Considerations in environmental science and management for the design of natural asset checks in public policy appraisal

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Summary

In 2010, the Government Economic Service Review of the Economics of Sustainable Development recommended that a natural asset check should be investigated for use in the appraisal of public policy options. Considerations in environmental science and management can help to ensure that issues such as the ecological thresholds, cumulative impacts, the selection of appropriate accounting units and risk are handled appropriately in any natural asset check. Based on assessment of the contribution of the UK National Ecosystem Assessment (UK NEA) and other work, this paper makes a series of propositions in relation to the design of a natural asset check:

1. While the UK NEA draws together much of the information needed to design a natural asset check, a development of this framework will be required in order to perform the check.
2. Some kind of accounting model is likely to be more useful as a basis for a natural asset check than the frameworks used for ecosystem assessments.
3. A classification approach that links ecosystem services to the natural assets that underpin them is probably more efficient in capturing what is important in policy terms, than one that is based on a more abstract and generic classification of assets.
4. There are sufficient data resources available for a preliminary audit of natural assets to be made.
5. While a focus on non-marginal or irreversible changes in natural systems is important, it would be too restrictive to make this the exclusive concern of any natural asset check.
6. What might be considered critical natural assets may change as knowledge develops or circumstances change. Therefore, a 'one-off' natural asset check is unlikely to be reliable for policy analysis in the long term. Periodic audit will be necessary.

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1. Introduction

Natural assets have been defined as: "*the biological assets (produced or wild), land and water areas within their ecosystems, subsoil assets and air*" (United Nations, 1997). The Report of the UK Government Economic Service Review of the Economics of Sustainable Development contains a recommendation that a natural 'asset check' should be investigated for use in the analysis of public policy options in Government (Price *et al*., 2010). This was based on the argument that such a check is requirement of the 'capitals approach' for assessing progress towards sustainable development.[1] A key question arising in relation to this is whether national public policies and projects might be degrading *critical* assets that are essential for sustaining long term social and economic well-being.

There are several reasons why the introduction of a natural asset check into public policy appraisal would be timely. Firstly, it has the potential to build on domestic initiatives such as the UK National Ecosystem Assessment (UK NEA). Secondly, it is consistent with wider international efforts to develop more formal and standardised integrated economic and environmental accounting frameworks.

It is also appropriate for Government to consider the idea of a natural asset check, given its commitment to the principles of the 'ecosystem approach' in the Convention on Biological Diversity (CBD). In its Action Plan for embedding an ecosystem*s* approach in decision making (Defra, 2007 and 2010), Defra consolidated the twelve principles in the CBD into the six shown in Table 1. An initial reading of the principles may not lead immediately to the conclusion that a natural asset check is needed for public policy appraisal. Nonetheless, access to the kinds of information that an asset check would provide is probably essential if an ecosystems approach is to be applied successfully. For example, the need for cross-sectoral perspectives implied by Principle 1 in Table 1 can only be achieved by developing an understanding of the ways in which natural (environmental), manufactured (physical) and social (human) capital are linked. Understanding this linkage is also vital in terms of ensuring that the full (not just monetary) value of the services that nature provides is to be recognised in decision making (Principles 2 and 6 in Table 1). Furthermore, the proposition that we should ground decision making on an understanding of the limits of ecosystem functioning (Principles 3 and 6 in Table 1) is part of what an asset check would deliver.

If an ecosystems approach is to be embedded in public policy, several key design challenges for the natural asset check emerge. For example, in relation to the issue of spatial scales[2] (Principle 4 in Table 1) we have to consider what the appropriate accounting units are for a natural asset check in the UK. We cannot presume that the national one is the most appropriate, or that the same accounting units can be used for different types of natural asset. Similarly, recognising that policy and management decisions usually have to be made in the face of uncertainty and that adaptive approaches are therefore necessary (Principle 5 in Table 1), it is important to consider how an asset check might deal with issues of risk. There will be a need to balance risk against the inevitable gaps in data and understanding.

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1 According to the 'capitals approach', wealth (natural, man-made and social capital) is the basis for the creation of future wellbeing. See Price *et al*. (2010).

2 While the principle stresses spatial scale, it should also consider temporal scales. The reason is that different time perspectives fundamentally change understanding of ecosystem dynamics.

Table 1: The principles underlying an ecosystems approach as proposed by Defra, together with associated implications for the design of a natural asset check.

Principles of an ecosystems approach	Implications for a natural asset check
1. Take a more holistic approach to policy-making and delivery, with the focus on maintaining healthy ecosystems and ecosystem services.	Integrated approaches to policy analysis require an understanding of capacity to deliver final ecosystem services, and the ecological integrity of the natural stocks and processes that underpin them.
2. Ensure that the value of ecosystem services is fully reflected in decision-making.	While an understanding of the value ecosystem services is a key part of policy analysis, insights about the importance of natural capital also depend on the costs and risks associated with its loss.
3. Ensure that environmental limits are respected in the context of sustainable development, taking into account ecosystem functioning.	While the identification of environmental limits is informed by environmental science considerations, they are also a question of societal choice or preference, and people's understanding of costs and risks. Thus any asset check has to be grounded on participatory approaches to decision making.
4. Take decisions at the appropriate spatial scale while recognising the cumulative impacts of decisions.	The consequences of cumulative change as well as non-marginal or irreversible changes should be part of any asset check.
5. Promote adaptive management of the natural environment to respond to changing pressures, including climate change.	Given the uncertainties that surround any asset check, these exercises should be iterative so that judgements can be modified as knowledge develops or circumstances change.
6. Identify and involve all relevant stakeholders in the decision and plan making process.	Different groups may prioritise assets differently and potentially make different judgements on the basis of the material provided by the asset check. Involvement in the scoping, design and interpretation of the asset check by all relevant stakeholders is essential if it is to be used effectively in decision making.

Note: In Defra's original formulation of the principles underlying an ecosystems approach, five were identified (see Defra, 2007). The sixth was added in Defra (2010).

In this paper, we consider what a natural asset check might entail, what the priorities may be, and how it can be used as part of the public policy appraisal process. In particular, we evaluate how feasible such an asset check is, given current knowledge and availability of suitable monitoring data. We also examine what the priorities should be. This includes whether a natural asset check should focus only on 'large and irreversible impacts' that are 'essential to social and economic activity', as specified by Price *et al*. (2010). Drawing on a wide variety of sources, we attempt to explore the issues that surround the notions of thresholds, cumulative impacts, appropriate accounting units and risk, with particular reference to the design of a framework in which natural asset checks can be conducted. In so doing, we draw upon work that is being undertaken elsewhere that may provide insights or lessons that can be used to inform the process.

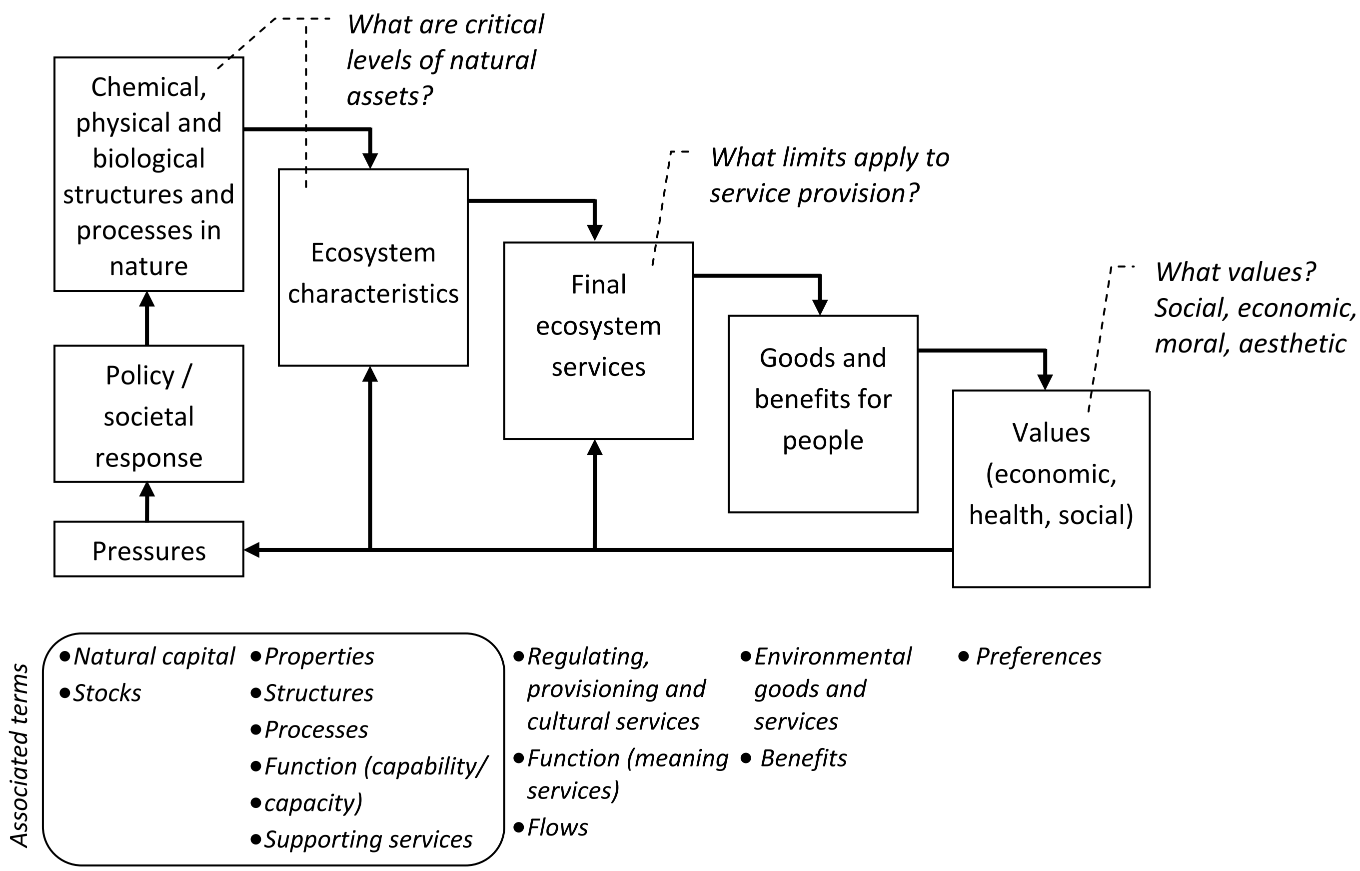
Explanation of a selection of key terms of importance to natural asset checks is provided in Annex A.

2. Asset checks, ecosystem assessments and environmental accounting

Natural systems are inseparable from the social and economic systems that underpin human well-being. Many have therefore sought to expand the notion of an ecosystem by emphasising that in managing the natural environment we are actually dealing with socio-ecological systems (SESs). For an example, see Anderies *et al*. (2004). The notion of ecosystem services is particularly useful in this context, because it re-emphasises the fundamental links between nature and society. In defining an ecosystem service, understanding of geographical location, societal freedoms, choices and values is as important as knowledge about the structure and dynamics of the natural environment (Potschin and Haines-Young, 2011). This is particularly the case in countries such as the UK, where virtually all the land surface is subject to direct human intervention. Natural, social and manufactured capitals are often difficult to analyse separately.

A wide range of terminology has been used to describe the components of socio-ecological systems. Figure 1 provides one perspective. It indicates the context in which a natural asset check might be undertaken (de Groot *et al*., 2010; Potschin and Haines-Young, 2011). The underlying idea is that there is a flow of benefits to people from nature. No component in this system can be considered in isolation. Within this system, natural assets are the chemical, physical and biological structures in nature and their arrangement in systems. The assets also include the ecosystem characteristics and processes associated with them, such as soil formation.

Figure 1: The relationship between natural assets and the values ultimately placed upon them. Based on Potschin and Haines-Young (2011); incorporating the UK NEA distinction between final ecosystem services and goods and benefits valued by people (UK NEA, 2011).



In accordance with the terminology used in the UK NEA, natural assets provide 'final' ecosystem services (such as pollination and water supply). The services then deliver the goods and benefits that are valued by people (such as food and flood control). A number of questions fundamental to sustainable development appraisal arise in Figure 1:

- Are there are critical or minimum levels of natural capital needed to deliver particular services?
- Where are the limits to the supply of ecosystem services?
- What criteria should be used in valuing different goods and benefits?

In the UK NEA, a distinction has been made between final ecosystem services, and the goods and benefits that they provide in order to make an economic valuation of ecosystem services (UK NEA, 2011; Bateman *et al*., 2010). In the UK NEA, the aim was to understand how changes in the stock and condition of different habitats might affect the output of services and hence changes in their *marginal* value to society. The idea of changes in marginal value is particularly important because it clarifies the difference between what is being attempted in an 'ecosystem assessment' and what an 'asset check' might involve.

The first phase of the UK NEA documented the current status and recent trends of ecosystem services at the national scale. In this context, the idea of measuring changes in marginal value is appropriate. This is because the emphasis is on understanding how output values change with variations in a given (usually small) quality and quantity of some ecosystem asset. The valuation exercise is thus a comparative one, and does not seek to give an estimate of the total value of any set of ecosystem assets. While Bateman *et al*. (2010) and others have proposed that this is the most useful approach to valuation for policy appraisal, there are limitations. For example, according to Fisher *et al*. (2008) this kind of valuation regime *only* applies if the ecosystem is operating above some 'Safe Minimum Standard' (SMS). The SMS represents the level of ecosystem structure and processes needed to maintain functional integrity. A natural 'asset check' should, therefore, also focus on these non-marginal changes.

Several important points emerging from the UK NEA need to be considered in the design of an asset check:

1. While the UK NEA conceptual framework makes reference to the existence of non-linear and irreversible changes in the capacity of the natural environment to provide ecosystem services, it did not set out to provide a comprehensive listing and systematic analysis of them. Questions about the limits of service supply of the levels of natural capital required to sustain ecological function remain. Even after the UK NEA, the situation that Fisher *et al*. (2008) described in more general terms remains; it is not possible to determine exactly where this safe point is for most ecosystems.
2. Despite its breadth, the UK NEA was not an exhaustive study of the functional relationships between the stock and condition of ecosystem assets and the output of ecosystem services. Information about recent changes in the extent or condition of habitats was assembled from various empirical sources. Estimates of changes in service output were made from other observational data. However, as the scenario component of the UK NEA demonstrated (Haines-

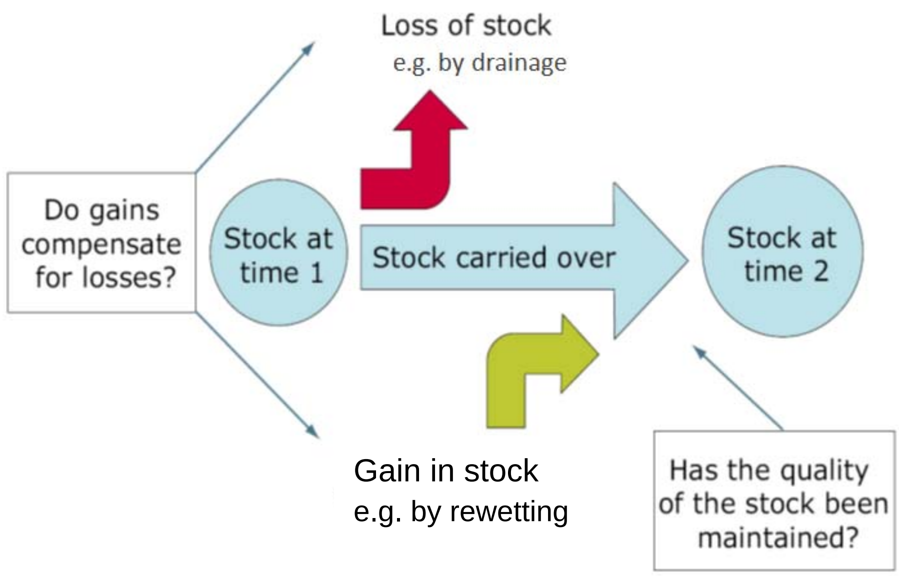
Young *et al*., 2011), we lack the tools needed to be able to predict, *even at the margin*, how service outputs will vary as the stock and condition of most ecosystem assets change.

3. The UK NEA was based on existing data. Further work is required to design future programmes to monitor how ecosystem services are changing over time. Most importantly, it is currently not possible to determine where trends are approaching some critical limit, where sudden or non-linear changes might occur. The UK NEA is useful in making the case for investing in environmental monitoring, following a critical evaluation of current datasets.

There is no simple process by which the results of the UK NEA can be translated immediately into what is needed for a rigorous natural asset check. **Our first proposition is that further development of the UK NEA framework will be required in order to perform the check.** Additional empirical work on ecosystem integrity is required before we can identify the critical levels of structure and function needed to produce a sustainable flow of ecosystem services.

The issue of what minimum levels of natural capital might be and how we might describe, maintain and restore them, has also been the focus of recent work on land and ecosystem accounting promoted by the European Environment Agency (EEA, 2006; 2010), as part of their contribution to the revision of the System of Environmental and Economic Accounts (SEEA) 2003. This work is useful because the idea of an environmental account brings a different perspective to the problem of constructing an asset check, compared to that provided by the UK NEA. For the purpose of policy analysis, the dynamics of the socio-ecological system shown in Figure 1 could be described as a series of accounts describing the various assets and service flows that they generate. More detail of what an account might look like is illustrated in Figure 2, which uses the example of land cover. As the diagram illustrates, the accounting model can also be used to look at some fundamental questions about land use and sustainability.

Figure 2: The accounting model as a framework for sustainability assessment (after EEA, 2006), using the example of wetlands.



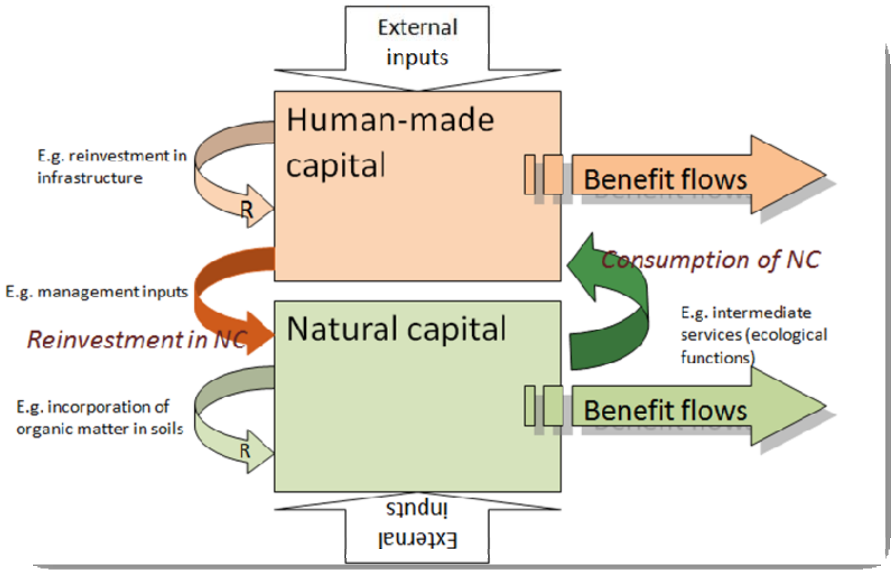
For example, in terms of the changing stock levels of a given land cover type, we may ask whether the gains in stock compensate for any of the losses that were experienced over the accounting period. Questions about compensation are fundamental to the issues associated with strong and weak notions of sustainable development. It is necessary to find ways of answering these questions in order to understand whether changes in the stock of different land covers are eroding our natural capital base (as exemplified by Smart *et al*., 2010). In terms of the stock of wetlands, for example, it would be necessary to determine whether land restoration schemes leading to the creation of new wetlands were making up for those that have been, or are being, lost to other development. This may include their overall capacity to store carbon or their contribution to coastal protection. The judgements we made as to whether these stock changes are really compensating each other would clearly influence any conclusion we make about progress towards sustainable development.

In considering questions about accounting further, we might ask whether the quality or condition of the stock of land cover carried over from Time 1 to Time 2 has been maintained in terms of the benefits it provides to people or the support it offers to wider ecosystem functions (Figure 2). Maintenance of the integrity of land cover assets or ecosystems is also fundamental to planning for sustainability. Using the example of wetlands, we may still have the same *area* (stock) of wetlands at the end of some accounting period, but its functionality may have been damaged. The same area of wetland, for example, might no longer be able to fix the same amount of carbon or regulate water quality and quantity as it previously did. The ability to form a judgement about the way in which the quality or condition of our different land cover elements is changing is also fundamental to understanding whether we are sustaining our natural capital base.

The EEA (2006; 2010) argue that while much of the current literature dealing with the problem of valuing the benefits from natural capital has focused on these final products or services, the importance of the intermediate or supporting services and the natural asset base on which they depend should not be under-estimated. The scale and/or value of the intermediate services consumed in the production of final goods should be identified. As shown in Figure 3, in the same way that society has to reinvest in human-made capital to take account of depreciation, we must also consider the level of reinvestment in our natural capital needed to sustain the output of ecosystem services (see also Bartelmus, 2009; Mäler *et al*., 2009).

The 'reinvestment' in natural assets may take many forms including: maintenance or management, protection and restoration costs. However, it could also include less tangible things like 'use forgone'; which can be thought of as the stock of natural capital that must not be appropriated to ensure that ecosystems retain their capacity to renew and sustain themselves. Resilience is a theme in much of the literature identified by this study (e.g. Vergano and Nunes, 2007; Deutsch *et al*., 2003). It is the capacity of an ecosystem to resist disturbance and still maintain a specified state (Brand, 2009). This is includes the capacity of ecosystems to supply ecosystem services. As with other benefits provided by ecosystems, resilience is not priced by current markets, but this does not mean that it is of no value to people (Walker and Pearson, 2007; POST, 2011).

Figure 3: Conceptual framework for natural capital accounting (Potschin and Haines-Young, 2011).



A key issue is therefore how to determine the level of natural capital that is needed and how much reinvestment is required to sustain it. In addition to reducing the risk of regime shifts and irreversible change, 'need' is also determined by policy goals and targets, and by societal preferences and aspirations. While avoiding any net loss of natural capital may be part of ensuring inter-generational equity, it is not the only part. Safeguarding inter-generational equity can also include avoiding excessive costs for future generations due to erosion of the current natural capital base.

Several important points emerge when thinking of the natural asset check in terms of an accounting exercise:

1. Provided that appropriate ways can be found to represent the stock and condition of natural assets, the accounting model is much closer to the 'capitals approach' for assessing sustainable development. It provides a framework in which questions of criticality and compensation can be examined in relation to the level of natural assets needed to sustain the output of ecosystem services. While it does not beg the question of *what* is critical, it provides a framework in which the implications of weak and strong positions on sustainability can be evaluated.
2. Although accounts represent the state of natural assets in physical terms, they allow the impacts of different policy options to be asked (in terms of sustainable development) without the necessity for economic valuation. The latter can, however, be used within the accounting framework where appropriate.
3. Accounts potentially allow both the costs (liabilities) and benefits to be documented (in physical and/or monetary terms) so that a more holistic assessment of policy options and implications might be made.

Our second proposition, therefore, is that in terms of constructing a natural asset check, some kind of accounting model is possibly a more useful foundation than the frameworks used for ecosystem assessments. While assessments like the UK NEA could draw on accounts, ecosystem assessments that follow the Millennium Ecosystem Assessment (MA) model may not generate the kinds of systematic information that a natural asset check for public policy appraisal would require.

An assumption that underpins this second proposition is that a natural asset check is not a 'one-off' exercise, like the UK NEA. Rather, it requires some periodic audit to determine how the stock and condition of ecosystem assets are changing. Similarly it involves assessment of changing views about the risks of crossing some critical environmental threshold or limit. In the remainder of this paper, we consider how natural assets might be classified in order to build such an accounting framework, and how changes in stock and condition might be evaluated. We also consider implications of basing an asset check mainly on identifying irreversible change.

3. Description and classification of natural assets

Defining natural assets

If a form of accounting framework is to be constructed in order to make a natural asset check, then an appropriate description and classification of natural assets is needed so as to provide a practical way to measure the implications of individual public policies on the natural environment.

'Asset' is a term used by economists to refer to something that can produce value. At the national level, assets may be tangible (such as built infrastructure) or intangible (such as the social capital referred to in Price *et al*., 2010). Some aspects of the natural environment can be conceived relatively easily as tangible assets (Table 2). This may be because they are owned or managed by people who assert rights to them. An example is groundwater bodies licensed for abstraction.

Natural assets may also be considered tangible because they can be described in relatively simple terms as discrete components of the wider natural environment. This is the case even if the boundaries are a construct of environmental science or policy, as in the case of 'habitat'.

Other aspects of the natural environment may be viewed more readily as intangible because they are multi-dimensional and have functional roles that have no clear spatial boundaries or ownership. An example is biodiversity; the variety of life on Earth and the natural patterns it forms. Biodiversity is usually considered in terms of species but, in considering natural assets, it is equally important to consider biodiversity in terms of genetic diversity, the diversity of ecosystems and even the diversity of ecosystem functions. Many individual species, particularly those that dominate agriculture and forestry, may constitute tangible assets. The role of others is less clear, particularly in ecosystems where many species appear to play the same functional role. Due to the rapidly evolving work on ecosystem valuation, the boundary between assets and the value derived from them may not always be clear cut.

While this paper envisages that a natural asset check might start with assessment of the condition of the UK land surface, there is a need to ensure that ultimately natural asset checks include the full spectrum of natural resources wherever they may be located in the world. This includes mineral resources and marine resources beyond UK territorial waters.

Table 2: Options for identifying and classifying tangible natural assets.

Classification option	*Examples of work that follows this classification*
Comprehensive (capable of covering all UK territory)	
Air Water Land (or soil) Habitats	CRITINC framework: Ekins and Simon (2003)
Broad Habitats (e.g. uplands, marine)	UK National Ecosystem Assessment Land Cover Map 2000, including land cover considered in the UK UK Environmental Accounts (Office for National Statistics) UK Biodiversity Action Programme.
Ecological landscapes	Barbier (2008)
Specific (not intended to encompass the whole UK territory)	
Specific habitat types	UK Biodiversity Action Plan priority habitats (such as intertidal mudflats, limestone pavements)
Areas of designated natural value	Sites of Special Scientific Interest, Landscape Character Areas
Individual species	Biological Records Centre, UK National Biodiversity Gateway
Individual ubiquitous components	Soils as natural capital (Robinson *et al*., 2009) Macro-elements (nitrogen, phosphorous)
Components closely associated with markets for environmental goods and services	Forests and fish stocks in the UK National Environmental Accounts

Ecosystem characteristics and final ecosystem service provision

The Government Economic Service Review (Price *et al*., 2010: p45) recommends a focus on assessing the impacts of policy on natural assets that are *essential* to social and economic activity. Therefore, any classification system for natural assets should ideally be based on the extent to which the links between ecosystem characteristics, services and values are explicit.

One potential framework for classifying natural assets is that suggested by Ekins and Simon (2003). These authors show how general ecosystem characteristics can be assigned to individual natural assets (land, air and water and habitats). For example, atmospheric properties and climatologic processes are assigned to air. Similarly, hydrological processes and properties are assigned to water. This approach is logical in that land, air and water are often the focus for key ecosystem properties. This approach does not, however, account for how ecosystem services typically result from the interaction between these components, and so it is difficult to determine which particular assets are *essential to social and economic activity.*

An alternative approach to classifying natural assets is contained in the 2003 revision of the UN System of Economic and Environmental Accounting (SEEA). SEEA 2003 identifies the three principle ‘functions’ of natural assets: namely its capacity to act as a ‘resource’, a ‘sink’ and to provide a service. The terminology used in SEEA 2003 is particularly unhelpful given the language that has developed around the idea of ecosystem services. A Common International Classification for Ecosystem Services’ (CICES) has been proposed that links the initial provisional classification of assets to the broad categories of ecosystem function proposed in the SEEA (Table 3) (Haines-Young and Potschin, 2010b; see also POST, 2011). This can be cross-referenced with the ecosystem service categories used in The Economics of Ecosystems and Biodiversity Study.

CICES was not proposed as a replacement for existing classifications of ecosystem services but as a way of translating between the different systems now being used. It does this by suggesting a hierarchical structure to the classification process and nesting more narrowly defined ecosystem outputs into broader themes and classes (Table 4). Its immediate application has been to find a way of linking ecosystem services to the various product and activity classifications used in national economic accounting[3]. This linkage is potentially useful in identifying those outputs of natural capital that might be important in relation to social and economic activity. Although not explored in the CICES proposal, the hierarchical approach may also be useful in understanding the dependencies of services on some set of underlying ecosystem assets.

Table 3: Relationship between the structure of CICES and functions of natural capital described in SEEA 2003 and the ecosystem service categories of TEEB (after Haines-Young and Potschin, 2010b).

CICES		SEEA	TEEB			
Ecosystem service theme	**Ecosystem service class**	**Correspondence to ‘functions’ of natural assets**	**Ecosystem service categories**			
Provisioning	Nutrition	Resource function	Food	Water		
	Materials	Resource function	Raw materials	Genetic resources	Medicinal resources	Ornamental resources
	Energy	Resource function				
Regulation and Maintenance	Regulation of wastes	Sink function	Air purification	Waste treatment		
	Flow regulation	Service function (environmental quality)	Disturbance prevention / moderation	Regulation of water flows	Erosion prevention	
	Regulation of physical environment	Service function (environmental quality)	Climate regulation	Maintain soil fertility		
	Regulation of biotic environment	Service function (environmental quality)	Gene pool protection	Life cycle maintenance	Pollination	Biological control
Cultural	Symbolic	Service function (amenity)	Information for cognitive development			
	Intellectual and experiential	Service function (amenity)	Aesthetic information	Inspiration for culture, art and design	Spiritual experience	Recreation and tourism

3 Namely: the International Standard Industrial Classification of All Economic Activities (ISIC V4), the Central Products Classification (CPC V2), and the Classification of Individual Consumption by Purpose (COICOP).

Table 4: Thematic, class and group structure proposed for CICES (Haines-Young and Potschin, 2010b).

Theme	Class	Group
Provisioning	Nutrition	Terrestrial plant and animal foodstuffs Freshwater plant and animal foodstuffs Marine plant and animal foodstuffs Potable water
	Materials	Biological materials Non-biological materials
	Energy	Renewable biofuels Renewable non-biological energy sources
Regulation and Maintenance	Regulation of wastes	Bioremediation Dilution and sequestration
	Flow regulation	Air flow regulation Water flow regulation Mass flow regulation
	Regulation of physical environment	Atmospheric regulation Water quality regulation Soil formation and soil quality regulation
	Regulation of biotic environment	Life cycle maintenance & habitat protection Pest and disease control Gene pool protection
Cultural	Symbolic	Aesthetic, Heritage Religious and spiritual
	Intellectual and experiential	Recreation and community activities Information & knowledge

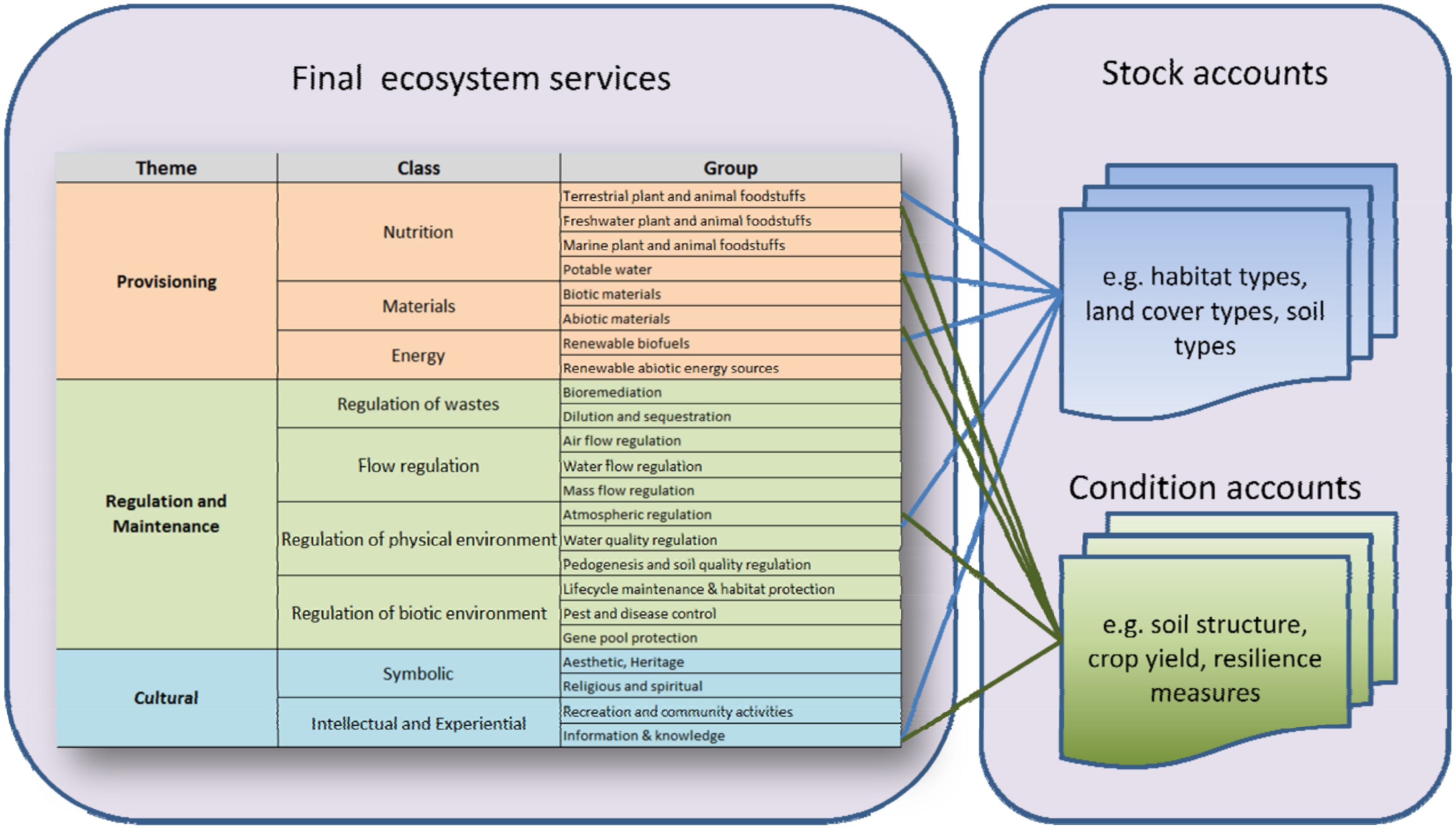
Setting aside the question of whether only these four categories are sufficient, the CICES classes could be placed alongside measures of the extent and condition of key components of the natural environment (Figure 4). This could be used as a framework for a set of accounts that then allows a periodic asset check to be undertaken, providing appropriate measures of stock and condition can be devised. The approach shown in Figure 4 would be more comprehensive if biodiversity and land cover could be included as asset classes.

The assessment of the condition of stocks could be based on their capacity to deliver supporting ecosystem services such as soil formation, nutrient cycling, and primary production. As part of this, assessment of the resilience of stocks in delivering these services (despite environmental change and short-term shocks) would be particularly important.

The placement of 'biodiversity' in the ecosystem service framework of the MA and UK NEA has been problematic because in different situations it can be either a final ecosystem service or a supporting one. While the existence of charismatic or edible species (e.g. whales, fungi) may the basis of cultural (whale watching) or provisioning services (wild food), other species play a more basic role in the provision of ecosystem services. An example is the soil organisms involved in the dynamics of nutrients and other substances needed for ecological function. In principle, the matrix approach suggested in Figure 4 offers a way of distinguishing between these different aspects of biodiversity. However, it is not apparent how the components of biodiversity might be represented in terms of an asset. Biodiversity may have important, non-linear effects on service output (Box 1) due to its supporting role. Its broader role in the generation of ecosystem services in complex ecosystems is only poorly understood[4].

4 See for example, the including the NERC Biodiversity and Ecosystem Service Sustainability Programme, http://www.nerc.ac.uk/research/programmes/bess/

Figure 4: Framework for a natural asset check, combining assessment of final ecosystem services with stock and condition accounts.



Box 1 – Links between biodiversity and ecosystem services

The following summarises the results of a literature review by Haines-Young and Potschin (2010a)

Most assessments of the relationship between biodiversity and ecosystem services are focused specifically on the links between specific aspects of biodiversity and supporting ecosystem services such as productivity and nutrient cycling. They do not link biodiversity in all its aspects with final ecosystem services.

As shown in Figure (Box 1), a variety of kinds of relationships between biodiversity and ecosystem function may occur in practice. According to a review of studies on this topic in the 1990's, Schwartz *et al*. (2000) concluded that linear relationships (line A in the Figure below) are rare. These authors concluded that ecosystem functions such as productivity do not increase proportionally above thresholds that represent a low proportion of the total number of species present at any one location. In practice, the relationships reported in the literature (curves A, B and C in the Figure below) depend on what is being studied. Key factors include the habitat, the specific aspect(s) of biodiversity, the ecosystem characteristic and the spatial scale. As a general rule, relationships are generally positive (Balvanera *et al*., 2006).

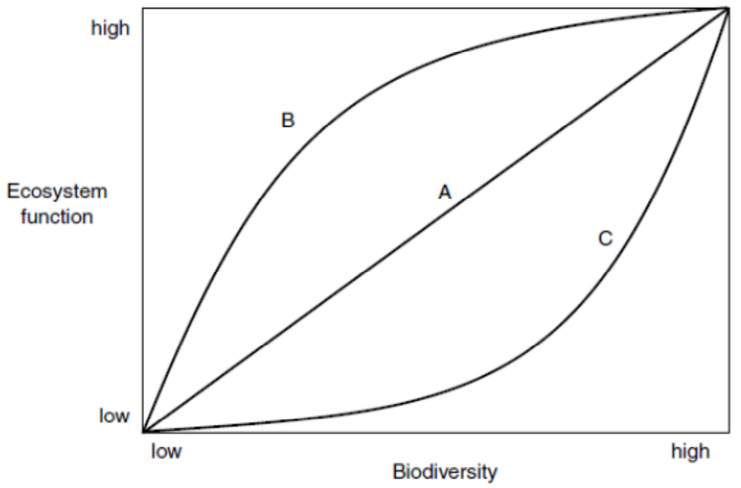


Figure (Box 1) - Potential relationships between biodiversity and ecosystem functioning (from Haines-Young and Potschin, 2010a). Based on Schwartz *et al.* 2000 and Kremen 2005.

Two key lessons are apparent from study of this topic to date.

1. **There is often a connection between the number of species occurring in any one place (species richness) and the rate of generation of biological material (productivity).**
   Productivity is important because it supports many final ecosystem services, not least provisioning services. Positive relationships between species richness and productivity have been demonstrated in grassland ecology and marine ecology. The reason for these links is often attributed to the complimentary roles that individual species have, in supporting the overall function of ecosystems.

2. **The presence of groups of species with particular properties and functions is a key determinant of ecosystem functions,** such as capacity to retain nutrients. In some cases, individual species can play vital roles in maintaining supporting ecosystem services. Evidence for the importance of having a diversity of functions in the organisms present in a habitat is particularly strong in relation to soil micro-organisms.

The placement of habitat, or more generally land cover characteristics, is also worthy of further scrutiny in terms of potentially extending the asset framework suggested in Table 5. While the definition of habitat in ecology is oriented around individual species, the term has been used to describe areas of land or sea where communities of species are able to co-exist. Consideration of habitats as discrete assets has the specific advantage of enabling consideration of physical, chemical and biological aspects of the environment as one system. This applies whether the habitat classification is broad (coastal margins, urban etc) or narrow (intertidal mudflats, urban green space etc). The broad habitat descriptions used in the Countryside Survey and UK NEA demonstrate the some of the advantages using a habitat classification as an assessment framework.

A limitation of using broad habitats as the basis for classification of natural assets is that many ecosystem characteristics operate across multiple habitats or whole landscapes (Haines-Young and Potschin, 2008). This is seen in the case of nutrient cycles, which are driven by components of many different habitats. Similarly, pest regulation depends upon habitat diversity (Bianchi *et al*., 2006). The nitrogen cycle, for example, also involves processes occurring in upland, lowland and marine habitats (European Nitrogen Assessment, 2011). In addition, places where population density is relatively high (often called urban habitats) cannot be considered as being distinct from their surroundings due to their reliance on energy and materials (ecosystem goods) from elsewhere.

If the framework suggested in Table 5 is developed as the basis of constructing an asset check, a topic for further investigation should be whether habitats or land cover types more generally are used as asset classes in their own right, or whether they are best used to construct a set of spatial accounting units, within which the stock and condition of other assets are represented.

On the basis of this review of different approaches to classifying ecosystem assets that are 'essential to social and economic activity', **our third proposition is that: despite methodological uncertainties an approach that translates ecosystem services to the ecosystem assets that underpin them, is probably more efficient in capturing what is important in policy terms, than one that is based on a more generic classification of assets (water, air, land etc.).**

4. Identifying trends and rates of change in asset quantity and quality

If the accounting or matrix approach suggested in Table 5 is to be used as a framework for a national asset check, then a first practical step would be to determine whether there is sufficient information available to make it possible. In this section, therefore we look at what data resources exist, and the extent to which they can be used to document changes in stock and condition at different spatial and temporal scales, and in particular to document the status of assets in relation to critical thresholds and limits.

Data sources and availability

Data are available to describe most biophysical aspects of the UK natural environment in detail. Information resources are increasingly being integrated so as to allow easy single-point access. For example, the Environmental Information Data Centre has been formed to facilitate access to environmental data in the UK (Box 2). The British Oceanographic Data Centre provides a parallel resource of data for the marine environment.[5]

[5] http://www.bodc.ac.uk/

Box 2 – The Environmental Information Data Centre

The Environmental Information Data Centre (EIDC) is the Natural Environment Research Council data centre for terrestrial and freshwater sciences, managed by the Centre for Ecology and Hydrology. It brings together wide-ranging nationally-important datasets, making them available via a single website. Examples of datasets included in the EIDC are shown below:

Dataset	Assets described by the dataset
Land Cover Map 2007 - land cover of Great Britain and Northern Ireland from satellite information, accurate to the field scale, and checked against ground survey.	Broad habitats Specific habitats
Countryside Survey – in depth field survey of a sample of 1 km^2 squares in the countryside. Conducted in 2007, 1998, 1990, 1984 and 1978.	Broad habitats Soils, streams, ponds
National Water Archive – incorporating the National River Flow Archive (daily and monthly river flow data for 1500 gauging stations) and the National Groundwater Level Archive	Rivers and groundwater
Environmental Change Network – the UK's long-term environmental monitoring programme using of 12 terrestrial and 45 terrestrial sites throughout the UK.	Biodiversity, rivers, soils, vegetation
Biological Records Centre - published distribution maps and atlases of 12,000 species.	Species

For the UK land surface, tools such as Landcover Map allow the mapping at 25 m^2 resolution. Such data can provide comprehensive stock maps for the broad habitats, for example. These data, coupled with the results of field component of Countryside Survey (Smart *et al*., 2010) could be used to help document longer term, broad-scale changes in a range of important ecosystem characteristics.

In addition to these efforts to provide comprehensive coverage of natural assets, data on specific assets are also available. An example is the Forestry Commission's National Forest Inventory, which describes the presence and condition of woodland across the UK. Along with its predecessors, the Inventory has occurred at 10 to 15 year intervals since 1924. Similarly, the Environment Agency's Water Quality Monitoring Programme, provides a picture of the changing chemical and biological status of waters across England and Wales.

Data on trends in biodiversity are available and take two forms: species presence and abundance (or biomass). The former cover more species, taking the form of distribution maps.[6] Data on the abundance of animals are heavily biased towards vertebrates, particularly birds. While soil micro-organisms are essential for many supporting services, data representing them at the national level are scarce.

[6] For example, see the National Biodiversity Gateway. http://data.nbn.org.uk/

For the UK marine environment, the 'Charting Progress 2, The State of UK Seas' Report (UKMMAS, 2010) consolidates the majority of understanding of the condition of UK seas.

Trends and rates of change in asset quality and quantity

Despite the range of environmental information available in the UK, the capacity of environmental datasets to demonstrate trends and rates of change in condition and extent of natural assets is variable. This due to the fact that the frequency of monitoring reflects the policy, management and research needs for the data, as well as rates of change in the assets themselves. Accordingly, some assets, such as groundwater, are monitored weekly or monthly. In contrast, the Landcover Map is produced every decade. Very often, raw data are available, but require formatting, synthesis and interpretation before they meet the particular needs of users.

A key scientific challenge in determining rates of change in asset quality is the length of monitoring periods represented by datasets. Routine hydrological monitoring extends back to the 1930s and 1940s, enabling long-term trends in quality and quantity to be readily identified. As a result, the links between precipitation and river flow are well characterised. Monitoring specifically for environmental change has, however, commenced only in the last 20 years. This includes the Environmental Change Network (ECN) for which monitoring first started in 1993. The field component of Countryside Survey also has much to offer in terms providing information about trends and rates of change in asset quality and quantity. These data have been used in the past to construct environmental accounts (Haines-Young, 1999), and more recently in the Countryside Survey Integrated Assessment (Box 3).

Box 3 – Countryside Survey Integrated Assessment: linking ecosystem characteristics with ecosystem services at the national level (Smart *et al*., 2010)

The Countryside Survey measured soil, water, vegetation and landscape quality at fixed locations across Great Britain in 2007, 1998, 1990, 1984 and 1978. The locations provide representative coverage a broad range of habitats, except coastal and urban habitats. During the 2007 Survey, 591 1 km^2 squares were surveyed across Great Britain.

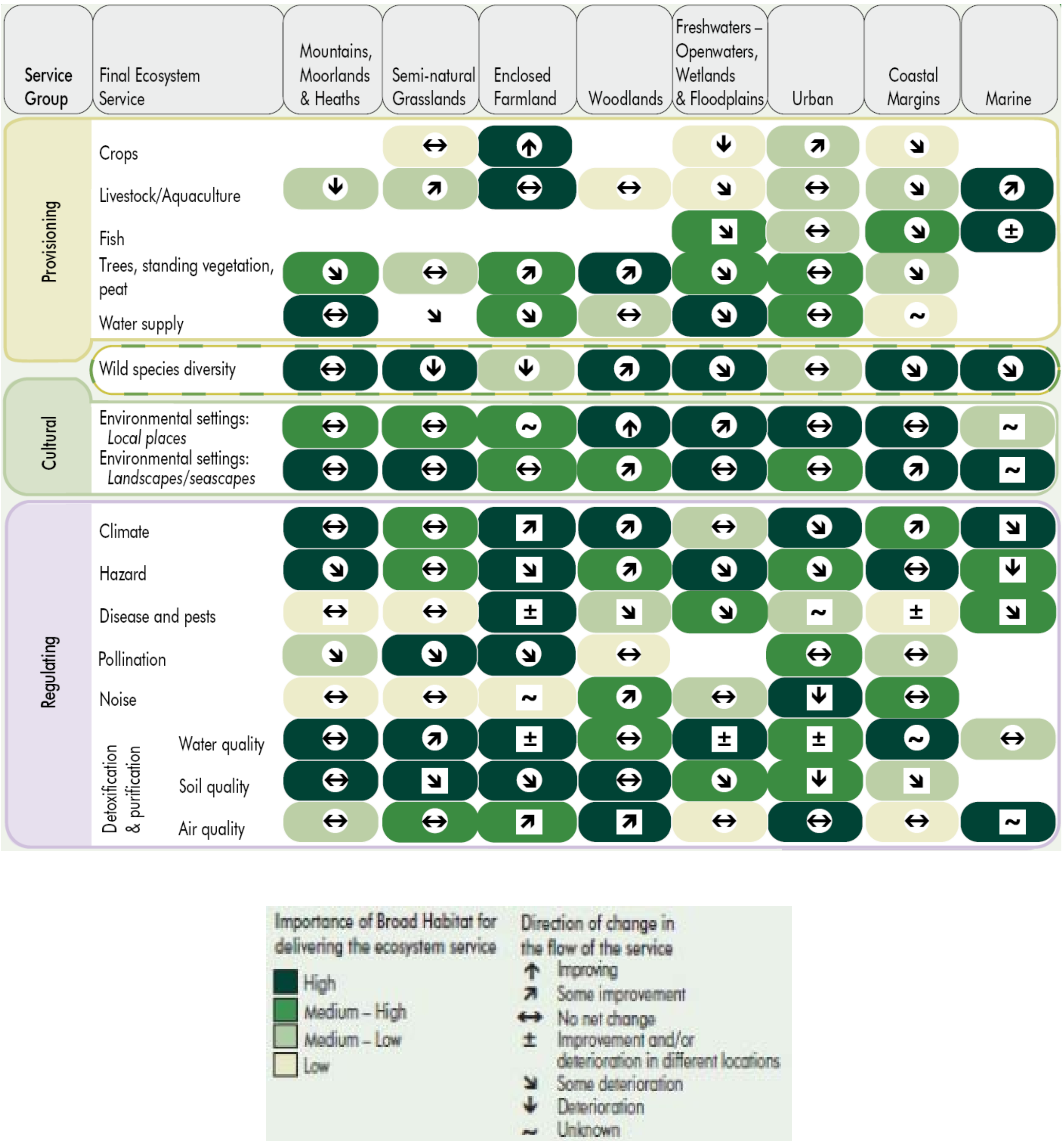
Following the 2007 Survey, 38 biophysical variables measured in the Survey were selected as indicators of ecosystem service provision at the national scale. This followed the classification of ecosystem services subsequently used in the UK NEA. The indicators related to measurements taken in the headwaters of rivers, ponds, soils, wild species diversity and cultural aspects of landscape. An example of an indicator is 'headwater stream biological water quality', which was used to represent the ecosystem service of clean water provision and based on survey of macro-invertebrates (organisms that are visible to the naked eye and lack a backbone). The trends, which were classed as 'stable', 'improved' or 'declined', reflect mainly to the 1990 to 2007 period although a number of soil and vegetation indicators date back to 1978.

Indicators linked to ecosystem services provided by freshwaters and soils were found to be stable or improving. In the southern and eastern lowlands of England for example, the estimated percentage of headwater streams in adequate condition has steadily increased from 15% in 1990 to 25% in 1998 and 29% by the time of the 2007 survey.

In contrast, indicators linked to the diversity of plants were declining (an 8% reduction in number of species in 200 m^2 vegetation plots between 1978 and 2007). In particular, there were declines in the diversity of nectar plants, which is one indicator of the regulating service of pollination. Analyses focused on nectar plants for bees. Declines were largest in the following habitat classes: Arable and horticulture, Neutral Grassland, Broadleaved, Mixed and Yew woodland and Coniferous Woodland. These all lost on average one species in the sample of 4 m^2 plots between 1990 and 2007.

Together with a range of other data, Countryside Survey data have also been used to characterise the current status and recent trends in final ecosystem services across in the UK NEA (Figure 5). In contrast to the indicator approach used to assess changes in habitat condition used by Countryside Survey, habitat condition in the UK NEA was assessed in terms of its ability to deliver ecosystem services. Given the nature of the data used in the assessment, the results of this analysis are highly generalised in their character (Figure 5).

Figure 5 – Relative importance of broad habitats in delivering ecosystem services and overall direction of change in final ecosystem service flow since 1990. From UK NEA (2011).



The trends shown in Figure 5 are useful in indicating broad directions of change in the condition of an asset. Nevertheless, they do not necessarily assist with the identification of irreversible changes in the capacity of natural assets to provide final ecosystem services. Rates of change in the provision of many services are important because they help to indicate the time when the levels of ecosystem service provision may become unacceptable to society. In some cases, such as provisioning services, rates of change can be monitored comparatively easily because of the availability of indicators such as agricultural yield statistics. In other cases, such as disease and pest control, rates of change are more difficult to determine because they are based on factors affecting the likelihood of occurrence, rather than direct measurement.

Spatial Patterns and Appropriate Accounting Units

As noted in the introduction, an ecosystems approach emphasises that policy analysis and decision making needs to be undertaken at an appropriate spatial scale. This requirement raises several important issues in terms of constructing a framework for an asset check. It suggests that we not only need access to spatially disaggregated data for ecosystem assets but also some agreement about what kinds of spatial unit are meaningful in terms of determining their status and trends (Haines-Young and Potschin, 2008). It is unlikely, for example that a single measurement at the national scale could tell us all we need to know about the ways in which changes in natural capital might impact on economic and social activities. The extent to which individual areas of peatland act as sources or sinks of greenhouse gases (see Dinsmore *et al*., 2009) illustrates the complexity of assessing the overall status of what may be perceived as a critical natural asset. Further complexities might arise in any assessment framework because different assets might require different types of spatial scale to be considered. Therefore, while catchments might be appropriate in a number of hydrological contexts, for soils other types of spatial unit relating to surface geology might be more meaningful.

The importance of spatially disaggregating accounts for land cover has been shown by the recent work of the European Environment Agency (EEA, 2006). Similar approaches are now proposed for a range of other ecosystem accounts, such as those for carbon and biodiversity. The mapping used in the UK NEA was very coarse compared to the 1 km resolution accounting grid used for Europe. Thus if the framework for a natural asset check is taken further, it would seem essential that the question of if and how data describing natural assets can be spatially disaggregated, and whether cross-scale comparisons were necessary. A recent scoping study undertaken for Natural England has shown how the National Character Areas for England might be used to characterise the importance of ecosystem services in different landscapes, and to assess the significance of landscape change upon them.

5. Approaches to prioritising natural assets

A full review of the adequacy of data resources and how they might be used to make a natural asset check is beyond the scope of this paper. **Nevertheless, on the basis of initiatives such as Countryside Survey, Charting Progress and the UK NEA, our fourth proposition is that sufficient data resources are available to make a preliminary audit of natural assets at the national level.** Given the many conceptual and analytical challenges that would need to be overcome, however, it is important that the work should focus on those areas which were most important from a policy perspective. Current reviews of monitoring networks (such as that being undertaken by NERC in reviewing its national capability strategy) represent an opportunity to ensure that environmental monitoring is fit for this purpose.

In terms of scoping future work, Price *et al*. (2010) emphasise that a natural asset check should primarily be concerned with “large, irreversible impacts on assets that are essential to social and economic activity” [p9]. While the identification of thresholds and potentially irreversible change is complex and not easy to specify *ex ante*, some progress might be made by using the qualitative results of the UK NEA shown in Figure 5, to select those habitats that have been judged as most important for the different services, and investigate in more detail what criticalities might exist in terms of the underlying supporting services associated with them, and how they might be assessed given current data resources.

The investigation of these criticalities should focus on the following two considerations:

- Whether the trends suggest that some ***limit*** of acceptable or desired change is being approached and if so how this relates to the erosion of some underlying asset. An environmental limit is simply a point or range of conditions, beyond which the benefits derived from a natural resource system are judged unacceptable or insufficient (Haines-Young *et al*., 2006; POST, 2011). Although these are informed by environmental science considerations, they are also a question of societal choice or preference. While they are reversible, crossing them can nevertheless damage social or economic activities.
- Whether there is any evidence that these trends could result in the crossing of a ***threshold*** that would result in a fundamental change in ecosystem dynamics. Much emphasis has been placed in the ecological literature on the existence of possible thresholds within the biophysical aspects of ecosystems. They are sometimes also referred to as ‘tipping points’ or ‘regime shifts’. Examples include pest outbreaks, algal blooms, and collapse of fish populations. Practical steps to predict the existence of thresholds have only recently begun (Andersen *et al*., 2008). In some cases thresholds may be a management construct, based on human decisions, rather than reflecting the relationship between ecosystem characteristics and ecosystem services in the natural world. An example of how a threshold may be characterised is provided in Box 4.

A further aspect of prioritising natural assets for inclusion in the check would be to investigate how the trends across services and habitats were linked. In particular, this trade-offs should be identified. Although the issue of trade-offs has not been investigated systematically in the UK NEA, it is clear that in some situations an expansion of one service have been achieved at the expense of others. It is therefore important to examine how the trends shown in Figure 5 are related. A number of studies have shown how specific assets can show the synergies and antagonism in ecosystem service delivery as a result of management options. Box 5 shows this in the case of the Somerset Levels and Moors.

Based on these arguments, our fifth proposition is that while a focus on irreversible change is important, it would be too restrictive to make this the exclusive concern of any natural asset check. Since thresholds are difficult to identify given the current state of knowledge, a more useful approach would be to explore notions of criticality also in terms of limits of acceptable change, and to consider how synergies as well as conflicts arise between services outputs via changes in supporting services or assets.

Box 4 – Wetland response to climate change in Britain (Acreman *et al.*, 2009)

Various approaches are available to assess the response of wetlands to a changing climate, ranging from the purely qualitative studies to detailed quantitative assessment that establishes the magnitude and probability of specific consequences. The detailed approaches are often dependent on large amounts of data and are therefore most practical for use at individual sites. Acreman *et al*. (2009) provide an intermediary approach suitable for use at the regional scale.

They used a conceptual understanding of the hydrology of wetlands, together with an understanding of vegetation response to water availability and climate predictions, to assess the degree of likely change in vegetation for rain-fed and river fed wetland in different parts of Britain. An example of the results is shown below. The green zone represents preferred conditions for the vegetation, the amber denotes tolerable conditions, and the red indicates conditions which the vegetation cannot withstand. The results show how the vegetation in wetland systems become vulnerable at particular times of the year. Thresholds should therefore not be considered as fixed sets of conditions. The study demonstrates variability across Britain in terms of how wetlands may respond to a changing climate.

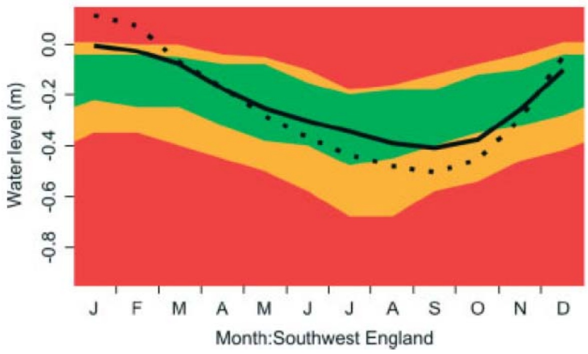


Figure (Box 4) Monthly mean water table levels (m) for the rain-fed wetland in South West England, superimposed on the water level requirements. The solid lines represent baseline (1961-1990) climate, the dashed lines show the projected values for the 2080s (2071-2100).

Box 5 – Trade-offs in ecosystem service provision in the Somerset Levels (Acreman *et al*., in press)

The Somerset Levels and Moors wetland system in Southwest England is the largest coastal and floodplain grazing marsh in England, covering 650 km^2. It provides a wide range of ecosystem services, including grazing for cattle, flood water storage and recreational opportunity. Since medieval times, efforts have been made to drain the land to increase agricultural productivity. After World War II, pumping stations were built to lower water levels. During the 1980's, incentives were introduced under the Environmentally Sensitive Areas Scheme to allow water to return to a more natural level and so improve the nature conservation and recreational value of the land.

There are now a range of management options which would have significant effects on the provision of different ecosystem services. These include raising water levels and increasing grazing. Acreman *et al*. (in press), studied the implications of these options for the spectrum of ecosystem services. This work showed that some ecosystem services are synergistic. For example, maintaining wet conditions supports bird life and reduces carbon dioxide emissions. In contrast, other services are potentially conflicting. For example, raising water levels may reduce potential flood water storage capacity and increase methane emissions.

Comparison of the services of the wetland with those of drier habitats reveals that carbon sequestration, bird habitat provision and hay production is greater in wetlands. In contrast, grazing quality and plant diversity may be reduced in the short term and distributions of disease vectors may be altered by wetland restoration through raising water levels.

This study illustrates that available options for managing specific natural assets are associated with contrasting mixes of ecosystem services.

6. Restoration of natural assets

A key consideration in ecology and economics is the extent to which natural assets can be restored either now or at some point in the future in order to build resilience or increase ecosystem service provision (Barbier, 2008; Rey-Benayas *et al*., 2009). Restoration encompasses a broad range of activities to assist with the recovery of an ecosystem that has been degraded, damaged or destroyed. The restoration of natural assets is a sub-set of this, being focused on restoration of ecosystem services (Aronson *et al*., 2007).

Despite a widespread assumption that ecological restoration increases the delivery of ecosystem services, this is not always the case, as the relationship between biodiversity and ecosystem services is non-linear and not necessarily positive (Box 1). Frequently, the aim of restoration is to increase biodiversity rather than the ecosystem services *per se*, and success may be measured either as restoring the ecosystem to a status comparable to a pristine undisturbed equivalent, or merely improving the habitat quality compared to the degraded state (or both). The former is the desired endpoint, and the latter is the starting point of the restoration.

A recent systematic global evaluation of restoration studies indicated that, on average, ecological restoration actions led to an increase in biodiversity of 44%, and increases in ecosystem services of 25%, in both cases compared to the original 'reference' degraded state (Rey-Benayas *et al*., 2009). Ecosystem service prevision remained below the levels illustrated by pristine ecosystems (at 86% and 80% of original biodiversity respectively). The time scale over which restoration of ecosystem functions occurs can be decades. For example, monitoring of restoration of wetlands in the USA shows that after 55 years soil organic carbon (an important aspect of soil function) was still only approximately 50% of that of undisturbed wetlands (Ballantine and Schneider, 2009). Studies done over shorter time periods confirm this slow build up of soil carbon (Meyer *et al*., 2008). This emphasises that long term restoration involves stages (known as successional stages). There is a need to explore how to 'jump start' such processes.

Meta-analysis illustrates that increases in biodiversity were positively correlated with increases in ecosystem services, particularly for regulating and supporting (but not provisioning) services (Rey-Benayas *et al*., 2009). This noisy yet positive relationship illustrates that there are also synergies between the restoration of biodiversity and ecosystem services, and that a greater understanding about the relationship between the two will enable better exploitation of those synergies, and avoidance of the conflicts. Problems are most likely to arise if single ecosystem services are targeted without a broader consideration of the interactions.

Our final proposition is that understanding of restoration potential is essential in order to identify where non-marginal and potentially irreversible changes in ecosystems exist. Natural assets that might be considered 'critical' may change as knowledge develops or circumstances change. As a result, a 'one-off' asset check is unlikely to be reliable for policy analysis in the long term. On-going, periodic audit is necessary.

7. Challenges for the design of a natural asset check

A natural asset check of the kind described by Price *et al*. (2010) is timely, not least because of the wider policy interest that the UK NEA has stimulated. While the UK NEA has made a valuable contribution to evaluating the status and trends of UK broad habits and the ecosystem services they provide, there is no simple process by which the results can be translated into what is needed for a rigorous natural asset check (***Proposition 1***). Furthermore, some kind of accounting model is likely to be a more useful as a foundation for an asset check than the frameworks used for ecosystem assessments (***Proposition 2***).

The implementation of a physical accounting approach to making a natural asset check would be consistent with current international initiatives to develop more general integrated economic and environmental accounting methods. It would also be consistent with Defra's understanding of an ecosystems approach. We recognise that a number of methodological questions remain before such an approach could be taken forward not least in terms of the way natural assets are classified in such an accounting system. Having considered potential typologies, however, we suggest that a classification approach that moves from ecosystem services to the ecosystem assets that underpin them, is probably more efficient in capturing what is important in policy terms, than one that is based on a more abstract and generic classification of assets (***Proposition 3***). Given the publication of the NEA, and the availability of other studies such as Countryside Survey, we consider that there are sufficient data resources available for a preliminary audit to be made (***Proposition 4***).

In scoping future work we suggest that while a focus on non-marginal or irreversible changes is important, to make this the exclusive concern of any natural asset check would be too restrictive (***Proposition 5***). Thresholds marking sudden, non-linear and irreversible change are difficult to identify in advance for most ecosystem assets, given the current state of knowledge. A useful picture of the status of natural assets could be built by looking more broadly at the limits of acceptable change. While changes across these limits may be reversible, they nevertheless can have important implications for economic and social activities in terms of the costs that cumulative changes might impose. We recognise, however, that a better understanding of the restoration potential of ecosystem assets is essential, if we are to identify where these non-marginal and potentially irreversible changes in ecosystems may occur. What might be considered critical may change as knowledge develops or circumstances change. Thus a 'one-off' asset check is unlikely to be reliable for policy analysis in the long term. On-going, periodic audit will be necessary (***Proposition 6***).

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9. Annex A – Explanation of selected terms

Critical natural capital – this concept of has emerged as a way of identifying those parts of the natural environment that must be conserved in order to maintain the capacity of ecosystems to carry out processes and ecosystem services important to human well being now and in the future (Brand, 2009; POST, 2011). Ekins and Simon (2003) demonstrate how critical natural capital can be identified by linking assets, characteristics, ecosystem services and pressures on those services. Defining critical natural capital is, however, not exclusively and environmental science question as it depends on societal values as to what ecosystem services are important.

Environmental limits – these are the points, or range of conditions, beyond which the benefits derived from a natural resource system are judged unacceptable or insufficient (Haines-Young *et al*., 2006). Therefore, while these are informed by environmental science considerations, they are primarily a question of societal choice, particularly with regard to the level or risk that is considered acceptable.

Ecosystem resilience – this is the capacity of an ecosystem to resist disturbance and still maintain a specified state (Brand, 2009). Adaptation to change is part of this. The concept has been reviewed in detail in POST (2011), where it is argued that ecosystem resilience is not solely a question of biophysical thresholds, but should include consideration of the interactions between physical, ecological and social processes.

Habitat – in ecology, this is used to refer to the environmental attributes required by a particular species (its ecological niche) (MA, 2003). The term is also used to describe areas of land or sea where communities of species are able to co-exist.

Natural assets – From United Nations (1997): "*Assets of the natural environment. These consist of biological assets (produced or wild), land and water areas with their ecosystems, subsoil assets and air*." In this paper (Howard et al.) natural assets the arrangement of inter-connected physical, chemical and biological components of the natural environment, together with the ecosystem characteristics ('supporting services') associated with them, such as pollination.

Natural capital – From United Nations (1997): "*natural assets in their role of providing natural resource inputs and environmental services for economic production*."