9 The first United Kingdom's National Ecosystem Assessment and beyond

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9.1 INTRODUCTION

As water and land resources become scarcer, further conflicting demands of different uses and users will arise (Vörösmarty *et al*. 2000). Sustainable management is required to secure water resources for future generations. Ecosystem services-based approaches aim to ensure that the values of a broad range of benefits to humanity that are provided by our natural environment are accounted for in policy making, in order to foster sustainable development (Chapter 2). National-level incorporation of sustainable development goals has propelled interest in large-scale assessments of ecosystem services which can help address complex problems of ecosystem change (Bateman *et al*. 2013).

The central question of this chapter is whether large-scale ecosystem services-based approaches provide an opportunity for improving water management. The UK National Ecosystem Assessment (UK-NEA) was the first analysis of the societal benefits of the UK natural environment (UK-NEA 2011a). Moreover, it was one of the leading initiatives worldwide to assess ecosystem services at national level after the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005) produced a global assessment. The first phase of the UK-NEA provided a wealth of policy-relevant information, and we use it here as a case study.

UK rivers, lakes, and ponds make up around 250 000 hectares (1.1%) of the UK total surface area. These surface waters, together with unseen groundwater systems, contribute significant ecosystem services and goods to human wellbeing in the UK. The quality of UK freshwaters has improved over the last 50 years following direct regulatory interventions in rural and agricultural practices and EU Directives, such as the Water Framework Directive (Watson 2012). These policies have led to a reduction of point and diffuse chemical pollution and improved ecological conditions. Nonetheless, pressures from agricultural, industrial, and domestic use on water resources remains high, both in terms of quality and quantity (Watson 2012). Agricultural practices and landscape modifications, such as use of fertilisers, habitat fragmentation, and degradation, reduce the ecosystem service provision and resulting human benefits. Under the Water Framework Directive, which commits member states to acquire good ecological status of water bodies by 2015, only 26% of rivers and 36% of lakes in England and Wales presently meet or exceed this target status. The supply of water from most natural habitats is decreasing (e.g. driven by urban expansion) and continued population growth will put increasing pressure on these water resources (UK-NEA 2011a).

We first introduce the conceptual framework underpinning the UK-NEA and highlight differences between ecosystem services-based water management approaches and traditional ones. Next, we provide an application of the UK-NEA framework to water-related ecosystem services. As an example of the UK-NEA 'at work', an assessment is included of the non-market values of recreation to water bodies under two contrasting scenarios. We discuss the impact of the UK-NEA on UK water-related policies and we end the chapter shortlisting some of the main challenges for integral management of water and other ecosystem services.

9.2 ECOSYSTEM SERVICE ASSESSMENT UNDER THE MILLENNIUM ASSESSMENT AND THE UK-NEA

9.2.1 UK-NEA conceptual framework

The conceptual framework of the UK-NEA builds upon the circular relationship between human societies (their actions and their wellbeing) and the environment and its ecosystem services provision, in line with core element 1 outlined in Chapter 2. The UK-NEA makes an explicit distinction between ecosystems processes and functions, and intermediate services which underpin the final ecosystem goods that are of human benefit (e.g. Fisher & Turner 2008). In turn, the wellbeing we derive from ecosystems, together with drivers such as changes in policy regimes, social institutions, and demographics, affects

Box 9.1 Key facts on UK-NEA

Start: mid May 2009

Findings published: June 2011

Impact: profound influence on 'The natural choice: securing the value of nature', the most fundamental overhaul of government policy regarding the English natural environment for 20 years.

Researchers: more than 500 natural, economic, and social scientists. 'The UK NEA was an inclusive process; many government, academic, NGO and private sector institutions helped to design the assessment, contribute information and analyses, review the preliminary findings, and promote the results' (UK-NEA website, http://uknea.unep-wcmc.org).

Core funders: The UK Department for Environment, Food and Rural Affairs (Defra), the devolved administrations of Scotland, Wales, and Northern Ireland, the Natural Environment Research Council (NERC), and the Economic and Social Research Council (ESRC). The economic analysis was part-funded by the Social and Environmental Economic Research (SEER) project (ESRC Funder Ref: RES-060-25-0063).

the way we manage the environment and its potential to deliver valuable services.

Figure 9.1 shows how the UK-NEA framework can be applied to water-related ecosystem services. Physical conditions affect the core ecosystem processes, such as nutrient and water cycling, or soil formation. These ecosystem processes drive various ecosystem functions, such as nutrient uptake by plants, but also aquifer recharge and storage of flood water that regulate water levels and thereby, among others, carbon storage in soils. The final ecosystem services that are of human benefit include better water quality and quantity, but also reductions in flood risk and climate regulation. The good(s) that people derive from these services range from basic needs, e.g. drinking water and food, to safety in terms of flood control and longer-term effects of climatic conditions. In many cases, final ecosystem services have to be combined with other resource inputs, such as manufactured or human capital, to generate valuable 'goods'. While some of the water-related final services are incorporated in commercial goods or services (e.g. the whisky industry heavily relies on water), other important benefits are non-marketed, with recreation and tourism benefits as an important example.

The new classification into final goods and intermediate services is also adopted in the UK-NEA. The classification recognises the complexity of ecosystems as it highlights the interactions and dependencies between ecosystem structures, processes, functions, and services. The main advantage of a focus on final outputs of ecosystem services is that it avoids double counting of benefits of ecosystem services that have both intermediate and final states, and thereby helps to avoid excessively high costs or benefits. Attention to double counting is of particular relevance for the valuation of water-related services (Fisher *et al*. 2008). A typical example of double counting is when nutrient retention (to improve water quality) integrally supports biodiversity conditions. Including both the value of biodiversity and of nutrient retention in benefit estimation would lead to overestimation of the welfare impact.

The UK-NEA is oriented around eight different habitats, including freshwaters. These broad habitat types capture the thematic diversity of the UK's natural environment (Jackson 2000). Mapping enables the spatial diversity of these habitats to be captured. A spatially explicit approach of the analysis of ecosystem services and benefits is one of the key characteristics of the UK-NEA (Bateman *et al*. 2011).

The spatial aspects are reflected in bio-physical models of ecosystem stocks and service provision, as well as in the economic models that underpin the benefits attached to these services. Moreover, the scenario analysis, which outlines the outcomes related to different policy interventions (Haines-Young *et al*. 2010), is subsequently related to corresponding maps of land use changes with associated welfare changes (Bateman *et al*. 2013). This spatially explicit approach demonstrates where costs and benefits of these interventions are expected to occur, where policies can achieve trade-offs, and synergies between ecosystem services, and may help to define areas where improving ecosystem conditions would have the highest net benefits for society.

The UK-NEA framework aims to raise awareness of the relationship between habitats, water quality and quantity, and final benefits; it stresses the necessity of better understanding of the bio-physical underpinnings of ecosystem functions and service delivery (core element 2, Chapter 2). However, the understanding of the links between ecosystem structure, functioning, habitat type, location, and size (and related issues of fragmentation) is far from complete (Maltby *et al*. 2011). Figure 9.1 is only a first attempt to sketch ecosystem links and interactions, and the arrows are by no means intended to indicate linear relationships. Links may be non-linear or bi-directional, with final ecosystem services influencing ecosystem functions. Interactions of freshwater characteristics, land types, and temporal hydrological dynamics define ecosystem services that are highly spatially heterogeneous.

The UK-NEA identified many knowledge gaps and highlighted the uncertainty about how changes in ecosystems affect

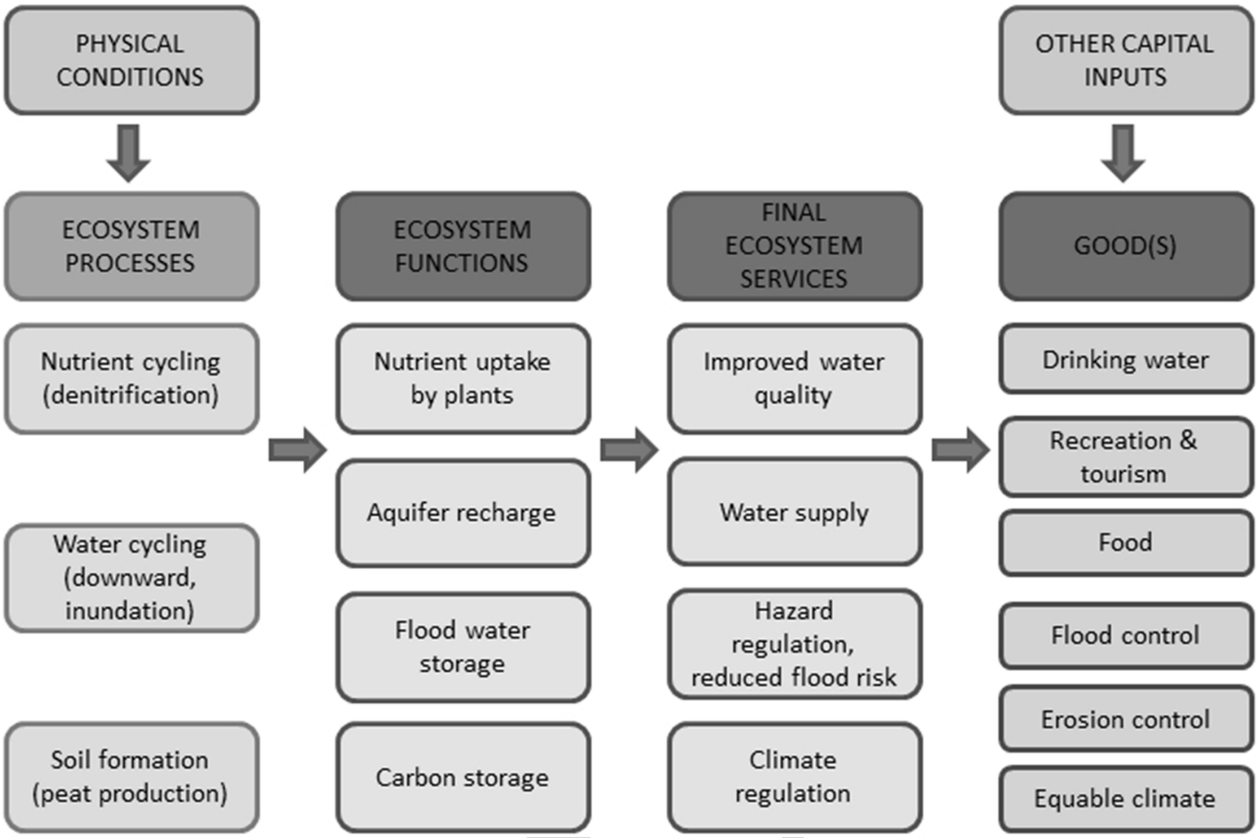

Figure 9.1 Schematic diagram of ecosystem assessment, linking processes to final goods.
Source: adapted from Maltby *et al*. (2011).

wellbeing, which make it difficult to operationalise ecosystem services-based approaches. For example, there are no hydrological models for the quantification of ecosystem service delivery that fully capture these relationships. Similarly, the value of ecosystems is not fixed, and benefits depend on timing and location of ecosystem service delivery, on the relationship between water quality and quantity, on other ecosystem services related to water and finally on stakeholders' preferences. Moreover, ecosystems and service provision may be vulnerable to 'regime' shifts (Maltby *et al*. 2011). Once a shift occurs, large losses of ecosystem services may occur which may be irreversible or difficult to restore.

9.2.2 Water management and ecosystem services-based approaches

Water management has traditionally focused on the key task of water supply to industry, households, and agriculture, while at the same time managing water quality in watersheds as well as sewage treatment. However, the true societal cost of water is not reflected in water pricing mechanisms and decisions on water allocation. For example, the negative effects of depletion of groundwater resources on future water supply are not reflected in water prices.

Establishment of the Water Framework Directive was a first step into managing water bodies at the integral level of river basins. Moreover, the Water Framework Directive made an explicit attempt to integrate economic values into water-related policies and adopted economic criteria to decide on the efficiency and disproportionality of costs versus the economic benefits of its implementation. This ignited a series of valuation studies to assess the non-market benefits of water quality and quantity improvements, including recreation, biodiversity conservation, and habitat improvements (e.g. Hanley *et al*. 2006; Bateman *et al*. 2011; Metcalfe *et al*. 2012).

Ecosystem services-based approaches will require responsible agencies to broaden their scope even more, towards management of the habitats and associated ecosystem services of which the water bodies form an integral part. This has several opportunities for improved water management, which are discussed in depth

by Blackstock *et al*. in this book. Exploring the bio-physical underpinnings of ecosystem service delivery in ecosystem services-based approaches (core element 2) may better reveal the trade-offs and synergy effects between water supply and other ecosystem services and help to address unintended negative consequences (Martin-Ortega 2012). On the positive side, the quantification of these services may reveal potential co-benefits of achieving improved water quality in terms of other ecosystem services, including effects on terrestrial ecosystems. Such co-benefits might justify investments in actions of which the costs would otherwise be deemed disproportionate, thereby changing policy outcomes (core element 4) (see Brills *et al*., this book, for the flagship example in New York City). It may also support decisions on water distribution among different stakeholders, ensuring that human needs as well as environmental demands are met. Last but not least, water and land managers may seek cooperation to strike a balance between on-site ecosystem service delivery and off-site water resources. For example, improved peatland management to reduce carbon emissions and conserve biodiversity could have positive effects on water quality (Martin-Ortega *et al*. 2014). Essentially, a more holistic approach may provide better understanding of the effects of ongoing land use changes on water resources (and vice versa) and subsequently on final ecosystem services and associated benefits.

Ecosystem services-based approaches have the potential to improve decision-making, but an inevitable consequence of broadening the scope of management is the increased complexity introduced in analysis as well as policy making. The considerable knowledge gaps with respect to the effect of ecosystem management on water-related ecosystem services introduce high uncertainty in decision-making. Different disciplines, stakeholders, and policy targets with conflicting needs and different nomenclature have to come together and cooperate: the trans-disciplinarity of ecosystem services-based approaches (core element 3, Chapter 2) is also of high relevance in water-related governance and decision-making. The risk is that this may lead to delay in implementation, and working towards ecosystem assessments should not cause inertia.

9.3 ECONOMIC ASSESSMENT OF THE CURRENT STATUS OF WATER ECOSYSTEM SERVICES IN THE UK-NEA

The first phase of the UK-NEA gave an overview of the wide range of water-related benefits by summarising the existing information on economic values of ecosystem services related to water, including a wide range of non-market ecosystem service values. We include some of the main findings and studies that provide aggregated values. Although these studies differ in accuracy, the results provide evidence that the UK population derives considerable wellbeing from water ecosystem services (see Table 9.1).

Mourato *et al*. (2010) use residential property transaction data to analyse how environmental characteristics influence house prices. They demonstrate that freshwater sites along with other natural characteristics (woodlands, green spaces, etc.) within a 1 km range from the property attract a significant price premium of around 1% of the value of average house market prices, reflecting the positive value that society attaches to living closer to environmental assets. In comparison, other services such as schools or rail stations provide a 2% increase in property values, but only if they are within a 200 m range.

Morris and Camino (2010) provide estimates of ecosystem services for inland wetlands based on a global meta-analysis of wetland valuation studies by Brander *et al*. (2008). Globally, flood control protection by wetlands is estimated to be worth

Table 9.1 *Summary of water ecosystem services studies in the UK-NEA**

Habitat	Ecosystem service	Aggregate value (10^6 per year) (£)	Reference
Wetland inland	Water supply	2	Morris and Camino (2010)
Wetland inland	Flood protection	366	Morris and Camino (2010)
Wetland inland	Water quality improvement through nutrient recycling	263	Morris and Camino (2010)
Rivers, lakes	Biodiversity, amenity, recreation	1140 (England & Wales)	NERA (2007); Morris and Camino (2010)
Inland surface water	Recreation	603	Sen *et al*. (2014)

* We only report studies that are related to specific habitats and are aggregated at national level. Note that the values provided by Sen *et al*. (2014), NERA (2007), and the water quality values by Morris and Camino (2010) reflect overlapping ecosystem services and, in order to avoid double counting, these estimates should not be summed.

Source: abstracted from UK-NEA (2011b) and follow-on work.

approximately £336 × 10^6 per year. The value of water supply by wetlands is very small compared to wetland water quality improvement and flood control protection (Table 9.1), also because wetlands mainly function as water flow regulators rather than suppliers. However, these estimates may not accurately reflect the values of water supply in the UK, and are based on the assumption that all wetlands deliver these functions (irrespective of their location relative to the population that would benefit from the wetland ecosystem services). Another study which attempted to provide national estimates of water ecosystem services is NERA (2007). This study used stated preference surveys to assess the value that households attached to water quality improvements in rivers and lakes that would affect biodiversity, aesthetic, and recreational quality. It showed that, on average, households are willing to pay £40 per year for a nation-wide improvement of water quality. Although the willingness-to-pay values are sensitive to the elicitation of formal and statistical models, the study clearly shows the importance that society attaches to water ecosystem services.

The spatially explicit approach of the UK-NEA is clearly demonstrated by Sen *et al*. (2014), who modelled the non-market value of open-air recreation. In this chapter we focus on the results of this study related to freshwater benefits. The model is based on a large survey about recreational behaviour among households in England (Natural England 2010). The model predicting annual visitor numbers takes into account a wide range of spatial characteristics, including habitats, population, and accessibility. One of the findings is that the number of trips to freshwater sites is higher than for most other types of habitat, including grasslands, mountains, or woodlands. This visitor number model is combined with a meta-analysis on the value per recreational trip across different types of habitats. The results show that the value per trip for freshwater areas is higher than that for grassland and farmland, but lower than for most other habitats (mountains, moors, heaths, woodlands, and marine and coastal areas). The rather low value of freshwater may reflect the abundance of the different ecosystem services in the UK. By multiplying the estimated number of visits by the value per trip, an estimate of the total annual value of visits to freshwater sites is obtained of approximately £603 × 10^6 per year (Table 9.1). This value is smaller than the estimates reported by NERA (2007), which also reflect non-use values.

9.4 SCENARIO ANALYSIS FOR WATER RECREATIONAL SERVICES

9.4.1 The importance and complications of scenario analysis

One of the key objectives of the Water Framework Directive is to foster sustainable water management and secure water resources into the future. Scenario analysis is a useful tool to evaluate current levels of ecosystem use, and support decision-making by examining the trade-offs implied by each of a set of feasible policy options. Scenario analysis aims to ensure that ecosystem services are incorporated into decision-making and policy prioritisation (core element 4). Economic valuation contributes to this by estimating the societal costs and benefits when moving from a baseline scenario to an alternative state, and helps to identify options with positive net benefits. Scenario analysis for ecosystem service assessments hence requires that services are not considered in isolation, but in combination, showing where trade-offs have to be made or synergies can be achieved in ecosystem management.

In the UK-NEA, a scenario analysis was undertaken to compare ecosystem services in the 2010 baseline with various possible future states in 2060. The UK-NEA scenarios team (Haines-Young *et al*. 2010) generated a number of plausible scenarios that are likely to arise under different policy formulations. Moreover, the conceptual framework of the UK-NEA helps to explore the effects on future water security and wellbeing of climate change exacerbation and human demand pressures.

While this scenarios analysis provides interesting insights for policy makers, it also requires a deep and flexible understanding of the impacts of many indirect and direct drivers (e.g. policy, technology, freshwater pollution) on ecosystem services. The impact of each driver varies over space and time and the UK-NEA scenarios analysis struggles to capture this dynamic. Furthermore, the understanding of the interaction of multiple drivers on a specific ecosystem service (e.g. nutrient cycles) is less well known and represents a major research challenge for the future. As a result, only a few of the water-related ecosystem goods and benefits were assessed in bio-physical and economic terms in the UK-NEA.

9.4.2 UK-NEA scenario analysis for water-related recreation

To demonstrate the scenario analysis of the UK-NEA, we provide an example of two scenarios (UK-NEA 2011a) and then describe how these impact freshwater recreational services.

- 'Green and Pleasant Land'. Here, economic growth is mainly driven by secondary and tertiary sectors as opposed to intensive primary land uses. Pressures on rural areas are assumed to be declining as a result of increased concern for the conservation of biodiversity and landscape. A key objective for policy makers is biodiversity preservation, and aesthetic values of landscapes are enhanced by increases in improved grassland (temporary or permanent grassland with reduced fertiliser), semi-natural grassland, and conifer woodland. This implies a decrease in food production which is compensated for by increased imports to offset the demands of a larger population.

Table 9.2 *Changes in recreational values for sites (1 × 1 km cells) with ≥1 ha freshwater*

	Visits (103)	Total value (10^3 per year) (£)*	Change in values ($\Delta 10^3$ per year) (£)*	
	Baseline	Baseline 2010	Green and Pleasant Land 2060	World Market 2060
England	257 347	414 393	327 448	–54 164
Scotland	71 915	157 904	142 214	–78 794
Wales	14 344	30 563	22 249	–15 386
GB	**343 606**	**602 861**	**491 911**	**–148 343**

* All values are converted to 2010 prices.
Source: abstracted after UK-NEA (2011b).

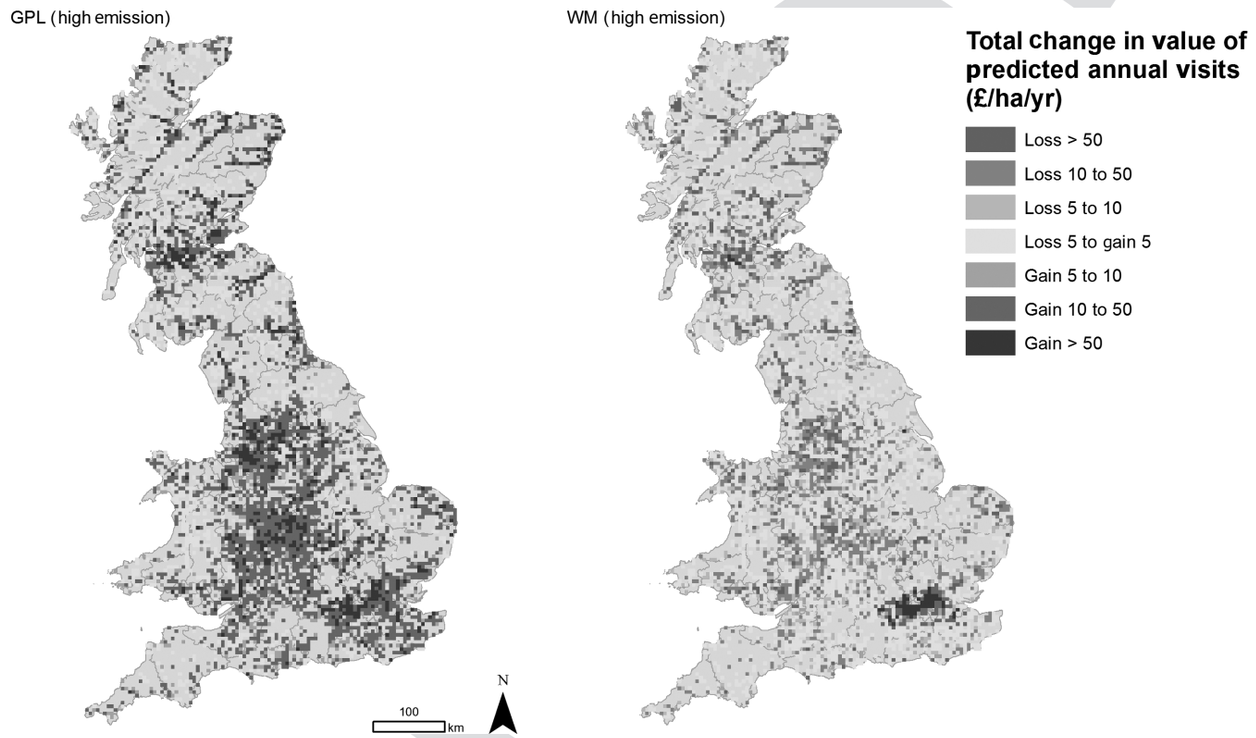

Figure 9.2 Differences in recreational value as we move from the baseline (2010) to two different policy options for 2060: GPL = Green and Pleasant Land (left) and WM = World Markets (right). A black and white version of this figure will appear in some formats. For the colour version, please refer to the plate section.
Contains Ordnance Survey data © Crown copyright and database right 2014.

- 'World Market'. In this scenario the area of arable land increases and improved grassland and semi-natural areas decrease to accommodate population-driven urban growth, which in turn drives further biodiversity declines.

The storylines of the Green and Pleasant Land and World Market scenarios were translated into alternative habitat maps for 2060 (UK-NEA 2011a). Both scenarios are analysed under the high CO_2 emissions trajectory for climate variables (see Murphy *et al.* 2009) and this will contribute for both to a modest increase in the percentage of freshwater land (currently 0.80%, in 2060 1.60%). The visitor number model of Sen *et al.* (2014) was applied to these new habitat maps to estimate the welfare changes of outdoor recreation. As population and habitats change under the scenarios, the predicted numbers of visits change, and so do the aggregate values of visits to sites.

Figure 9.2 presents two maps with the spatial changes in the value of recreation under these two scenarios for sites with freshwater habitats. This comparison shows that there is a stark contrast between the recreational benefits under both scenarios relative to the baseline, with much higher recreational values under the Green and Pleasant Land scenario.

The sum of country-level changes for recreational benefits is reported in Table 9.2 (alongside baseline estimates for reference). Note that these values do not reflect the financial value of the tourism sector (which would be captured by gross domestic product changes), and excludes any benefits that international visitors may attach to these freshwater areas. Also, freshwater sites may contain other broad habitats where they are spatially indistinguishable, e.g. a mountain stream.

Under the Green and Pleasant Land scenario, preservation of biodiversity and aesthetic quality of landscapes results in major increases in the benefits over the baseline, especially around urban areas, of almost £500 $\times$ 10^6 per year. This effect comes at the expense of a decrease in primary sector production, substituted by imports.

In the World Market scenario, major recreational losses are found around small urban centres and in remote areas. There are still considerable benefits enjoyed by the population in and around large urban centres where a substantial reduction of urban and peri-urban recreational areas (including urban greenspaces) is envisioned under the scenario and therefore an increase in water recreation values is expected. However, overall the World Market scenario results in substantial losses of recreational values, mainly for Wales, while for England and Scotland the impact is less severe.

9.5 THE IMPACT OF THE UK-NEA FINDINGS IN WATER-RELATED DECISION-MAKING

The results of the first phase of the UK-NEA were published in 2011 (UK-NEA 2011a) and the ultimate impact on policy making will only be apparent in years to come. Nevertheless, there have already been some important achievements and shifts in policy making, where the UK-NEA has contributed. The UK-NEA has strongly influenced the development of the Natural Environment White Paper (H.M. Government 2011a), described as the most important change in UK policy for the past 20 years (Watson 2012). This policy argues for an adoption of the ecosystem services-based approach at the national scale across the UK. Subsequent water-related policies such as the Water White Paper (H.M. Government 2011b), the Water For Life policy (Defra 2011), and the National Policy Statement for Waste Water (Defra 2012) also build upon the findings of the UK-NEA and seek to reform the water industry in ways which sustain and improve ecosystem services.

Change in decision-making is also being driven through private-sector initiatives. Rather than their traditional focus upon end-of-pipe, treatment-oriented approaches to delivering water supplies, the private sector is getting involved in joint initiatives with environmental organisations and statutory bodies to seek out solutions for using better environmental management of ecosystems as mechanisms for delivering improved water-related services (BES & UK BRAG 2011). In north-west England, United Utilities has developed a sustainable catchment management programme in collaboration with the Royal Society for the Protection of Birds to both improve water supplies and reduce carbon emissions.[1] This wider scope is also reflected in the assessment of the potential of woodland management to contribute to the achievement of the objectives of the Water Framework Directive (Nisbet *et al*. 2011). Another example is provided by the South West Water 'Upstream Thinking' initiative in Cornwall and Devon. This seeks to work with farmers to improve the quantity and quality of water through land use change as an alternative to engineering and chemical treatment options.[2]

These private-sector initiatives are being actively encouraged through public-sector changes in the rules governing water company operations and through an extension of Payments for Environmental Services schemes (Defra 2010). Water-related Payments for Environmental Services schemes are an example of the potential of capturing benefits when downstream beneficiaries pay for the benefits they derive from better land management by land users upstream, but well-working schemes can be hard to define (Muradian *et al*. 2010).

9.6 DISCUSSION AND CONCLUSION

One of the core findings of the UK-NEA was that many of the ecosystem services provided by natural habitats, including freshwater habitats, remain poorly identified and under-valued in policy-making, resulting in ongoing habitat loss, degradation, and modification. This argues for a number of developments in both academic research and policy development.

A key issue for assessments of water-related ecosystem service using land cover or habitat maps is that it does not reflect the complexity of ecosystems and it is often unclear what the implications of changes in the extent of natural habitats on changes in ecosystem services such as water provisioning will be. There are still important knowledge gaps and methodological issues related to quantitative analysis of ecological and economic linkages, and their relation to water values. This includes temporal and spatial effects: it is not yet well understood what the longer-term effects of current water uses are and how resilient and resistant freshwater ecosystems are, and what the interactions of various freshwater and land types and their effects on spatial ecosystem service delivery are. With better understanding of dynamic and spatial effects and interactions, the transition paths in scenario analysis could be explored.

[1] http://corporate.unitedutilities.com/scamp-index.aspx
[2] http://www.financeforthefuture.co.uk/Upload/PageAttachments/page1577/files/South%20West%20Water%20case%20study%20final.pdf

Furthermore, the non-financial nature of many water-related ecosystem goods and benefits and the absence of relevant economic value estimates increase the risk that these benefits are ignored in policy making. The UK-NEA framework, such as presented in Figure 9.1, provides insight into the changes in human welfare that may result from environmental changes and understanding of the service delivery process. It may enhance communication and integration between natural scientists and economists, with several potential improvements, e.g. (1) including a wide(r) range of goods and services in economic assessment as a result of the evaluation of a range of impacts of environmental change; (2) building valuation scenarios on adequate ecological knowledge. However, additional funding for primary research and valuation studies may be required for a reliable assessment of the full set of water-related goods and services.

The UK-NEA framework provides guidance on the economic assessment and mapping of ecosystem goods and benefits, and spatially explicit scenarios can be used to inform efficient land use policies. However, the importance of services such as water and flood protection may override considerations of cost–benefit ratios. When, besides efficiency, equity criteria play a role, further insight in the distribution of benefits and costs of changes in water-related goods and services among stakeholder groups in society will be required. Economic assessments can be extended by, for example, the disaggregation approach by Krutilla (2005) to address equity considerations. We have provided a range of examples of recent policy initiatives that have adopted the UK-NEA approach, although there is still considerable room for enhancement of the institutional engagement with ecosystem services-based approaches. Particular challenges include:

Box 9.2 Key messages

- The UK-NEA provides a useful, national-level model for the assessment of changes to ecosystem services.
- As such it has generated substantial policy impact both in terms of general natural capital decision-making and for specific issues such as those relating to the water environment.
- Addressing water policy through ecosystem services-based assessment may help reveal the importance of water and ecosystems to human wellbeing.
- Many of the water-related services provided by ecosystems are not traded in markets, yet they are of significant value to society.
- The full assessment of water-related ecosystem services will require more knowledge development to better understand how ecosystems contribute to human wellbeing.
- robustly valuing ecosystem services in ways which reflect the inherent variability in those services across locations;
- incorporating dynamic effects such that decisions become more robust across time;
- engaging with and generating enhancements to existing legislation;
- drawing in and incentivising the various actors necessary to ensure that decisions are effectively and efficiently turned into actions.

This is, we recognise, a substantial research agenda and one which we expect to provide a major focus for both researchers, public and private institutions, and indeed society for many years to come.

References

Bateman, I. J., Mace, G. M., Fezzi, C., *et al*. (2011). Economic analysis for ecosystem service assessments. *Environmental and Resource Economics* **48**, 177–218.

Bateman, I. J., Harwood, A., Mace, G. M., *et al*. (2013). Bringing ecosystem services into economic decision making: land use in the UK. *Science* **341**, 45–50.

BES and UK BRAG (2011). Where next for the UK National Ecosystem Assessment and IPBES? Report of a joint session between the British Ecological Society (BES) and the UK Biodiversity Research Advisory Group (UK BRAG), 13 September, Council Chamber, Octagon Centre, University of Sheffield.

Brander, L. M., Ghermandi, A., Kuik, O., *et al*. (2008). Scaling up ecosystem services values: methodology, applicability and a case study. Final Report, EEA. Fondazione Eni Enrico Mattei. Available at: www.feem.it/userfiles/attach/2010471736364 NDL2010-041.pdf (last accessed 21 October 2014)

Defra (2010). *Payments for Ecosystem Services: A Short Introduction*. Defra, London.

Defra (2011). *Water for Life: Market Reform Proposals*. Defra, London.

Defra (2012). *National Policy Statement for Waste Water*. Defra, London.

Fisher, B. & Turner, R. K. (2008). Ecosystem services: classification for valuation. *Biological Conservation* **141**, 1167–1169.

Fisher, B., Turner, R. K., Zylstra, M., *et al*. (2008). Ecosystem services and economic theory: integration for policy-relevant research. *Ecological Applications* **18**, 2050–2067.

Haines-Young, R., Paterson, J., Potschin, M., *et al*. (2010). *The UK NEA Scenarios: Development of Storylines and Analysis of Outcomes*. UNEP-WCMC, Cambridge.

Hanley, N., Wright, R. E., & Alvarez-Farizo, B. (2006). Estimating the economic value of improvements in river ecology using choice experiments: an application to the Water Framework Directive. *Journal of Environmental Management* **78**, 183–193.

H.M. Government (2011a). *The Natural Choice: Securing the Value of Nature (the Natural Environment White Paper)*. The Stationery Office, London.

H.M. Government (2011b). *The Water White Paper*. The Stationery Office, London.

Jackson, D. L. (2000). *Guidance on the Interpretation of Biodiversity Broad Habitat Classification (Terrestrial and Freshwater Types): Definitions and the Relationship with Other Habitat Classifications*. Joint Nature Conservation Committee, Peterborough.

Krutilla, K. (2005). Using the Kaldor–Hicks Tableau format for cost–benefit analysis. *Public Policy Analysis and Management* **24**, 864–875.

Maltby, E., Omerod, S., Acreman, M., *et al*. (2011). *Freshwater: Open Waters, Wetlands and Floodplains*. UNEP-WCMC, Cambridge.

Martin-Ortega, J. (2012). Economic prescriptions and policy applications in the implementation of the European Water Framework Directive. *Environmental Science and Policy* **24**, 83–91.

Martin-Ortega, J., Allot, T. E., Glenk, K., & Schaafsma, M. (2014). Valuing water quality improvements from peatland restoration: evidence and challenges. *Ecosystem Services* **9**, 34–43.

Metcalfe, P. J., Baker, W., Andrews, K., *et al*. (2012). An assessment of the nonmarket benefits of the Water Framework Directive for households in England and Wales. *Water Resources Research* **48**, W03526.

Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: A Framework for Assessment*. Island Press, Washington, DC.

Morris, J. & Camino, M. (2010). *Economic Assessment of Freshwater, Wetland and Floodplain Ecosystem Services*. UK-NEA, Cranfield.

Mourato, S., Atkinson, G., Collins, M., *et al*. (2010). *Economic Assessment of Ecosystem Related UK Cultural Services*. The Economics Team of the UK-NEA, London.

Muradian, R., Corbera, E., Pascual, U., *et al*. (2010). Reconciling theory and practice: an alternative conceptual framework for understanding payments for environmental services. *Ecological Economics* **69**, 1202–1208.

Murphy, J. M., Sexton, D. M. H., Jenkins, G. J., *et al*. (2009). *UK Climate Projections Science Report: Climate Change Projections*. Met Office Hadley Centre, Exeter.

Natural England (2010). *Monitor of Engagement with the Natural Environment: The National Survey on People and the Natural Environment*. Natural England, Sheffield.

NERA (2007). *The Benefits of Water Framework Directive Programmes of Measures in England and Wales*. NERA, London.

Nisbet, T., Silgram, M., Shah, N., *et al*. (2011). Woodland for water: summary report. Environment Agency and Forestry Commission.

Sen, A., Harwood, A. R., Bateman, I. J., *et al*. (2014). Economic assessment of the recreational value of ecosystems: methodological development and national and local application. *Environmental and Resource Economics* **57**, 233–249.

UK-NEA (2011a). *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC, Cambridge.

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

Vörösmarty, C. J., Green, P., Salisbury, J., & Lammers, R. B. (2000). Global water resources: vulnerability from climate change and population growth. *Science* **289**(5477), 284–288.

Vörösmarty, C. J., McIntyre, P. B., Gessner, M. O., *et al*. (2010). Global threats to human water security and river biodiversity. *Nature* **467**, 555–561.

Watson, R. T. (2012). The science–policy interface: the role of scientific assessments – UK National Ecosystem Assessment. *Proceedings of the Royal Society A* **468**, 3265–3281.