networks of best practice. The networks also support cultural services including farm visits and leisure. However, the role of such networks is less certain under the other scenarios. Voluntary initiatives may have little place in the World Markets scenario, in which agriculture is dominated by large corporations that control the supply chain from field to fork, and have their own knowledge exchange and extension facilities for the farmers that work for them under contract. In the National Security scenario, there will be strong national extension services and regulation to support increasing production of food and bioenergy, regardless of other ES. Therefore, voluntary networks may well create a distinct role in sharing knowledge about how to do so without eroding the natural capital basis for future agriculture, and may well generate positive impacts on all ES, although these impacts will be relatively weak. Under the Local Stewardship scenario, the emphasis on localism suggests a reduction in national, formal methods of research and knowledge exchange in the agricultural industry, in turn suggesting a much greater importance for informal networks to swap ideas and experiences from locality to locality. Such networks may be peer-to-peer based, like Facebook, rather than having the more formal structures of those such as LEAF, but will still allow the sharing of good practice around the world. Such networks may have great value in supporting the delivery of all ES from agricultural land.

Urban food production

The UK has a long tradition of growing food in urban settings, in gardens and allotments. However, in recent years there are new initiatives seeking to raise its importance. A new generation of urban food production projects and networks is appearing, following the example of Incredible Edible Todmorden[27], by using food planting as a way to bring communities together and enhance their resilience. On the technical side, LED light sources are becoming available that allow horticulture inside dark buildings, allowing large-scale food production inside warehouses and other structures. Architects are now starting to include vertical gardens and other structures to enhance provision of food, regulate water and temperature, and provide beauty. The current impacts of this intervention are largely cultural and social (Redwood, 2008), through the satisfaction gained through gardening and the creation of local social networks to support the local environment. Food production may be locally important to particular communities.

This intervention has the potential for substantial impacts on cultural services especially, under all scenarios (**Table 8.5**). The Nature@Work scenario envisages that urban food production becomes common. At the moment, the impact on overall provisioning is small, but this could grow over time in this scenario, especially as more urban food production techniques become available, though it will remain small compared with rural areas. It may reverse the current trend for concreting over gardens which will benefit water regulation by slowing run-off from urban areas, and may enhance

[27]http://www.incredible-edible-todmorden.co.uk/

the supporting service of soil formation through composting. The cultural and social benefits are likely to grow in coming decades, but could decline in the longer term as urban food production becomes more centralised and planned. Urban food production is likely to increase somewhat under Local Stewardship, not so much to increase food production, but rather to help develop local communities and social capital and enhance the sense of local sustainability. The main impact will be on cultural services, though there will be smaller increases of the others.

The World Markets scenario may witness increases in food production within urban areas, from specialist commercial units, including horticulture facilities in city centres serving the surrounding suburbs, keeping transport costs down. The trend towards more home and community based food production will continue, driven by the need for affordable food among the poor, rather than for cultural reasons. However, such gardens will still provide a wide range of ES. The National Security scenario suggests the extensive development of urban and peri-urban agriculture, replacing gardens, parks and keeping horses. The provisioning of food therefore increases substantially. The effects on regulatory services are variable, but may prove to be negative on balance, as large areas of urban and peri-urban grassland are brought into cultivation, releasing carbon from the soil to the atmosphere. The loss of public space and land for leisure will reduce cultural services, not least urban biodiversity.

Food labelling to encourage healthy diets

An important development in the agri-food industry in recent years has been the use of food labelling to help people choose healthy foods within a balanced diet, for example, using traffic lights to indicate levels of fats (n.b. as opposed to labelling addressing the food production system or provenance). While dietary labelling has the potential to impact on ES by changing the proportion of land use for livestock and for crops, any such effect cannot be observed at the moment. This labelling is an addition to information on provenance and the sustainability of the supply chain.

It seems less likely that this intervention is relevant to World Markets or National Security; in the former scenario, food labelling and advertising will be aimed at profit maximisation, though nutritional labelling could be used to support differentiation between brands, while in the latter, the agri-food system is directed at maximum self-sufficiency, not the quality of the food (**Table 8.5**). The Nature@Work scenario envisages improved nutrition and changes to diets away from animal to plant protein, driven in a top-down way. Food certification and labelling will be an important intervention to support consumer choices, potentially alongside policies designed to change the supply of different foodstuffs. The promotion of reduced meat and dairy consumption should reduce GHG emissions and the risks of diffuse pollution. Land requirements for food production may fall, with reduced risk of biodiversity loss globally, but possible local biodiversity loss locally due to under-grazing. The Local Stewardship scenario also envisages a healthier population, not least because of improved nutrition, again involving less meat consumption and consequent changes in land use. The role of labelling is uncertain in this scenario; it may be used as a way of communicating the nutritional value of foods, but it could also wither away as more emphasis is placed on local, informal food supply chains.

High frequency and resolution agro-environmental sensing

Larger farms and agricultural contractors are turning to information technology to guide how to manage crops, livestock and their environments, internal and external, indoor and outdoor. This intervention is a natural extension of precision agriculture, which uses satellite tracking, Geographic Information Systems and information technology in combination with agricultural machinery to better target the application of fertilisers, pesticides and other inputs. The use of higher resolution data allows much more rapid and accurate responses to threats to production, be they weather events, pest outbreaks or equipment breakdown. The technology is currently used by very few farmers, but is developing rapidly. It could have very high impacts on food production, by enabling adaptive management in response to weather extremes and outbreaks of disease. It will also support regulatory and supporting services by the fine-tuning of management to support efficient bio-geochemical cycling in agricultural soils, thereby improving water quality. In the longer term, this work may benefit biodiversity and other cultural services, by controlling the natural resources used for provisioning services.

This intervention has a place in all scenarios (**Table 8.5**). The Nature@Work scenario involves technological advances in agronomy, control of pollution and responsiveness to climate change. Improved monitoring of the agricultural environment supports all of these goals, and is consistent with the top-down development and application of technologies. The World Markets scenario envisages a shift towards intensive management of crops and livestock, which could be supported by high resolution monitoring of both the environment (outdoor and indoor) and the target organisms themselves. Whilst aimed at increasing food production, it is also aimed at increasing resource use efficiency, with benefits for regulatory services. Maintenance of supporting services will be of low priority under this scenario. The National Security scenario requires a shift towards more intensive food production, especially of crops, with less emphasis on cost-effectiveness than for World Markets. High resolution monitoring would be aimed at increased food production rather than for efficient resource utilisation, suggesting that there may be few impacts on non-provisioning ES. The Local Stewardship scenario suggests a move away from top down, high-tech approaches. While the use of high frequency sensing seems unlikely to thrive under this scenario, there are many potential roles depending on how the capital investment is structured and data are disseminated. An early example might be the use of apps using monitoring data to support decision-making for smallholders.

Research into spatial optimisation of agricultural land use

Agricultural land has always been organised spatially, taking into account both the capacity for production of particular areas and distances to markets. The desire to deliver multiple ES from landscapes poses a rather new challenge, which is how to optimise the spatial arrangement of different land uses. This is both a biophysical challenge (where to manage the land for different purposes) and a socio-economic one (how can an 'optimum' landscape be delivered that is appropriate to the many conflicting interests) (Firbank, 2005).

The creation of multi-functional landscapes is central to the Nature@Work scenario (**Table 8.5**). Such planned landscapes should maintain the provision of food, water and energy whilst enhancing other ES, including the regulation of water supply and the maintenance of cultural landscapes with

space for leisure, exercise and biodiversity. Decisions need to be made that take climate change into account (Lawton *et al.*, 2010).

The emphasis in the National Security scenario is to enhance self-sufficiency at the national level. Part of the challenge is to know which areas of land can be converted to (ideally, arable) food and bioenergy production, and so this intervention should enhance provisioning of food, energy and water and those regulating services essential to the nation (not least, reducing flood risk). If spatial optimisation is introduced at a large spatial scale, the changed patterns of land use may well redistribute cultural services away from the more productive arable land, with the potential loss of certain valued landscapes. These trends could increase over time.

Under the Local Stewardship scenario, decisions on ES provision are delegated to local levels. If landscape optimisation research is to be applied at all, it may be for particular localities of complex landscapes and social needs, for example the Lake District, where it may be used to inform the development of multi-functional land use plans, or in and around cities, where land is allocated for food production. **Table 8.5** suggests that this intervention will result in some improvements to all ES, but there is much uncertainty (**Figure 8.3**). Under the World Markets scenario, land use is driven purely by the market place; research into optimal patterns of land allocation is therefore not relevant.

Research into climate change adaptation in agriculture

UK weather patterns are in flux (Francis & Vavrus, 2012), and research is required to ensure that food production can be maintained under the more variable weather patterns that are expected (Pretty *et al.*, 2010). However, such research has had little impact as yet on UK farming systems (**Table 8.5a**).

A central feature of the Nature@Work scenario is enhanced resilience to climate change, enabled by scientific research and innovation (**Table 8.5b**). Such research will need to encompass the resilience of plant and animal growth, as well as secondary effects of climate change, such as increased fluxes in plant and animal diseases. This is expected to have a highly beneficial effect on the provisioning of food and bioenergy compared with levels of production in the absence of this intervention, but they could still be lower than at present. A more climate-resilient agriculture in the UK will reduce the potential pressure on ES in other parts of the world. It will also benefit regulation of water and support nutrient cycling, as water becomes more scarce (at least in some places and at some times) and methane and N_2O emissions are curbed by regulation. The improved efficiency of water use may benefit biodiversity and access to rivers and lakes in the future, by reducing the extraction of surface waters. In the longer term, there is scope for enhancing the supporting service of crop photosynthesis through genetic modification.

The requirement to maintain national levels of food production are paramount under the National Security scenario, and so support for research into agricultural adaptation to climate change will be strong. While the initial boost to food production expected under this scenario is due to land use change, research will make an increasing contribution to food production later this century, possibly by enhancing tolerance to extremes of drought and temperature. The focus on cost-efficiency will

reduce waste and therefore will enhance some regulatory services. This intervention will have no effect on cultural services, as landscape changes will take place regardless of this kind of research.

The priority to enhance food production under climate change may be lower under the Local Stewardship scenario than Nature@Work and National Security, not least because of the very small population growth rate, but it still remains. However, its focus will be on maintaining soil function and resilience, rather than through high-technology approaches to genetics, precision farming and livestock housing. This intervention will yield small improvements in provisioning, supporting and regulating services that may increase over time.

Adaptation to, and mitigation of, climate change are not priorities in the World Markets scenario, so this intervention will have little effect on any ES. Adaptive capacity to climate change may be restricted to changing crop and livestock types. Food production may well fall over time, with the shortfall in demand made up by imports, a situation that may not prove stable.

8.A4.2 Forestry

Forestry has been a focus for policy for the past century. Only 5% of woodland cover remained in the UK in the early 20th Century, and the lack of timber supply during wartime created policy imperative to build a strategic reserve. This resulted in the establishment of the Forestry Commission in 1919, and the initiation of a substantial afforestation programme through state and private planting which was maintained over most of the 20th century. Woodland cover has increased from 5% in 1924 to 9% by 1980 and is now 13% (Quine *et al.* 2011).

During the latter half of the 20th century, a series of legislative and policy changes shifted the goal for forestry away from simply provisioning towards a mix of ecosystem services. This shift was in response to concerns over impacts of new forests on cultural landscapes and on designated species and open habitats, the relevance of a strategic reserve in a nuclear age, and opportunities for enhanced public good from a land use which did not offer high rates of financial return. The shift was described initially as multi-purpose forestry, and involved specific initiatives around increasing the broadleaved component, restricting expansion in valued landscapes (e.g. in upland England and the Flow Country), and enhancing protection afforded to the remnants of ancient woodland. This involved both regulation and incentive schemes. The Convention on Biological Diversity (and the expression of the ecosystem approach) stimulated the emergence of 'sustainable forest management' and multi-objective forestry was modified to require explicit consideration of environmental, economic and social objectives. Since then, policy development in Britain (and recently as devolved to the countries) has sought to support forestry that reflects the three pillars of sustainability, as well as to respond to the threat of climate change through mitigation and adaptation (Read *et al.* 2010). Most recently, with the arrival in the UK of a number of new pests and pathogens, tree health has become a focus of policy concern (Defra and Forestry Commission 2011).

The forestry policy for Scotland (Forestry Commission, 2006) embraces seven key themes and probably has the most strongly articulated economic objective. England (Forestry Commission, 2007) and Wales (Forestry Commission, 2008) focussed on ecological restoration and public good. In

England, a recent statement of policy has been published (Defra, 2013a), incorporating the response to the report of the Independent Panel on Forestry (IPF, 2012) and a review of regulations (Regulatory Task Force, 2011). The IPF was set up in the wake of controversy over proposals to sell off the public forest estate in England.

Sustainable forest management is the current paradigm within which forestry policy is articulated and the forestry sector operates, and has considerable overlap with the goals of an ecosystem approach and the development of ecosystem services (Quine *et al.* 2013). A variety of mechanisms have been developed to support the implementation of sustainable forest management and adaption to, and mitigation of, climate change. These include foundational measures, such as a strategy and funding for applied research, provision of knowledge and advice, professional bodies and societies; enabling measures such as legislation (including restrictions on tree-felling and conversion of forest land), forest policies, and the UK Forestry Standard; and instrumental measures such as a variety of financial incentives (both tax and grant aid, evolved with different targeting over the past decades), the development of voluntary certification schemes, and early steps to develop voluntary carbon markets (through derivation of a code of practice).

A subset of the current responses, across a range of types, response maturity and geographic focus, was selected for stress-testing. The results of stress-testing this subset of seven forestry response options are shown in **Table 8.7** and **Figure 8.4.**

UK Forestry Standard

Sustainable forest management describes a sectoral framework, consistent with the Ecosystem Approach (MCPFE, PEBLDS 2006), which seeks to explicitly consider environmental, economic and social objectives. The United Kingdom Forestry Standard (UKFS) was developed in 1998 to articulate the basis for sustainable forest management and provide a framework for the pursuit of multiple benefits, whilst minimising consequences on other environmental qualities both within and outside the forest boundary. The third edition of the UKFS (Forestry Commission, 2011) describes seven sets of supporting guidelines (biodiversity, climate change, historic environment, landscape, people, soil and water) which together contain 39 legal requirements, 59 requirements of good forestry practice and 316 elements for sustainable forest management. Forestry Commission approval of operations and payment of grants (e.g. for enhanced public access; nature conservation; protection of watercourses) depends upon conformity to the UKFS (see http://www.forestry.gov.uk/forestry/INFD-8BVECX).

In the stress-testing, this option appeared relevant within the Nature@Work, National Security and Local Stewardship scenarios (**Table 8.7**). The option appeared to have increasing relevance over time in National Security, reflecting the increase in state control and regulation, but decreasing relevance in the Nature@Work and Local Stewardship scenarios, linked to the shift from national to local decision-making and increases in private ownership and local economies. The option was associated with a positive effect on each group of services in Nature@Work and Local Stewardship, although this was associated with a moderate degree of uncertainty (**Figure 8.4**). However, within National Security the primary focus is on provisioning services 'with every last resource ... utilised for the provision of services', especially at the expense of cultural and supporting services. This option

appeared to have little relevance in World Markets, reflecting the lack of state control with 'reduced planning regulations on housing, agriculture and industry'.

Voluntary markets

The recently developed Woodland Carbon Code (WCC) seeks to underpin a voluntary market in carbon credits by providing a best practice guide for organisations, including businesses wishing to create woodland, to remove carbon from the atmosphere and mitigate their emissions. The Code is confined to woodland creation, where "additionality" can be proven, i.e. the planting (and carbon uptake) would not have happened without the income generated through the Code. Independent certification to this standard provides assurance and clarity about the carbon savings of these sustainably managed woodlands (see http://www.forestry.gov.uk/forestry/infd-84hl57).

In the stress-testing, this option appeared strongly relevant within the Nature@Work and World Markets scenarios, with increasing relevance over time in the latter (**Table 8.7**). It was associated with a positive effect on the delivery of provisioning services and associated regulating services, but a negative effect on cultural and supporting services. This reflects the focus of the option on a category of readily quantifiable services with clear financial markets. There was concern that potentially within Nature@Work, as reflected in the uncertainty score (**Figure 8.4**), this option may undermine community evaluation of multiple ecosystem services due to the quantifiable and financial focus on provisioning/regulating. This option was seen to have low relevance, and neutral effects, under National Security where the UK is an uncompetitive economy with a strong reliance on state support and a strong influence on regulation/intervention rather than voluntary measures. There would also be limited relevance under Local Stewardship where there is a reduced focus on economic activity and greater focus on local needs of the community and self-sufficiency.

Grant aid with specific spatial targeting

This response option considers the particular formulation of grant aid for new woodland creation that has been designed to encourage planting in specific geographic areas or with a particular spatial arrangement. This has been achieved by describing specific areas of interest (e.g. past challenge funds naming e.g. Buchan, or the woodlands in and around towns (WIAT) initiative in central Scotland) or describing by way of a scoring system (e.g. JIGSAW) or GIS tool (e.g. Highland Woodland Premium scheme), the benefits of location in close proximity to existing woodland (see e.g. Quine & Watts, 2009).

Interestingly, in the stress-testing this option appeared to have moderate to high relevance in each of the possible futures, albeit with declining relevance over time in the World Markets and Local Stewardship scenarios (**Table 8.7**). It was most relevant, and increasingly so over time, under National Security which places a heavy reliance on government subsidies to direct and control land use. Uncertainty for this option under the National Security scenario was considered to decrease over time as the influence of the national policies and plans provided a stronger context for it. In contrast, as the government is weak under World Markets and has little control over private businesses, this response option seems to have little place as government subsidies and support disappear by 2060 and market forces take over. Uncertainty around this scenario (**Figure 8.3**),

however, relates to the degree to which this option could be used to further reinforce the markets, further damage non-provisioning services, or attempt to protect other ecosystem services from market forces. The response was associated with mixed effects on ecosystem services (arguably reflecting interpretations on what it would be targeted) with positive effects generally within Nature@Work, but potentially negative effects on regulating, cultural and supporting services in World Markets and National Security.

Collaborative management groups

This response reflects a variety of arrangements that seek to achieve collaborative management across multiple ownerships (and large spatial scales); some are facilitated through public sector support whilst others are less formally arranged and constituted. For example, The Deer Initiative is a broad partnership of statutory, voluntary and private interests dedicated to "ensuring the delivery of a sustainable, well-managed wild deer population in England and Wales" (see http://www.thedeerinitiative.co.uk/). Another group, the Red Squirrels in South Scotland, have had both charitable and governmental support and have now combined with others to shift focus from regional to national collaborations (see, for example, http://www.red-squirrels.org.uk/about-us.asp).

In the stress-testing the collaborative management option appeared to have most, and increasing, relevance within the Nature@Work and Local Stewardship scenarios with positive effects across each group of services (**Table 8.7**). These scenarios place a strong emphasis on local collaborative management, evaluation and decision-making to meet local needs. This option was considered to have little relevance and no effect on service delivery within World Markets and National Security – in both cases because greater forces (the market, the state) were considered to predominate.

Voluntary certification

Voluntary certification reinforces the standards described by the UK Forestry Standard (UKFS) and provides additional benefits of access to markets. The UK Woodland Assurance Standard (UKWAS) is a certification standard, independent of the UKFS, aligned with the Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC); see http://ukwas.org.uk/.

Interestingly, in the stress-testing this option appeared to have low relevance in all the scenarios, except for World Markets, but even here it was perceived to have declining relevance over time as regulation declines and global rather than domestic market forces take over (**Table 8.7**). Within World Markets it was perceived that this option could possibly give improved access to financial markets, whilst still protecting and maintaining a balance of other ecosystem services especially cultural and supporting (e.g. by maintaining the balanced approach previously described by the UK Forest Standard). Although it was seen as a potentially important mechanism within a free market, and with potential to protect a wider suite of ecosystem services, it was associated with high uncertainty (**Figure 8.3**); this largely related to the extent to which consumer demand would develop, national schemes would be maintained or have traction within a global market – or whether other standards would predominate, or even price and supply would be the main

influencing factors. The response was associated with positive or neutral effects on ecosystem services across the scenarios.

Community woodland groups and community forests

This response describes a variety of contexts and arrangements in which members of the local community have a say in the management of woodland; the community may or may not own the woodland. Ownership and governance reflect different traditions, national legislation and local aspirations (Lawrence & Molteno, 2012).

In the stress-testing, this option appeared to be most, and increasingly, relevant within Local Stewardship and Nature@Work, reflecting the shift towards more local-scale decision-making (**Table 8.7**). The relevance for this option was slightly lower in Nature@Work, than in Local Stewardship, as it was single-sector focussed and less integrated with other land uses and ecosystem services. The relevance for this option was perceived to be low in World Markets and National Security where financial markets and national control ruled, respectively. In the two scenarios where it was deemed relevant, the option was associated with positive effects across all groups of services, although with a stronger emphasis on service provision in Local Stewardship.

Knowledge exchange (advisory services and visits)

Forests and woodlands are owned and managed by a wide range of people (e.g. in England there are believed to be more than 60,000 owners) – some with strong professional knowledge in land management, but many with little or no knowledge. Provision of knowledge and advice – and particularly direct contact from advisers visiting the land in question, is considered to be an effective way of mobilising land management, improving standards, and drawing attention to the regulations and incentives with which management might be steered and encouraged (see Lawrence *et al.* 2010).

In the stress-testing, this option appeared to be most relevant within the Nature@Work and Local Stewardship scenarios where it would inform community evaluation of ecosystem services and underpin local decision-making (**Table 8.7**). In both these futures, the option appeared to have increasing relevance over time and a positive effect on each group of ecosystem services, especially within the Nature@Work scenario where 'balanced service provision is key'. However, within the Local Stewardship scenario it was thought the balance would be skewed towards provisioning services, in order to meet the local demand for timber and energy. In contrast, under World Markets, in which free market capitalism dominates, the option although of low relevance was perceived to have a potentially negative effect on regulating, cultural and supporting services as it would be targeted towards improved provisioning to meet the market economies. It was perceived to have low relevance and little effect under the centralised and regulated control of the National Security world.

8.A4.3 Biodiversity

Traditionally, policy initiatives in the biodiversity sector have had a strong emphasis on the role of protected areas (e.g. Natura2000, SSSI, etc.) to conserve key locations with high biodiversity value. Although this importance remains, more recent developments have seen a broadening agenda that also places more emphasis on the wider landscape (or seascape), such as the RSPB Futurescapes and the Wildlife Trusts Living Landscapes initiatives. Many areas outside the protected area network also have a significant biodiversity value, including the presence of priority species and habitats defined by the UK Biodiversity Action Plan and EU Habitats Directive[28]. Furthermore, as highlighted by the recent Lawton Review in England (Lawton *et al*. 2010), there is increasing recognition that the current protected site network may not be coherent enough to allow species movements in response to climate change due to the degradation and fragmentation of habitat in the wider landscape. Climate change is already having a significant impact on biodiversity in the UK and this is expected to substantially increase in the future, particularly in combination with other pressures such as land use change and pollution (Brown *et al*. 2012; Morecroft & Speakman, 2013).

This broadening of the policy agenda has led to a greater emphasis on initiatives that can enhance biodiversity by improving ecological integrity, functioning and connectivity in the wider landscape. This shift also acknowledges the fundamental interdependencies of biodiversity with other sectors, particularly agriculture in the UK as the dominant land use and through the role of agri-environment schemes in conserving biodiversity (e.g. Natural England, 2009). More recent initiatives include Nature Improvement Areas; the role of green and blue infrastructure, particularly in peri-urban areas; and explicit characterisation of the additional benefits provided by biodiversity through ecosystem services. These latter initiatives remain in the early stages, therefore, limited evidence is currently available on their implementation. In addition, there is increased policy support for initiatives to raise awareness of direct and indirect benefits, including via Local Nature Partnerships. At the international level, these developments are mirrored by the shift in emphasis provided by new agreements from the UN Convention on Biological Diversity, notably the framework established to redress past biodiversity loss by 2020 ('Aichi Targets'), which explicitly includes the wider benefits of biodiversity for human well-being.

A subset of the current responses, across a range of types, response maturity and scales, was selected for stress-testing. The results of stress-testing this subset of eight biodiversity-related response options are shown in **Table 8.9** and **Figure 8.5**.

Protected networks/Ecological networks

Ecological networks seek to (re)establish connectivity between natural or semi-natural ecosystems in order to overcome the problems of fragmentation, which can decrease habitat and species viability and increase their vulnerability to other stresses. They can also contribute to overall resilience to climate change by facilitating species' movements in response to climate change. They also can enable ecosystems to continue in their delivery of ecosystem services, although protected areas are set up for particular feature(s) of interest and are not managed to deliver a wide range of ecosystem

[28] The Habitats Directive now also requires status reporting of priority habitats from non-protected areas

services. Ecological networks may operate at a local scale, but they can also build upon existing protected sites, including Special Protection Areas, Special Areas of Conservation and Sites of Special Scientific Interest, which form part of the European Natura 2000 network. Some of the species and habitats which make up ecological, and especially protected, networks may be adversely affected by climate change and this may affect their delivery of cultural services in particular.

The stress-testing for protected networks/ecological networks showed a negative effect on provisioning services under all scenarios because of their use of land and the inability to use this land has an increasingly negative effect in 2060 under World Markets and National Security scenarios (**Table 8.9**). They do, by their existence, deliver some regulating services under all scenarios. These networks were particularly valued in Nature@Work for the delivery of biodiversity and ecosystem service objectives since by 2060 there is the "need to create multi-functional landscapes to maintain ecosystem services and quality of life". Under the World Markets scenario, the networks are not so important. Land competition for the delivery of provisioning services means that biodiversity loses out, and that the existing networks will have a severe impact on food production goals. Ecosystems within these networks will become increasingly important for the delivery of cultural services and other social benefits. As with Nature@Work, protected/ecological networks have a medium relevance for National Security, but they are important for delivering cultural services as provisioning services are prioritised on land elsewhere. They are less important under Local Stewardship than Nature@Work because cultural services are also provided by the more diverse landscape that comes from localisation. There is generally low uncertainty about the effects of this response option on ecosystem services given our knowledge about it and its current implementation (**Figure 8.5**).

Compulsory set-aside

Compulsory set-aside schemes were originally subsidised by the EU Common Agricultural Policy, primarily to take arable land out of production to reduce over-production. The benefits for protecting and enhancing biodiversity have been increasingly recognised (IEEP, 2008), whilst benefits from ecosystem services were transferred from a loss in provisioning services (specifically crop production) to gains in regulating and supporting services; implications for cultural services depend on the local context. Although set-aside schemes, as originally defined, would be compulsory, land managers can choose which land is taken out of production, therefore, this may not be the most suitable land to enhance ecosystem services. The gains for biodiversity and ecosystem services may therefore be localised or limited, meaning set-aside may be considered a more blunt policy tool than more targeted schemes. The benefits from such schemes are linked to subsidies to address 'income foregone', therefore, a key requirement is a continuation of subsidies. Recent changes in the EU Common Agricultural Policy that reduce the set-aside requirement from 20% to 0% highlights how priorities can change.

In addition to a requirement to provide subsidies to take land out of production, investment in monitoring and surveillance to ensure compliance is required. Analysis against the scenarios suggest that this commitment would be negated by a reluctance to pay subsidies in a free market (World Markets scenario), or a prerogative to maximise the productive capacity of agricultural land for food security (or for bioenergy) (National Security scenario) (**Table 8.9**). This commitment would be more

likely to be met in the Nature@Work or Local Stewardship scenarios, particularly if it was related to defined environmental outcomes. Expected changes in ecosystem services would likely be similar in 2060 compared to 2030, particularly if the set-aside land remained in a similar location on farms, but with more uncertainty.

Incentive-based agri-environment schemes (AES)

AES are a well-established response that provides annual payments to land managers for environmentally friendly practices (Natural England, 2009). Funding is provided by the national Rural Development Programmes supported by the UK Government (and devolved administrations) and the EU Common Agricultural Policy (CAP, Pillar 2). Agreements are voluntary and typically last for 5-10 years. Schemes are associated with rigorous monitoring to demonstrate value for money against scheme targets and to review good practice. Since the late 1990s, AES have increasingly been identified as key delivery mechanisms for the UK Biodiversity Action Plan, but can also provide protection for the historic and cultural environment (e.g. archaeology), and are increasingly linked to ecosystem services. An important requirement for successful AES is ongoing investment in R&D to establish a sound evidence base to review scheme design against net benefits, particularly in the context of responding to climate change. By comparison to set-aside schemes, AES have the potential to be more targeted and to facilitate coordination of landscape-scale initiatives to deliver wider benefits; the latter is particularly important for regulating ecosystem services, such as purification for water quality in river catchments.

Future scenarios which imply that central funding sources for AES may decline, either due to a decrease in the Common Agricultural Policy budget or national budgets (World Markets scenario) imply that there will be less schemes with a resultant overall impact on ecosystem services, unless schemes were substantially better targeted for maximum benefits (**Table 8.9**). In addition, a shift in emphasis towards agricultural production (National Security scenario) may divert some funding with similar implications. However, those AES that produce benefits for food/energy production, such as by protecting against pests and diseases, or facilitating pollination, would be likely to be specifically incentivised in the National Security scenario. In addition, requirements for initial investment in schemes in the prospect of longer-term benefits may not be fulfilled under all future scenarios. A key dependency is investment in shared knowledge-based systems to ensure schemes can adapt to change, particularly climate change. It is most likely that these conditions are fulfilled in the Nature@Work scenario, whereas successful schemes may be more localised in the Local Stewardship scenario as knowledge of adaptive management is less widely disseminated. Therefore, the stress-testing suggests that a key issue for AES is whether they can incorporate adaptive management within good practice.

Biodiversity offsetting

The application of Biodiversity offsetting is in its early stages in the UK, although established in other countries (e.g. USA, Australia). Key principles have been established (Defra, 2011a) and further implementation of schemes has been recommended by the Ecosystems Market Task Force (2013) with several pilot projects currently underway. Offsetting schemes are based upon the basic

principle of 'no net loss' of biodiversity, therefore if new developments cause unavoidable loss at one location, it is intended that this is compensated at an alternative location.

There are a variety of different types of offsetting schemes which differ in terms of important details. As biodiversity in its entirety is impossible to measure, a metric is used to provide a surrogate measure for biodiversity to provide a basis for the offset, but there are variations on this metric and how it is used. For the stress-testing exercise (**Table 8.9**) we have assumed a national-level scheme operating on a large scale to encourage market efficiencies and using a metric based upon 'habitat hectares' (Defra, 2011a). The habitat hectares metric aims to combine distinctiveness, quality (condition) and extent of different habitat types into a transferrable metric. Offset providers are required to deliver a number of biodiversity units to compensate for unavoidable losses from development.

As our knowledge of ecological processes is incomplete, there is no definitive guarantee that ecological restoration can deliver biodiversity gains. Furthermore, in assessing the change to ecosystem services it should be acknowledged that our knowledge of services is similarly incomplete, with the link between biodiversity and ecosystem services often a key uncertainty for the present-day, regardless of future change. A fundamental issue for offsetting is how this risk is handled, and the institutional framework in which it is managed. Therefore, although offsetting schemes may be particularly favoured by market-based futures (exemplified by the World Markets scenario), a characteristic of unregulated markets is that they may fail to deliver non-market goods and services. Therefore, the presence of weak regulation by the World Markets scenario may lead to the loss of cultural services and supporting services whilst market-based provisioning services would be likely to gain. By contrast a stronger regulatory framework could produce a more balanced offset as particularly exemplified by the Nature@Work scenario and the gains in regulating services in the National Security scenario. It is also possible that a large scale offsetting scheme whilst providing an efficient market may lead to neglect of local services because offsetting can occur over larger distances; this is likely to act against cultural services unless the value of these services are explicitly recognised as would particularly occur in the Local Stewardship scenario. This analysis highlights not only the risks that change has for offsetting schemes, but the importance of local context in the evaluation of offsetting. Delivery of 'no net loss' from offsetting schemes could be particularly challenged by high rates of climate change unless an associated scheme to manage this additional risk (e.g. compulsory insurance; habitat banking) is provided. This uncertainty would increase relative to the time horizon, therefore it is greater for 2060 compared to 2030 (**Figure 8.5**).

Land sparing

The idea of land sparing and land sharing is relatively new and they represent different approaches to combining biodiversity conservation and farming (e.g. Green *et al.* 2005; Fischer *et al.* 2008; Phalan *et al.* 2011). Land sparing involves the separation of high intensity farmland from (semi)natural habitats for biodiversity conservation, thus protecting them from agricultural expansion. The alternative strategy is land sharing, whereby biodiversity conservation is integrated into agricultural production on the same area of land. There is not such a sharp divide in practice with protected areas being towards the land sparing end of the spectrum and agri-environment

schemes, such as Environmental Stewardship in England, being towards the land sharing end. It is unlikely to be directed affected by climate change.

Land sparing was seen as having low relevance across all scenarios in 2030, although it could become more important for Nature@Work in 2060 as a means of achieving more balanced service provision (**Table 8.9**). This response option was assessed as having little or no effect on the provisioning services under National Security and Nature@Work , but negative effects for Local Stewardship as it involves the intensification of agriculture on some areas of land, while it could be positive under World Markets as it could encourage a more industrialised approach to farming. The intensification of agriculture was assessed as having a slight negative effect on regulating services, as certain areas would have high inputs, which would impact on soil and water quality and carbon storage, but these might be able to be managed under Local Stewardship leading to a positive effect. Cultural services were seen as being enhanced in 2060 under World Markets and National Security through the sparing of (semi)natural habitats, thus enabling the delivery of a wider range of services, such as recreation. There is mostly medium uncertainty about the effects of this option on ecosystem services as it is one that has not been tested in practice, with high uncertainty under Nature@Work related to how it might affect the desired balance of ecosystem services (**Figure 8.5**).

Voluntary quality-assurance schemes

Voluntary schemes provide a distinct alternative to statutory approaches or government-led economic incentives by emphasising the added value of goods or services associated with good environmental stewardship. Typically schemes are associated with a recognised marque that signifies a quality threshold and provides assurance to consumers, with the benefit that consumers may pay an extra premium or provide more business. Notable exemplars that emphasise benefits to biodiversity include the LEAF (Linking Environment and Farming) scheme (stress-tested in Section 8.3.3.1), the Forest Stewardship Council, and the Marine Stewardship Council, each of which has a wider international extension. However, other schemes also gain their value-added environmental credentials from association with a specific locality or landscape that has biodiversity value. Usually, participants must register to undertake a regular environmental audit to ensure good practice in order to be licensed to use the marque. Schemes require participants to undergo a regular environmental audit and may operate in tandem with, or independent of, government initiatives. If independent, then participants recognise a self-identified need to collaborate to establish minimum standards.

A key uncertainty would be whether such schemes could grow beyond small consumer niches in a completely unregulated free market and without major pro-environmental consumer behaviour (World Markets scenario), limiting the benefits for ecosystem services (**Table 8.9**). It is possible, however, that an increased emphasis on biosecurity and provenance of goods and services could act in their favour and provide a competitive advantage (National Security scenario), although it is likely that both government and consumer support would be most favourable in the Nature@Work scenario, thereby providing benefits across most ecosystem services with the possible exception of cultural services. In a more localised world, an emphasis on the value of local produce would be likely to be particularly favourable (Local Stewardship scenario) and this would be most likely to be also associated with a clear identification of the benefits from cultural services. Potentially, good

practice within these schemes could also be designed to incorporate adaptive responses to climate change whilst still maintaining quality standards. Well-designed schemes could deliver proportionately higher benefits in 2060 compared to 2030.

Nature-based partnerships

Nature-based partnerships are an enabling response option, which may include ecological networks and landscape-scale initiatives for enhancing connectivity, involve a range of actors, such as Government, statutory agencies and NGOS, and relate to policy directives or incentives. One of the most significant nature-based partnerships is the Local Nature Partnerships (LNPs) set up as an outcome of the Natural Environment White Paper, 2011. They seek to bring together a range of local organisations, businesses and people with an aim of improving the local natural environment, but also the (ecosystem) services for the economy and local people. Currently there are 48 LNPs in England, with a further two pending approval, but there is concern about their viability given the lack of funding which makes it difficult for them to gain traction and influence alongside similarly scaled bodies, such as the Local Enterprise Partnerships and Health and Wellbeing Board. Another nature-based partnership that has emerged from the Natural Environment White Paper is Nature Improvement Areas (NIAs). Their aim is similar to LNPs and is to ensure that land is used sustainably to achieve multiple benefits for people, wildlife and the local economy. Both are seen as operating at the landscape-scale. Given the different backgrounds of partnership members it is anticipated that considerable knowledge exchange will occur.

The nature-based partnerships are particularly relevant in the case of Local Stewardship where actions are undertaken at a local level (**Table 8.9**). Under Nature@Work they have medium relevance, as society seeks to regulate economic activity while minimising environmental externalities, as nature-based partnerships could have role in developing multi-functional landscapes. Under the other two scenarios the drive (World Markets) or need (National Security) for economic growth will make it difficult for the partnerships to operate effectively with balanced objectives. They could have no (Local Stewardship) or a negative effect on provisioning services as they seek to involve biodiversity objectives, though in some cases win-win or win-neutral outcomes are possible through adopting different production practices (Everard, 2009 and 2012a).They could have a positive effect on regulating services as land for biodiversity is maintained or enhanced. They will be important in facilitating the delivery of cultural services under all scenarios, but especially by 2060 in scenarios where nature is less valued, while the partnerships seek to ensure benefits to both for the economy and for people and wildlife. There is, however, high uncertainty as to whether they would be able to achieve this under the World Markets and National Security scenarios (**Figure 8.5**).

8.A4.4 Water

Water is the key resource underpinning all planetary systems and provides a myriad of services for society. The water cycle connects atmospheric, terrestrial and marine systems through various exchange, flow and storage processes (including groundwaters), but this supporting role can be readily degraded. Freshwaters are among the UK's most productive and naturally diverse

ecosystems. Water supply is the most obvious form of provisioning service for domestic, agricultural, industrial and power generation, whilst widely distributed ecosystems such as wetlands, rivers, floodplains and lakes provide multiple benefits including the regulation of floods and detoxification of polluted water. Enjoyed by millions, freshwaters are also a major source of cultural services because they play host to a diversity of wildlife and provide land and waterscapes.

Despite the centrality of water to all our lives, the integrity of freshwater systems has been neglected and once highly connected habitats are now widely fragmented and functionally compromised. Pressures on available supplies have risen steadily due to population growth, industrialisation and agricultural intensification. Regional variations in water consumption are high and likely to increase as demographic changes mean the UK population is increasingly concentrated in the warmer and drier southeast of Britain. Other key issues include increased flood risk associated with urbanisation and climate change, protecting native species diversity and providing more equitable access to the amenity and well-being benefits of healthy waterscapes (Maltby *et al.,* 2011).

The water sector has a crowded policy landscape with much new legislation introduced to help implement European-led legislation, including the EU Water Framework Directive (2000) and the Floods Directive (2007). What is especially noteworthy in relation to new policy and regulatory practice is the promotion of greater systems-thinking meaning a shift away from over-reliance on water quality measures and greater attention to the underpinning role of ecosystem services. It is widely recognised that restoring historically damaged habitats, controlling lingering problems around diffuse pollution from agricultural land and restoration of the natural flood buffering capacity of wetlands and floodplains can yield multiple benefits to society and the natural environment.

The subset of the current water sector responses, across a range of types, maturity and scales, selected for stress-testing is shown in **Table 8.11** and **Figure 8.6**.

Blue Networks

Blue networks are interconnected waterways comprising river channel corridors, lakes and wetlands that are augmented by connectivity with artificial water bodies including reservoirs, excavated and flooded pits and canal networks. A growing literature attests to the linkages between health and well-being and access to safe and clean water bodies. Miller *et al.* (2012) found the strongest evidence for salutogenic (health-giving) effects were on mental health and particularly psychological restoration. More generally access to water networks promotes well-being through 'quality of place and waterscape appreciation' and recreational benefits associated with active and passive water sports. In London the 'Blue Ribbon Network' was established by the Mayor's London Plan to give identity and enhance the Thames and its tributaries, the canal network, and other open water spaces, including docks and reservoirs which are water arteries running into, out of, and through the city (http://www.london.gov.uk/thelondonplan/). The Blue Ribbon Network celebrates the vital corridors and connections made possible along the network and establishes mechanisms to enhance their quality in expectation of improved amenity, economic attractiveness and multiple health and well-being benefits.

A response option of fostering the identity and supporting the quality, extent and connectivity of blue networks is likely to realise some gains in ES across all four scenarios considered (**Table 8.11**). Nature@Work and Local Stewardship would most likely promote the most extensive uptake of this option as there is improved understanding and general acceptance of the importance of ES, especially in the face of climate change. In World Markets the more materialistic and fragmented society would tend to suggest that there would be limited gains or declines relative to the current day and there would be limited political interest in pursuing the blue network agenda. National Security, on the otherhand, might be expected to achieve better outcomes because of the anticipated increase in water infrastructure provision, in particular, new reservoirs serving the growing population of southern Britain could be incorporated into blue networks with minimum resource expenditure.

Water Framework Directive

The European Water Framework Directive (WFD), introduced in 2000, promotes sustainable water management and management of ES (although not explicitly stated, e.g. mitigate the effects of floods and drought); it has at heart the ambition of sustainable water environments. The WFD places a statutory duty on all Member States within the European Union to restore degraded surface and groundwaters to at least 'Good Status'. Along with chemical compliance, this is essentially a measure of ecological integrity as measured against natural reference conditions. The WFD is an enabling response option and one of a suite of legislative frameworks (e.g. Wild Birds, Habitats, Nitrates and Floods Directives) promoting environmental protection and recognising that degraded surface and groundwaters need to be restored to reap the full range of ES benefits. Distinguished by its systems-based approach, the WFD is administered through River Basin Management Plans (RBMPs) that are reviewed on a six-yearly cycle, the overall purpose being to prevent deterioration, and where necessary protect and restore, water body status. The WFD has an important underpinning economic provision which asserts that the drive to achieve environmental objectives must be tempered against societal needs (enough affordable water of the right quality and in the right place) to provide provisioning, regulating and cultural services as required, but avoiding disproportionate and unsustainable mitigation/restoration obligations. Here, the responses under consideration reflect whether adequate funding and suitable governance structures are present to manage water resources in line with European legislation.

The WFD was hugely ambitious in conception and provides a suite of regulatory commitments that in theory should minimise differences in practice amongst the four NEA scenarios. **Table 8.11** suggests a broadly neutral response in relation to provisioning services, with the exception of the National Security scenario where increased water supply may be needed to underpin increased domestic food production. Under both the World Markets and National Security futures it appears likely that regulating, cultural and supporting services will all experience some decline. Regulation will be less strictly enforced under World Markets as government is characterised as being weak and the economy dominated by big business. Under National Security, regulation and enforcement might also be expected to be weaker, with provisioning (water supply at minimal cost) being prioritised over wider environmental considerations. By contrast, Nature@Work and Local Stewardship both promote gains in cultural services (amenity, recreation) coupled to gains in regulating function (water quality, flooding, biodiversity), with greater resilience achieved by

strengthening underpinning supporting services. Within Nature@Work society accepts there will be multi-functional landscapes.

Managing flood risk (natural flood management)

The environmental, economic and social costs of fluvial, pluvial (and coastal) flooding have been given prominence by a series of devastating flood events impacting Europe in recent decades. Floods in 2007 cost the UK approximately £3.5 billion, and, as a result of climate change, flooding events are likely to become more frequent, posing risk to UK infrastructure. Traditional responses to flood risk have emphasised structural defences (channel re-alignment, levees, upstream reservoirs, etc.) centred on high asset value infrastructure in the built environment. More widely, river channels and floodplains have also been extensively modified for flood control through construction of embankments and land drainage, whilst upland peat and lowland wetlands have been widely drained, funded through agriculturally-orientated 'land improvement programmes'. Following the Pitt Review (2008) the devolved administrations of the UK have enacted new legislation and required Statutory Authorities to develop comprehensive flood risk management plans and to explore more fully the potential of reducing flood risk through non-structural land based natural flood management (NFM) and Ecosystem-based Adaption (EbA) approaches (Iacob *et al.,* 2013). The fundamental response option being considered here is, therefore, to 'slow down the flow' by retaining water in floodplains and wetlands and, thus, restoring natural hydrological function at the landscape scale.

Managing flood risk will remain a key social and political issue in the future and in all the scenarios an increase in flood risk is unlikely to be tolerated, particularly under the threat of more frequent extreme flooding linked to climate change. Under Nature@Work and Local Stewardship grant-aid and government agencies will promote catchment-wide programmes on wetland function and restoring connections between river channels and their floodplains – leading to flood peak attenuation and reduced flashiness (increased time to peak) (**Table 8.11**). Such measures are likely to be resisted under National Security as the drive for increased food production is likely to result in greater land (including wetland) conversion to farmland and arguments for reconnecting floodplains and channels are similarly likely to be resisted. World Markets also anticipates major rises in food prices, especially towards 2060, encouraging continued or indeed extended agricultural focus on drained sites and floodplains which will continue the long-term degradation of floodplain soil quality, the simplification of habitat structures and resulting declines in wild species diversity. Under World Markets it is also likely that the social costs of flooding will be increasingly inequitable. The greatest burden will be experienced by the least socially and economically mobile parts of society living within present and future flood prone areas (both as a result of weak development control and rising insurance costs). Nature@Work will deploy scientific and technological advances to the fullest and links to Integrated Catchment Management (an option which was also stress-tested) where NFM is one element of a broader ecosystem-based adaptation agenda.

Water industry services (public water supply controls and demand-side measures)

The water industry provides drinking water and wastewater treatment to residential, commercial and industrial sectors of the economy. The UK water industry has over £250 billion invested in water infrastructure of varying age and condition and spends around £8 billion per year on capital and operating costs. Of this, at least £225 million is spent treating potable supplies for pesticides, nutrients, faecal organisms and erosion-derived suspended solids (LWEC, 2012). The water industry faces enormous challenges (and opportunities) in finding the lowest cost solutions that deliver a balance between supply and demand across different water zones. In the future it is likely that water companies will face greater financial constraints and duties to ensure security of water supply whilst complying with increasingly stringent greenhouse gas (GHG) emission control targets. Responding to changing demographic and demand patterns and promoting greater resilience against climate and other operational shocks are also major challenges. There is a broad consensus suggesting that consumer behaviour will be insufficient to avoid major new infrastructure developments. As a result, a combination of new supplies along with management of demand across all users are likely to be needed between now and 2060 (*cf.* UK Infrastructure Transitions Research Consortium, see http://www.itrc.org.uk/outputs/fta/water-supply/). Public water supply measures were stress-tested separately from demand-side measures.

Public water supply measures

Public water supply controls comprises high level investment in water supply infrastructure which includes *inter alia* reservoirs, inter-basin water transfer schemes, groundwater recharge and desalination as well as leakage reduction and in the future more water recycling plants. Individually or collectively these measures aid security of supply in both capacity and flexibility of resource use.

The World Markets and National Security scenarios both place a premium on increased provisioning (**Table 8.11**). Under World Markets it is envisioned that desalinisation plants would be located on the increasingly populous and drought-stressed east coast, with attendant energy implications necessitating a greater role for nuclear power. Impacts on aquatic environments (e.g. dealing with residual brines from desalination and water mixing through inter-basin transfers) are likely to be widespread. Under Local Stewardship ES provision would remain broadly stable relative to the present situation, whilst in Nature@Work there would be widespread adoption of low carbon innovations and technologies, including restoration of windmills for water lifting and recharging depleted groundwater storage. This conclusion also recognises there is likely to be widespread geographical difference in demand and that a few major infrastructure projects, carefully planned with industry-leading technology, would probably result in a national net gain in ES provision.

Demand side measures

It is estimated that 14 billion tonnes of water are abstracted annually of which 6 billion tonnes are for public water supply. Around 50% is used in homes (c. 150 L/person/day), 25% is leakage from pipe network and 25% is used by business. Agriculture accounts for around 1% of demand, thus the focus here is on public water supply as the dominant consumptive use of water. 'Future Water' the national water strategy for England suggests a reduction target of per capita consumption of 130 L/person/day by 2030 (Defra, 2008). Meeting this target will require new building and plumbing

codes to meet higher water efficiency standards, extension of metering where cost-effective and innovative new tariff systems. In the non-domestic sector, tax incentives (enhanced capital allowance) could be offered to businesses investing in water saving technology, allied to a programme of raising awareness and offering practical advice. Targets could also be introduced to promote reductions in water consumption across all supply chains, with water utilities having additional and regionally specific water efficiency targets developed by the regulator (Ofwat). Leakage targets could also be introduced with social and environmental costs augmenting hitherto exclusively economic appraisals.

In the stress-testing, Local Stewardship would advocate decentralisation away from a national water grid and promote greater local self-sufficiency (**Table 8.11**). However, this could lead to an increased vulnerability to shocks, particularly in the dry and increasingly populous southeast (perhaps causing increased service disruption in the 2060s). Under National Security the emphasis would more likely be on vigorous price and regulatory measures to reduce demand with added benefits of reducing energy use. Economic growth is generally low and society is less profligate which might encourage greater rainwater harvesting and reuse of greywater. Under World Markets it is not anticipated that ES would change relative to the present day, but under National Security economic growth is low and society is less profligate

Integrated catchment management

Integrated catchment management (ICM) is a progressive process for coordinating the sustainable development and management of water and land together and offers great potential to tackle the pervasive and persistent issue of diffuse water pollution. Distinguished from agri-environment schemes which reward individual farmers for good land management, ICM emphasises cooperation and partnership across whole catchments (Defra, 2013b). Key to this is identifying and characterising high-risk areas and tailoring management plans to remove sources and disconnect pathways yielding improved water quality and financial savings to landowners and downstream water treatment costs. 'Priority catchments' is a capital grant scheme funded by government and administered across 80 catchments by Natural England. Equivalent schemes similarly exist in Wales, Northern Ireland and Scotland to deliver the objectives of each country's first RBMP produced under the aegis of the WFD. In the private sector, 'Upstream Thinking' is the flagship programme of the utility company South West Water (SWW) aimed at improving water quality in order to reduce water treatment costs. Following early pilot study successes, the water regulator Ofwat approved SWWs spend of £10 million worth of capital works (2010-2015) for wetland restoration and farm pollution reduction on moorland and farmland not owned by the company, but expected to yield greater savings in terms of reduced treatment costs and wider benefits, including biodiversity gains, landscape and amenity improvements and reduced flooding equating to a cost-benefit ratio of 1:65 (http://upstreamthinking.org/).

Integrated catchment management schemes are knowledge-based (foundational) response options which promote a better understanding of the linkages between water quality and quantity, and system integrity. Top-down enabling mechanisms in the form of policies, institutions and governance are important, but education programmes also offer an important mechanism to change wider social attitudes. In terms of the stress-testing, ICM performs very well within Nature@Work and Local

Stewardship, with significant increases across the provisioning, regulating, supporting and cultural services (**Table 8.11**). Under World Markets, whilst there is no further decline in provisioning services, some expected loss of cultural services might be anticipated associated with land conversion to food production (e.g. biodiversity and amenity losses). The picture is, however, complicated by the example from the West Country where SWW are demonstrating that ICS can be commercially viable. Similarly, it might be anticipated that some of the gains achieved under Local Stewardship might well involve private-public partnerships where the local/regional markets can play a role through privately financed and managed schemes involving locally hypothecated funds to deliver projects.

Sustainable urban drainage systems (SUDS)

Sustainable Urban Drainage Systems (SUDS) seek to mitigate the environmental impacts of urbanisation and associated sealing of the land surface. SUDS comprise a suite of water management techniques designed to accommodate storm runoff generated from low permeability and sealed soils within urban areas more sustainably than simply routing traditional pipe and culvert runoff into a watercourse, or sewer. SUDS comprise three objectives: water quantity control, water quality treatment/improvement and provision of amenity (this could be for habitat, biodiversity, recreation, etc.). Such schemes typically involve the creation of urban ponds and detention basins for surface water storage with controlled slow release and sediment trapping; establishing wetlands and conveyance features such as vegetated swales to intercept sediment and promote pollutant filtration. Planning authorities and the SUDS Approval Body (SAB), recently established under the Flood and Water Management Act 2010, require compliance with national standards for new build schemes (Defra, 2011b). Great potential also exists to retrofit new SUDS schemes to existing developments, particularly those with surface water management problems.

Tighter development control can limit urban sprawl and continued soil sealing. Development potential inside urban areas can be used instead, for example, through the regeneration of abandoned industrial areas (brownfields). Mitigating measures include using permeable materials instead of cement or asphalt, supporting 'green infrastructure', and making wider use of natural water harvesting systems. Where on-site mitigation measures are insufficient, compensation measures that enhance soil functions elsewhere may be considered. SUDS are regulated under the Water Environment (Controlled Activities) Regulations (2011), since when there is a general requirement for new development to ensure that any surface water drainage discharges pass through approved SUDS schemes. Beyond the legally binding regulations there is clearly scope for spatial planning and developers to work together to ensure the water environment is protected. In terms of future-proofing, seeking to deal with the effects of climate change will necessitate retrofitting of SUDS into established communities (e.g. Counter's Street project; Environmental Agency and Thames Water) and the use of rain gardens to reduce flow into combined sewer systems.

It is anticipated that the adoption of such measures would be widespread under Nature@Work with advanced monitoring, modelling and sharing of best practice leading to significant gains in regulating, supporting and cultural services (**Table 8.11**). Under Local Stewardship local communities would also recognise the benefits of SUDS being adopted for all new build and most likely there

would be local programmes of water-centred urban regeneration schemes again with significant gains in regulating services and improved quality of place metrics from amenity, civic and residential property prices, i.e. waterside locations typically result in 3-5% property value lift. Under World Markets there are likely to be similar incentives to SUDS adoption as at present and no significant change in ES provision is anticipated, whereas under National Security a small improvement in regulating services with SUDS programmes may be considered a rationale response to the challenges posed by climate change.

River Trusts (environmental NGO-led action)

River Trusts are waterway societies, typically charities, established to manage catchments with a primary concern to maintain and enhance the fisheries interests. Scotland's river systems support one of the largest and most diverse Atlantic salmon resources in Europe, and anglers alone annually spend over £113 million and support the equivalent of c. 3,000 full-time jobs. The Atlantic Salmon Fishery Board (ASFB) overseas Scotland's 41 District Salmon Fishery Boards (DSFBs) and has statutory duties to protect and improve salmonid fisheries. The ASFB creates policies seeking to enhance fisheries by achieving wider environmental gains in habitat and biodiversity and so grow the economic benefits to the rural economy attributable to angling. The ASFB works closely with the Rivers and Fisheries Trusts of Scotland (RAFTS), the representative body for all Fishery Trusts in Scotland. Fishery Trusts promote research, monitoring, conservation, education, training, practical restoration work, and provide advice to fishery and riparian owners.

The key to this response option is the promotion of stakeholder engagement and community participation. Currently the most prominent example of progressive catchment management that is engaged in environmental improvements extending well beyond fishery interests is the West Country Rivers Trust (http://www.wrt.org.uk/index.html), which is achieving notable multiple wins in terms of habitat restoration, water purification, carbon sequestration and improved biodiversity. Such voluntary bottom-up schemes which rely on local cooperation and organisation translate well into the Nature@Work and, particularly, the Local Stewardship scenarios and the aggregate scores in terms of ES gain are very positive across all four service categories (**Table 8.11, Figure 8.6**). Under World Markets the role of the voluntary sector has only limited effectiveness and consequently is considered neutral in relation to the current situation. Under National Security the food production imperative would likely result in less conservation-orientated land management practices, e.g. greater use of agro-chemicals on larger fields and heavier farm machinery with consequent impact on biodiversity, landscape complexity and overall decline in cultural services.

8.A4.5 Urban, including energy and transport

A subset of the current responses, across a range of types, response maturity and scales, was selected for stress-testing. The results of stress-testing this subset are shown in **Table 8.13** and **Figure 8.7**.

National Planning Policy Framework (NPPF)

The NPPF is guidance for local planning authorities and decision-makers for drawing up plans and determining planning applications, and represents a radical overhaul of the previous planning process. It specially aims to simultaneously deliver sustainable solutions and growth. The framework does not deal with nationally significant infrastructure projects that are addressed under separate National Policy Statements (NPS) dealing with energy, transport, water, waste water and waste. Spatially the Framework only covers England, whilst the NPSs cover England and Wales with some impact in Scotland when the infrastructure crosses borders, for example, oil and gas pipelines. In Northern Ireland planning consent is devolved to the Northern Ireland Executive.

Whilst there is variation in the requirements of the planning processes across the UK, a commonality is the increasing recognition of the importance of early stakeholder engagement. There has been promotion of a culture change in the role of the public and communities in EU planning directives, such as the Strategic Environmental Assessment (SEA) Directive (2001) which is applied with a strong focus on sustainability and the environment. The Environmental Impact Assessment (EIA) Directive (2011) uses some ES language and includes the need to address the direct and indirect effects on climate. There is new guidance on integrating climate change and biodiversity into SEAs. Across the UK there is a growing recognition of the concept of 'place making' and the role and value of green infrastructure at differing scales within spatial planning. Planning practitioners are not currently using specific language associated with the Ecosystems Approach, but do use concepts and approaches which can be closely related to this approach. There is an appetite within the planning community to recognise and report the wider benefits of spatial plans (social, environmental, educational), but what is needed is the knowledge and structural capacity.

The stress-testing showed that at present the NPPF currently considers environmental benefits and recognises protection and designations (**Table 8.13a**). Provisioning services are positively recognised as economic development is a key driver in planning and development. Regulating services are also considered by SEA and EIAs, whilst cultural services are strongly taken into consideration through consultation and public acceptance, as well as through the social and educational benefits from development. Supporting services are addressed via climate change considerations. In terms of the scenarios, under Nature@Work, National Security and Local Stewardship, the planning process continues to have a positive effect on all categories of ES (**Table 8.13b**) indicating synergies with spatial and integrated planning response options evaluated under other sectors. It is assumed that SEAs and EIAs would continue to be pragmatically applied leading to continued positive effects on regulating, cultural services and supporting services. In contrast, under World Markets, the NPPF would not operate as it does under present conditions due to weak government, leading to a score of low relevance and neutral to negative impacts for provisioning and supporting services as time progresses from 2030 to 2060.

Energy related EU legislation

This response option has been considered in broad terms and includes consideration of the effects of several EU directives. Some of these are introduced briefly below prior to description of the response scoring.

The Large Combustion Plant Directive (2001) introduced measures to regulate the emissions of oxides of nitrogen, oxides of sulphur and particulates from combustion plants that have a thermal input of over 50MW. The aim of the directive was to reduce the emission of these pollutants to the air since they can cause harm to human health and the environment. The Energy Efficiency Action Plan 2011 is part of the EU commitment to the 2020 vision where consumption of primary energy is reduced by 20% by the year 2020.The action plan proposes that economies should be developed in a way that acknowledges the limitations of the global resources, use low carbon systems, maintain energy independence and understand the key issues of future energy security. 2009/28/EC promotes the usage of energy from renewable sources which is to be delivered by Member States renewable energy action plans. For example, delivery in Scotland is promoted by the 2020 route map policy proposing that 100% of Scottish electricity demand and 11% of the heat demand will come from renewable resources by 2020. Rapid advances are being made in technology and application of renewables, but there are recognised limitations and barriers to delivery, some of which are likely to have negative impacts on marine and terrestrial habitats.

Whilst the need for provision of energy will be highly relevant under all scenarios, the means of its production and delivery alter considerably under each scenario (**Table 8.13b**). Key to the allocated effects scores (notably neutral under National Security and neutral to very negative under World Markets) is the reduced relevance and /or implementation of EU legislation due to weak government and exploitation of national energy reserves, respectively. With respect to Nature@Work, ES provision of resources for energy production will be valued (biomass production), with implications for response options within water, forestry and agriculture sectors associated with the need to balance the energy/water/food nexus. In the Local Stewardship scenario increased common law and common resources agendas within this scenario may promote and support community co-production of energy and food crops (again highlighting cross-sectoral issues with regard to agriculture). Combined heat and power from multiple fuels at a local or community scale could increase in importance, but again (for these scenarios) this falls outside the influence of the EU legislative scope. The certainty/uncertainty associated with this scoring is derived directly from the scenario descriptions in terms of the relevance of EU legislation under these potential futures (**Figure 7**).

Multi-functional green infrastructure (GI)

Providing opportunities for cross-sectoral linkages with the response options considered for the water sector, such as blue networks and SUDS, a 'green grid' is defined as an integrated network of green (e.g. parks, allotments and gardens), blue (e.g. rivers and waterways) and open (e.g. green belt) spaces. Development of the All London Green Grid (ALGG) is cited as central to London's approach to the 'provision, enhancement and management of GI'. Its associated spatial planning guidance advocates an integrated approach to the delivery of GI by boroughs, developers and communities to enable a range of benefits to be derived ranging from sustainable travel, flood management and healthy living, to creating distinctive destinations with the economic and social uplift these support. In Scotland, the Glasgow and Clyde Valley Green Network Partnership (GCVGNP) was developed as an output of a spatial development plan which recognised that whilst GI is an essential part of planning, capacity to implement the approach was lacking. Work undertaken by the GCVGNP has included opportunity mapping (measuring the distance between where people

live and the nearest green space), as a strategic approach to identifying and prioritising locations for new green spaces. However, while the recognition of the need for GI is growing (e.g. Scottish Government, Defra, Royal Town Planning Institute and Chartered Surveyor have issued statements on it use), its application still often 'falls over' at the construction stage (i.e. designed out) as GI is a concept in guidance rather than policy.

Although operating at different geographic scales, the relevance of this response option is considered high under Nature@Work and Local Stewardship and medium under National Security where the primary drivers are valuing nature and making better use of its goods and benefits (**Table 8.13**). It is considered to be of low significance under World Markets where it is assumed the consumerist society would value nature less and opt for technological as opposed to green responses. Under World Markets, this response option is predicted to have a neutral impact on the delivery of supporting services under the 2030 and 2060 timeslices, associated with the assumed low uptake of GI. In contrast, the higher level of implementation of GI under the Nature@Work, National Security and Local Stewardship scenarios is predicted to have a positive impact on the delivery of all categories of ES driven by the fact that working sustainably with nature is a policy priority (Nature@Work and Local Stewardship) and pragmatic necessity (National Security). Uncertainty in this option centres on unknowns in relation to how quickly (if at all) GI would be implemented in reality, and what types would be socially acceptable under differing scenarios (**Figure 8.7**). Ownership and 'adoption and maintenance' of infrastructure elements is a key aspect of this option and will have to be resolved in terms of ES provision and benefits both currently and under 2030 and 2060 time frames.

Art, humanities and culture projects

Many local art, humanities and culture projects exist. At a national level the Arts and Humanities Research Council (AHRC) are leading a cross research council funding programme called 'Connected Communities'. The programme is designed to build upon, and complement, the existing substantial body of Research Council-funded research on community-relevant issues. One area of focus for the programme is Communities, Cultures, Environments and Sustainability (established in 2012). The collaborative project SPARKS (Social Parks) was an AHRC Connected Communities funded project that supported the production of a film about users of a small urban park in Rawmarsh, Sheffield. 'A day in the life of a park' involved filming and interviewing local park users about their likes, dislikes, memories and hopes for their park. The film was professionally produced and had its 'premiere' within the park where it was projected onto the side of a youth centre at night. This is just one example of many community arts projects with an environmental or sustainability focus. At present, AHRC and Arts Council initiatives exist to promote art and environment projects (**Table 8.13a**). Many local initiatives are also running with respect to local authority agendas and city of culture bids, etc. The benefits of these initiatives include raising awareness of issues and conflicts, knowledge exchange, capacity building, and increased social capital.

The stress-testing indicates a weak to strong positive impact on the delivery of cultural services under all scenarios and both timeslices, which is associated with knowledge exchange and capacity building as activities that are associated with cultural and art projects, helping to found more cohesive community partnerships and networks (**Table 8.13b**). A neutral impact on other categories

of ES is predicted under all scenarios for 2030, with predicted neutral impacts reported for 2060 under World Markets and National Security scenarios in-line with these scenarios comparatively limited enthusiasm for these types of options. In direct contrast, embedding of equal environmental and social equity values over time under Local Stewardship and Nature@Work impacts on environmental management measures implemented, leading to the transition from neutral to positive impacts over time. There is uncertainty as to how this option will play out over longer time periods as some initiatives are started and will succeed whereas other fail for reasons that are not fully understood at present (**Figure 8.7**).

Urban ecosystem assessments (including valuation studies)

The term urban ecosystem assessment (UEA) relates to the 'ecosystems within cities' scale category as defined under urban environmental transition theory (Piracha & Marcotullio, 2003). In keeping with this, UEA, as considered here, focuses on an assessment of the services, goods and benefits associated with urban green spaces, such as parks and waterways, and the impact of their valuation on their delivery. Relevant UK urban local scale examples include the evaluation and valuation of the benefits derived from the Mayes Brook River restoration programme (Everard *et al.*, 2011) and the current work being undertaken by CIRIA (Construction Industry Research and Information Association) with regard to putting a monetary valuation on the ecosystem services, goods and benefits generated by sustainable urban drainage systems (SUDS).

Whilst the Ecosystems Approach is not primarily an economics tool, as with climate change, 'putting a value on nature' has propelled the concept up both policy and economic agendas around the world. Policy-makers are familiar with the idea of valuation, comfortable in using economic arguments to inform and justify policy decisions and, hence, the development of economic metrics which support ecosystem sustainability appears to be a productive way forward. Likewise, as businesses begin to adopt the payments for ES approaches, a cascade effect can be imagined whereby recognition of the economic value of ecosystems drives forward environmental protection from local to international scales. Although discussions with stakeholders indicate that at present many view the ES approach as a complicated cost-benefit analysis, further hampered by the lack of a standard methodology, the work of TEEB and the UK NEA are helping to mainstream the economics of ES and their use within both policy-making and business environments.

As with GI, UEA is predicted to have a positive impact under all categories of ES under Nature@Work and Local Stewardship. In contrast, whilst positive impacts on provisioning and regulating services are predicted under National Security and World Markets, neutral impacts are predicted with regard to cultural services (both scenarios) and supporting services (national Security only) in-line with this scenario's focus on economic necessity over environmental concern. With a focus on multi-functional use of urban green and blue spaces, there are clear cross-sectoral synergies between this response option and selected response options explored under agriculture (e.g. urban food production) and water (e.g. blue networks, SUDS).

Sustainable modes of transport

The Renewable Energy Directive sets a goal for a 10% share of renewable energy in transport by 2020 in order to achieve overall emissions reductions of 34% on 1990 levels. In 2011, the EC White Paper entitled "Roadmap to a Single European Transport Area" adopted 40 initiatives to improve mobility and achieve a 60% reduction in greenhouse gas emissions from transport by 2050. The goals include removing conventionally fuelled cars in cities, increased use of low carbon fuels in aviation, reducing emissions from shipping, and shifting medium distance and freight travel from road to rail or waterborne transport. The Scottish Government's Climate Change Delivery plan seeks to deliver significant decarbonisation of road and rail transport by 2050 through improvements in technology and infrastructure, and encouraging greater use of public transport and active travel in partnership with groups such as Sustrans.

The stress-testing considered the impact of sustainable transport in terms of the direct impact on ES and the direct influence of technological innovation. The stress-testing showed that at present sustainable transport is seen as desirable and is promoted in current policy (**Table 8.13a**). As with the arts, humanities and culture project and UEA response options, predicted impacts on ES indicate similar impacts under both Nature@Work and Local Stewardship scenarios, and similar (although different to the former scenarios) impacts under National Security and World Markets. For example, under Nature@Work and Local Stewardship scenarios positive impacts are reported on all ES, with the exception of supporting services in both cases where the impact is considered neutral in-line with their pragmatic, more efficient use of natural resources and emphasise on meeting local agendas, respectively. Under World Markets and National Security, impacts are generally predicted to be neutral, with any adoption of sustainable transport initiatives having associated impacts on reducing levels of air pollution with associated positive effects on the delivery of cultural services. Uncertainty considerations for this option include the availability and cost of fossil fuels within the time frame, also the availability of land and/or marine environments for biomass production (**Figure 8.7**). The lead time for technologies from development to implementation is also uncertain and may exceed the period of interest considered here.

Technology to deliver water saving to urban dwellings and industry (on-site greywater re-use)

The use of technology to reduce our energy, carbon and water footprints is seen by many as a smart way to achieve enhanced environmental performance without compromising on product performance. A local UK example of this instrumental response is the on-site use of greywater as an alternative to public mains water supply, which can contribute to meeting a range of non-potable uses in the home, workplace and garden. As greywater systems become more popular, there is a need for standardisation to protect the public and to ensure that reliable systems are designed, installed and maintained. To support meeting this need, British Standards published BS 8525-1:2010 Greywater systems - Code of practice in 2010.

The use of technologies as a generic response option is considered highly significant under all scenarios and timeframes, being of potential value and utility in supporting achievement of a diverse set of goals. However, the stress-testing as presented in **Table 8.13** specifically focuses on the use of on-site greywater re-use, with this example highlighting the fact that a highly relevant response option may have limited impact on ES delivery on a case by case basis. The general trend for impacts on ES under all scenarios is one of weakly to strongly positive associated with increased efficiency of

water uses and knock-on effects on the functioning of the water cycle. An exception to this is the impact on cultural services (allocated neutral under all scenarios), due to the negligible impact of an indoor piece of technology on the delivery of cultural services by outdoor environments.

Research on planned adaptation to climate change in urban areas

Research into planned adaptation to climate change – potentially leading to knowledge exchange, sustainable management of ecosystems and development of new technologies - could have a significant impact on the delivery of ES. Currently significant levels of EU and research council funding are committed to identifying and assessing the performance of solutions to anticipated climate change impacts. In this area of research transdisciplinary approaches are increasingly important, and some co-funding research opportunities which cross scientific disciplines are emerging. However, more is needed in order to marry traditional scientific studies focused on specific disciplinary areas (and necessary to meet ambitious university-driven targets) with new research in emerging transdisciplinary areas of ES research. This is an issue which needs to be addressed as the research area develops to ensure it continues to attract high-quality researchers.

Allocated a high or medium relevance under all scenarios, the focus of this option on tackling climate change concerns resonates strongly with the ethos of valuing nature's resources, leading to highly positive impacts on the delivery of many ES under Nature@Work and Local Stewardship scenarios (**Table 8.13**). Whilst research is valued (and therefore relevant) under the World Markets scenario, the impact of research on planned adaptation is neutral across all categories of ES for 2030 as there is little initial interest in, or implementation of, adaptation research within a materialistic society that assumes it can 'buy its way out of trouble'. However, it is assumed this situation changes due to, for example, the high demand for water, driving new and innovative thinking, leading to renewed interest in adaptation approaches and associated weak positive impacts on ES by 2060.

8.A4.6 Marine and coasts, including fisheries

Marine and coastal environments provide a range of important ES that contribute to human welfare (Austen *et al*., 2011). In recognition of the ongoing degradation of marine and coastal systems, significant policy development has occurred over the past decades to support sustainable development of the marine environment. The European Union has competence for many aspects of the marine environment including for fisheries, nature conservation and wider environmental protection. Many of the policy drivers therefore stem from European Directives and Regulations, for example the Common Fisheries Policy, the Marine Strategy Framework Directive, Water Framework Directive and the Habitats and Wild Birds Directives. At a national level, the UK Marine & Coastal Access Act 2009 (and Marine (Scotland) Act 2010, the Northern Ireland Marine Bill and enabling regulations in Wales) provide a new framework for marine management in UK seas. Ongoing implementation of European and national legislation over the coming decades has the potential to deliver significant improvements to marine and coastal environments and the ES that such environments provide.

Significant features that increase the challenges of effective management in marine environments relate to the relative lack of scientific understanding of marine environments and the openness of

marine systems which both contribute to uncertainty. In addition, the nature of ownership rights, for example, common law rights of navigation, the lack of rights-based fisheries and limited seabed ownership rights, serve to compound the management challenges.

A subset of the current responses, across a range of types, response maturity and scales, was selected for stress-testing. The results of stress-testing this subset of nine marine and coastal (including fisheries) response options are shown in **Table 8.15** and **Figure 8.8**.

No-take zones

No-take zones and marine reserves are intertidal or subtidal areas in which the environment is protected. They can be used as tools for fisheries management to protect part of a fish stock, spawning or nursery area, or they can be used to protect other features of the natural, cultural or historic environment. They can contribute to the provision of multiple ES, including biodiversity, tourism, cultural/aesthetic and provisioning services, although quantitative assessments of their benefits are lacking. A network of marine protected areas (MPAs), Marine Conservation Zones (MCZs), is to be established in English waters under the Marine and Coastal Access Act 2009, with the first tranche established by 2013. Recommendations for Scottish nature conservation marine protected areas are expected in 2013 and similar initiatives are being taken forward for waters off Wales and Northern Ireland. The application of Article 6 of the Habitats Directive to fisheries may also result in the reduction or removal of fisheries pressures in Special Areas of Conservation.

No-take zones are likely to be more relevant under Nature@Work and Local Stewardship, although the contribution of such zones to ES provision on their own is likely to be limited (**Table 8.15**). Such schemes may have greatest influence under Local Stewardship and Nature@Work owing to a supportive environment and could contribute to a wider range of services. While the supply of provisioning services would be expected to increase, the final benefit that humans derive from the service might decrease, at least in the short-term, to facilitate ecosystem recovery. Effects under World Markets and National Security are likely to be limited. In the former, the number, size and level of protection afforded to both fisheries no take zones and MPAs could be reduced. Under the latter, while fisheries no take zones might be supported to help maximise fisheries production, there may be less support for MPAs. Expected outcomes would be broadly similar in 2060 compared to 2030; some enhanced benefits could be observed beyond 2030 depending on the rate of fish stock recovery, particularly under Nature@Work and Local Stewardship. Uncertainty for all scenarios is assessed as medium (**Figure 8.8**).

Conservation measures in fisheries

There are innovative approaches to fisheries management which provide incentives for the fishing industry to adopt sustainable fishing practices. For example, the Scottish Conservation Credits Scheme rewards fishermen with extra days at sea in return for reductions in cod mortality, as part of the cod recovery plan. If they use a larger mesh size they receive more days at sea; if a vessel enters a seasonal closure put in place to protect spawning cod aggregations, it loses days at sea. A catch quota scheme provides vessels with a higher quota, if no discards are made (monitored through

CCTV). The proposed reform of the Common Fisheries Policy is likely to allow social and environmental criteria to be used for the allocation of fishing opportunities.

Conservation measures would be expected to be of low relevance under World Markets, but more relevant under Local Stewardship, Nature@Work and National Security, reflecting stronger support for environmental objectives under Local Stewardship and Nature@Work and the necessity of maximising fisheries production under National Security (**Table 8.15**). They are likely to provide no to limited benefit under World Markets and National Security, but could contribute more significantly to enhancing the supply of provisioning services under Nature@Work and Local Stewardship, although exploitation of fish resources may decline initially to support stock recovery. Expected outcomes would be broadly similar in 2060 compared to 2030 with possibly some greater benefit in 2060 as a result of ongoing recovery of fish stocks. Uncertainty for all scenarios is generally assessed as medium.

Marine Plans

Marine Plans guide decision-making for planning with a view to managing and balancing the many activities, resources and assets in the marine environment, aiming to ensure a sustainable future for coastal and offshore waters. A system of statutory marine planning has been established under the Marine and Coastal Access Act 2009 (and the Marine (Scotland Act) 2010, the impending Northern Ireland Marine Bill and secondary legislation for Wales), and will provide a comprehensive set of plans for UK seas. The first Marine Plan (East of England Marine Plan Areas) should be published in 2013, and the full set (for England) should be ready by 2020. Marine Plans will provide greater certainty to developers (offshore wind farms, wave power, etc.), but there are concerns whether they will be able to deal with cumulative effects and, hence, be able to manage trade-offs between sectors. It is also unclear how uncertainty will be addressed in the context of the precautionary principle. ES are not explicitly addressed. Marine planning provides a statutory framework for delivering policy objectives for the marine environment. Plan policies will therefore be important in guiding marine licensing and management decisions. Significant learning is expected to occur through the sequential process by which plans are developed.

Owing to the statutory nature of marine plans they are likely to be highly relevant in the Nature@Work, National Security and Local Stewardship scenarios where national and local governance is strong. They are also likely to have a significant influence on the state of marine and coastal environments as they are a material consideration for development decisions and, thus, would have a large effect on future ES provision under all scenarios. However, marine plan objectives (and the accompanying policies) are likely to differ under the alternative scenarios reflecting different economic, social and environmental priorities. Under World Markets and National Security, economic objectives related to provisioning services may be prioritised over environmental and social objectives leading to a long-term diminution of regulating, cultural and supporting ES provision due to damage caused by a focus on extracting abiotic services, such as oil, gas and aggregates (**Table 8.15**). In contrast under Nature@Work and Local Stewardship, marine plan policies could support delivery of significant ES benefits across all categories. Expected outcomes would be broadly similar in 2060 compared to 2030. Uncertainty is generally assessed as being at a medium level, as marine planning is still in its infancy (**Figure 8.8**).

Managed realignment

Managed realignment allows the sea to breach flood defences, either in a controlled or an uncontrolled way, to enable intertidal habitats to be recreated. This allows the restoration of various ES, including carbon sequestration through the creation of saltmarsh habitat, flood protection, biodiversity, fish recruitment and recreation/tourism. The first managed realignment sites were established in 1991 and over 50 sites currently exist. Implementation is expected to increase, partly in response to climate change and sea level rise.
Managed realignment is likely to be more relevant under Nature@Work and Local Stewardship owing to the more supportive climate for the option, for example, governance structures and social and environmental priorities (**Table 8.15**). Effects are likely to be minor under all scenarios owing to the relatively limited scale at which managed realignment is undertaken (compared to existing intertidal extent). Greater reliance on hard defences under World Markets and National Security may mean that little if any managed realignment is delivered under these scenarios except where it offers a strong cost-benefit return tied to the profitability of a few marketed services. Expected outcomes would be broadly similar in 2060 compared to 2030. Uncertainty for all scenarios is generally assessed as medium (**Figure 8.8**).

Beach nourishment

Beach nourishment or beach recharge involves the importing of sand or gravel to make good losses due to erosion. Nourishment schemes can vary from a few truckloads to repair a blow out or other small eroded area up to multi-million pound schemes requiring sea delivery of sand dredged from the seabed. A wider beach can reduce storm damage to coastal structures and provide coastal protection from storm surges and unusually high tides. Beach nourishment is typically a repetitive process, since it does not remove the physical forces that cause erosion, but simply mitigates their effects. It also provides amenity, tourism and recreational value.

The relevance of beach nourishment is considered to be low under all scenarios owing to its spatially limited application (**Table 8.15**). Under Nature@Work and Local Stewardship it is possible that beach nourishment could make a minor contribution to natural hazard protection (regulating service). Under World Markets and National Security, reliance on hard defences could require a significant expansion of beach nourishment programmes to protect these hard defences. While this could contribute to natural hazard protection (regulating service), it could also have negative impacts on other provisioning, regulating and some cultural services, for example, nature watching. Effects may increase over time if climate change also increases demand for beach nourishment. However, given the relatively low relevance of beach nourishment, effects in 2060 are still considered to be minor. Uncertainty for all scenarios is assessed as medium in 2030, increasing to high for 2060, reflecting the uncertainty of climate change impacts.

Certification (fisheries and aquaculture)

Certification of fisheries and aquaculture are independently-monitored schemes that verify that an individual fishery or aquaculture operation meets a set of pre-defined standards, that may be

environmental, social or both. Participation in such schemes is voluntary on the part of the fisheries/aquaculture operations involved, but they are market-based mechanisms which aim to create incentives for consumer purchasing decisions. They may be local (an individual aquaculture farm or inshore shellfish fishery) to regional (e.g. a North Sea fishery with multiple stakeholders involved).

Certification schemes are likely to be more relevant under Nature@Work and Local Stewardship, although the contribution of such schemes to ES provision on their own is likely to be limited (**Table 8.15**). Such schemes may have greatest influence under Local Stewardship and Nature@Work owing to a supportive environment and contribute to a wider range of services. They may also have some relevance to World Markets, although under this scenario and National Security the benefits may be very limited as there is likely to be a focus on the quantity of fish harvested rather than on quality or consideration of the environment. Expected outcomes would be broadly similar in 2060 compared to 2030. Uncertainty for all scenarios is assessed as medium (**Figure 8.8**).

Coastal partnerships

Coastal partnerships are a bottom-up approach to integration and management of actions and activities on the coast, bringing together an area's coastal community to address issues of concern, share best practice and resources, and facilitate communication. They play a role in the integration and management of actions and activities on our coasts and can contribute to integrated coastal zone management. Since the early 1990s, over 50 Coastal Partnerships have been set up around the UK coast. These partnership initiatives have evolved from a 'bottom-up' approach, with people involved from local communities, clubs and user groups to local authorities, statutory agencies, industries, water companies, port and harbour authorities, and NGOs.

Coastal partnerships are likely to have greater relevance under Nature@Work and Local Stewardship, but are likely to be marginalised under World Markets and National Security, reflecting differences in governance structures and the support for environmental objectives (**Table 8.15**). The effect on ES is likely to be minor under Nature@Work and Local Stewardship owing to the limited influence of partnerships. No effect on ES provision would be expected under World Markets and National Security. Expected outcomes would be broadly similar in 2060 compared to 2030. Uncertainty varies across the scenarios. For World Markets and National Security uncertainty is assessed as low as it is relatively certain that the influence of partnerships would be low (**Figure 8.8**). For Local Stewardship uncertainty is assessed as high as while partnerships may be particularly active under this scenario, it is unclear whether they could exert sufficient influence to deliver ES benefits.

Marine monitoring

Charting Progress 2 provided a detailed review of evidence on the state of UK seas (UKMMAS, 2010). The importance of marine monitoring within an overall system of marine management is increasingly recognised. Improvements to existing marine management arrangements will necessarily require better information on the state of the marine environment and its response to human pressures. The Marine Strategy Framework Directive is currently an important driver that is

widening the scope of existing marine monitoring programmes. It requires establishment of a monitoring programme by 2014, will include monitoring of progress towards Good Environmental Status, for which indicators are being developed. These will complement objectives and targets established for transitional and coastal waters under the Water Framework Directive.

The scale and nature of future marine monitoring programmes will depend on which drivers are prioritised within marine management and the availability of funding for monitoring activity. It has been assumed that there will be limited focus on marine monitoring under World Markets and National Security because environmental protection (which is the focus of much marine monitoring) is unlikely to be a priority under these scenarios. Marine monitoring is likely to be supported to a greater degree under Nature@Work and Local Stewardship which will increase its relevance under these scenarios as better monitoring will facilitate better management decisions to deliver improvements to marine and coastal environments (**Table 8.15**). However, while monitoring will facilitate better management, its overall contribution to ES provision is considered to be minor. Expected outcomes would be similar in 2060 compared to 2030. Uncertainty is generally assessed to be at a medium level except for World Markets where there is a higher degree of certainty that the benefits of monitoring will be reduced (**Figure 8.8**).

Environmental NGOs

Owing to the technical complexity of the marine environment and the challenging nature of many marine issues, environmental NGOs tend to campaign collectively for delivery of improvements to the marine environment, aiming to change social attitudes/awareness, and influence policy decisions in line with their priorities. Their main focus is on wild species diversity, associated with public use of the coast and marine environment, but the wide variety of local, national and international NGOs cover an equally wide remit, particularly related to environment and social priorities.

Under World Markets and National Security, the influence of environmental NGOs is likely to be marginalised such that they will have little relevance and little if any influence on the provision of ES (**Table 8.15**). Under Nature@Work and Local Stewardship, environmental NGOs could have much greater relevance and influence, although under Local Stewardship the benefits to ES provision may be tempered by greater exploitation of the marine environment. Expected outcomes would be broadly similar in 2060 compared to 2030. Uncertainty for World Markets and National Security is assessed as low as it is likely that environmental NGOs will be marginalised under these scenarios (**Figure 8.8**). For Nature@Work and Local Stewardship uncertainty is generally assessed as medium.

References

Austen, M., Malcolm, S., Frost, M., Hattam, C., Mangi, S. and Stentiford, G. (2011). Marine. In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment. Cambridge: UNEP-WCMC, pp. 459-498.

Brown, I. *et al.* (2012). UK Climate Change Risk Assessment: Biodiversity and ecosystem services. Sector report.

Collins, A.L. and McGonigle, D.F. (2008). Monitoring and modelling diffuse pollution from agriculture for policy support: UK and European experience. *Environ. Sci. Policy* **11**, 97-101.

Department for Business, **Innovation and Skills** (2013). A UK Strategy for Agricultural Technologies. HM Government, London.

Defra (2008). *Future Water.* The Government's water strategy for England. Available from: http://archive.defra.gov.uk/environment/quality/water/strategy/pdf/future-water.pdf.

Defra (2011a). Biodiversity offsetting: guiding principles for biodiversity offsetting.

Defra (2011b). National Standards for sustainable drainage systems. Designing, constructing, operating and maintaining drainage for surface runoff. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/82421/suds-consult-annexa-national-standards-111221.pdf.

Defra (2013b). Catchment Based Approach: Improving the quality of our water environment. A policy framework to encourage the wider adoption of an integrated Catchment Based Approach to improving the quality of our water environment. Available from: https://www.gov.uk/government/publications/catchment-based-approach-improving-the-quality-of-our-water-environment.

Defra and Forestry Commission (2011). Action plan for tree health and plant biosecurity. Defra, London. Available from https://www.gov.uk/government/policies/sustaining-and-enhancing-trees-forests-and-woodland/supporting-pages/tree-and-plant-health.

Ecosystem Markets Task Force (2013). Realising nature's value. Final Report.

Everard, M., Shuker, L. and Gurnell, A.M. (2011). The Mayes Brook restoration at Mayesbrook Park, East London: an ecosystem services assessment. *Environment Agency Evidence Report*. Environment Agency, Bristol.

Firbank, L. (2005). Striking the balance between agricultural production and biodiversity. Annals of *Applied Biology* **146**, 163-175.

Firbank, L., Bradbury, R., McCraken, E. and Stoate, C. (2011). Enclosed Farmland. In: Assessment, U.N.E. (Ed.), United Kingdom National Ecosystem Assessment Technical Report. UNEP - WCMC, Cambridge, pp. 197-240.

Firbank, L., Elliott, J., Drake B. and Gooday, R. (2013). Evidence of sustainable intensification among British farms. *Agriculture, Ecosystems and Environment* **173**, 58-65.

Fischer et al. (2008). Should agricultural policies encourage land sparing or wildlife-friendly farming? *Frontiers in Ecology & Environment,* **6**, 380.

Foresight (2011). The Future of Food and Farming: Challenges and choices for global sustainability. The Government Office for Science, London.

Francis, J.A. and Vavrus, S.J. (2012). Evidence linking Arctic amplification to extreme weather in mid-latitudes. *Geophys. Res. Lett*. **39**.

Green, R.E., Cornell, S.J., Scharlemann, J.P.W. and Balmford, A. (2005). Farming and the fate of wild nature. *Science*, **307**, 550-555.

Hillier, J., Walter, C., Malin, D., Garcia-Suarez, T., Mila-i-Canals, L. and Smith, P. (2011). A farm-focused calculator for emissions from crop and livestock production. *Environ. Modell. Softw*. **26**, 1070-1078.

Iacob, O., Rowan, J.S., Brown, I. and Ellis, C. (2013). Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. *Hydrological Research* (in press).

IEEP (2008). The Environmental benefits of set-aside in the EU: a summary of evidence. Report to Defra.

Lawrence, A. and Molteno, S. (2012). Community forest governance: a rapid evidence review. A report by Forest Research on behalf of the Independent Panel on Forestry. Available from: http://www.forestry.gov.uk/fr/INFD-8UCAGS.

Lawton, J.H., Brotherton, P.N.M., Brown, V.K., Elphick, C., Fitter, A.H., Forshaw, J., Haddow, R.W., Hilborne, S., Leafe, R.N., Mace, G.M., Southgate, M.P., Sutherland, W.J., Tew, T.E., Varley, J. and Wynne, G.R. (2010). Making Space for Nature: a review of England's wildlife sites and ecological network. A report for Defra.

LWEC: Living With Environmental Change (2012). Taking Responsibility for Water: United Kingdom Water Research and Innovation Framework 2011 – 2030. RCUK Publications, http://www.lwec.org.uk/.

Maltby, E., Ormerod S. *et al.* (2011) Freshwaters – Openwaters, Wetlands and Floodplains. In: Watson, R.T. and Albon, S. (Eds). The UK National Ecosystem Assessment Technical Report. UNEP-WCMC, Cambridge, pp. 295-360.

McGonigle, D.F., Harris, R.C., McCamphill, C., Kirk, S., Dils, R., Macdonald, J. and Bailey, S. (2012). Towards a more strategic approach to research to support catchment-based policy approaches to mitigate agricultural water pollution: A UK case-study. *Environ. Sci. Policy* **24**, 4-14.

MCPFE, PEBLDS (2006) Joint position of the MCPFE and the EfE/PEBLDS on the Pan European understanding of the linkage between the ecosystem approach and sustainable forest management. Geneva – Warsaw.

Miller, D., Roe, J., Brown, C., Morris, S., Morrice, J. and Ward Thompson, C. (2012). *Blue Health:* Water, health and wellbeing. Centre of Expertise for Waters, James Hutton Institute, Aberdeen. Available online at: www.crew.ac.uk/publications.

Morecroft, M. and Speakman, L. (2013). Terrestrial biodiversity report climate change impacts report card 2012-13. LWEC.

Natural England (2009). Agri-environment schemes in England 2009: a review of results and effectiveness (NE194).

Pretty, J., Sutherland, W.J., Ashby, J., Auburn, J., Baulcombe, D., Bell, M., Bentley, J., Bickersteth, S., Brown, K., Burke, J., Campbell, H., Chen, K., Crowley, E., Crute, I., Dobbelaere, D., Edwards-Jones, G., Funes-Monzote, F., Godfray, H.C.J., Griffon, M., Gypmantisiri, P., Haddad, L., Halavatau, S., Herren, H., Holderness, M., Izac, A.M., Jones, M., Koohafkan, P., Lal, R., Lang, T., McNeely, J., Mueller, A., Nisbett, N., Noble, A., Pingali, P., Pinto, Y., Rabbinge, R., Ravindranath, N.H., Rola, A., Roling, N., Sage, C., Settle, W., Sha, J.M., Luo, S.M., Simons, T., Smith, P., Strzepeck, K., Swaine, H., Terry, E., Tomich, T.P., Toulmin, C., Trigo, E., Twomlow, S., Vis, J.K., Wilson, J. & Pilgrim, S. (2010). The top 100 questions of importance to the future of global agriculture. *Int. J. Agric. Sustain*. **8**, 219-236.

Quine, C. and Watts, K. (2009). Successful de-fragmentation of woodland by planting in an agricultural landscape? An assessment based on landscape indicators. *Journal of Environmental Management*, **90**, 251-259.

Quine, C.P., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A. and Valatin, G. (2011). Chapter 8 Woodlands. *In: UK National Ecosystem Assessment Technical Report*. UNEP-WCMC, Cambridge.

Quine, C.P., Bailey, S.E. and Watts, K. (2013). Sustainable forest management in a time of ecosystem services frameworks: common ground and consequences. *Journal of Applied Ecology*. doi: 10.1111/1365-2664.12068.

Redwood, M. (2008). Agriculture in Urban Planning: Generating Livelihoods and Food Security. Earthscan.

UKMMAS (UK Marine Monitoring and Assessment Strategy) (2010). *Charting Progress 2. The state of the UK seas*. TSO, London.