UK National Ecosystem Assessment Follow-on

Work Package Report 1:

Developing the evidence base for a Natural Capital Asset Check: What characteristics should we understand in order to improve environmental appraisal and natural income accounts?

Principal Investigator: Ian Dickie[1]*

Lead Authors: Ian Dickie[1]*, Philip Cryle[1]

Contributing Authors: Lindsay Maskell[2]

Report Review Editor: Bridget Emmett[2]

Natural Capital Asset Check Case Studies and Method Development:
Alan G. Jones[3], Alistair McVittie[4], Lindsay Maskell[2], Tiziana Luisetti[5], Emma Jackson[6], Ciaran Ellis[7], Katherine Simpson[7], Rosie Hails[2], Luke Brander[8]

Work Package Advisors:
Giles Atkinson[9], Tim Sunderland[10], Nick Hanley[7], Julian Harlow[11]

Internal Reviewer:
Ece Ozdemiroglu[1]

*Correspondence to: Ian Dickie, **ian@eftec.co.uk**

Affliations:
[1]eftec
[2]Centre for Ecology and Hydrology
[3]Aberystwyth University
[4] Scotland's Rural College (SRUC) Research
[5]CEFAS
[6]Central Queensland University
[7]University of Stirling
[8]Independent consultant
[9]London School of Economic
[10]Natural England
[11]Natural Capital Committee Secretariat

eftec

eftec
73-75 Mortimer Street, London W1W 7SQ
tel: 44(0)2075805383 fax: 44(0)2075805385
eftec@eftec.co.uk www.eftec.co.uk

THE BRITISH ASSESSMENT BUREAU ISO9001 UKAS MANAGEMENT SYSTEMS 4307

eftec offsets its carbon emissions through a biodiversity-friendly voluntary offset purchased from the World Land Trust (http://www.carbonbalanced.org) and only prints on 100% recycled paper.

Suggested citation: Dickie, I., Cryle, P. & Maskell, L. (2014) UK National Ecosystem Assessment Follow-on. Work Package Report 1: Developing the evidence base for a Natural Capital Asset Check: What characteristics should we understand in order to improve environmental appraisal and natural income accounts? UNEP-WCMC, LWEC, UK.

Contents

List of abbreviations and acronyms

ANGSt	Accessible Natural Greenspace Standard
ANS	Adjusted Net Saving (also called genuine saving)
CBA	Cost-Benefit Analysis
Defra	Department for Environment, Food and Rural Affairs
ES	Ecosystem Services
EU	European Union
E&W	England and Wales
GDP	Gross Domestic Product
MRV	Marginal Resilience Values
NCAC	Natural Capital Asset Check
NCC	National Capital Committee
NCI	National Capital Initiative
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
R&D	Research and development
SD	Sustainable Development
SEEA	System of Environmental-Economic Accounts
UK NEA	UK National Ecosystem Assessment
UK NEAFO	UK National Ecosystem Assessment Follow-on
UN	United Nations
WFD	Water Framework Directive
WP	Work Package
WTP	Willingness to Pay

Key Findings

A clear, shared definition of 'natural capital' is necessary to enhance our understanding of how natural capital is integral to our economy. Better understanding and agreement on what natural capital is can improve the way society manages it. The Natural Capital Committee (2013) defines natural capital as "...those elements of nature which either directly provide benefits or underpin human well-being". This highlights that natural capital generates value for people. A more technical definition is proposed by the UK NEAFO, which includes *how* natural capital generates value*: a configuration of natural resources and ecological processes which contributes, through its existence and/or in some combination, to human welfare.*

The definition proposed is based on 'configurations' – the way natural capital assets work together (in time, space, function and/or with other capital) to be productive. This distinguishes natural capital from other analytical approaches. Natural capital assets can be identified through existing environmental classifications of ecosystems (e.g. habitat types) and other natural resources (e.g. living/non-living, renewable/non-renewable). This link to existing classifications facilitates the use of existing data.

The focus on productive combinations has practical implications for analysing ecosystem services. It requires economics to use a holistic approach which takes into account ecological properties. Rather than looking at ecosystem services from habitats, it examines how parts of ecosystems *combine* to produce services. For example, in analysing the role of saltmarshes in commercial fisheries, there are a number of different natural capital assets involved, including fish species (e.g. bass) and the habitat (intertidal saltmarsh). To be productive, they need to work in certain combinations of space, time and function, and with other capital in the commercial fishing fleet. These combinations define this capital asset as they support the growth of juvenile fish (measured as biomass gain in fish stocks over time – an ecosystem service), which results in increased fish landings (goods) and has value to people as reflected in price of food.

An approach to extend current economic and scientific analysis to take account of these features of natural capital is proposed: the UK NEAFO Natural Capital Asset Check (NCAC). This offers a way of analysing available evidence to provide insights into the productive relationships that define natural capital through the following questions: (a) How much of a natural capital asset do we have? (b) What does it produce? (c) How do our decisions affect (a) and (b) over time? Examples of the key effects of our decisions identified in (c) include thresholds and/or trade-offs in the relationships between natural capital assets and the goods and services they produce. Analysis of such thresholds and trade-offs helps us to understand risks to society: our management of a natural capital asset to increase the productivity of certain goods or services may affect our ability to produce those, or other, goods and services now and in the future.

Thresholds can arise from tipping points, or chronic changes. They may become evident when productivity decreases with the decline in integrity of the natural capital concerned, or when the capacity of the natural capital to recover decreases. This highlights the importance of resilience as part of the value that ecosystems provide within natural capital assets. Data on exactly where thresholds are is rarely available to inform decision-making. A NCAC helps us to use the best data available; for example, observations of different examples of natural capital management can provide data on systems that are above and below thresholds (such as healthy versus collapsed fish stocks). The consequences of crossing thresholds depend on environmental factors, such as the speed with which productivity will recover, and economic factors, including the value of goods and services produced and the substitutes available.

Examples of applying the NCAC provide evidence on how it can help us to understand thresholds, trade-offs and other aspects of natural capital management. While extensive data on ecosystems and their services has been compiled, our understanding of the productive relationships that define natural capital is still limited. However, NCAC case studies provide examples of how declines in the integrity of natural capital can be linked to that capital's productivity; for instance, a decline in fish stocks and saltmarsh nursery habitat, results in a decrease in fish landings. This evidence supports strategic management of natural capital, and the consideration of whether it is being used sustainably or not.

Different types of natural capital are easier to analyse using a NCAC than others. The NCAC is best used when natural capital can be specifically defined by a clear spatial boundary and/or the productive configurations that provide goods and services. It is best implemented by multi-disciplinary teams (involving natural scientists and economists, for example) with existing knowledge of the best available data.

The analysis in a NCAC provides important contextual information to help construct and interpret national environmental accounts. Firstly, a NCAC helps identify the various parameters (such as the properties of the asset and the services that it produces) that can guide thinking about whether particular natural capital assets are being used unsustainably. In helping decision-makers work towards a definition of 'unsustainable use', a NCAC can provide guidance (e.g. on metrics) that can be translated into useful information for extended national accounting. Secondly, a NCAC differs from the marginal valuation of ecosystem services by emphasising the ecological properties and characteristics of natural capital assets that give rise to these services in the first place. This provides a practical mechanism that can aid ongoing efforts to construct environmental accounts linked to national accounting concepts of income and productivity, as well as balance sheets.

Summary

The concept of capital is used to describe anything that can produce goods and services that contribute to human welfare. Given the now extensive evidence on how the natural environment, through ecosystem services, supports human welfare, this Work Package has further investigated the application of the concept of natural capital. It first develops a definition of natural capital then discusses how this can be applied in analysis to support decision-making through a natural capital Asset Check (NCAC). The NCAC idea was subject to a scoping study for Defra (eftec *et al*. 2012), and the method that emerged from that study has been further examined, tested through case studies, and refined through this work. Lessons are drawn from doing so, including on how the analysis supports development of adjusted national income accounts that reflect changes in natural capital.

A clear, shared and practical definition of natural capital will help to link UK NEA evidence to decision-making. A definition is proposed based on the productive configurations (in time, space, functionally and/or with other capital) of natural capital assets as illustrated in **Figure 1.S.1**. The Natural Capital Committee (2013) defines natural capital as "...those elements of nature which either directly provide benefits or underpin human wellbeing. In this way, natural capital generates value for people." A more technical definition is proposed here which includes *how* natural capital generates value: *'A configuration (over time and space) of natural resources and ecological processes, that contributes through its existence and/or in some combination, to human welfare':*

- 'natural resources' refer to the biotic (living) and abiotic (non-living) components of nature that can contribute to human welfare;
- 'ecological processes' refer to intrinsic ecosystem characteristics whereby an ecosystem maintains its integrity;
- 'through its existence' recognises the benefits people attribute to the continued existence of the natural environment, its wildlife, landscapes etc;
- 'some combination' reflects the interaction between the living and non-living components of the environment, but also the combination of natural assets with other forms of capital in a way that makes these assets productive; and
- 'human welfare' means the benefit or value that accrues to humans.

Natural assets are defined through existing environmental classifications of ecosystems (e.g. habitat types) and other assets (e.g. renewable/non-renewable, living/non-living). The link to existing classifications facilitates use of existing data, but the focus on productive combinations distinguishes natural capital from other analytical approaches.

It is possible to regard all of the natural environment[1] as natural capital, as it can all be argued to have existence value to people or be part of some productive combination, and therefore support human welfare. While a valid argument, this is often not sufficient to provide practical information for decision-making. A more detailed analysis using this natural capital definition will identify when, how and where different combinations of natural capital and other forms of capital are more productive for society (in human welfare terms). For example, all coastal habitats have existence value and help support marine food webs. However, a specific coastal habitat, for example, the intertidal nursery habitat, can be particularly influential: reducing the extent of this habitat could be a limiting factor on a commercial fish stock. In this case the integrity (i.e. the extent and condition) of this natural capital asset (made up of the combination of the intertidal area and the juvenile fish that enter it to feed) is having an influence on society's welfare.

[1] 'Natural environment' is defined as a combination of abiotic and biotic components that occur naturally consisting of ecological systems, natural resources and physical phenomena.

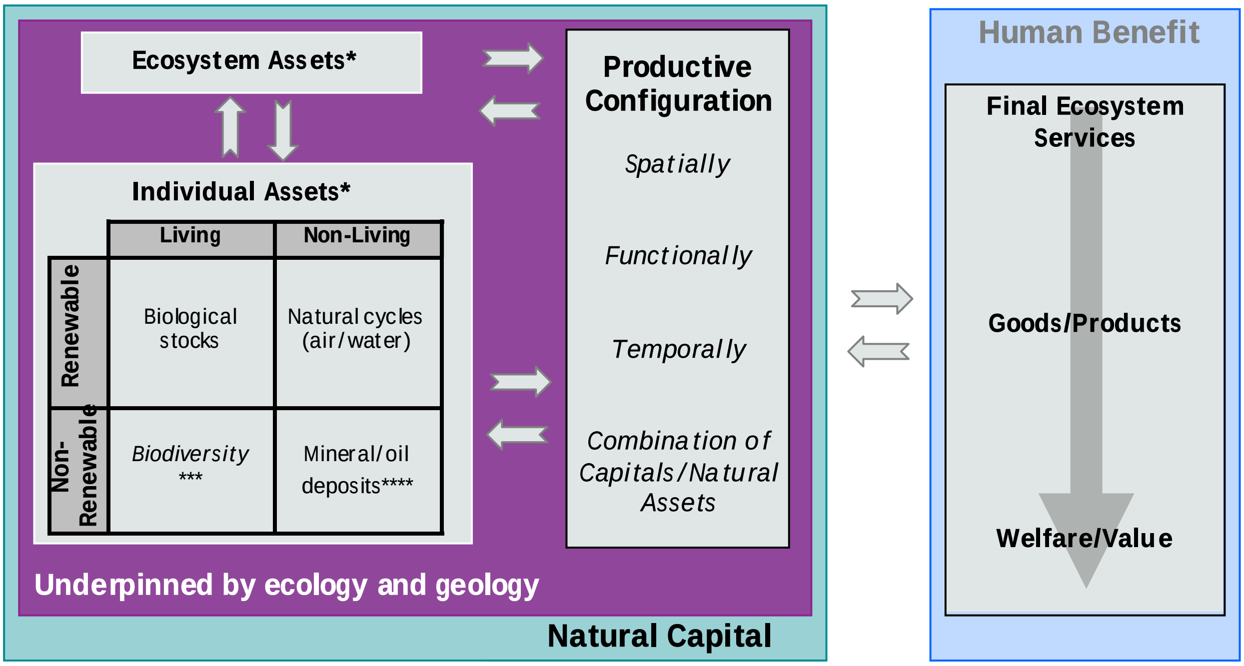


Figure 1.S.1. A natural capital definition

Thinking about natural capital in this way goes beyond current applications of traditional economic analysis approaches to the environment. It provides a way of analysing available evidence to give insights into the productive relationships that define natural capital: a) How much of a natural capital asset do we have? b) What does it produce? c) How do our decisions affect a) & b) over time? Examples of key affects identified in c) are that there may be thresholds and tradeoffs. Thresholds can arise from tipping points or chronic changes, and may be evident in increasing losses of productive capacity as the integrity of natural capital declines, or as a restriction on the ability of natural capital to recover. This highlights the importance of resilience[2] as part of the asset value that ecosystems provide.

Thresholds are approached as the condition and extent of natural capital declines (as illustrated by the line, F, in **Figure 1.S.2**; it should be borne in mind that the linear relationship shown is an over-simplification, many non-linear relationships exist in nature). A Natural Capital Asset Check (NCAC) provides a way of organising available evidence to give insights into thresholds, tradeoffs and associated welfare impacts. This evidence is built up in a series of questions organised in the five sections of a NCAC, each sections relates to a part of **Figure 1.S.2** (labelled (1) – (5)):

(1) Defines the natural capital asset based on the goods and services it produces, applying the definition shown in **Figure 1.S.1**.
(2) Considers the integrity of the natural capital (defined by its extent and condition).
(3) Considers how the integrity of the natural capital influences the goods and services it produces, such as whether there are thresholds in this relationship and the consequences of crossing them. Thresholds may be where the relationship between the condition and extent of natural capital and benefits derived by society changes (e.g. healthy and collapsed fish stocks). Thresholds may also be where natural capital degrades so that the recovery path to restore its extent and condition is compromised (e.g. would take a lot longer or is no longer possible). The consequences of crossing thresholds depend on environmental factors (e.g. speed with which productivity will recover) and economic factors (e.g. value of goods and services produced and substitutes available).

[2] Resilience is defined as the ability to withstand pressures and/or shocks.

(4) Considers available data on where thresholds are (i.e. A in Fig S2). This data is rarely available to inform decision-making, but observations of different examples of natural capital management (e.g. points B*, Bi or Bii) can provide data on systems that are above and below different types of thresholds.
(5) Combines preceding data to consider whether natural capital is being managed in a way that poses risks to society (e.g. through risks of crossing thresholds with significant consequences). This highlights a challenge for ecologists: to understand thresholds and, in particular, being able to detect the earliest warning signs that thresholds are being approached. This is highlighted in **Figure 1.S.2** by the increasing the density of red shading as the threshold is approached.

The sequential sections of the NCAC, and the high-level issues they address, are shown in **Figure 1.S.3**.

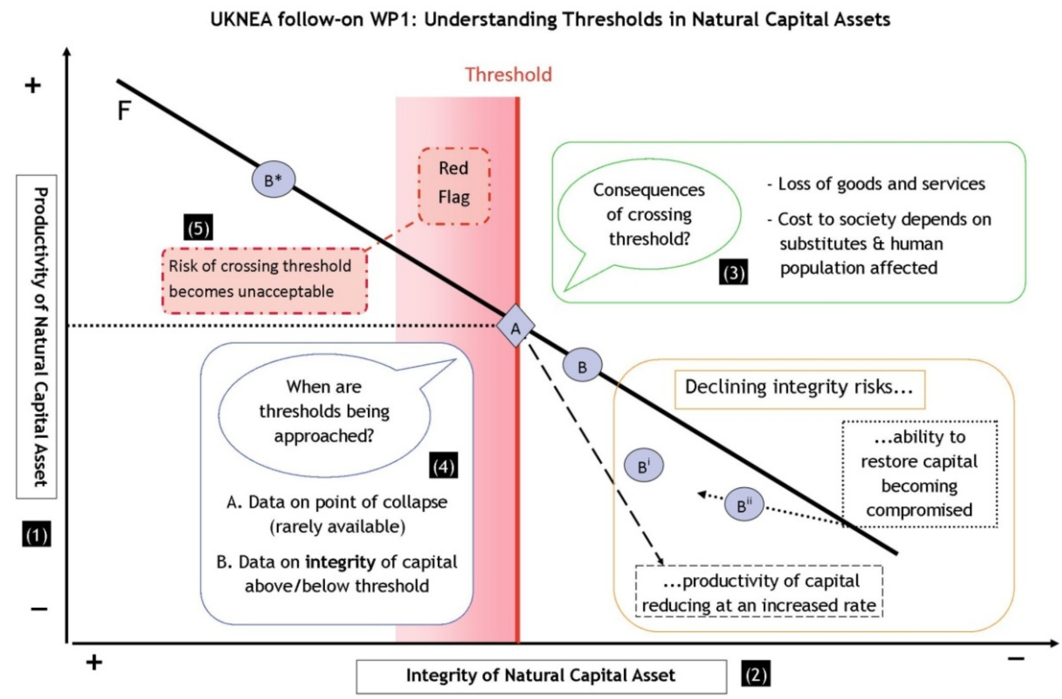


Figure 1.S.2. Thresholds and the Natural Capital Asset Check

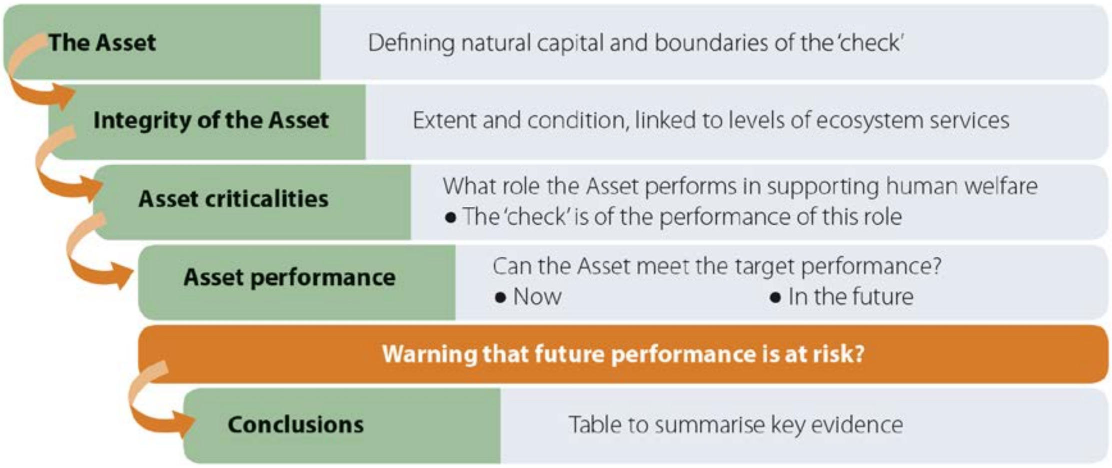


Figure 1.S.3. Steps in a Natural Capital Asset Check

A NCAC provides a way of analysing what society aims to obtain from natural capital – i.e. its performance. As productivity of natural capital can have opportunity costs, we can't expect to maximise the performance of all natural capital. Instead a desired level of performance is aimed for which balances society's different requirements now and in the future. Policy targets (e.g. for maximum sustainable yield or maximum economic yield of fish stocks; carbon concentrations that avoid dangerous climate change; nature conservation targets) give indications of desired performance, but these can be conflicting and/or ambiguous.
Completing a NCAC can fulfil the following objectives:

- to gather available evidence on thresholds relating to a natural capital asset, and understand how it will behave after crossing them, and the consequences of this; and
- to identify society's desired performance from natural capital assets.

This can help guide appropriate answers to the questions the NCAC asks. These questions can also be used to scope whether it is worthwhile to undertake a NCAC for a particular natural capital asset.

In carrying out the NCAC case studies, greater understanding has been gained of how an asset check should work:

- A NCAC can be applied to different definitions of natural capital – particular ecosystem services (e.g. pollination), particular habitats (e.g. seagrass beds) or ecosystems (e.g. soils), or a subset of the ecosystem services from particular habitats (e.g. recreational services from urban green space).
- It can be applied at different scales – nationally, regionally or locally (e.g. an estuary).
- Its application to very diverse and/or larger scale (i.e. national) natural capital assets appears difficult, but may be feasible as part of detailed/strategic Government reviews.
- Asset checks that focus on a specific ecosystem service (e.g. pollination) appear to work better, but such narrow focus risks ignoring tradeoffs between services. These tradeoffs should at least be noted, even if not quantified.
- An asset check summarises evidence on the underlying condition of the natural capital assets that will support valuable future ecosystem services. Examples of applying the NCAC provide evidence on how this thinking can help understand aspects of natural capital management. While extensive data on ecosystems and their services have been compiled, our understanding of the productive relationships that define natural capital is still limited in many areas. However, NCAC case studies show examples of where declines in integrity of capital (e.g. fish stocks and their spawning habitat) can be linked to its productivity (e.g. fish landings). This evidence supports strategic management of natural capital, and consideration of whether it is being used sustainably.

- The UK National Ecosystem Assessment (UK NEA) describes the important contribution of the natural environment to society's wellbeing. For other key contributors to our wellbeing, like economic activity, we check the condition of the underlying assets that support them. For example, educational qualifications, R&D spending and business investment data inform us about trends in the underlying condition of built and human capital that support economic activity. A NCAC aims to provide similar information about the underlying condition of the natural environment – something that currently, decision-makers often lack.
- In doing this, a NCAC could help reflect the bigger picture about the condition of the natural environment and the possible impacts of future changes – for example the impact of cumulative effects (e.g. how individual actions that increase surface water runoff can collectively increase flood risks in a catchment), or whether there are thresholds beyond which benefits from the environment will fall irreversibly (e.g. fish stock collapse).
- Thinking about natural capital in this way goes beyond current applications of traditional economic analysis approaches to the environment by considering thresholds and tradeoffs. These need to be effectively understood if we are to manage natural capital optimally for society's long-term needs.
- Undertaking a NCAC requires a significant amount of environmental and economic data, so may take at least 10 days work by a combination of ecological and economic experts to collate available evidence on the natural capital asset, spread across more than a month of time. This means it may need to be undertaken proactively for more critical environmental assets (e.g. those with highest value to society and/or considered to be at high risk), rather than reactively, unless in response to significant decision-making needs (e.g. major policy reforms or reviews). Completed NCACs could be kept as a catalogue to be referenced in the identification and/or comparison (e.g. through cost-benefit analysis) of policy options appraisal on the environmental issues they cover.

Analysis in a NCAC can also provide important contextual information to help construct and interpret national environmental accounts. A NCAC helps identify the various parameters – such as the properties of the asset and the services that it produces – which could provide the basis for account construction, and which describe aspects of ecosystems that may (or may not) be already measured in national accounts. In helping work towards a definition of 'unsustainable use', a NCAC can provide guidance (e.g. on metrics) that can be translated into guidance for extended national accounting. A NCAC differs from marginal valuation of ecosystem services by emphasising the ecological properties and characteristics of natural capital assets that give rise to these services in the first place.

1.1 Introduction and scope of Work Package 1

This is the draft final report for the UK National Ecosystem Assessment Follow-on (UK NEAFO) project's Work Package 1 (WP1). The intention of WP1 is to develop the framework for a Natural Capital Asset Check and address evidence issues that need to be resolved to implement it. The rationale for this work stems from the lack of routine assessment on the state of our natural capital and its ability to support critical future ecosystem services. Contemporary techniques exist across a range of disciplines which make such analysis possible.

The asset check, and hence this Work Package, both links to the inclusion of natural capital in the national accounts, and provides a new framework to enable the value of nature to be better reflected in impact assessments and environmental appraisal. This Work Package aims to provide a methodologically robust yet resource efficient approach to assessing the state of natural capital that can feed into analyses of environmental change and improve decision making.

This WP builds on an initial scoping study for Defra that looked at the concept of a natural capital asset check (eftec *et al.* 2012). It develops case studies to illustrate how an asset check framework might be applied to different elements of natural capital and at different scales. The focus of the check is primarily on 'assets at risk' (e.g. risk of breaching ecological thresholds through their unsustainable use). As part of WP1, the team also further developed the definition and conceptual framework of natural capital. This framework sought to combine science and economic evidence on changes in both stocks and flows over relevant spatial and temporal scales. It also aimed to link with the asset check section of WP1 by incorporating thinking on thresholds and (un)sustainable uses of natural capital assets.

1.1.1 Aims and objectives

The primary aim of WP1 is to address the following question: *What characteristics of natural capital assets should we understand in order to improve environmental appraisal and national income accounts?* In order to achieve this, the project has two objectives:

- to develop a definition and a comprehensive framework for thinking about natural capital that can be used to guide future data collection, research and analysis across the sector more broadly; and
- to develop the asset check tool and address evidence issues arising from the scoping study on the Natural Capital Asset Check.

To deliver these objectives, the project undertook the following tasks:

- Undertake a short review of literature and thinking on definitions and frameworks/typologies of natural capital.
- Identify a potential analytical framework to define natural capital.
- Review and develop the asset check tool developed in the scoping study, researching, in more depth, any evidence and technical issues highlighted.
- Review and develop further information on (i) data inputs and (ii) relationships between natural capital assets. This may include research into issues such as quantification, quality assessments, resilience, valuation and sensitivity analyses.
- Conduct further case studies and testing of this approach in decision making and appraisal situations.
- Seek solutions to issues for implementation as highlighted in the scoping study report for Defra.
- Examine the links from this thinking to modified national income accounts (incorporating ecosystem services values).

1.1.2 Methodology

Following on from an initial scoping study for Defra that looked at the concept of a natural capital asset check (eftec *et al.* 2013), this project developed natural capital asset check concepts. A synthesis of evidence on existing definitions and frameworks of natural capital as well as expert input from a range of disciplines led to a proposed definition and conceptual framework of natural capital. This fed into the development of the asset check approach.

To further explore the natural capital asset check, a set of eight experts (see contributing authors) were selected to apply the approach to a set of illustrative case studies. The case studies considered were chosen to reflect the priorities drawn from the UK NEA respresenting different scales, ecosystems and issues within the UK:

- freshwater ecosystems;
- a scoping study of carbon in seagrass beds;
- pollinators;
- soil quality;
- cultural services from urban green space;
- saltmarsh as a nursery ground for commercial fisheries;
- upland soils; and
- the Tees Estuary.

Workshops with case study leads took place in January and April 2013 to discuss the asset check methodology. These considered why an asset check might be useful; where it might be applied; when it might be most relevant; what type of experts are needed to complete a check; and how an asset check case study might be undertaken.

The project was organised through a core eftec team and a wider study group of experts. The core team had responsibility for:

- synthesising and critically reviewing literature and expert opinion to develop an operational definition and framework for natural capital assets;
- critically reviewing existing frameworks of natural capital and liaising with experts to develop a natural capital asset check approach and case study exemplars, and
- organising and overseeing the development of case studies, workshops to discuss and develop case study approach as well as case study scrutiny.

The study group were asked to:

- review the asset check tool methodology developed;
- suggest asset check case studies that they could lead based on their existing expertise and knowlegde of data;
- involve individuals from other disciplines (in particular those with scientific knowledge) as partners in their case study; and
- input to meetings in order to draw conclusions from the work and refine the asset check method used.

In addition a review was undertaken, with input from ONS, of how the case studies link to developing methods for constructing modified national accounts for natural capital.

1.2 Defining natural capital

This Section examines definitions of capital (Section 1.2.1), the particular characteristics of natural capital (1.2.2) and then outlines a proposed analytical framework defining of natural capital (1.2.3). A short example illustrates this definition in Section 1.3.4.

1.2.1 What is capital?

The general underlying concept is that capital is productive: it produces goods or services that are useful to people. The value of capital is therefore related to the value of the goods and services it has capacity to produce, and a general definition of capital could be:

> *'anything which can, either directly or indirectly, yield flows of value to people over time.'*

Apart from natural capital, here are different types of capital that are commonly defined in line with this:

- Manufactured capital: machinery, buildings etc.
- Human capital: knowledge and skills of individuals, some of which will be in the workforce.
- Social capital: the value of social interactions between people, organisations and/or networks, and associated reciprocities to achieving mutual goals (Baron, Field & Schuller, 2000) (e.g. the benefits of membership of a professional network or groups that organise community events).

By considering the definition of capital given above in more detail, we can begin to construct an idea of what a framework for natural capital might look like:

- The wording *"directly or indirectly"* refers to the fact that capital can provide value directly (e.g. natural landscapes) and indirectly, in combination with other types of capital (e.g. fish stocks provide commercial landings when exploited using manufactured capital like fishing boats). Often the link from natural capital to this value is highly indirect, as in the various processes which ensure soil fertility and hence food production.
- The term "*flows*" links to economics in that it is flows (i.e. changes) that are valued rather than the existence of a physical quantity of a resource, and the term flows is used in accounting. It also links to ecosystem services frameworks, whereby flows of services (measured in units with a time dimension) are valued and the underlying stocks or assets are generally not valued.
- *Time* is mentioned explicitly to reflect the durability of capital as opposed to consumption goods which provide value over a confined period (i.e. the timescale over which flows are measured).
- *Value* refers to the change in human well-being (or utility) generated by capital. Note that value may or may not be (fully or partially) reflected in market prices.
- The reference to *people* is a reminder that economic values expressed by individuals can only be anthropocentric definitions of value. Whether nature has *intrinsic* value as well as human-attributed values is an important question, but it outside the scope of this analysis.

The value of capital is sum of the value of individual 'capital assets' and any synergies, if these are possible to account for. The conventional definition of an asset is *anything that is capable of being owned or controlled to produce positive economic value*. The term 'assets' is used in accounting to allow value to be carried forward from one accounting period to the next. Assets therefore reflect the attribution of capital values to particular people or groups (which could be an entire nation). There are clearly inconsistencies with applying this definition of assets to natural capital: some natural assets (e.g. clean air, migratory birds) are not owned in a conventional sense; and the productivity of natural capital often relies on combinations of natural assets.

Two conclusions are drawn from this. Firstly, that the term 'assets' is one that attributes capital to owners or other beneficiaries. Secondly, the conventional definition of capital does not apply neatly to natural capital. The definition of natural capital is considered further in the following section.

1.2.2 Characteristics of natural capital

Each type of capital (manufactured, human, social, natural) has particular characteristics which influence exactly how the capital is defined and analysed. The characteristics of nature are discussed in this Section with a focus on how these inform a definition of natural capital. The subsequent section (1.2.3) on defining natural capital seeks to address the issues raised here.

1.2.2.1 Nature as a public good

The conventional definition of a capital asset includes ownership and control of that capital, these being necessary conditions of its manipulation to produce goods or products for people. However, the characteristics of many natural capital assets are such that this definition cannot be simply extended to apply to them. Many environmental resources such as the gaseous composition of the atmosphere are pure public goods that are not owned, can be accessed by all and controlled by none. Whilst humans impact this composition through the production of greenhouse gases, and while we can reduce this impact, we have little ability to manage the outcome except in the very long term.

1.2.2.2 Complexity of nature

A key feature of natural capital is the level of ecological complexity that characterises the biotic elements of assets and their relationships with each other and with abiotic elements. Understanding this complexity is the key task of the natural sciences, and therefore economics-based analysis of natural capital needs to draw on relevant scientific knowledge. The key aspects of this complexity that make natural capital distinct from other capital is that natural capital is (usually) a self-sustaining system that can function and adapt without intervention from people.

In developing a framework for the proposed definition of natural capital the following factors require consideration based on relevant scientific understanding. Other relevant aspects of this science that are not explored in detail here are resilience to pressures and shocks; the substitutability and criticality of natural capital in producing goods and services; and the spatial heterogeneity in the value of goods and services provided by natural capital.

Interrelationships
Complex interrelationships exist within ecological systems. These can be positive, whereby in order to produce ecosystem services, the various components of the system have to perform in combination. One component may be more or less important to the performance of the system and/or may be closer or farther from *its* optimal condition and therefore be exerting greater or lesser influence on the production of ecosystem services by the ecological system as a whole. Other interrelationships can be negative. For example, as the UK NEA identified, greater levels of provisioning services from agricultural land has sometimes been achieved at the expense of regulating services.

Uncertain knowledge
The interrelationships set out above mean that a component of an ecosystem that we think is not valuable may actually be crucial to the productive functioning of the system as a whole. Alternatively, we may not have sufficient scientific understanding of the value of a functioning system itself. For example, when UK peatlands have been drained in the past, their value for climate and water quality regulation was not recognised. As scientific understanding has improved, the value of peatlands for carbon sequestration and water regulation has been recognised, meaning that much restoration is now taking place.

Time lags
The time period between a component of an ecological system changing and the impact on the productivity of that system is unclear. Often these changes are not immediate and so it may not be clear when the productivity of a system has been compromised.

Renewability
Natural capital assets can be renewable or non-renewable. Renewable assets can continue to provide goods and services without any human intervention, or provided appropriate management is in place to ensure their capacity to provide goods and services is not compromised. Non-renewable assets are finite sources whose depletion is a zero-sum game, as is the case for mineral deposits.

Links between capitals
Within a collection of assets that combine to make ecological systems productive there may be other non-ecological assets such as human, manufactured or social 'capital' assets.

1.2.3 A definition of natural capital

1) The complexity and interconnectedness of nature makes defining natural capital in terms of explicit capital assets challenging. Given the role of productivity in defining capital, general classifications of all the components of the natural environment (e.g. minerals, soil, forest, water, biodiversity) are impractical to use when constructing a framework for natural capital. A practical definition of natural capital needs to be specific in setting out how different natural assets combine to contribute to human welfare.

1.2.3.1 Proposed definition of natural capital

As described in Section 1.2.2, there are many components of ecological systems that combine to produce ecosystem services. Natural assets can be abiotic resources (e.g. minerals), ecological processes (e.g. nutrient cycling in soil, water filtration, pollination) or manifestations of ecological processes (e.g. forest stock, agriculturally productive land, productive soils, clean water and air). In defining natural capital a careful distinction is needed as to what constitutes a capital asset (that is currently productive) and what is simply an asset (with a value that can be carried forward, possibly only reflecting potential productivity, but is not currently productive).

Existing definitions of natural capital within the literature have overlapping elements insofar as the benefits from certain natural assets are also captured by other assets. For example, the Natural Environment White Paper (Defra, 2011a) defines natural capital as:

> *'the stock of our physical natural assets (such as soil, forests, water and biodiversity) which provide flows of services that benefit people (such as pollinating crops, natural hazard protection, climate regulation or the mental health benefits of a walk in the park)'*

Other definitions highlight the 'role' (OECD, 2005) or 'ability' (Natural Capital Declaration, 2012) of natural assets to produce goods and services, for example:

> '…*the ability of ecosystems to provide flows of goods and services…a stock of forest or fish will provide a future flow of timber or food, which if used sustainably will provide long-term benefits to people… the stock of ecosystems that yields a renewable flow of goods and services'* (OECD, 2005)

This corresponds, in principle, to the National Capital Initiative (NCI) definition of natural capital as:

> *'the part of the environment that supplies our basic needs; air to breathe, water to drink, food to eat and the physical world to sense.'* (Natural Capital Initiative, 2009)

However, for further analysis, a more specific, yet clear, definition that will be acceptable to all concerned (even if not all encompassing) is suggested in this report:

> ***'A configuration (over time and space) of natural resources and ecological processes, that contributes through its existence and/or in some combination, to human welfare':***

- 'configuration' means both the spatial and temporal incidence;
- 'natural resources' refer to the biotic (living) and abiotic (non-living) components of nature that can contribute to human welfare;
- 'ecological processes' refer to intrinsic ecosystem characteristics whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling and fluxes of nutrients and energy;
- 'through its existence' recognises the benefits people attribute to knowing that natural capital is supporting the continued existence of the natural environment, its wildlife, landscapes etc;
- 'some combination' reflects the interaction between the living and non-living components of the environment, but also the combination of natural assets with other forms of capital in a way that makes these assets productive; and
- 'human welfare' means the benefit or value that accrues to humans.

Natural capital is therefore defined as the configurations of natural assets and/or other capitals (e.g. hydrocarbon extraction, forest ecosystem or agricultural crop production), which produce flows of goods and services (e.g. fuel, timber or food). It is argued that natural capital should be defined in terms of productive configurations in order to distinguish natural capital from all components of the natural environment.

To enable effective analysis of natural capital, a framework through which this definition can be operationalised is needed. This is developed in the remainder of this Section. Together the definition and framework aim to help identify different natural capital assets, the measurement and apportionment of value to these capital assets and an assessment of the sustainability of changes in their quantity and quality.

The natural capital definition presented here is developed into a framework in the following sections by considering how it presents:

- Ecological and geological underpinnings;
- Production of environmental goods and services; and
- Links between the natural capital and human welfare.

An example of its application is then given in Section 1.3.

1.2.3.2 Ecological and geological underpinnings

To make the definition of natural capital proposed above operational we need to be able to measure the relevant configurations of natural resources and ecological processes. Much existing environmental terminology, classifications and data collection are based on 'habitats'. They are used in the UK NEA to subdivide the UK natural environment for detailed analysis. Data on the extent and condition of habitats is a practical starting point giving 'accounting units' from which to consider ecosystems' role as assets **(ecosystem assets).** However, data is also gathered on individual parts of ecosystems (both living such as water resources, numbers of trees, and populations of birds, and non-living including geological resources and process). These components of nature can alternatively be termed '**individual assets**'. They may be final ES in and of themselves, or may be part of intermediate services that contribute towards final ES production. Using these classifications facilitates use of existing data in analysis of natural capital. However, it is noted that other classifications are possible.

Both individual assets and ecosystem assets rely on biotic and abiotic processes that underpin the ability of the natural environment to produce goods and services that benefit people (and therefore be classified as natural capital). These processes are referred to here as ecological and geological underpinnings in **Figure 1.1.**

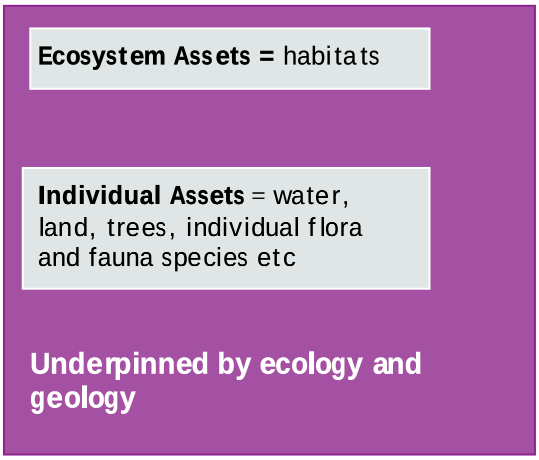


Figure 1.1. Ecological and geological underpinnings and assets.

Individual assets consist of a range of 'living' (biotic) and 'non-living' (abiotic) components. These components may also be 'renewable' or 'non-renewable' as shown in **Figure 1.2**. This is an important distinction to consider because it will impact the sustainability of use/ demand for ES. The rate at which assets can renew themselves is an important consideration for the same reason.

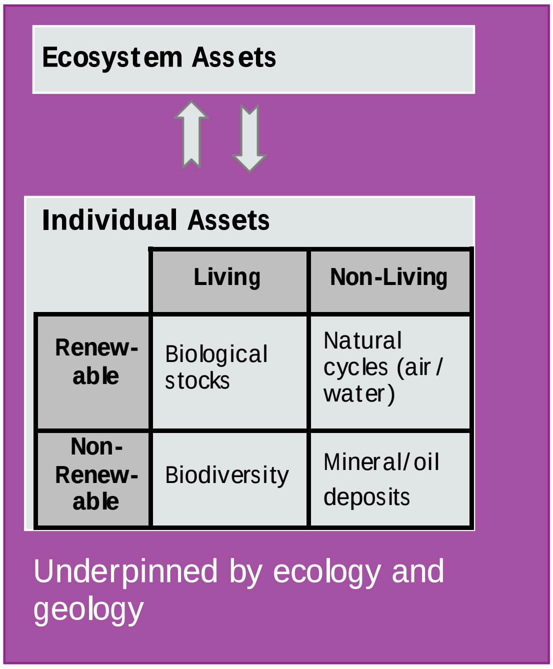


Figure 1.2. Natural assets.

Changes in the characteristics of individual assets (e.g. changes to the water table, a non-living renewable asset) can change ecosystem assets (e.g. drying out a wetland). Similarly changes to an ecosystem asset (e.g. degradation of a habitat) can change the individual assets within it (e.g. loss of biological stocks). Hence the individual assets and ecosystems assets boxes are linked by arrows going both directions in Fig 2.2. Together, ecosystem assets and individual assets can be termed natural assets or natural resources.

1.2.3.3 Producing environmental goods and services

The core of the suggested definition of natural capital is the combinations in which individual natural assets become productive. These combinations can take different forms described as '**productive configurations**' in **Figure 1.3**:

- **Spatially** – through spatial location, this may be links between ecosystem assets (such as networks of habitats that support migratory species), or the location of different assets within the landscape (e.g. upland habitats that regulate water resource flows into permeable bedrock maintaining river flows lower in the catchment).
- **Functionally** - in terms of what combination of ecological and geological processes underpin the production of final ES flows. For example, pollination services need to function in areas with appropriate soils in order for crop production to take place. These processes can be complex and the products from their interrelationships may be uncertain in terms of final ES production.
- **Temporally** - in terms of the timescales that are involved in providing the functions (e.g. water filtration times differ depending on percolation rates/ geology, carbon sequestration rates vary over time depending on growth rates of trees).
- **Combinations of capitals/natural assets** – many goods and services are only provided through specific combinations of natural assets, or of combinations of natural capital with human, social and/or manufactured capital (e.g. harvests of timber rely on felling machinery).

The identification of natural capital assets should include all these types of productive configurations. This is important conceptually, but also practically in order to evaluate if natural capital is being used sustainably (by asking whether productive configurations are being damaged).

There are three important points to note here. Firstly, for the purposes of this work, we are **only** concerned with natural assets in their productive form (i.e. that which produces ES and value to society) and therefore any assessment must be consistent with this. Biodiversity is particularly complex in this regard. It can be assessed for its own value as an individual asset, but its functions contribute to intermediate services within ecosystem assets. In both these roles it forms productive configurations with other assets that result in final goods and services.

Secondly, there may be parts of the natural environment that appear to produce less value to society, but caution is needed in drawing such conclusions due to the complexity and interelatedness of ecological systems. In making this assessment we should consider how natural assets contribute indirectly to society, through different productive configurations, and what substitutes they might have. There are attribution problems if one seeks to link goods and services directly to ecological processes, as one good or service might rely on ecological processes that originate from a number of alternative sources. For example, pollination services can be provided from a number of alternative sources (insects and birds from different habitats). Therefore, attributing the value of an ES such as food production to the different configurations of pollination and other ecological processes across ecosystems may be impractical. Defining natural assets using habitats, and/or the distinctions between living and non-living, and renewable and non-renewable resources, potentially provides more tractable delineation of components of natural capital.

Thirdly, some parts of the natural environment may currently be underproductive, but still hold an option value. For example, contaminated land has little commercial value for housing or agriculture (although noting that brownfield land can have high nature conservation value). Therefore, its capacity to provide goods and services is likely to be impaired because the underlying ecological processes that may have once existed have been damaged by contamination. However, there is a value associated with potential flows of goods and services in the future should society take action to decontaminate the land.

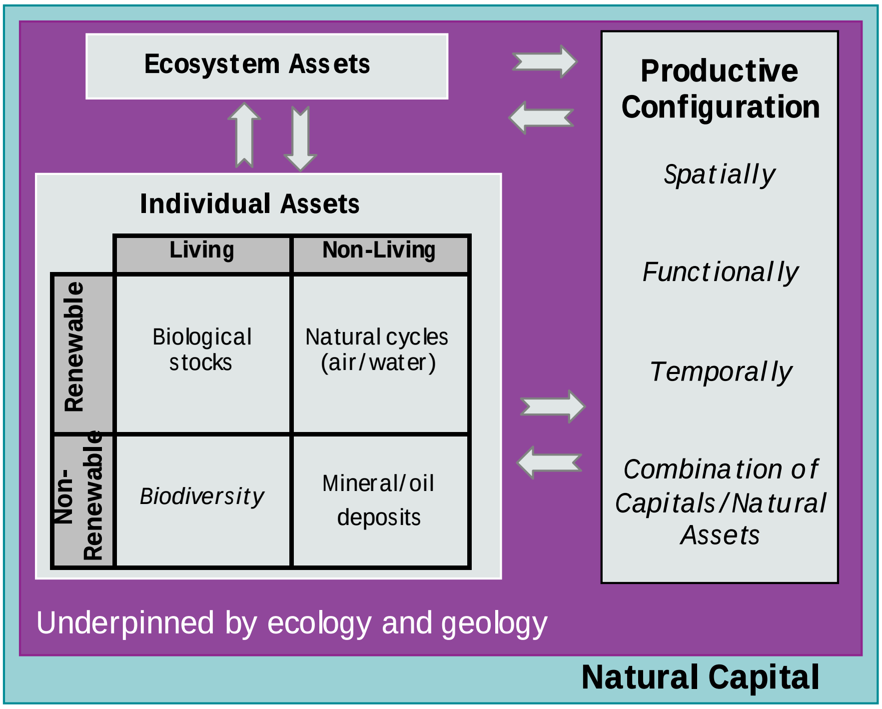


Figure 1.3. Components of natural capital.

1.2.3.4 Natural capital and human benefits

The productive configurations in **Figure 1.3** provide us with a framework to consider how natural capital assets are arranged. It provides a link from the ecological and geological underpinnings through to goods and services, and human benefits. The UK NEA's framework defined final services (e.g. fish, water supply) resulting in goods and products for people (e.g. food, drinking water) that support human welfare (i.e. are of value to people). This is shown in the human benefit box on the right hand side of **Figure 1.4**.

The monetary valuation of these goods and services helps decision makers to assess trade-offs with other factors that influence human welfare. However, we should note that monetary valuation is not complete and other biophysical and qualitative data should also be used.

The 'supporting services' in the UK NEA approach correspond to ecological processes within what is referred to here as ecological and geological underpinnings. These underpinnings and the productive configurations of ecosystem and individual assets are, as shown in **Figure 1.4**, collectively referred to as natural capital.

The arrows within **Figure 1.4** reflect the dynamic nature of the environment, which means that the state of natural capital and the services produced do not remain constant over time. Depreciation in the value of natural capital can occur when the future potential production of human benefits is decreased. It is only when the use of natural assets hinders the capacity to produce goods and services, that the capital can be said to have degraded. For non-renewable resources (e.g. minerals), consumption means depreciation, whereas for renewable resources, consumption or other impacts may or may not depreciate the capital (i.e. its ability to produce future services) temporarily or permanently. This has implications for the sustainability of resource use and the degree to which compensation of future generations is required to ensure their welfare is not compromised by our use of resources today.

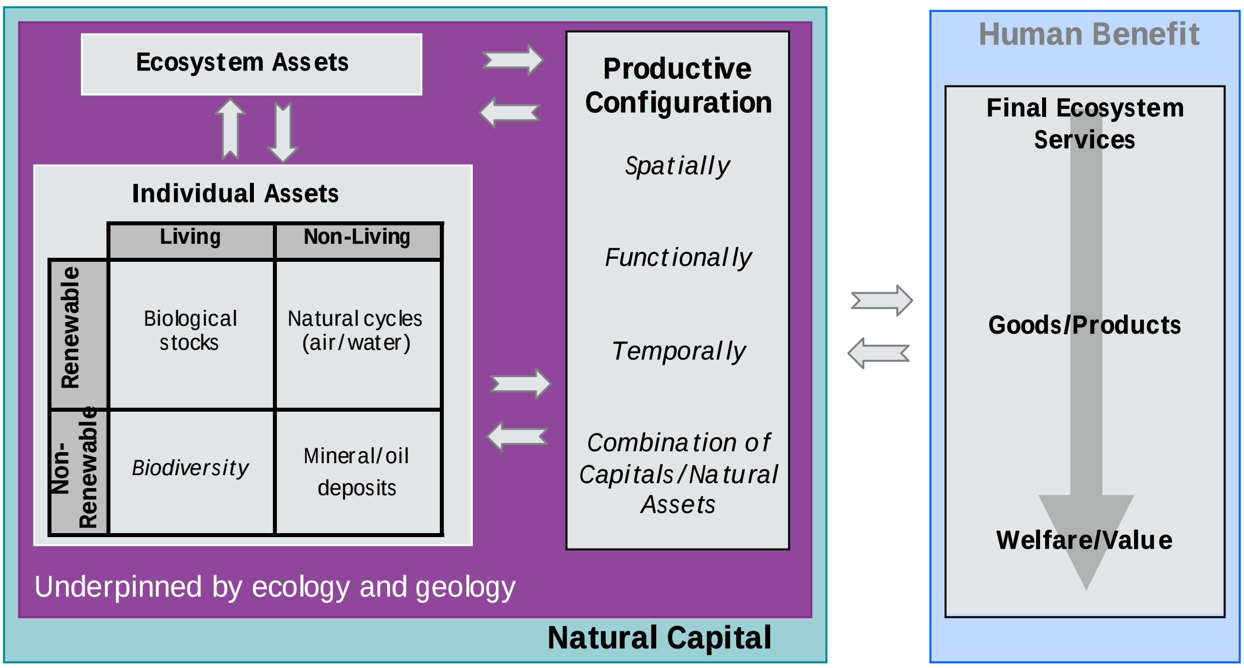


Figure 1.4. Framework for defining natural capital.

The definition and framework is also based on the need for it to be practically applied: for example, analyses with different starting points (such as a specific ES, or of a particular habitat) are compatible with this framework for defining natural capital. This provides sufficient flexibility to enable thinking on how natural capital fits within any assessment of the sustainable use of the natural environment. This is a pragmatic approach given pre-existing policy concerns, data collection and environmental terminology.

1.2.3.5 Example illustrating the framework for defining natural capital

The framework defined above needs to be practically applied to assist with analysis of natural capital, including through a natural capital asset check discussed in Section 1.3. This application is described here with reference to the natural capital asset analysed in one of the natural capital asset check case studies (the role of saltmarsh in commercial fisheries) in Annex 1.2.

In this asset check, the natural capital analysed is coastal saltmarsh habitat and its supporting services to commercial fish stocks. The definition of this natural capital is based on the discussion around the four diagrams (1.1 – 1.4) in the previous section.

The ecological underpinnings of coastal saltmarsh habitat (as per **Figure 1.1**) can be identified as the life cycle of the commercial fish species (bass) and the habitat (intertidal saltmarsh). There are both natural assets (defined as habitats, e.g. saltmarsh) and a series of individual assets involved (as per **Figure 1.2**):

- living renewable assets (the stock of fish species, e.g. bass);
- non-living renewable assets (the wave power and coastal morphology which provide the accretion of sediment in saltmarsh habitat), and
- living non-renewable assets (the biological diversity that provides the biota that cycle nutrients underpinning the productivity of the saltmarsh).

The configuration of these assets is important to the natural capital (as per **Figure 1.3**):

- spatially, through the juxtaposition of nursery habitat with other locations used in fish species life cycles;
- temporally, providing feeding grounds at right time seasonally to support juvenile fish growth;
- functionally, with high primary production resulting in rich nursery feeding grounds, and
- with other capitals, i.e. human and manufactured capital in the fisheries sector.

These combinations define this capital asset by supporting growth of juvenile fish (measured as biomass gain within harvestable fish stocks over time, an ecosystem service) which results in increased fish landings (goods) and which has value to people (reflected in price of fish).

1.3 Applying the definition of natural capital

This Section considers the application of the definition and framework of natural capital from the previous section in decision-making on the natural environment. The public goods properties of many environmental goods and services means that changes to natural environment management are often organised through public policy. Therefore, this section focuses on Government decision making processes. However, it is recognised that the private sector has a major influence over the management of natural capital, and therefore application of natural capital thinking in their operations is also worthy of further research.

1.3.1 Natural capital assets in UK Government economic appraisal

The UK Government is committed to Sustainable Development (SD), understood as inter-generational equity[3]. The Government Economic Service review of the economics of SD (Price *et al*. 2010) recognised the difficulties in operationalising SD. The review argued that cost-benefit analysis (CBA), when done well, took us quite a long way towards good decision making for SD. However, there are weaknesses in existing economic tools that need to be addressed.

Firstly, when potential non-marginal consequences of exploiting natural capital exist, using CBA based on marginal economic valuations is unreliable. An alternative approach to analysis is needed, looking at the changes to natural capital in a more strategic way.

Secondly, the concept of 'critical natural capital' recognises that substitution between different forms of capital (man-made, human and natural) is not always possible. This conflicts with assumed perfect substitutability between assets in economic analyses such as adjusted GDP approaches which are built on the foundations of weak sustainability. Weak sustainability assumes that any non-substitutability between capitals is insignificant from a sustainability point of view. This argument has been rejected by Price *et al* (2010) due to recognition that some natural capital provides critical life support systems and so does not have substitutes.

Ecosystem services analysis, which marries economic and ecological concepts, and definitions of natural capital, offers methods to address these weaknesses of existing economic analyses. It can be used to highlight where critical (parts of) natural systems are under-threat. However, it can only inform consideration of whether enough natural capital is being provided (through protection and/or restoration) for the future. To assess this latter point requires consideration of whether there are cumulative long-term impacts on natural capital that may be outside the boundaries of individual decision-making processes, but are collectively significant for future generations' well-being. The idea of a Natural Capital Asset Check (NCAC) aims to generate economic and scientific information to support decision making that affects natural assets.

To conceptualise the potential role of an asset check, we suggest an analogy to economic management. Headline UK GDP figures on the performance of the economy are complemented by data on human capital (labour – i.e. training and qualifications; and innovation – e.g. R&D spend) and built capital (e.g. investment in infrastructure) because these inform us about trends in the underlying condition of these capital assets that support GDP.

While the existing ecosystem services data tell us about current values from the environment and sometimes predict future values, the data are usually too dispersed to fully capture the state of the underlying environmental assets (i.e. natural capital) providing these services. An asset check should ideally involve a practical way of providing simple and concise evidence on the underlying integrity of the natural capital assets that will support future values of goods and services.

1.3.2 Extending natural capital analysis

This Section applies the definition and characteristics of natural capital described in Section 1.2, to identify important questions that a Natural Capital Asset Check (NCAC) can help to answer. Evidence on the integrity of natural capital assets can be characterised in terms of the extent (i.e. amount, such as spatial area) and condition (i.e. health) of those assets. The relationship between the

[3] i.e. the widely recognised Brundtland Commission definition of SD: '...*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*.' (1987 Brundtland Report, "Our Common Future").

integrity and productivity of natural capital, and in particular the existence of thresholds, is a complex area of scientific analysis.

This relationship is illustrated as a simplified linear function (F) in **Figure 1.5**. It is understood in many natural capital assets that there are one or more thresholds, and the level of productivity (e.g. levels of ecosystem services) associated with this threshold may be known. Note, however, that the threshold is defined based on the integrity of the natural capital (i.e. its extent and condition), rather than the level of productivity, although productivity may be an indicator of integrity.

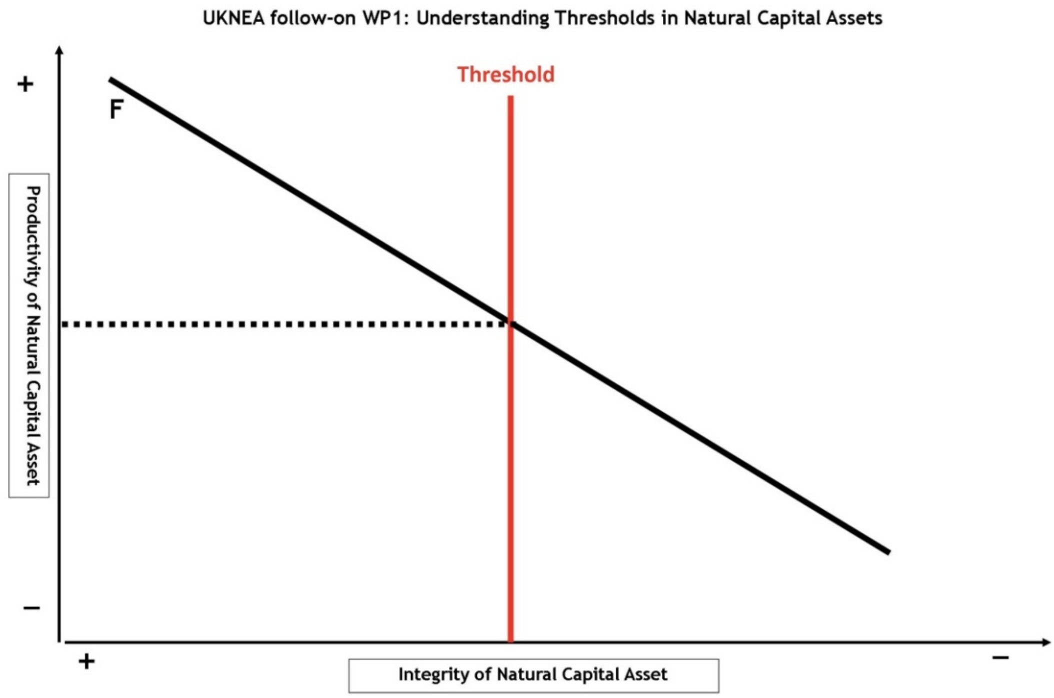


Figure 1.5. Relationship between integrity and productivity of natural capital.

Image A. Reference Saltmarsh **Image B.** Nutrient-enriched Saltmarsh

Reprinted by permission from Macmillan Publishers Ltd: [Nature] Deegan et al., copyright (2012)

An example of the relationship in **Figure 1.5** is provided by Deegan *et al*. (2012), who examined how the integrity of saltmarsh habitat varies in response to nutrient loading. They found that lower root densities and increases in decomposed organic matter, water content and drag by tidal currents on fallen plants are all associated with nutrient enrichment and cause cracks to develop in creek banks over time. This is illustrated by comparing **Image A**, a reference case with B which shows a nutrient enriched saltmarsh. Compared to **Image A**, **Image B** shows the overall combination of nutrient-enrichment in saltmarshes as being: (1) lower root density, (2) the drag by tidal currents on plants which had fallen over and the rise in (3) decomposed organic matter and (4) water content.

Figure 1.6 illustrates this increasing linear relationship through a linear function between fracture density in creek banks and years of nutrient enrichment. Different points (illustrated by circles or squares) represent different years of measurement of nutrient enrichment over time.

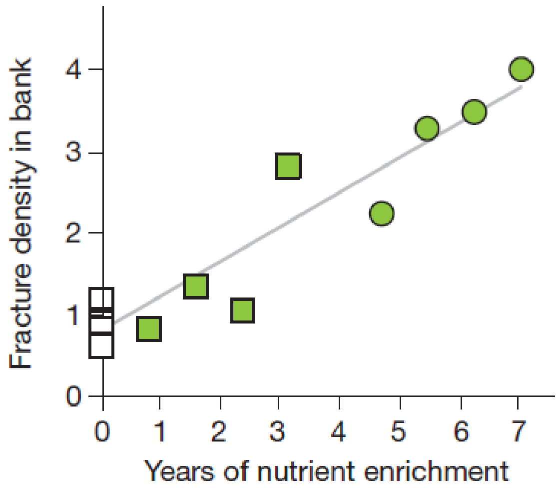


Figure 1.6. Linear relationship between nutrient loading and fracture density. Reprinted by permission from Macmillan Publishers Ltd: [Nature] Deegan et al., copyright (2012)

This kind of scientific evidence is useful for determining impacts on ecosystem service provision as a result of human induced pressures such as nutrient loading. A reduction in the structural integrity of saltmarsh reduces their capacity to provide important ecosystem services such as nutrient removal and storm protection. Identifying the consequences of nearing such thresholds (e.g. where increasing fracture density inhibits ecosystem service provision to unacceptable levels) is the intention of a NCAC.

The relationships between integrity and productivity after a threshold has been crossed are characterised in **Figure 1.7**. When the threshold is crossed a regime shift takes place: the level of productivity may reduce at an increasing rate, and/or the ability to restore productivity by restoring the integrity of natural capital may be compromised. This restoration has an important time dimension, as impairment to recovery may be permanent or temporary over differing times.

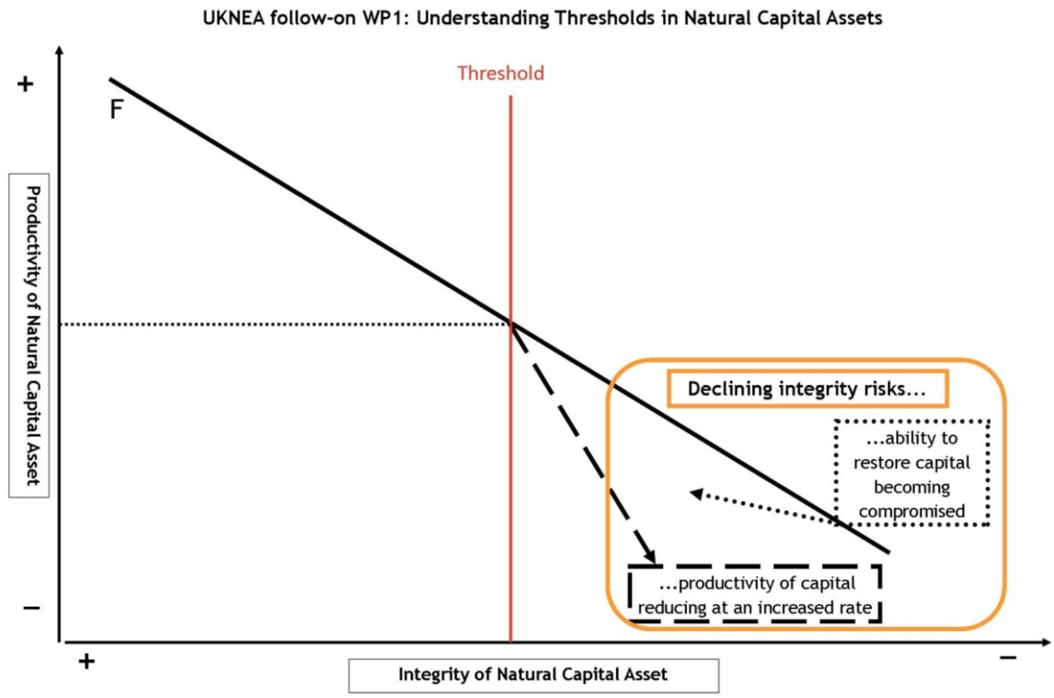


Figure 1.7. Changes to integrity-productivity relationship after crossing threshold

The socio-economic consequences for society of crossing the threshold can be understood through environmental economics. As shown in **Figure 1.8**, the consequences of lost productivity of natural capital include the loss of ecosystem goods and services that the natural capital contributes to. The value of these services depends not just on the amount of service lost, but also on factors like the number of people affected, over what time periods, and the availability of substitutes.

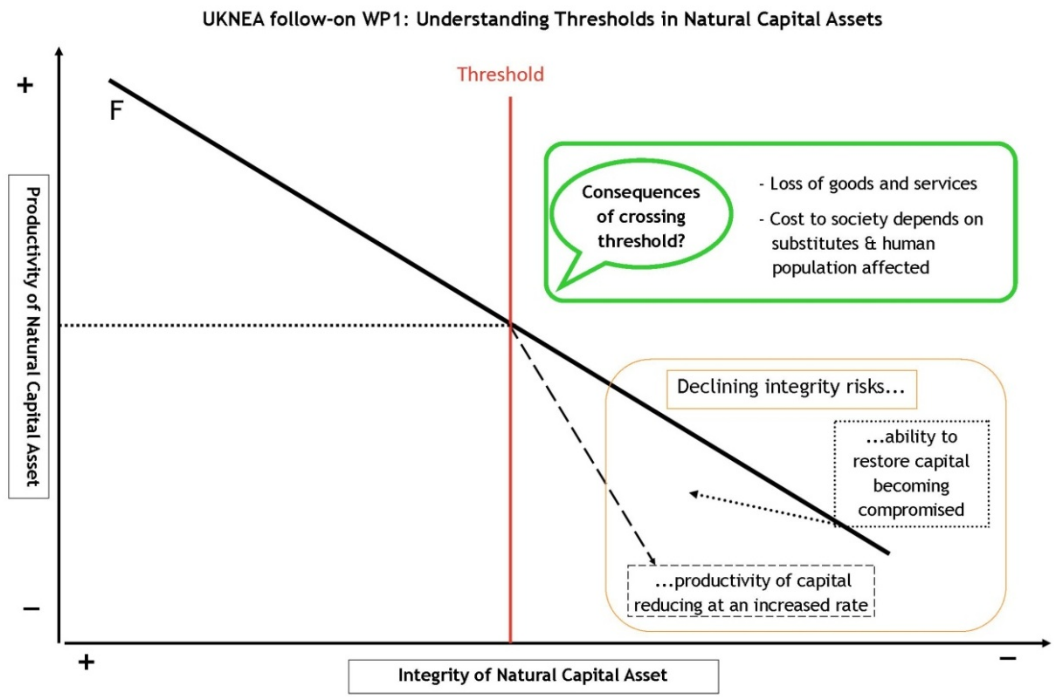


Figure 1.8. Consequences of crossing threshold

Our understanding of exactly where thresholds are (i.e. point A in **Figure 1.9**) is rarely available to inform decision-making, but observations of different examples of natural capital management can provide data on systems that are above and below thresholds. Examples of this include fish stocks that are healthy and those that have collapsed and are recovering slowly, and agricultural systems with intact populations of wild pollinators and where these have declined and been replaced with hand-pollination. These might provide data at points on the line like B* (healthy/intact) and/or B^i/B^{ii} (increased rate of productivity loss, compromised restoration trajectory), as shown in **Figure 1.9**.

There can be many healthy/intact points, but an optimal point for B* is described as where the desired performance from a natural capital asset for society is achieved. Note the optimal point for society (B*) may not be where productivity is maximised because of the interrelationships between natural capital assets. Where productivity is dependent on combining natural and other forms of capital, deploying other capital to maximise productivity from one piece of natural capital has opportunity costs elsewhere in society. For example, utilising shallow seas to develop wind farms will have impacts on marine biodiversity and require investment that cannot then be used for other energy projects.

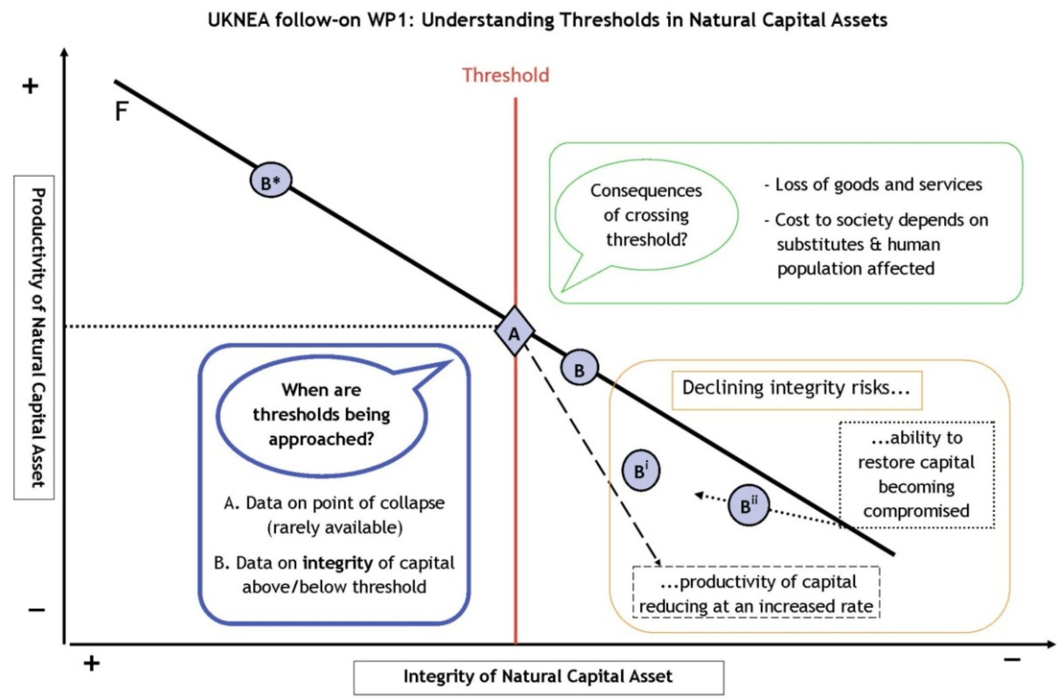


Figure 1.9. Evidence about thresholds.

Given the presence of a threshold, the concept of a red flag, where society is alerted to the risk of crossing the threshold and the (potentially irreversible) consequences this would bring, becomes relevant. The width of the red flag zone (the shaded area in **Figure 1.10**) is greater when:

- A is not known, so evidence of B*, B^i, B^{ii} is relied on;
- when data on B* and B^i/B^{ii} are further apart (and therefore further from A); and
- when the consequences of crossing the threshold (discussed in relation to **Figure 1.6**) are greater.

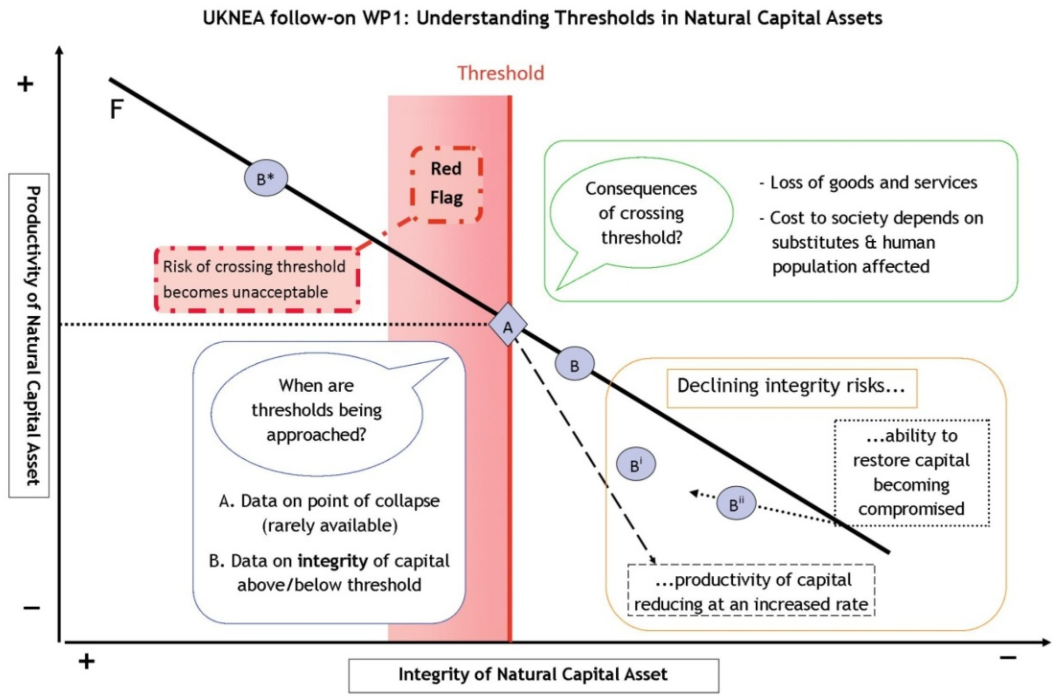


Figure 1.10. Defining red flags

The questions in the NCAC approach are designed to help answer questions raised in this diagram. The relationship between the five Sections of the NCAC and the diagram are shown in the numbered blocks (1) – (5) in **Figure 1.11**.

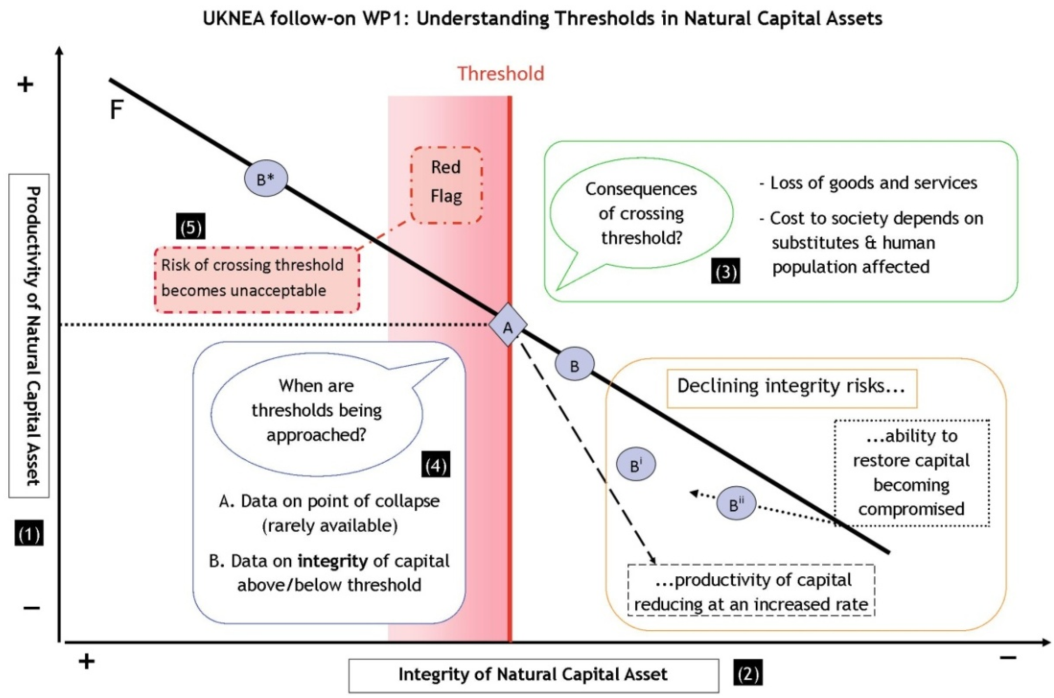


Figure 1.11. Thresholds and the Natural Capital Asset Check.

There are overlaps between the information required to address the different questions shown in **Figure 1.11**, and therefore some overlaps exist between the answers to questions in sections (1) – (5). In completing a NCAC, the purpose of the analysis, as described in the questions relating to **Figure 1.8**, should be borne in mind:

- What evidence do we have of thresholds?
- How will natural capital behave after crossing the thresholds?
- What are the consequences of this?
- Can we identify society's desired performance from natural capital assets?

These questions can also be used to scope whether it is worthwhile to undertake a NCAC for a particular natural capital asset. Further guidance on when the analysis is appropriate is provided in Section 1.4.3.

1.2.3 A Natural Capital Asset Check

This section sets out what a natural asset check is as well as issues that have arisen from the application of our proposed approach. It then sets out why an asset check might be useful; where it might be applied; when it might be most relevant; who is needed to complete a check; and how an asset check case study might be undertaken.

The current version of the proposed NCAC approach is shown in Annex 1.3. At the start of the natural capital asset check approach, guidance is provided on its application. Firstly, the purpose of a natural capital asset check is defined so as to assess how changes in a natural capital asset affect human well-being. It incorporates concepts of integrity, performance, red flags and sustainability. It organises a series of questions in five Sections, to give insights into the relationship between the integrity and productivity of natural capital.

The questions are laid out in tables, with guidance *on answering the questions in italics in the 'answer' boxes* that can be overwritten as the proposed approach is completed. There is inevitably uncertainty in this type of analysis, and so guidance encourages use of the following terminology, adopted from the UK NEA:

- *Well established evidence:* high agreement based on significant evidence.
- *Established but incomplete evidence:* high agreement based on limited evidence.
- *Competing explanations:* low agreement, albeit with significant evidence.
- *Speculative:* low agreement based on limited evidence.

Completed examples of asset checks are summarised in Annex 1.2 for practitioners and decision-makers to refer to. Practitioners are also advised that to use the NCAC approach:

- it is anticipated that inputs from natural sciences and economics will be needed; and
- it is worth doing a rapid 'top of the head' run-through of the approach to understand information needs and interaction between questions (how the evidence builds up).

Applying the NCAC approach raises difficult questions about defining natural capital assets. In line with the definition in Section 1.2.3, practitioners are reminded that all environmental resources can be considered natural assets, but natural *capital* assets are the productive arrangement of these assets, i.e. how they combine spatially, functionally, temporally and/or with other forms of capital (built, human) to produce something useful for people.

The NCAC also introduces the concept of performance of natural capital (i.e. its ability to provide a certain level of ecosystem services). Performance is a concept used in asset management (e.g. a water pump has a capability to move a certain volume of water). Defining desirable levels of environmental goods and services is difficult because of the *constraints* on natural capital assets that are imposed by the fact that the environment is finite. This means that there are trade-offs occurring within the portfolio of natural capital assets, and that 'desired performance' of natural capital assets must be assessed in this context.

1.3.4 Results of NCAC Case Studies

Annex 1.2 contains conclusions from seven NCAC case studies. The following summary provides an overview of the key issues raised through each of the nine case studies attempted (including two that are not published in full). Each of these case studies faced different challenges and provided different lessons on application of the NCAC approach. The case study asset checks can be found in Annex 4.

1.3.4.1 Key Issues in the NCAC Case Studies

Case Study 1: Pollinators
This case study illustrates how an asset check can be applied to a natural capital asset that is present in a diffuse way across the landscape. This is enabled by the focus on the capital providing a single ecosystem service, with this capital being made up of individual and ecosystem assets supported by agri-environmental management and networks of habitat (wild pollinators), and by a combination of human and natural capital (e.g. in managed bee colonies).

The case study identifies uncertainties over reliance on the natural capital assets that provide wild pollination. Farmers can use other commercialised pollinators alongside wild pollinators and honeybees, and the impacts of changes in proportions of these assets are discussed. Different crops have different pollination requirements making some more or less vulnerable than others to changes in pollination services. The case study illustrates the importance of maintaining a diverse assemblage of pollinators, both to reduce the impact of fluctuations in populations, and to prevent over-reliance on one pollinator group which may not be appropriate for providing pollination to crops with diverse needs and may reduce the ability for services to be provided in the future. The decline of wild pollinators does not appear to have crossed a threshold in terms of its inputs to crop production. However, the case study illustrates the loss of option value when natural capital declines, bringing the risk that our requirements for wild pollinators may increase beyond the current capacity of this asset to provide the service. This risk could arise should our crop production patterns change significantly. Such changes are entirely possible, as reflected by past changes in crop production (e.g. the massive increase in oil seed rape cultivation means we need 40% more pollinators), and further changes that are expected in the context of climate change.

Case Study 2: Upland Soils
An attempt was made to conduct a natural capital asset check for "The Uplands". Due to the very broad range of habitat types, ecosystem services and human activities this encompasses, this case study faced severe problems in defining capital asset being analysed. It attempted instead to focus on upland peat soils and their role in storing carbon. However, the land-use systems involved necessitated consideration of non-peat upland soils in order to adequately assess trade-offs in levels of ecosystem services.

It is not regarded as impossible to apply a NCAC to the uplands, but this would require defining the many natural capital assets present within this geographical area. As a result it would be a major piece of analysis, requiring substantial time and ranges of expertise. The analysis suggests that upland soil management justifies more detailed analysis and we note that peatland carbon has been analysed in detail in a recent Climate Change Committee report (see Section 1.3.4.8).

The case study did identify data that indicated challenges and potential thresholds in upland peat soil management (e.g. where gullying and erosion of upland peat result in loss of climate and water regulating ecosystem services). However, it did not reach conclusions on the existence of red flags due to complex interactions (e.g. to the extent that restoring water regulation services has tradeoffs with provisioning services and/or can be substituted with human capital).

Case Study 3: Rivers

An attempt was made to conduct a natural capital asset check for "Rivers". This case study faced severe problems in utilising the wide range of available river data to define thresholds in future performance. This case study illustrates how policy areas with strong monitoring regimes, such as the UK's rivers, do not necessarily have readily available data to inform a national assessment of whether the capital assets are being used sustainably.

Case Study 4: Arable Soils

This case study defined a natural capital asset based on ecosystem boundaries (the soil layer) and related human activities (arable farming). Perhaps aided by this, it was able to identify several potentially appropriate metrics of soil that would characterise it as a natural capital (e.g. its carbon or biodiversity). However, it still faced challenges in using these metrics to describe soil function, which relies on the interaction between those individual properties, and reflects a definition of natural capital that includes productive configurations of components of the natural environment (see Section 1.2.3.3). Data on soil Ph and soil carbon are used, and allow consideration of potential red flags at smaller spatial scales.

Case Study 5: Lakes

This case study illustrates a good example of the existence of different thresholds. A major challenge in managing this asset is nutrient enrichment, and there are different thresholds in relation to the provision of different services:

- Certain species are adapted to low-nutrient conditions, and nutrient enrichment can damage the biodiversity conservation value of freshwater lakes in the UK. These thresholds can be defined through conservation targets in UK Biodiversity Action Plans, and once passed the capacity of systems to recover may be impaired.
- Recreational use of lakes is impaired by nutrient enrichment that causes algal blooms. There are thresholds when the recreational ecosystem services derived from the lake have a non-linear response to the increase in nutrient levels:
    - Firstly, algal blooms can limit biological diversity and reduce recreational users' enjoyment of the lake. These are thresholds in that once a bloom has occurred, the damage to other species in the system may take a significant period of time to recover after nutrient levels have receded to pre-bloom levels.
    - Secondly, algal blooms can give rise to human health risks through particular types of algae, ending the use of the lake for water-contact recreation activities or possible all water-edge activities (e.g. dog-walking) too.

This analysis benefits from data obtained from the Lake Registry. The analysis illustrates how appropriate data sets are essential in refining research questions and informing an investigation of whether natural capital assets are being used sustainably.

Case Study 6: Tees Estuary

This case study illustrates how an asset check can be applied to a geographically defined natural capital asset. Whereas the other case studies examine natural capital assets defined in ecosystems terms (i.e. either through particular functions such as pollination, or particular ecosystems such as lakes) this case study examines the many ecosystems that make up an estuary. Conducting a case

study in this way requires detailed knowledge of the geographical area in question and the different types of available data about the many ecosystems and human activities present.
The work to complete this case study engaged with a local environmental management body (the Tees Industry Nature Conservation Association). This engagement enabled the asset check to reflect examples of the trade-offs and inter-dependencies present in a complex dynamic system such as an estuary.

Case Study 7: Blue Carbon
This case study was undertaken at a scoping level due to uncertainties in data availability for marine habitats. It illustrates the challenges of considering natural capital management in a data-poor environment (marine habitats) and in particular where baseline data (on current and previous extent of habitats) is absent.

This case study scoped an asset check on a particular ecosystem service (climate regulation) from a particular habitat (seagrass beds). The results suggest that such a narrow boundary may limit consideration of context questions, such as the significance in changes to an ecosystem service from one particular habitat to that service's value from all habitats. This is unsurprising because an asset check is designed to consider overall outcomes for society from natural capital management.

Case Study 8: Saltmarsh and Fisheries
This case study illustrates how natural capital assets can be defined through productive configurations (in time and space, see Section 1.2.3.3). It illustrates observations of where the state of natural capital becomes a limiting factor for the provision of ecosystem services and therefore welfare of society. This case study seems to benefit from defining a natural capital asset at an appropriate scale for undertaking a NCAC with the resources available to this work[4]: a national resource across which tradeoffs could be considered as well as a key service of which with adequate data could be focussed on. The service here is providing nursery habitat for commercial fish species. The necessary data comes from fish stock status and commercial landings. It illustrates the potential definition of a red flag.

Case Study 9: Urban Green Space
This case study illustrates challenges of handling incomplete data issues, in particular spatial data. This is an example of a natural capital asset whose productivity is highly spatially dependent, both in terms of its proximity to beneficiaries and substitutes. It is also one for which society has substantial evidence of human welfare supported (recreation, health benefits), but lacks monetary valuations of these benefits that can be widely applied in policy decisions. In this case study, the conclusion is that what is considered to be happening to a natural capital asset is sensitive to the choice of policy targets and baselines – by some definitions, this asset is being managed unsustainably.

1.3.4.2 Defining natural capital in an asset check

A fundamental challenge in analysis of natural capital, including through the NCAC approach, is defining natural capital. This remains the case despite the term being in widespread use for decades. This work defined natural capital according to the productive relationship between natural assets (See Section 1.2.3), but the application of this definition was not straightforward for all case studies. For example, the urban green space case study considered both the amount of green space (the asset) and its recreational amenity (a service provided), but was restricted by availability of

[4] Although note that this case study was initially developed in eftec (2012), and benefitted from considerable existing knowledge of fisheries issues in the author's organisation (Cefas).

information on the largely qualitative factors (e.g. quality of facilities) that determine the productivity of the asset.

The case studies were more successful in undertaking the NCAC when the definitions of natural capital were more clearly understood. Broader subjects such as uplands and rivers were less amenable to the analysis. Assets based on a specific service (e.g. pollination) or a service delivered from within a geographical boundary (e.g. amenity from urban green space) worked better. This observation is related to data availability. The estuary asset check despite it covering a broad range of habitats and ecosystem services was satisfactory as it was also based on a tightly defined geographical boundary with good data availability (through existing estuary management activities). In general, the clearer and tighter the definition of the natural capital asset, both conceptually and practically in terms of data, the more effectively the check can be applied.

Overall it must be borne in mind that a NCAC is a way of organizing lots of important information about how natural capital is being managed for decision-makers. It therefore needs to present sometimes technical information and data to non-specialist audiences through careful explanation and interpretation. In doing so it should avoid value judgments.

The uplands case study had to focus on the productivity of upland soils on regulating ecosystem services in order to make the analysis manageable. Clearly an analysis of all productivity from the natural capital of the uplands of England and Wales (which is a large scale and very varied piece of capital) would be a substantial undertaking, akin to a Government evidence review. Even if sufficient resources were available for such a review, it is unclear if a NCAC is manageable at such a scale in theoretical terms. For example, the complexity of synergies and tradeoffs between services may render either analysis impractical or too generalised to give real insights.

A further complication in defining natural capital is that productivity often relies on interactions with other forms of capital (e.g. human, built). These capitals can be both complements (e.g. a reservoir stores water whose flow has been regulated by upland soils) and substitutes (e.g. a reservoir stores water that has runoff a catchment more quickly as a result of upland soil degradation). At the margin, reduced integrity of natural capital can often be readily substituted with other capital, but this can hide reductions in natural capital integrity such that society is unaware of the associated increases in risks of crossing thresholds (e.g. when uplands soils degrade such that water siltation requires treatment with built capital).

This discussion reflects the need for flexibility in how definitions of natural capital can be applied in analysis to make information gathering and processing manageable. It also raises prospects for further manipulation of the data gathered. For example, several case studies consider carbon sequestration and/or storage services (e.g. seagrass, saltmarsh, upland soils). Such information could be reorganised to provide an asset check of biotic habitats' storage of carbon. The fact that the Tees Estuary and Saltmarsh asset check case studies both consider saltmarsh as a natural capital asset, but with very different boundaries, reflects the fact that one asset check may not be sufficient to fully assess the sustainability of use of a natural capital asset.

The reason for this is the different ecosystem services (ES) that each case study is concerned with. The Tees Estuary case study is concerned with (locally specific) ES such as recreation, biodiversity etc. The saltmarsh asset check is concerned with the sustainability of the asset with regard to the provision of fish for food (which is less locally specific). Therefore, the scope of asset checks do not have to cover the extent of the entire natural capital asset (e.g. all saltmarsh in England and Wales and all of the ES it produces) but can focus on the specific aspect of saltmarsh, and the other natural and other forms of capital it combines with, that is important for the production of specific ES. This is pragmatic given the complexity of ecological systems, the trade-offs that exist between ES from the same capital asset and data availability.

1.3.4.3 Performance of natural capital

The NCAC approach defines the performance of a natural capital asset in terms of its ability to support human welfare. Performance is a concept used in asset management (e.g. a water pump has a certain capability to move water). This then allows distinction between whether it is performing to its maximum capability (is it working efficiently to move this volume of water?) and whether this performance is adequate (is this maximum capacity enough to support the water network it is part of?).

Performance can be characterised with reference to existing policy target or objectives. Most of the case studies found a way of defining performance satisfactorily for their analysis, but it is noted that that they used a variety of different objectives and policies with different legal and political status. For example, the freshwater case study made reference to Water Framework Directive targets, defined in EU legislation, whereas the urban green space case study referred to Accessible Natural Greenspace Standard ANGST standards, which are not formally adopted by central Government.

There are some limitations to the information used for defining performance. For example, some targets relate to the state of the natural capital asset (e.g. Water Framework Directive targets). In other cases, targets relate to the level of services (e.g. there are other freshwater and bathing water targets on water quality that is suitable for recreation), but not for the state of the natural capital assets providing these services (e.g. in terms of capacity of ecosystems to absorb nutrients and toxins). A NCAC can help distinguish between these types of policy targets and goals.

While the definitions of performance were predominantly in terms of targets in legislation, the Tees Estuary case study also considered its role in maintaining the industrial/economic performance of the region (via providing a sheltered deep water port). Examining the contribution to economic performance is seen as a useful alternative approach to defining performance.

The concept of performance of natural capital raises a variety of further issues:

- There can be considerable heterogeneity of performance, especially across a capital asset across a large spatial scale: national performance levels can hide local variations in the extent and condition of capital assets.
- Measured performance can vary independently of the state natural capital is in, for example, depending upon what other forms of capital it is combined with.
- For complex natural capital assets, the NCAC case studies had to be pragmatic and focus on certain ‘key’ ES to define performance. These services were sometimes seen as ‘flagship’ services, being correlated with levels of a wider range of services.

1.3.4.4 Data

The NCAC is data-hungry, and this is a key limitation on the results it can produce. It also means it is less able to capture qualitative factors. For example, the urban green space case study quantifies availability of green space. The data used does not reflect the quality of green space, which is absolutely critical as poor quality green space could be a disamenity. Broadly at a national level the ability of the asset to support ecosystem services has been maintained or improved. At specific locations where there is a limited extent of urban green space and declining condition this is not the case.

The ideal link to human welfare is through monetary values, but valuation of ecosystem services and natural capital is rarely straightforward (see Annex 1.3). Therefore the asset check encourages, but does not require, use of valuation evidence. The 'value' of a natural capital asset may be exemplified in a range of ways in a NCAC. Monetary valuation is discussed further in Section 1.3.5). An alternative or complement to monetary valuation are quantitative non-monetary measures of welfare such as:

- the physical extent of ES that a natural capital asset produces relative to the total production of ES within E&W;
- the number of people who benefit from these ES; and
- the extent of decisions to afford protection to natural capital assets (e.g. through conservation designations).

The NCAC uses data from different time periods to describe trends. The use of historical data in describing trends can be controversial, as it can be taken to imply an objective to return to previous eras and technological situations. The choice of timescales used in a NCAC should be justified as to why they are relevant to decision-makers.

1.3.4.5 Long-term factors

The NCAC can help to understand how a natural capital asset produces value. For example, the pollinators case study examines the structure of pollinator populations, identifying which pollinators are providing which services where. This helps thinking about what is needed in the future (i.e. performance that supports crop production). It also helps identify the risks from loss of pollinator diversity, namely the risk of loss of service to some crops, and the loss of resilience of the service.

A NCAC can help with long term or strategic thinking about the implications of changes to the integrity of natural capital. For example:

- In the pollinators asset check, the loss of option value from declines in wild pollinators is highlighted – the option to rely on these species to pollinate increased areas of crop types that require pollination in future has been largely lost.
- In the saltmarsh and fisheries case study, the long term loss of extent of saltmarsh has compromised the performance of certain services (e.g. providing nursery habitat). This data illustrates an economic threshold in ecological deterioration in relation to water services – the deterioration has become severe enough in some locations to make restoration of the natural capital in order to restore ecosystem service values more efficient that replacement of the services with built capital (e.g. further downstream water treatment).

The NCAC has limitations in considering performance of natural capital into the future. While trends are analysed, complex modelling would usually be needed to give reliable insights into future ecosystem services. For example, climate change may increase the value of the role green space in managing urban heat levels. However, accurately characterising this change in the future value of services can only be reflected in an asset check if it is already subject to reliable data, which for much natural capital is not the case. In this case a NCAC needs to make reference to Option value about how the natural capital asset might be useful to society in the future. The pollination case study illustrates the loss of option value when natural capital declines, bringing the risk that our requirements for wild pollinators may increase (as crop production changes) beyond the current capacity of this asset to provide the service.

In taking into account long term trends, a NCAC can overcome shifting baseline flaws in more short-term analysis. A shifting baseline arises as generations' expectations of the baseline level reflect changes that are embedded within a system (Pauly, 1995). For example, fisheries scientists may compare stock declines against a baseline of fish-populations from the start of their career, rather than comparing to maximum potential stock levels that have been supported. Traditional cost-benefit analysis and other policy appraisal approaches applied to natural capital generally reflect recent situations in the baseline.

The sea grass beds case study illustrates this. It identifies a long term trend (the lack of recovery since the 1930s collapse in habitat extent), and the implications of this for ecosystem service levels (e.g. carbon sequestration, fish productivity). This is important context for considering performance of natural capital and the potential benefits of natural capital restoration: these should not be constrained to recent performance levels.

1.3.4.6 Thresholds

As discussed in Section 1.3.2 environmental analysis often faces a problem with regard to understanding thresholds. Natural capital assets can have different types of thresholds, and these thresholds can be defined with more or less certainty. Thresholds may be where the relationship between the condition and extent of natural capital and benefits derived by society changes. An example from the freshwater lakes case study is where the level of cyanobacteria in lakes is an absolute threshold based on WHO health considerations and once this is crossed, no recreation can take place. Another example is the difference between healthy and collapsed fish stocks. Thresholds may also be where natural capital degrades such as the recovery path to restore its extent and condition is compromised (e.g. would take a lot longer or is no longer possible).

For natural capital assets we often have observations from either side of a threshold, indicating states when it was functioning well, when it was collapsed and when possible restoration was underway. This can indicate when a threshold lies within a range, but not provide exact quantification – so risk and uncertainty language is needed. However, interpretation of data in this manner is complex – for example, it is necessary to distinguish crossing a threshold from a shift to an equally acceptable, but different equilibrium.

A key observation from a NCAC is where the integrity of natural capital is a limiting factor on the provision of welfare to society. The case study on coastal saltmarsh illustrates this concept. Saltmarsh plays key role in development of juvenile fish, but the productive capital is the coincidence of suitable saltmarsh nursery grounds with sufficient spawning stock biomass (i.e. the source of juvenile fish). The current supply of coastal saltmarsh habitat is potentially insufficient to support demand for some fish stocks (i.e. it could be a limiting factor). As the extent and condition of coastal saltmarsh continues to decline and the majority of commercial fish stocks continue to be overexploited, the reduced integrity of this natural capital contributes to the risk that non-linear declines in fish stocks will occur (if the threshold for stock collapse is breached), and this may be irreversible.

In the absence of precise data on where the condition of a natural capital asset becomes a limiting factor on human welfare, the precautionary principle may be appropriate to guide management. In the example above, this would suggest that sufficient saltmarsh should be maintained in order to support demand for commercial fish landings.

The issue of whether natural capital integrity is a limiting factor on human welfare raises specific questions, which evidence from the natural sciences does not always answer. For example, in the soils case study, although there is well established evidence for the status of most of the ecosystem services considered, the precise functional relationship between soil quality as the natural capital asset and these services is less certain. Evidence on limiting factors, considering the productivity of natural capital in the context of welfare it supports and substitutes for this, is identified as an avenue for further research.

1.3.4.7 Spatial Analysis in an Asset Check

Undertaking a NCAC faces many of the spatial scale challenges faced by ecosystem services analysis. The NCAC case studies generally are applied to natural capital at national scale (e.g. using UK or country data), but the Tees Estuary and urban green space cases illustrate how the concepts can apply equally well to local scale natural capital. The urban green space case study collates nationally representative data from four city case studies, which indicates that the analysis could readily be performed at a city level.

Considering the results at different scales reveals the importance of the distribution of natural capital in assessing thresholds and performance. For example, in the urban green space case study, there is sufficient green space overall (measured as hectares of green space per 1,000 population); but only between 30% and 90% of populations studied meet criterion for desired proximity to green space. It concludes that while there is no prospect of a general collapse of the services from urban green space, the provision of services is highly localised, and in some areas the natural capital may be highly under-provided.

The Tees Estuary case study illustrates how a NCAC can be useful at a local scale to help inform management decisions; a request was made by local stakeholders to present the analysis as an input to a meeting about the purpose and objectives of estuary management. This case study illustrates how the NCAC can combine some very specific sources of local information with ecological and economic expertise of the analyst. Where sufficient data is available, this local/regional application of the NCAC provides a way to reinterpret national ecosystems knowledge to a smaller scale.

In other case studies, reliance on national data sets inhibits the ability to capture spatial variation in natural capital integrity and productivity, restricting consideration of tradeoffs, thresholds and synergies, all of which vary in a spatial context. For example, arable soils are a particularly spatially variable asset and further insight could be gained through smaller-scale analysis of spatial policies such as crop rotation or set-aside. Capturing spatial variation in the natural environment has long been a challenge for environmental economics, and this remains the case.

1.3.4.8 NCAC in Strategic Government Reports

A different solution to the challenge of spatial heterogeneity, and to other challenges faced in undertaking a NCAC, is to commit greater time and analytical resources to undertake very detailed asset checks. Deploying such resources is costly and therefore it is considered unlikely that significant additional new resources can be found for this purpose. However, a more realistic option is available, as the public and private sector in the UK regularly undertakes detailed analysis of natural capital assets in reports or reviews of specific environmental challenges. This work can be organised in several different ways:

- through Government departments;
- by temporary independent bodies set up to undertake reviews, such as the Independent Panel on Forestry[5] that reported to Government in January 2013;
- by permanent independent advisory bodies such as the Committee on Climate Change[6]; and
- through the Government Office of Science and Technology's Foresight Programme[7], which was formed in 1994 to help the UK Government think systematically about the future.

The reports or reviews produced through such bodies are referred to here as 'detailed strategic reports' because they provide detail about the strategy (i.e. the high level plan) for achieving society's objectives.

When these detailed strategic reports are undertaken, they will often gather much of the information about natural capital assets required for a NCAC. Therefore, they potentially offer a route to undertake NCACs or at least answer key NCAC questions. An example of such analysis by the Committee on Climate Change on the role of ecosystems in climate change adaptation[8] is examined here to illustrate the interactions between a recent detailed strategic report and the NCAC.

Comparison of NCAC to 'Managing Land in a Changing Climate' Report
The NCAC approach and the Committee on Climate Change (CCC) report ('the report') have very similar structures and share many common features. When the report was planned the NCAC approach had only been scoped (eftec, 2012) and was not in use within Government. Therefore, the report does not make reference to the NCAC approach, but it effectively checks the status of the natural capital in the UK it analyses. Both approaches face scoping challenges, in that analysis must pragmatically be constrained to a subset (and sometimes only one) ecosystem service. This means other services are mentioned and described, but are not analysed at the same level of detail, and trade-offs between services are not fully investigated. The report summarises information in Tables that include some of the same headings used in a NCAC summary table (e.g. using columns for 'Risk', 'action', 'trend', 'indicators', 'implications').

There are several other similarities between the report and a NCAC. Firstly, they both try to assess resilience, and apply analysis ex-post and ex-ante to inform about future policy requirements. Secondly, like the NCAC case studies, the report's chapters each analyse a specific ecosystem service or services provided by a habitat (e.g. coastal habitats – flood and erosion protection; peatlands – regulating services such as carbon storage; etc). Thirdly, the report looks at the condition of the natural capital asset, and the implications of this for current and future levels of goods and services, including option values for services not currently fully utilised.

Fourthly, both consider current and future risks. The NCAC extends this to attempt to identify 'red flags', and compares this to future 'target' or desired performance based on societal goals. However,

---

[5] http://www.defra.gov.uk/forestrypanel/
[6] http://www.theccc.org.uk/about/
[7] http://www.bis.gov.uk/foresight/about-us
[8] This report by the Committee's Adaptation Sub-Committee aims to assess how the country is preparing for the major risks and opportunities from climate change. The choice of this example is in now intended as a criticism of the Committee's work.
http://www.theccc.org.uk/publication/managing-the-land-in-a-changing-climate/

unlike the report, a NCAC does not explicitly consider specific policy measures (for example in response to potential ‘red flags’).

The NCAC also covers some other questions that are omitted or are analysed in less detail in the report. These include threshold effects, reversibility of changes in natural capital, the issue of possible substitutes for the natural capital and the concept of ‘performance’ introduced in the NCAC (see Section 1.3.4.3). The report’s authors aim to adopt these aspects of the NCAC, to the extent their resources allow, when updating their analysis in 2015 (Alex Townsend, Committee on Climate Change, pers com, Nov 2013). The NCAC also has a structure for recognising uncertainty more explicitly, and is more closely linked to DPSIR language, allowing pressures to be more easily identified.

It is suggested that Government, and other bodies in the public sector such as the CCC, considers integrating the questions from the NCAC into the terms of reference for detailed strategic reports. The purpose of this is to encourage analysis of the state of natural capital assets, and their future capacity to provide different levels of those goods and services. This can help build awareness, within current processes for strategic thinking by Government and other public bodies, of whether natural capital assets are being used unsustainably – even if full quantification or monetisation is not possible.

1.3.4.9 When is a NCAC useful?

As discussed in Section 1.3.2, the purpose of a natural capital asset check is to inform decision makers about how changes in a natural capital asset affect human wellbeing. It incorporates concepts of integrity, performance, red flags and sustainability. The case studies summarised above have highlighted the difficulties of setting an appropriate boundary for a NCAC (e.g. see Section 1.3.4.6 on scale issues). The question over where to draw the boundary is problematic because all ecosystems are connected, and because the proposed definition of natural capital specifically mentions those connections (in terms of ‘productive configurations’).

The connectivity between assets (e.g. links between uplands, rivers, estuaries) could be missed in an asset check with too narrow a boundary. But to be practical, a NCAC needs to focus on where a natural capital asset is a significant driver of changes to ES. As an asset check can consider more than one ecosystem type and it can link up knowledge from within the UK NEA (which treats habitats separately).

As a result of this, a NCAC can challenge the geographical and policy boundaries within which resources are managed. The information it provides will be possibly most useful in strategic decision-making, but can input in a variety of ways to:

- scope knowledge of an issue and understanding (can we answer the questions about sustainability?);
- analyse a specific ES/capital relationship (e.g. pollination);
- analyse a discrete local site (e.g. large estuary);
- develop the terms of reference for government’s detailed reviews of strategic environmental issues (see Section 1.3.4.8 above); and
- build a picture of complex choices on natural capital: in which case iterations of analysis may be needed, starting with a large scale NCAC (like the majority of those in this project), from which critical areas of capital are identified. These could then be subject to further analysis of where capital is at risk of being used unsustainably, and these results could be fed back into the larger scale NCAC.

The complex questions raised by a NCAC often raise 'what-if' questions, which can be answered through modeling or scenario analysis. Modeling has the advantage of being based on existing data/trajectories. Scenarios are a valuable tool for discussing the future management of ecosystems. They can therefore inform a NCAC in a number of ways. For example, by helping people explore how:

- important natural assets might change under a range of plausible futures;
- risks associated with current trends might be better identified and understood (Questions E & F in NCAC part 2);
- trade-offs are considered (Question W in NCAC part 5); and
- to measure the potential loss in welfare if the extent and condition of the asset is compromised.

A further timing question relates to the frequency with which NCAC should be carried out. Assuming a NCAC has provided useful analysis, the efficient interval before it is worth updating it will vary according to a number of factors such as:

- the criticality of issues facing the natural capital asset, if the asset has a 'red flag' or is believed to have crossed a threshold, the asset check should be updated more frequently;
- the frequency of collection of relevant primary data; for example, biotic resources with annual breeding cycles (e.g. fish stocks) will have data updated annually, whereas other assets (e.g. soils) may only be surveyed periodically; and
- the time period over which natural capital assets can recover; some ecosystems (e.g. wetland habitats such as saltmarsh or reedbed) can be re-created and some of their functions (including supporting biodiversity) restored within a relatively short time period (e.g. 5 – 10 years). For other ecosystems (e.g. woodlands, uplands) recovery of ecosystems can take much longer, and responses to ecological, policy or economic drivers of change are also slower.

Analysis of the feasibility of re-creating selected habitat types and their relative time-scales is attracting greater attention as part of natural capital management and restoration (e.g. Natural Capital Committee, 2014). Restoration and re-creation timescales and effectiveness are dependent on existing condition of the habitat where they take place. Less degraded/damaged examples of habitats will usually be quicker and more cost-effective to restore.

For some habitats restoration is feasible in relatively short timescales. For other habitats re-creation may take decades or up to a century or more of time, and in these cases restoration at less degraded sites is likely to offer the only feasible option for restoring the natural capital. In other habitats, re-creation is not a realistic option within society's normal decision-making timescales. The speed with which different natural capital assets can recover could be subject to further research to guide analysis of how their productivity could be recovered when it is found to be degraded. In all cases, there is uncertainty about whether habitat recreation or restoration will return all ecosystem functions.

1.3.4.10 Who can undertake a NCAC?

The questions in a NCAC clearly cover multiple disciplines, and therefore completing a NCAC requires multi-disciplinary input, including from scientists (particularly natural scientists) and social scientists (including environmental/ ecological economics). The teams undertaking the case studies were intentionally formed to include economists and natural scientists to ensure multidisciplinary inputs. The case studies were lead by individuals with significant expertise in and familiarity with the natural capital assets covered. They therefore had strong knowledge of data (and data gaps) on the natural capital assets and ecosystem services involved. This is especially relevant for the later sections of the asset check, where data is interpreted. Involvement of economists in project teams is necessary to apply capital as an economic concept, and where economic valuation (both market and non-market) information is available. Different economic valuation approaches, and how they relate to natural capital, are discussed in Section 1.3.5.

Access to appropriate experts to undertake a NCAC may not always be straightforward. In this respect it could be helpful for a research institution that supports Government to develop a database of appropriate experts to undertake, or perhaps more realistically to advise on, a NCAC. A database of this kind exists in relation to agricultural science and advice. In practice, it should be feasible for those with appropriate expertise to guide less experienced researchers to complete an asset check.

The time taken to complete the NCAC case studies undertaken for this work ranged between 3 days (for the scoping study of seagrass beds) to 10 days (for the more complex analyses like uplands). A key determinant to the time needed to complete the asset check is data availability, with experts knowledge and expertise and contacts (especially for sub-national data) being important to enable efficient data gathering and interpretation. Without this knowledge, undertaking the NCAC would have been a much more time-consuming activity.

1.3.4.11 Summary of NCAC Approach

A Natural Capital Asset Check (NCAC) is an assessment of the current and future performance of natural capital assets, with performance measured in terms of their ability to support human well-being. It does this through analysis of:

(1) How much of a natural capital asset do we have? (amount, condition)
(2) What does it produce? and
(3) How do our decisions affect a) & b) over time?

The steps in the analysis to answer these questions are shown in **Figure 1.12**.

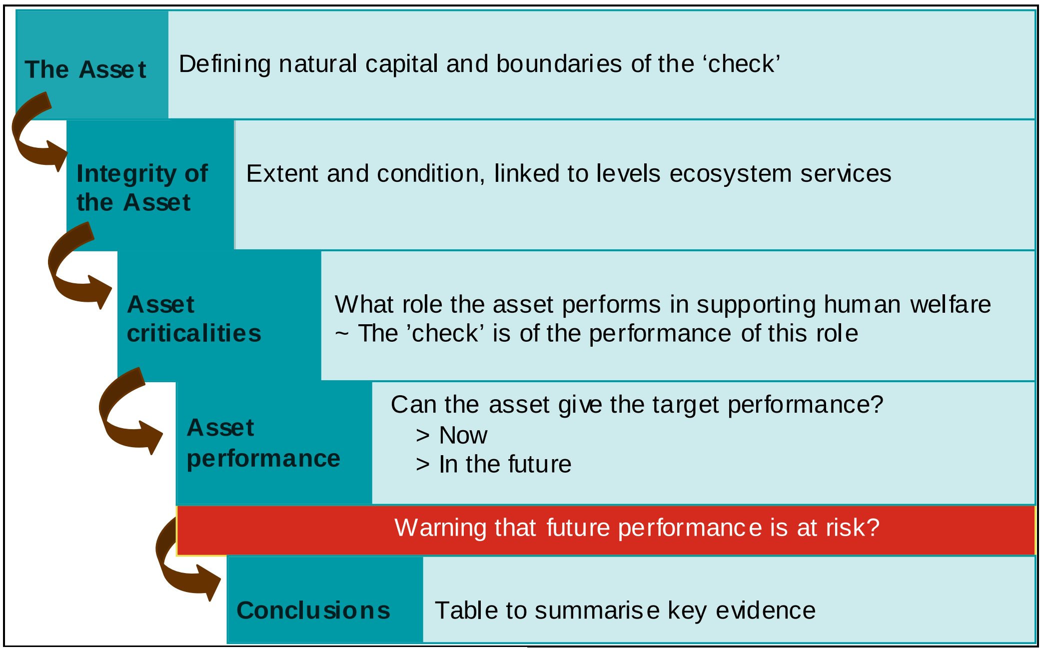


Figure 1.12. Steps in a Natural Capital Asset Check

A NCAC summarises evidence on the underlying condition of the natural capital assets that will support valuable future goods and services. The NCAC case studies show how the approach enables organization of interdisciplinary information from ecologists and economists to investigate the sustainability of use of natural capital. It can also highlight data deficiencies and future research needs. The experience gained with these case studies indicates a number of issues with the approach used in the case studies, which are reflected in the version of the NCAC in Annex 1.3, and some pros and cons of the approach:

Pros to NCAC

- Incorporates, and builds on, the ecosystem services approach.
- Reviews knowledge and evidence gaps - exposes data availability, data limitations and future data needs (e.g. is current pollinator monitoring adequate to monitor this natural capital asset?).
- Summarises the state of natural capital.
- Provides an immediate perception of past and future trends in the environment.
- Can focus on a subset of ecosystem services for practical analysis, but then consider synergies and links to other ecosystem services.
- Can stimulate analysis incorporating different perspectives and a holistic look at a natural capital asset.
- Gives explicit consideration of criticalities in the use of natural capital.
- Thinking of natural capital as combinations of natural assets requires consideration of the underlying processes (i.e. the ecological properties and characteristics of the natural capital assets) and other factors that give rise goods and services, and that are sometimes overlooked.

Cons

- It is very dependent upon data availability.
- Performance data is sometimes only available, or can only be gathered, on a subset of relevant goods and services – this influences the scope and focus of the asset check.
- Definition of geographical and policy scopes can be problematic – wider scope enables a more holistic approach, but may not be feasible if sufficient knowledge and data are not available.
- Dealing with a range of ecosystem services makes it difficult to define ‘performance’ given the potential trade-offs between services: for example where increasing recreation is at the expense of biodiversity.
- Lack of knowledge of thresholds given ecological complexity and policy uncertainty can be a limiting factor.
- There is a danger of being subjective in the completion of the document based on ‘expert opinion’, especially where interpretation of data/supporting evidence is needed.
- High level expertise is needed to undertake the check, which usually comes at a cost.

1.3.5 Valuation of natural capital and accounting

The latter steps of the NCAC allows for use of economic valuation data were available. There are different types of economic value data (market/non-market), reflecting different types of economic values (e.g. current use of option value), and that can be ellicited in different ways (e.g. revealed or stated preference). Natural capital produces goods and services that support human welfare. This welfare can be from ecosystem services that are directly used (food), indirectly used (carbon sequestration) or not used (existence, altruistic, bequest). Any definition and associated framework of natural capital needs to consider how there can be a link to valuation work and to national accounts. This section focuses specifically on how the concept of natural capital may link to economic valuation. It discusses different ways of identifying values that can be used in natural capital analysis and/or accounting: willingness to pay, replacement cost and genuine savings. Technical features of these approaches are discussed here, but their practicality must also be borne in mind, including whether there is available data to implement them.

There are many different aspects to the link between natural capital, valuation and national accounting, but some basic relationships are that: economic valuation of the environment provides unit values that can potentially be used to construct adjusted accounts; these values relate to changes in flows of goods and services from natural capital assets; the expected values of these flows over time (technically infinitely, but a practical timescale of 30 years is used by the World Bank) can be capitalised (calculated as the Net Present Value (NPV) of future flows) to value the assets. These links depend on the type of national accounting: there can be natural capital accounts (quantifying the amounts of assets and flows of goods and services), monetary accounts (covering the same assets and flows but in monetary terms) and environmental accounts (which value changes in the natural environment).

The extent and condition of capital assets typically can be added to through investment and can be depleted as they are used (depreciation). Investing in the natural capital asset could then be either adding to its physical stock (plant more trees) or improving its functioning (reduce non-native invasions). While trees are themselves a natural capital asset, both these actions would be measured in terms of how they augment the woodland's capacity to deliver future flows of goods and services. Similarly, depreciation would happen when a reduction in either the physical extent of the asset or its functioning negatively affects future services.

1.3.5.1 Willingness to Pay

Conventional notions of natural capital define it as something that is productively valuable. It is widely recognised that valuing non-marginal changes in goods/services (i.e. loss of the total stock of cod stocks for example) is meaningless because the value becomes infinite when any positive willingness to pay figure is compared to a counterfactual where no value exists. Therefore for national accounting it is necessary to value the 'flow' of ecosystem services that produce welfare from this 'stock', add these values up over time and discount them into present terms.

Therefore, value should be defined as society's willingness to pay for goods and services, and the current value of natural capital is **technically** given by the sum of discounted net benefit to society over time. Alternatively, and possibly more practically, value can be derived from changes in levels of goods and services produced in a discrete time period (e.g. 1 year). Both these approaches are described in more detail and illustrated with examples in Annex 1.

Society's use of natural capital can be deemed to be 'sustainable' when it balances current and future use in order to maximise this value/welfare across generations. However, such an approach does not explicitly address issues around the features of natural capital such as thresholds, renewability and uncertainty which mean that the value of stocks (manifest through future flows of ES) may not respond linearly to depletion drivers.

1.3.5.2 Replacement cost

An alternative to valuing benefits/ES flows from natural capital is to value the costs of maintaining these benefits or replacement cost proxies of valuation. It focuses attention on valuing/costing the on-going service capability of natural capital because it is this which is the welfare generating element. So long as humans do not deplete the natural capital 'stock' beyond the self-generating 'threshold' the natural capital asset will continue to provide welfare (in the form of goods and services) to society and there is no need to cost capital restoration. However, once the capital is degraded to a level that is deemed to be unsustainable, the cost of returning the natural capital stock to a sustainable level needs to be assessed.

This assessment may be formed through a series of questions that raise 'red flags' (or cause for concern), such as whether the levels of fish/forest capital 'stocks' suggest unsustainable depletion (i.e. deteriorating at levels above annual growth rate), but more importantly (given the above discussion) whether the ecological and geological processes that underpin the productivity of the natural capital show signs of deterioration. The cost of sustaining/replacing stocks to achieve these 'sustainable' levels may provide data that is suitable to be inputted into national accounts.

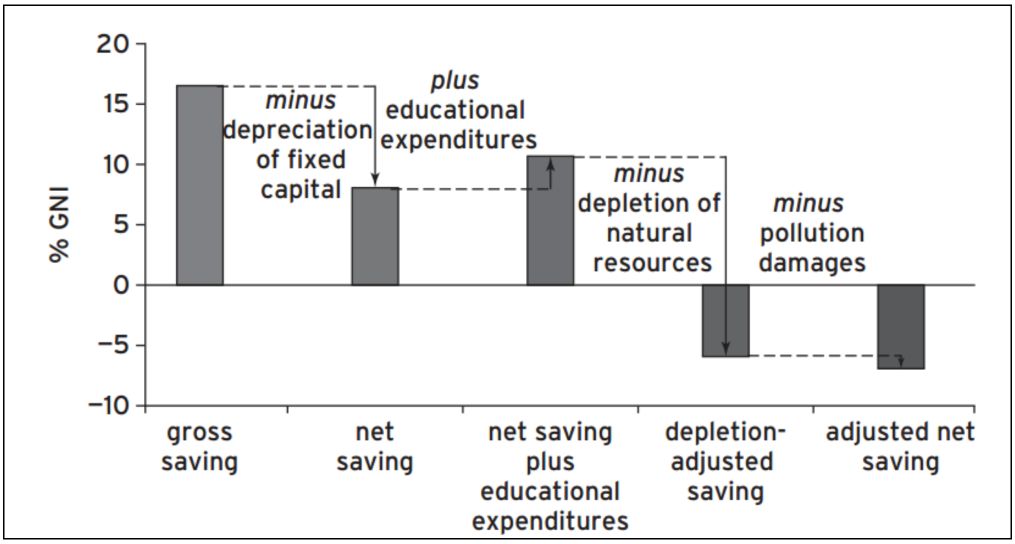
Data/information is therefore required on the risks to the sustainability of ES flows from natural capital. This provides an implicit link to the ecological processes (supporting services) that underlie the productive capacity of natural capital, the assessment of which in isolation may be overly complex. The cost of reducing these risks to a level that will ensure the continued provision of ES is the cost that should be determined.

This valuation approach is considered in more detail and illustrated with examples in Annex 1.1.

1.3.5.3 Genuine savings

One means of utilising the information that might emerge from a NCAC is as a constituent element of the value of changes in natural capital assets within an estimate of a country's adjusted net saving (ANS, also called genuine saving). This is the approach used by the World Bank (2011), albeit currently with a focus on a rather narrow range of natural capital assets. Broadly speaking, ANS is defined as national net saving adjusted for the value of resource depletion and environmental degradation and credited for education expenditures (a proxy for investment in human capital). Since wealth changes through the creation of net saving and investment, ANS should provide a more comprehensive measure of the change in a country's national wealth. This can be seen in **Figure 1.13** which sets out ANS for Sub-Saharan Africa in 2008.

Figure 1.13. Calculating Adjusted Net Saving for Sub-Saharan Africa, 2008[9]



[9] World Bank (2011) The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium.

In practice, the World Bank distinguishes different impacts on capital in terms of changes to commercial renewable and non-renewable natural resources. In addition, some consideration is also given to local pollution (the health impacts of particulate matter) and the global social costs of national carbon emissions. The basic rule for interpreting ANS is relatively straightforward: if ANS is negative, then a country is running down its capital assets and future well-being may suffer; if ANS is positive, then this country is adding to its capital assets.

The World Bank distinguishes different impacts on capital in terms of changes to renewable and non-renewable natural resources, and levels of pollution. Natural capital is deemed to comprise of agricultural land, protected areas, forests, minerals and energy. The rule for interpreting ANS is simple: if ANS is negative, then we are running down our capital stocks and future well-being will suffer; if ANS is positive, then we are adding to wealth and future well-being.

It makes a distinction between renewable and non-renewable natural resources through the focus on the depletion of natural resources, and thereby links to issues around substitutability and sustainability of resource use. ANS is theoretically sound, relatively easy to implement and has been produced for more than 120 countries. In addition, it is consistent with accounting procedures and terminology through a 'managing asset portfolio' approach.

In this approach, the link to welfare is not made explicit, for example there is no application of the ecosystem services approach. In addition, although the value of comprehensive wealth may be similar for countries, the well-being of citizens may be quite different, due to factors such as cultural capital that cannot be incorporated in economic values.

The genuine savings approach has several weaknesses in terms of valuation of natural capital. Firstly, it assumes a very high degree of substitutability among different forms of capital and as such does not convey the idea of environmental limits to substitutability. Furthermore, it only provides a snapshot of the condition of natural capital and makes no assessment of the extent and condition of the underlying stock; impending thresholds for natural capital, or possible irreversibilities and catastrophic events are not accounted for.

Secondly, it underestimates the value of natural capital, and for specific countries this omission can be significant, as stocks of resources such as some mineral resources, fisheries, hydropower, biodiversity and carbon storage and aesthetic services, are not included.
Thirdly, some features of natural capital, such assets that provide regulating ecosystem services, or changes in the capacity of natural capital to produce goods and services, only appear implicitly in the accounts. For example, the value of natural pollinators or groundwater is assumed to be incorporated in the value of agricultural land. Fully accounting for the value of these ecosystem services would not add to the wealth of nations but would change its composition.

1.4 Linking NCAC with national accounts

1.4.1 Introduction

In this section, some implications are traced for thinking about a Natural Capital Asset Check (NCAC) from a natural capital accounting perspective. "Natural capital accounting" is defined here as a term reflecting two related accounting activities. The first uses accounting principles to organize data being assembled under, for example, an ecosystem assessment. As such this can be viewed as part of the effort to understand empirically not only ecosystem services but also the underlying asset(s) giving rise to those flows (and, indeed, changes in those underlying assets). The second element seeks to links those measurement efforts to the existing accounts of a nation. Ideally, of course, the first activity should always be carried with the second element in mind.[10]

In this section, two (related) questions are addressed: (a) what is the relationship between what information might be found in a NCAC and natural capital accounts? and (b) what lessons can each approach offer the other? However, one point is important to make from the start. The NCAC case studies, in the main, cannot be used to construct practical accounts as things stand. That is, there is insufficient quantitative information in order to facilitate this. Having said that, all of the case studies set out foundations providing the basis for which further investigation and elaboration could be conducted for this purpose. Just as importantly, the case studies are useful for at least five reasons:

- As an illustration of practical issues in defining and conceptualizing "natural capital" in the context of ecosystem assets.
- By spelling out, in some detail, various parameters – such as the properties of the asset and the services that it produces – which could provide the basis for account construction.
- By identifying issues for thinking about natural capital accounting at the national level. Hence, we discuss how a NCAC and these national accounting approaches are linked as well as discuss how the NCAC have begun to describe aspects of ecosystems which may (or may not) be already measured in national accounts.
- Through the explicit emphasis on thresholds begins to make clear the importance of resilience as part of the asset value that ecosystems provide.
- In providing some initial indications are provided that might guide thinking about whether particular natural assets are being used unsustainably.

This section considers each of these points in more detail.

1.4.2 Defining natural capital

An earlier section of this report has sought to spell out in detail a definition for natural capital and, importantly, the rationale for this definition. The NCAC case studies illustrate such definitional issues by considering the characteristics or properties of ecosystem assets including, for example, soil, hydrology, geology, topology, climate, location as well as biodiversity (Hamilton, 2013). So, for example, in the uplands case study, the asset is land but one of the main elements of interest is peat soil as a key property of this system. Combined with other properties of the ecosystem, peatland then leads to services such as flood protection. In turn, changes in these properties, via e.g. peat/ soil management, affects provision of this service.

---

[10] There are different traditions here too. The UN SEEA (System of Environmental-Economic Accounts), in the context of ecosystem accounting is a thorough attempt to integrate ecosystems as an adjunct to the full UN system of national accounts (UN, 2012). Initiatives such as the *Inclusive Wealth Report* seek to build metrics of natural wealth and construct more rudimentary, but illuminating extended balance sheets for nations (UNU-IHDP/ UNEP, 2012).

From the point of view of accounting, however, some consistent conceptual starting point is desirable. One practical approach is to define ecosystem assets using land as a basic unit of account. This can be traced, in the natural capital accounting literature, to contributions by Hartwick (1992, 1993), Hamilton and Atkinson (2006) and most recently, Barbier (2012). Barbier (2010) sets out why this emphasis, on the land area occupied by a single ecosystem, is justified in terms of its starting point for thinking about accounting for ecological wealth. From this perspective, 5 of the 8 NCAC case studies broadly correspond to a focus on the land area characterized by specific ecosystems as the asset in question:

- Upland (peatlands) ecosystems;
- Seagrass ecosystems;
- Saltmarsh (intertidal);
- Arable land (agricultural soil); and
- Urban green space.

A further case study is looks at a geographical area which comprises a number of different (but related) natural assets:

- Estuaries (specifically, the Tees).

Within this ecological landscape a number of ecosystems sit side by side. This is a little bit different to the previous cases. Yet, this emphasis – in the estuaries case study – on a portfolio of geographically related ecosystem assets raises an important point. These distinct ecosystem assets within the boundaries defined by the Estuary presumably interact with one another. Accounting for these interactions could be important for making natural capital accounts relevant to estuary management.

The final case study is different again. It looks at the stock of:

- Pollination services (or pollinators).

This focuses on the sustainability of a service that is consumed. The focus on the stock of pollinators is also interesting given that some of these species give rise to other types of ecosystem service in addition to pollination. While this moves away from the land-unit focus of the other case studies, there are linkages of course. One of the chief services that the stock of pollinators provides will be capitalized in ecosystem assets which can be characterized by land as the basic unit. Moreover, these land assets support the pollinator population too.

1.4.3 Natural assets in the national accounts

1.4.3.1 Natural capital accounting and its links to a NCAC

Significant attention around the world is currently being devoted to natural capital accounting. The emphasis here is on frameworks and metrics which are linked to the national accounts of countries. Some of this work has its roots in the United Nations statistical processes – particularly the System of Environmental-Economic Accounts or SEEA – which has developed from guidelines for constructing accounts for natural resources (UN, 2012a)[11] to the more recent emphasis on ecosystem accounting (UN, 2012b). A parallel tradition takes as its starting point the economic theory of growth and development that both underpins and allows interpretation of what is in the national accounts (World Bank, 2010; Arrow *et al*. 2012; UNU-IHDP/ UNEP, 2012). A recent challenge

[11] This includes non-living resources such as sub-soil assets and living resources such as forests and fisheries. In most part, UN (2012a) deals with commercial natural resources.

has been to enrich this conceptually inspired approach with a deeper and more realistic understanding of ecological processes than has hitherto been contemplated or possible (see, for example: Walker *et al*. 2010; the World Bank's WAVES partnership[12]).

These approaches should not be seen as disparate especially in terms of the practical aspects of what is being measured.[13] Perhaps the most crucial complementary link is the emphasis of these approaches on constructing and expanding balance sheets that describe the (changing) state of a nation's capital assets. Natural capital (and its components), therefore, comprises one crucial element of this portfolio. Moreover, it is this element for which data gaps are arguably the most apparent: hence, the importance of natural capital accounting in addressing this imbalance.

A practical illustration of this, for the United Kingdom, can be found in the recently published *Roadmap* (for natural capital accounts) of the Office for National Statistics (ONS) (ONS, 2012). A particular focus of this work is constructing pilot ecosystem accounts for the UK with the idea of a balance sheet at the heart of these efforts. For example, this balance sheet is intended to describe opening and closing stocks of identified ecosystem assets as well as the reconciliation of these two items by recording intervening (net) changes to assets – e.g. net accumulation – that occur over the accounting period.[14]

If this capital asset is an ecosystem then those flows of output that are understood as 'ecosystem services' can be thought of as simply the return on the asset described in the balance sheet. A further distinction could be made here between gross output and net output of ecosystem services provided by some asset.[15] This would reflect then the changing state of the asset perhaps because perhaps of a change in its extent (e.g. land use change) or its condition/ characteristics (pollution pressure, loss of biodiversity etc.).

Just as it is important not to view seemingly distinct approaches to doing natural capital accounting as wholly separate from one another, it is absolutely crucial not to see NCAC as fundamentally different to the extended national accounting described above. NCAC needs to be based on the same principles of stocks and flows and the (natural capital) balance sheet as the vital framework for organizing what is being measured. Put this way, natural capital accounting within national accounts can be seen as a NCAC at the national level. Yet, the NCAC case studies described in this chapter offer important insights to how this work at the national level might evolve. We turn to this in the remainder of this section. Before we do so, it is also worth stating that NCAC offers additional and complementary perspectives. That is, a NCAC might enable a more *project*-focused or *geographically*-focused perspective on (changing) ecosystem assets. The crucial point remains that this focus is still based on accounting principles (that are shared with the national accounts).

---

[12] Wealth Accounting and the Valuation of Ecosystem Services: http://www.wavespartnership.org/waves/.

[13] See, however, Edens and Hein (2013) for an interpretation of where differences in approach might lead to divergences on issues of substance particularly on (non-market) valuation in national accounts.

[14] If what is being constructed is a monetary account then there is also to consider a further balancing item for re-valuation of the asset between periods. For example, closing stocks might be revised if prices change over the accounting period (although, see Hamilton and Atkinson, 2006, for a discussion of these revaluations for assessing sustainability).

[15] The former refers simply to total flow of current ecosystem services. The latter notion adds to this any positive accumulation in ecosystem assets. Thus if ecosystem assets are lost over the accounting period, this measure of net output will reflect the fact we are unable to enjoy as high a level of ecosystems in the future (other things being equal) as we are 'currently'.

1.4.3.2 Lessons of the NCAC for natural capital accounting

Considerable attention understandably has been devoted to the idea of extending national accounts in this way. However, the NCAC case studies also make clear that the national accounts already reflect some of this information. The pollination case study offers an exemplar in this respect. To the extent that honeybees are commercially owned, conventional national accounts will record the value of these assets to their owners. What will not be attributed to beekeepers, however, is the value that these species confer through pollination of crops to others. Yet these values do appear in the accounts in the form of higher arable land asset values. The key issue is that the value of this externality provided to farmers is not identified in the accounts. Hamilton (2013) argues that these instances where the national accounts already reflect the value of services provided by ecosystems are possibly ubiquitous.

A further example is provided by the urban green space case study. Principal amongst the services provided by this asset category is surely the recreational benefits that are enjoyed chiefly (presumably) by those who live locally to these green spaces. If urban green spaces are being lost/ degraded or augmented/ enhanced then there is some change in the balance sheet of *that* asset. Moreover, this balance sheet for example might be construed in terms of the present value of the recreational opportunities that will be enjoyed in urban green spaces in the future. Valuation studies of what people are willing to pay for recreation in these areas then could be used as the basis for constructing these accounts.

Yet, Gibbons *et al*. (in press) makes it clear that much of this value could be captured already in national accounts. That is, the amenities that are enjoyed as a result from living nearby to urban green space are capitalized in domestic property prices.[16] The value of these fixed/ produced assets are included in the national accounts. There are clearly some nuances here to consider. For example, can 'amenity' (as in Gibbons *et al*.) and recreation be treated as synonymous? Given, however, that there is surely some correspondence then this raises the prospect of double-counting if these ecosystem asset values are simply combined with the conventional national accounts.

The flood protection services provided by other assets (specifically saltmarsh and uplands) considered in the NCAC case studies also raise these issues. As previously discussed, the balance sheet in the national accounts, in principle, should reflect the value of fixed assets such as buildings and other structures as well as agricultural land. That is, in principle, these properties should be worth more because of these flood protection services.

All of this suggests that there is a further empirical challenge, for natural capital accounting, in sorting out what is currently in the accounts and what is not. In some cases, however, the ecosystem values implicitly reflected in the accounts will not capture the full value. Saltmarsh provides recreational angling opportunities. Some of the value of this will be reflected in the accounts in terms of the outlay costs that anglers incur in order to participate in this activity.[17] Whether this reflects the whole of the value that these anglers place on their recreation is another matter. Moreover, while it is more plausible to speculate that ecosystem values might be included (at least partly) in conventional estimates of income and product as well as certain assets, it is less clear that

---

[16] Note, however, that the study by Gibbons *et al*. (forthcoming) estimates values – capitalized in the prices of domestic properties – as a result of amenity from other types of ecosystem (land) asset.

[17] To the extent that angling takes place in privately owned waterways, the value of this asset will appear in the balance sheet. However, this does apply presumably to salt-marsh which will be publicly owned and therefore outside of the conventional national accounts.

measures of depreciation (i.e. capital consumption) will contain this information (Hamilton, 2013). The reason for this is that the valuation basis for this depreciation is unlikely to include ecosystem values implicit or otherwise.

A number of the NCAC case studies identify non-use value associate with the asset in those studies. The pollination case study, for example, indicates non-use values are likely to be held for 'charismatic' bumblebee species. Even here, some non-use is likely to be in the accounts: e.g. the subscriptions that people pay to environmental organizations will reflect in part non-use motives. This observation notwithstanding, accounting for non-use would broaden and expand in a significant way the definition of consumption in national accounts. Pursuing these substantial extensions, however, is likely to be more problematic (Edens and Hein, 2013; Hamilton, 2013). Concerns here include whether it is currently possible to provide sound valuations, using methods available, for low experience, non-use goods. And of particular note whether these non-use values can be said, in practical terms, to relate to a specific and discrete unit (rather say than the existence of 'something' more generally). Put another way, while it seems less controversial to assert that non-use values exist, the physical "unit" to which these values should be attributed is, on reflection, not at all obvious.

As things stand, it is not possible to say anything too precise – in empirical terms – about the links between these NCAC case studies and natural capital *accounts*. There is one possible exception here. A number of the case studies provide a broad indication of carbon stored: these include the uplands case study for example. In principle, this sort of information could provide the basis for a (cross-cutting) carbon balance sheet. To be complete this balance sheet should not only include the value of the *asset* that is represented by carbon currently stored in UK ecosystems. The *liability* represented by UK past carbon emissions should also be included. For example, World Bank (2009) estimates this liability for a number of countries by calculating the accumulated emissions of each (net of dissipation in the atmosphere) at a point in time: that is, the end of an accounting year.

The empirical study by the World Bank raises an interesting issue about how these stocks should be valued. The carbon stock is a non-marginal quantity and rather than value its extent using the usual marginal social cost of carbon, what is required therefore is a valuation procedure based on average social cost.[18] An issue for further discussion is the extent to which it makes sense to value this entire inventory of stored carbon in this way. On the one hand, the number would undoubtedly be large. This would help in the rhetorical effort to demonstrate the value of natural wealth and, for example, extending the focus of UNU-IHDP/UNEP (2012) on a rather narrow range of natural assets that can be owned and that, as such, command commercial values. On the other hand, a deeper answer arguably depends on whether this asset base can be managed and/ or is at risk (in terms of the stock changing over time).

In the uplands case study, there is a clear indication that the stock of carbon in peat (or part of it) can be thought of as potentially releasable. That is, the way in which soil is managed is the difference between these uplands accumulating, on balance, carbon (or at least being a stable net store) and releasing, on balance, carbon. Moreover, if a significant portion of the stock is potentially releasable given say existing management practices then it makes sense to reflect the current value of that conserved stock in a carbon balance sheet.

---

[18] Specifically, for example, if upland ecosystems store a given amount of carbon then valuation entails taking account of the way in which the social cost of carbon would change if this carbon were in the atmosphere rather than stored in the ecosystem (other things being equal).

Of particular interest here then is the way in which natural capital in these NCAC case studies is changing, and crucially the way in which an asset check can be used as the basis for assessing changes in the underlying capital asset. In other instances, these changes arise because of an appreciation in the asset value perhaps as a result of deliberate actions. An example might be the enhancement of urban green spaces as a consequence of local institutions seeking 'green flag' status for these resources. Restoration targets are also driving a number of these positive changes such as in the Tees Estuary.

The case studies make clear, however, that such changes are not always straightforward to ascertain. In the Tees Estuary study, there is an improvement in the condition of the asset (or assets) relative the baseline of some decades ago. However, a number of drivers still exist that put pressure on the resource and raise the potential for deterioration. Improvement in the asset here seems itself to be a rather complicated net effect. Understanding how changes in ecosystem properties influence the asset is key then to measuring these changes. This puts approaches to valuing ecosystem services which model this production relationship at a premium (Hamilton, 2013). In the uplands case study, for example, the functional form of depreciation of the asset is important to understand. That is, the loss of carbon sequestration services in some current accounting period appears to be positively linked to cumulative losses in the last.

One final point to make here is that if an ecosystem asset is changing in extent then some consideration needs to be made of whether change impacts on a balance sheet elsewhere. For example, the arable land case study indicates that a decline in the amount of this asset has resulted as a consequence of restoration of woodland. In other words, what has happened here is a change in composition of the broader portfolio of ecosystem assets.[19]

1.4.4 Further lessons: accounting for resilience

Much of the activity being carried out or planned under the heading of ecosystem accounting offers significant potential for complementing existing ecosystem assessment more generally. There is much that it might miss out as well. In particular, one of the services by ecosystems (and biodiversity) can be likened to a form of insurance (see, for example, Pascual *et al*. 2010 following from earlier contributions such as Gren *et al*. 1994). On this view, a more diverse and/ or larger (ecosystem asset) portfolio has a distinct value as insurance against future shocks and stresses that might otherwise threaten the sustainability of the resource (and the services it provides). As Section 1.2.4.1 has already made clear, one way of thinking about this in terms of the resource stock (and is composition) that is needed to maintain resilience: that is, the capacity of a system to persist, in some state, in the face of shocks and stresses that it might experience (Perrings, 2006; Mäler *et al*. 2009).

Contributions by e.g. Mäler *et al*. (2009) treat this "ecological resilience" as a separate stock. In other words, the ability of an ecosystem to withstand stresses and shocks (and to continue to provide services) has a distinct asset value which can be degraded (or enhanced) over time. Hamilton (2013) suggests that another way of integrating this important concept into natural capital accounting is to model resilience as influencing the *expected* value of wealth.

[19] In addition, there are further measurement issues. Clearly, other services that change as a result of the land-use switch need to be accounted for. The broader balance sheet, for example, will reflect the loss in agricultural output and so on. There are also presumably conversion costs associated with changing land use and those investment costs should also be accounted for (Hartwick, 1992, Hamilton and Atkinson, 2006, Barbier, 2012).

For example, assume there is some threshold beyond which some ecosystem asset changes state in such a way that it no longer provides services as it did previously. As the threshold is reached/ breached it becomes extremely likely that the system will 'flip' (to use the terminology in Walker *et al*. 2010) to a new and substantially less productive state. Moreover, as the threshold is approached there is a greater probability that system will produce this abrupt flip. Put another way, other things equal, the expected value of a unit of the resource stock declines as the stock approaches the threshold: there is an insurance premium to maintaining a stock above the critical amount.

Making this accounting operational clearly requires information about, for example, the location of thresholds, the probability of system flips (at different stock levels) as well as an understanding about whether the flip is itself (ultimately) reversible.[20] However, a number of the case studies begin this process of illustrating nicely the link of these asset checks to this concept of (ecological) resilience.

In the case of the saltmarsh case study, the discussion of thresholds indicate that there is likely to be a point at which there is a high chance of the critical decline in the ability of the asset to provide a nursery for young fish. The complication here is that there may not be one single notion of a threshold. That is, there is a threshold if the extent of the asset changes: a shrinking area of saltmarsh is likely to have a greater chance of not providing future services. Nutrient loading of saltmarsh is another type of threshold. More and more nutrients added to the saltmarsh increases the prospect of a 'flip' to a state which is unable to provide services (i.e. where the saltmarsh has become un-vegetated mud). Similarly in freshwater lakes, there is one threshold in water quality, where increased nutrient levels reduce species diversity significantly. There is a further threshold at a higher nutrient level, at which algal blooms are likely that pose risks to human health and therefore halt recreational activities that involve human contact with the water.

1.4.5 Checking the unsustainable use of natural assets

By providing a framework for assessing in a systematic way the state of (and changes in) natural capital, asset accounting provides the empirical basis for judging whether this natural capital is being used sustainably or otherwise. What constitutes 'unsustainable use' is a question that lies outside of the accounts. Nevertheless, the theory that underpins asset accounting can be used to provide an answer to this question. In turn, asset accounts can be constructed to give practical content to this answer.

There are a number of ways in which unsustainable use of natural capital can be conceptualized. Each, in turn, is associated with a specific rule for managing assets. These include notions that:

- What is to be sustained into the future is a generalized bundle of consumption (broadly construed). Satisfying this criterion requires that the broad portfolio of a nation's assets be maintained. Natural assets comprise part of that wealth.
- A somewhat different focus might be placed on particular elements of consumption within this bundle. One example might be the need for clean water. This puts the emphasis on sensibly managing particular assets that provide services that ensure this particular element of consumption is sustained. Plausibly then this requires a greater focus on managing particular types of natural asset. Of course, the extent to which, in this example, there is say a technical substitute (e.g. water treatment plant) then natural assets are one element in a division of some portfolio of assets that need to be monitored and managed.

[20] See, for example, Walker *et al*. (2010) for an application to salinization of arable land in South East Australia.

A further set of ideas about sustainable use puts the emphasis more squarely on what is sustaining consumption of services from natural assets. For example:

- There could be some threshold, or critical, level of some natural asset. The idea here is that the threshold must not be breached if the resource is to continue to provide services into the future (i.e. the resource stock might 'collapse' after this point). In these instances, asset accounting needs to identify these thresholds and monitor natural capital in relation to these critical reference points.
- There may be good reasons to manage natural assets so as to stay as far away from thresholds as is tolerable in socioeconomic terms. This could be because of the resilience/ insurance argument reviewed previously. That is, keeping reasonably well clear of critical thresholds contributes to maintaining resilience and provides greater assurance that future options are left open.

This, in turn, might emphasise maintaining current stocks of some specific element of natural capital or restoring natural capital to some previous level. One reason might be to maintain or enhance resilience. It might also/ instead serve the purpose of meeting some socially determined limit on the desired stock for the resource. Again, once the appropriate management rule is determined then asset accounting can be used to monitor progress (or otherwise) in relation to such criteria.

The NCAC case studies, by assembling structured thoughts on natural assets and (where practical) empirical data, provide some basis for beginning an assessment about unsustainable use of natural assets. In addition, these case studies offer information on trends and the drivers that might explain those trends. These are possibly important inputs for the type of natural capital *risk register* proposed in NCC (2013). These efforts are supplementary to natural capital accounts but no less crucial for that.

Almost all of the NCAC case studies identify a shrinking natural asset. For example, saltmarsh is in decline through a mixture of drivers within and outside of the control of domestic policy. Significant attention has been given to restoring saltmarsh; however, the location of this new investment matters in terms of producing services that are valued and consumed. In other words, restoration in itself does not necessarily create a capital *asset*. In the uplands case study, while the extent of the asset is apparently not changing markedly, the case study describes a process of cumulative erosion (in part because of policy actions to create other categories of natural asset such as woodland). In the case of seagrass ecosystems, the case study describes the legacy of a catastrophic decline in the stock of this asset because of disease a number of decades ago. Efforts to restore the asset have taken place in the context of new driving pressures. Moreover, the case study identifies challenges inherent in investing in fragmented assets and whether restoration genuinely can reverse long-term decline.

Needless to say, there is some uncertainty in the data available as to what is happening to these assets. This is the case for the saltmarsh study as well as the Tees Estuary study. In the latter, for example, data may not exist as things stand (in the case of link of restoration of the Estuary to commercial fisheries) or improvements are being realized in the context of continued pressure and depreciation of the assets within the boundaries of the Estuary.

1.5 Conclusions

Ecosystem assessment typically has used benefit assessment in order to demonstrate the economic value of ecosystems. The discrete counterpart of this is the appraisal of the benefits and costs of (forecast or proposed) changes in the provision of ecosystem services. Natural capital accounts complement this focus by providing an organising framework for data on ecosystem-related stocks and flows as well as providing links to the bigger picture in the national accounts. An important question then is what further role is there for a NCAC?

There is a case for saying a NCAC might be viewed as a conduit between a cost-benefit approach and natural capital accounts. The case studies discussed earlier illustrate that a NCAC is one way in which questions about ecosystem thresholds, substitutability and resilience can be addressed. In time, all of these questions are relevant too to cost-benefit appraisal (as well as national accounts). However, a NCAC could be one way of experimenting with these matters within a complementary analytical framework.

A more general point is that while the benefit assessment approach has proved adept at dealing with challenges in the valuation of ecosystem services, the emphasis of a NCAC is squarely on the natural capital – and the ecological properties and characteristics of those capital assets – that give rise to these services in the first place. This provides a natural connection to on-going efforts to construct ecosystem accounts linked to national accounting concepts of income and product as well as balance sheets. For example, a NCAC considers data on the extent and integrity of natural capital, and on future ecosystem flows. These link ecosystem accounting approaches, looking at stocks of assets and discounted flows of ecosystem services, respectively, that are currently being developed research under WAVES and other programs.

In this section, a number of issues related to the NCAC, in relation to natural capital accounting, have been identified and discussed. While these case studies, as they stand, could not be used to construct comprehensive accounts it is clear that these offer important lessons. These lessons are several and include: the identification of the natural capital that is embodied in particular ecosystems and the implications for (e.g. the spatial) breadth and depth of natural capital accounts; the beginnings of a description of aspects of (the value of) ecosystems which may (or may not) be already measured in national accounts; an explicit emphasis on thresholds and so on begins to make clear the importance of resilience as part of the asset value that ecosystems provide.

Just as importantly, what these NCAC case studies provide are initial indications to guide thinking about whether particular natural assets are being used unsustainably. As to what ‘unsustainable use’ is exactly, is a question that lies outside of the national accounts. However, a NCAC might be one medium where the experimental metrics needed to provide candidate answers can be considered. In due course, what is learned can then translated into guidance for extended national accounting.

References

Appleton, Albert F. (2002). *How New York City Used an Ecosystem Services Strategy Carried out through an urban-rural Partnership to Preserve the Pristine Quality of its Drinking Water and Save Billions of Dollars*. Available online: http://www.ibcperu.org/doc/isis/8095.pdf

Arrow, K.J., P. Dasgupta, L.H. Goulder, K.J. Mumford and K. Oleson (2012) "Sustainability and the Measurement of Wealth", *Environmental and Development Economics*, 17(3): 317-353.

Barbier, E.B. (2012) "Ecosystem Services and Wealth Accounting", In UNU-IHDP/ UNEP (eds.) *Inclusive Wealth Report*, Cambridge University Press, Cambridge.

Barbier, E.B. (2009) "Ecosystems as Natural Assets", Foundations and Trends in Microeconomics, 4(8): 611-681.Baron, S. R., Field, J. & Schuller, T. (2000) *Social capital: critical perspectives.* Oxford, Oxford University Press.

Bateman, I.J., Mace, G.M., Fezzi, C., Atkinson, G. and Turner, R.K. (2011) Economic analysis for ecosystem service assessments. *Environmental and Resource Economics.* 48(2): 177-218

Boorman (2003) Saltmarsh Review: An overview of coastal saltmarshes, their dynamic and sensitivity characteristics for conservation and management. *JNCC Report*. No. 334 [Available Online: http://jncc.defra.gov.uk/pdf/jncc334.pdf]

Brainard, J., Lovett, A. and Bateman, I. (2003) Carbon Sequestration Benefits of Woodland. *Report to Forestry Commission*. Available Online: http://www.forestry.gov.uk/pdf/Carbonseqrep0603.pdf/$file/Carbonseqrep0603.pdf

Christie, M., Crabtree, B. and Slee, B. (2000) 'An economic assessment of informal recreation policy in the Scottish countryside', *Scottish Geographical Journal*, Vol. 116, Issue 2 (2000), 125 – 142.

Cosman, D., Schmidt, R., Harrison-Cox, J., Batker, D. *et al* (2011) How Water Utilities Can Spearhead Natural Capital Accounting. *Solutions* (2) 6

Collins, N (2011). *Wind Turbine Costs More Than it Saves*. The Telegraph. Available Online: http://www.telegraph.co.uk/earth/energy/8315304/Wind-turbine-costs-more-than-it-saves.html

DECC (2009). Carbon Valuation in UK Policy Appraisal: A Revised Approach, Department of Energy and Climate Change. Available Online: www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/valuation/valuation.aspx

DECC & HM Treasury (2010). Valuation of energy use and greenhouse gas emissions for appraisal and evaluation. Department for Energy and Climate Change,London.

DECC (2012) Updated short term traded carbon values for UK public policy appraisal. Available Online: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/41794/6667-update-short-term-traded-carbon-values-for-uk-publ.pdf

Deegan, L.A., *et al*. (2012). Coastal eutrophication as a driver of salt marsh loss. *Nature*, **7420**, 388-392.

Department of Energy and Climate Change (DECC) (2013). Electricity: Section 5, Energy Trends. Available Online: https://www.gov.uk/government/publications/electricity-section-5-energy-trends

Defra (2010). Future funding for flood and coastal erosion risk management: Consultation on the future Capital Grant-In-Aid allocation process in England, London.

Defra (2011a) The Natural Choice: Securing the Value of Nature. [Available Online: http://www.official-documents.gov.uk/document/cm80/8082/8082.pdf]

Defra (2011b) Slowing the Flow at Pickering. Available Online: http://www.forestry.gov.uk/pdf/stfap_final_report_Apr2011.pdf/$file/stfap_final_report_Apr2011.pdf

EC (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020 [Available Online: http://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/1_EN_ACT_part1_v7[1].pdf]

Edens, B. and Hein, L. (2013) "Towards a Consistent Approach for Ecosystem Accounting", Ecological Economics, 90: 41-52.

eftec (2006) Economic valuation of environmental impacts in severely disadvantaged areas, *Report to Defra*.

eftec (2010a) Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal, Case Study 2 – Valuing Benefits of Changes in Upland Land Use *Management*. Available Online: http://archive.defra.gov.uk/environment/policy/natural-environ/using/valuation/documents/case-study2.pdf

eftec (2010b) The economic contribution of the public forest estate in England. *Report to the Forestry Commission.*

eftec (2010c) Flood and Coastal Erosion Risk Management: Economic Valuation of Environmental Effects*. Handbook for the Environment Agency*.

eftec (2011) Scoping Study on Valuing Ecosystem Services of Forests Across Great Britain. [Available Online: http://www.forestry.gov.uk/pdf/VES_FinalReport_eftec_Oct2011.pdf/$file/VES_FinalReport_eftec_Oct2011.pdf]

eftec, Haines-Young R, Atkinson G and Hails R (2012) Scoping Study to Develop Understanding of a Natural Capital Asset Check. *Report to Defra*.

Environment Agency (2010) State of Environment Regional Reports. [Available Online: http://www.environment-agency.gov.uk/static/documents/Business/SoE_March_2010.pdf]

Forestry Commission (2004) International Markets in Wood Products. Information Note. Available Online: http://www.forestry.gov.uk/pdf/fcin060.pdf/$file/fcin060.pdf

Forestry Commission (2012) Forestry Statistics 2012 - Finance & Prices. Timber Prices. Available Online:

http://www.forestry.gov.uk/website/forstats2012.nsf/LUContents/928864E00426DD598025735C002BE2EE

GES (2010) Review of Economics of Sustainable Development. Available Online: http://archive.defra.gov.uk/evidence/economics/susdev/documents/esd-review-report.pdf

GHK (2006). UK Biodiversity Action Plan: Preparing Costings for Species and Habitat Action Plans. Available Online: http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/Biodiversity.pdf

GHK (2011) Costing potential actions to offset the impact of development on biodiversity – Final Report. Available Online: http://archive.defra.gov.uk/environment/biodiversity/offsetting/documents/110714offsetting-technical-costing-potential.pdf

Gibbons *et al* (in press) TBC

Green, B., Smith, D. J. and Underwood, G. (2012) Saltmarsh Fish Ecology. http://www.essex.ac.uk/bs/research/Environmental_Biology/Projects/MFB%20PROJECTS/Saltmarsh%20Fish%20Ecology%20and%20Habitat%20Connectivity.pdf

Hamilton (2013) "Biodiversity and National Accounting", in Helm, D. and Hepburn, C. (eds.) *Nature in the Balance*, Oxford University Press, Oxford.

Hamilton, K. and Atkinson, G. (2006) *Wealth, Welfare and Sustainability*, Edward Elgar, Cheltenham.

Hartwick, J.M. (1992) "Deforestation and National Accounting", *Environmental and Resource Economics*, 2, 513-521.HMT (2003) The Green Book. Available Online: http://www.hm-treasury.gov.uk/data_greenbook_index.htm

Inmam, A. (2006) Soil erosion in England and Wales: causes, consequences and policy options for dealing with the problem. Discussion Paper, prepared for WWF by Tamar Consulting.

McBain, C. and Curry, J. (eds) (2010). *The Farm Management Handbook 2009/10*, Scottish Agricultural College, Edinburgh

Morris, R. K. A., and P. Barham (2007) The Habitats Directive as a driver for sustainable development in the coastal zone: the example fo the Humber estuary in B. A. Larson, editor. *Sustaianble development research advances*. Nova Publishers. National Academy Press, Washington, D.C.

National Research Council. (2004) Valuing Ecosystem Services: Toward Better Environmental Decision-Making *National Academies Press.* Washington, DC. Report summary

Natural England (2008) State of the Natural Environment Report [Available Online: http://publications.naturalengland.org.uk/publication/31043?category=118044]

Natural England (2009) Economic valuation of upland ecosystem services. Available Online: http://publications.naturalengland.org.uk/publication/48003

NCC (Natural Capital Committee) (2013) *State of Natural Capital*, NCC, London.

Natural Capital Committee (2012) Principles for guiding decision making regarding forestry in the UK [Available Online: http://www.defra.gov.uk/naturalcapitalcommittee/files/NCC-Principles-regarding-forestry1.pdf]

Natural Capital Committee (2014) The State of Natural Capital: Restoring our Natural Assets. https://nebula.wsimg.com/b34b945ccada11d4e11a23441245d600?AccessKeyId=68F83A8E994328D64D3D&disposition=0&alloworigin=1

Natural Capital Declaration (2012) The Natural Capital Declaration Roadmap to Account for Nature for the Financial Industry. [Available Online: http://www.naturalcapitaldeclaration.org/wp-content/uploads/2012/07/NCD_Roadmap.pdf]

Natural Capital Initiative (2009) Valuing Our Life Support Systems. http://www.naturalcapitalinitiative.org.uk/sites/default/files/docs/090429/nci_summary_lo.pdf

OECD (2005) Statistical Glossary. [Available Online: http://stats.oecd.org/glossary/index.htm]

ONS (Office for National Statistics) (2012) Accounting for the Value of Nature in the UK: A Roadmap for the Development of Natural Capital Accounts within the UK Environmental Accounts, ONS, London.

ONS (2012) UK Environmental Accounts 2012 [Available Online: http://www.ons.gov.uk/ons/dcp171778_267211.pdf

Parliamentary Office of Science & Technology (2011): Living with Environmental Limits [Available Online: http://www.nottingham.ac.uk/cem/pdf/postpn_370-environmental-limits.pdf]

Pauly, D (1995) "Anecdotes and the shifting baseline syndrome of fisheries." *Trends in Ecology and Evolution*, 10(10):430.

Payne, S. (2012). The Great British Wind Scam. Available Online: http://www.spectator.co.uk/features/8766481/the-great-british-wind-scam/

Seattle Public Utilities (SPU) (2012). Cedar River Watershed. Available Online: http://www.seattle.gov/util/environmentconservation/education/cedarriverwatershed/

Scottish Executive (2005) Indicators of Sustainable Development for Scotland: Progress Report. [Available Online: http://www.scotland.gov.uk/Resource/Doc/57346/0017025.pdf]

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

UNEP (2008) Green Breakthroughs. Solving Environmental Problems through innovative Policies and Law. Available Online: http://www.unep.org/pdf/Green_Breakthroughs.pdf

United Nations (2012a) System of Environmental-Economic Accounting: Central Framework (Final Draft), United Nations, New York.

United Nations (2012b) SEEA Experimental Ecosystem Accounts (Exposure Draft), United Nations, New York.

United Kingdom Marine Monitoring and Assessment Strategy (UKMMAS) (2010). Charting Progress 2: Productive Seas.

United States Environmental Protection Agency (USEPA) for New York City Department for Environmental Protection (2007). City Filtration Avoidance Determination. July 2007. Available Online: http://www.nyc.gov/html/dep/pdf/reports/2007_fad.pdf

United Utilities (2013). SCaMP. Available Online: http://corporate.unitedutilities.com/scamp-index.aspx

UNU-IHDP/ UNEP (eds.) (2012) *Inclusive Wealth Report*, Cambridge University Press, Cambridge.

Walker, B., Pearson, L., Harris, M., Mäler, K-G., Li, C-Z, Biggs, R. and Baynes, T. (2010) "Incorporating Resilience in the Assessment of Inclusive Wealth: An Example from South East Australia", *Environmental and Resource Economics*, 45(2): 183-202.

Willis, K., Garrod, G., Scarpa, R., Powe, N., Lovett, A., Bateman, I.J., Hanley, N. and Macmillan, D.C. (2003) The social and environmental benefits of forests in Great Britain. *Forestry Commission*.

Woodland Trust (2010). Briefing Paper for the House of Lords debate on halting the decline in biodiversity in the UK, 28 July 2010. Available Online: http://www.woodlandtrust.org.uk/en/campaigning/our-views-and-policy/Documents/biodiversity-decline-lords-briefing-july-10.pdf

World Bank (2011) The Changing Wealth of Nations, Measuring Sustainable Development in the New Millennium. Available Online: http://siteresources.worldbank.org/ENVIRONMENT/Resources/ChangingWealthNations.pdf

World Bank (2010) *The Changing Wealth of Nations*, World Bank, Washington DC.

Glossary

Abiotic: Describes the non-living component of the environment, including soil, water, air, light, nutrients and the like

Biodiversity: The complexity of ecological interactions as well as the diversity of species that develop over near-geological timescales.

Biotic: Describes a living component of the environment.

Capital: Anything which can, either directly or indirectly, yield flows of value to people over time. The different types of capital commonly defined are: Natural capital (see below), manufactured capital (for example, machinery and buildings), human capital (for example, knowledge and skills) and social capital (for example, levels of trust and connections amongst people).

Depreciation of Natural Capital: Occurs when the use of natural capital assets decreases the ability of the natural capital asset to sustain flows of ecosystem services in the future.

Ecological Function: An intrinsic ecosystem characteristic related to the set of conditions and processes whereby an ecosystem maintains its integrity (such as primary productivity, food chain, bio-geochemical cycles). Ecosystem functions describe the 'role' of processes such as decomposition, production, nutrient cycling and fluxes of nutrients and energy.

Ecological Process: An intrinsic ecosystem characteristic whereby an ecosystem maintains its integrity. Ecosystem processes include decomposition, production, nutrient cycling and fluxes of nutrients and energy.

Ecological and Geological Underpinning: The ecological and geological processes that underpin the health of the natural environment.

Ecosystem: A dynamic set of interactions between plants, animals and microorganisms and their abiotic environment that form a recognisable, functional unit. Where people are part of an ecosystem, the term socio-ecological system may be used to emphasise that social and economic factors may need to be considered analysing the factors that explain ecosystem structure and function.

Ecosystem Assets: The extent and condition of different natural habitats.

Ecosystem Services: Are the outcomes from ecosystems that directly lead to good(s) that are valued by people.

Habitats: A spatial delineation based on assemblages of species, and they reflect human interventions in land management (e.g. forestry, farmland).

Human welfare: The benefit or value that accrues to humans.

Individual Assets: The range of 'living' and 'non-living' components of the natural environment.

Natural Asset: Any natural resource (biotic or abiotic) or ecological process that has a value to society due to its function in combination with other assets (includes both ecosystem assets and individual assets).

Natural Capital: A configuration of natural resources and ecological processes, that contributes through its existence and/or in some combination, to human welfare

Natural Capital Asset Check: An assessment of the current and future performance of natural capital assets, with performance measured in terms of their ability to support human well-being.

Natural Resource: The biotic and abiotic components of nature that can contribute to human welfare.

(Productive) Configuration: The arrangements (e.g. spatial and temporal incidence) and the interactions within ecosystems that produce ecosystem services.

Resilience: The capacity of a system to persist, in some state, in the face of shocks and stresses that it might experience.

Threshold: A point at which going beyond will cause benefits from the environment to fall irreversibly (e.g. fish stock collapse). Thresholds are approached as the condition and extent of natural capital declines. They can arise from tipping points or chronic changes, and may be evident in increasing losses of productivity as the integrity of natural capital declines, or as a restriction on the ability of natural capital to recover.

Annexes

Annex 1: Valuation of natural capital

Decision-makers often require that natural capital is valued in monetary terms in order to assess trade-offs with other factors contributing to human welfare. Whether such trade-offs exist, and if they do, their influence over decisions, depend on the view taken of substitutability between natural capital and other forms of capital (i.e. weak or strong sustainability, GES, 2010). Values can be marginal values, reflecting specific changes, or stock values as measured by the (discounted) sum of the annual values of future ecosystem services over a relevant timeframe, as captured in national accounts.

Three valuation approaches (restoration/recreation costs; values of ecosystem services flows; and stock values) are applied across three types of natural capital (a watershed; timber resources; and oil and gas reserves) in this Annex. The results are shown in **Table A1**.

Each of the approaches works reasonably successfully in different ways across the different resources. There is more uncertainty with the ES flows values, which also suffer from attempting to produce total values for the stock of natural capital using marginal value data. While in general the market values appear more certain, they also have uncertainties for valuing capital (e.g. in distinguishing gross vs net value, depreciation in non-renewable reserves).

None of the data is perfect, but each offers a different insight into the value of the capital assets and when taken into account together the data enable a comparison of the value (sometime just the order of magnitude of this value) provided by different capital assets to society. This may be useful for prioritising at a policy level which capital assets are important to society.

While these valuation approaches are distinct and disparate, they can be related to one another around a concept of a minimum or safe level of some resource stock (X*) that is needed to be sustained. Given the current stock of X, depreciation in an 'accounting period' takes us either further:

- *toward* X* (i.e. the closing balance for X is greater than X*); or,
- *away from* X* (i.e. the closing balance for X is less than X*)

In the former case, depreciation arguably should be valued according its marginal value to "users", for example as measured through changes in the value of ecosystem service flows. One reason for this is that what is lost is, by implication, the 'substitutable' portion of X. (That is, some amount of X is lost but the critical stock is still intact.) This resulting value would be the amount to deduct to estimate genuine saving.

In the latter case, depreciation arguably should be valued according to the costs of restoring the asset. What is lost is, by definition, the non-substitutable portion of X. The relevant question is what are the costs of moving back towards the desired level?

One question is whether we can identify X*. Sometimes we can only once X* has been passed, but it is much harder ex-ante. It may be possible to express X* within a range, but even this range may not be known. A cautious/ practical view might be to say that the current stock should be sustained (i.e. X* = current value). Doing so might imply that a cost-based approach is needed to value depreciation. So the relevant question is: what is the cost of restoring the stock to the current level if depreciation takes place? However, it probably makes sense to estimate both the value of depreciation based on marginal value to "users" (i.e. loss of ecosystem service flows (f)) and the costs of restoration (c). Comparing the two estimates might provide useful information: i.e. if (f) > (c) then this would indicate that it makes sense to restore the asset in that the broad signal is that we might have too little of it.

Note that the values of (f) and (c) might both change with the proximity of X to X*, particularly where X* is uncertain. As X* is approached, the marginal value of a unit of X increases to reflect risk-aversion, as the risk of more wealth being lost when depreciation occurs increases as thresholds are approached. In other words, as X* is approached, further depreciation of X brings an escalating loss of resilience for the resource.

Table A1. Examples of natural capital valuation approaches.

	A. Watershed	B. Forest	C. Oil and Gas
1a Restoration cost	New York, USA: Catskill Watershed Restoration cost of $1.5bn. SCaMP, UK: habitat restoration cost £10.5m, farm buildings and fencing investment £2m.	Restoration *in situ* to meet UK BAP goals estimated to cost £12m from 2010-2015 and £11m from 2015-2020. Creation of new habitats to meet UK BAP goals estimated to cost £19m from 2010-2015 and £20.5m from 2015-2020.	It is not possible to restore oil and gas reserves as they are non-renewable.
1b Replacement cost	Seattle, USA: Cedar River Watershed, avoided $200 million water filtration costs and $3.6m annual operating and maintenance costs. New York, USA: saved an estimated $6 to $10bn through avoiding the costs of a new filtration plant plus $400m in annual maintenance and operation costs.	Social cost of carbon values indicate the cost of replacing sequestration benefits from woodland: £57/tCO2e for sectors not covered by the EU ETS and £5.98/tCO2e for those in the EU ETS, both rising over time to £212/tCO2e (£733/tC) by 2050 at 2011 prices.	Replacing the electricity produced by oil and gas with that produced by wind generation would cost £6.42bn in subsidies at current rates.
2. Changes in ecosystem service flows	SCaMP, UK: the annual flow of ES is estimated (with strong caveats,) to be; £0.5m for informal recreation; £0.5m for non-use value; £0.05m for greenhouse gas regulation.	Market Value:, Average unit values for domestic timber £70.5/m³ in 2003. 85% of domestic demand for wood is met from imports Non-market Value: total estimated non-market value of the benefits provided by woodland in Great Britain is approximately £1bn/year.	Market Value: total income from domestic oil and gas extraction was £39.7bn in 2008, with the industry as a whole accounting for an estimated £37bn GVA.
3. Total stock value	SCaMP, UK: selected ecosystem services are estimated to have a PV of £10.2m over 50 years and £16.2m over 100 years. The NPV of the ecosystem services that can be valued is estimated to be £-4.8m over 50 years and £0.4 m over 100 years.	In 2011 the total area of the UK covered by woodland was 3.08m hectares, the gross estimated market value of UK woodland was £9.0bn. The total value of net carbon sequestration benefits from future planting is approximately £1.1-1.3bn.	The market value of the UK's gas reserves up to 1,802bn cubic metres and oil reserves of 2.5bn tonnes, at the end of 2010 was £139.7bn.

Examples and units

This section aims to illustrate how each of the approaches set out in Table A1 would work in practice. The same case study is used in order to facilitate comparison and draw out the pros and cons of each approach relative to one another. The units that could be used are also set out here and illustrations provided.

The case study used is of the role of saltmarsh in supporting commercial fish landings. The natural capital is the productive combination of spawning fish populations (which produce juvenile fish) and saltmarsh habitat (which provides nursery grounds that enable the juvenile fish to mature). This case study was examined in detail in the NCAC scoping study (eftec et al. 2012).

Each of the approaches is flexible in terms of the 'starting point' for defining natural capital. Broadly the final ES of concern are commercial fish landings, and we are concerned about the natural capital which supports its productivity. However, this natural capital also supports other final ES as well, and any analysis should consider these wider impacts. For the purposes of illustration, commercial fish landings are termed primary (1º) ES benefits and other final ES are termed secondary (2º) final ES.

This Annex provides brief examples of how we may record the value of natural capital. It looks at three examples which illustrate a range of natural capital assets:

- **Watersheds**: which largely provide non-market ecosystem services (water resource regulation) through biotic and abiotic filtration processes which are renewable/ non-finite.
- **Forests**: which largely provide a mixture of market (timber) and non-market (biodiversity, landscape) services through biotic processes which are renewable/ non-finite.
- **Oil and Gas**: these are market goods and effectively finite resources.

A further example of a project creating a forest to manage a watershed is also discussed. For each of these natural capital assets, the applicability of three valuation approaches is tested as set out in Table A1. These three approaches are explained below.

Many benefits of the natural environment do not have a monetary value attached to them due to the absence of a market (i.e. they are non-market goods/services). In order to ascertain values for these benefits it is necessary to use economic valuation approaches. Values can be obtained using surrogate prices, willingness to pay (WTP) or cost based methods. WTP measures individuals' total economic value to avoid the loss of, or to gain the value of, these benefits. Alternatively, willingness to accept compensation (WTA) to tolerate the loss of, or to forgo the value of, these benefits. The choice between the two measures depends on identifying whether individuals have a (property) right to a given level of benefits (for example, if not, WTP is the preferred measures). Literature to date mostly uses WTP as this is found to be a more credible measure when applying valuation methods in practice.

Approach 1: Replacement/restoration cost

This is the cost of restoring natural capital *or* the cost of replacing it through manufactured capital or creating new natural capital:

- **Cost of natural capital restoration (or re-creation):** This is the cost of restoring natural capital *in situ,* in terms of the ecological processes that produce services of value to people. The advantage of this approach is that in addition to the main ecosystem services (ES) of concern (e.g. water regulation by watershed habitats), associated and complimentary benefits are obtained (e.g. landscape value).
- **Cost of replacement through capital substitution:** This is the cost of replacing natural capital functions. Substitution can be with manufactured capital (e.g. water filtration in watershed habitats substituted by a water treatment plant); or alternatively through creating new natural capital *ex situ* (e.g. through biodiversity offsets) which acts as a substitute for the productive aspect of nature concerned (e.g. supporting wild species diversity).

Manufactured capital generally substitutes specific functions provided by the natural capital, but may not act to protect the many other aspects of the natural environment associated with a particular natural capital asset (e.g. a water treatment plant can replace the water filtration function of a watershed habitat, but cannot replace its landscape value). Natural capital substitution through re-creating habitats also has implications for the range of values obtained. Although the relevant functions may be re-created, the different location may change the values of the ecosystem services provided, as proximity to beneficiary populations is important for many ES.

Under this approach:

Change in value = $(K_{NAT}^{t0} - K_{NAT}^{t1}) * (C_{MAN}^{t1})$

Total value = $K_{NAT}^{t0} * (C_{MAN}^{t1})$

Where:

K_{NAT}^{t0} = Quantity of Natural Capital at time t0

K_{NAT}^{t1} = Quantity of Natural Capital at time t1

$(K_{NAT}^{t0} - K_{NAT}^{t1})$ = Change in Natural Capital over time period t0 to t1

C_{MAN}^{t1} = Unit cost of Manufacturing Capital at t1

The change in value function assumes that the quantity of natural capital falls/rises over time (i.e. between t0 and t1) and is replaced by/replaces manufactured capital at time t1. A simplistic assumption is made here that the unit cost of replacing natural capital with manufactured capital is constant (as given at time t1), whereas in reality it may not be constant, e.g. due to technological learning and economies of scale.

Approach 2: Changes in annual ecosystem service flows
This is the value of the annual flow of ecosystem service (ES) benefits that are lost or gained due to changes in the extent or condition of the underlying natural capital stock. This approach is in line with conventional marginal economic analysis and fits with cost-benefit analysis methods at the project or programme level.

Under this approach:

Change in value = $[(ES^{t0} – ES^{t1}) * £^{t1}]$

Where:

ES^{t0} = Quantity of ES at time t0

ES^{t1}= Quantity of ES at time t1

£ = Value of ES at time t1.

Value can be captured through willingness to pay for unit changes in non-market goods or through prices for market goods.

Use of this function must reflect the fact that willingness to pay to avoid declines in ecosystem service provision can vary with the direction of, scale of and starting point for ecosystem service change, as well as in response to the supply of the ES.

It should also be noted that market prices do not reflect the societal value of ES and so where possible shadow prices should be used.

Approach 3: Stock value

The value of natural capital over time can be calculated by the (discounted) sum of the annual values of future ecosystem services over a relevant timeframe. This is the values from approach 2, discounted over time, and can be referred to as stock value. Where only benefits are known, this produces the present value (PV) of benefits. It is also relevant to note (where possible) the costs, including opportunity costs, of projected ES benefits from natural capital assets (i.e. reflecting the costs of maintaining the natural capital and the foregone benefits arising from alternative uses). The discounted sum of annual benefits minus costs is known as net present value (NPV).

The World Bank (2011) view of a relevant timeframe is for generational accounting to be set over 25 years as we cannot be sure what the value of assets would be beyond that period. Whilst it is true that we have no idea what oil as a capital asset may be worth in say, 50 years, we know that demand for freshwater will be sustained into the future and is likely, given predictions of climate change and population growth, to continue to grow strongly. Therefore we suggest that any stock value is assessed over a short term (e.g. 25 year) and a longer term (e.g. 100 year) time horizon where possible.

The extent and condition of the stock can rise (appreciation) as well as fall (depreciation). Where appreciation occurs through increasing the extent of the asset, this may replace other forms of natural capital and the opportunity costs[21] of this need to be taken into account. Accounting for opportunity costs is important because humans have unlimited wants and needs, and limited responses.

For example, afforesting large areas of agricultural land would increase the ES benefits that flow from woodland, but this could have an opportunity cost in terms of agricultural output (and other ES provided by agriculture) forgone. This fact will be reflected in robust valuation studies which note that the per-unit value of virtually all goods is rarely constant (see Bateman et al., 2011), but tend to increase as supply falls.

Moreover, afforestation gives rise to a change in the composition of the broader portfolio of ecosystem assets. Climate regulation services (through carbon sequestration and storage) will increase as a result of afforestation, but there can also be a loss in climate regulation services provided by the habitat it replaces (e.g. agricultural land) (NCC, 2012). Whilst we do not address opportunity costs or the changing composition of the portfolio of natural capital assets, we note it here as making the assessment of net changes in services important, and as a caveat to the values provided in Table A1.

A final issue to note is the adopted discount rate when converting the future value of natural capital into present day terms. For now, we are using studies that adopt the HMT (2003) decreasing long term discount rate, but note that sensitivity analysis around the relevant discount rate may be appropriate in a more comprehensive analysis.

---

[21] Opportunity cost is the value forgone in order to obtain a good or service.

Under this approach:

Total value in t1 = $$\sum_{t=0}^{n} \frac{(£ * \Delta \mathrm{ES})^t}{(1+r)^t}$$

Where:

£ = Value of ES

Δ ES = Change in ES over time

r = discount rate

t = year

n = time horizon for analysis (years)

This function represents the net present value of all ES (market and non-market) by discounting their future value and then summing these values over a relevant time horizon.
Table A1 illustrates values derived for the different types of capital using the different approaches. In reading this Table, it should be noted that:

- The rows or columns are not additive
- Evidence from the literature is used for illustration and is not necessarily comprehensive. For example, forest restoration costs do not relate to all UK forests, as only UK BAP targets are used (there are also non-BAP forests).
- The references for each cell can be found in the notes describing each value that follow. These are identifiable in the following text based on the numbers of rows (1a, 1b, 2, 3) and the letters of the columns (A, B, C), so that for example, oil and gas value over time is C3.
- The available examples and the evidence that exists for them are very different, so precise comparisons between them may not always be appropriate. For example, while the SCAMP and New York examples deal with similar ecosystem services (related to water), the important benefits of SCAMP for water provision are not estimated.

Watershed information

Schemes background

Catskills, New York, USA - The Catskill and surrounding watershed system extends from 120-200km north of New York City and provides 90% of its daily drinking water (4 billion litres). It is a 5,200 square kilometre catchment, some 73% of which is under forest and much of the remainder consists of farmland. Between 1830 and 1905 the City of New York opted to make long term, large scale investments to collect abundant, pristine water for the City from unspoiled rural watersheds in the north:

> '*The drivers of this water strategy have always been the assumption that fresh water released from an intact forested catchment would be fit to drink without further treatment, but that preventing harm to the catchment forests would best be achieved if the City has actual ownership (or other direct control) over activities within the catchment. Based on these assumptions, it was considered more cost effective to acquire control over catchment*

lands and protect their forests, than to invest in expensive water filtration or other treatment facilities' (UNEP, 2008).'

The City's water has met the criteria for avoiding US filtration requirements since 1993, and has been given clearance to avoid fabricated filtration (subject to testing) until 2017 (New York City, 2011).

For more information on the Catskill watershed, see:
http://www.nyc.gov/html/dep/html/home/home.shtml or
http://www.unep.org/pdf/Green_Breakthroughs.pdf

Cedar River watershed, Seattle, USA - The City of Seattle's Cedar River watershed, a protected area 60km south east of Seattle, supplies over 4.5 million litres of drinking water per day to some 1.4 million people in the greater Seattle area. It covers 36,680ha through the Cascade Mountains, a landscape including wetlands, snow-capped mountains, and old-growth forests, and includes several small lakes and two storage reservoirs; Masonry Pool and Chester Morse Lake. Dams within the watershed are operated for flood control, water storage, and the generation of hydroelectric power. Flowing through a region of deep, porous glacial till, the Cedar River, through natural water filtration, is one of the few rivers in the US used for drinking water that bypasses the need for filtration in a water treatment works (SPU, 2012).

For more information on the Cedar River watershed, see:
http://www.seattle.gov/util/environmentconservation/education/cedarriverwatershed/

The Sustainable Catchment Management Programme (SCaMP), Cumbria, Lancashire and the Peak District, England - SCaMP is a partnership between United Utilities, the RSPB, local farmers, and other stakeholders, to invest in the conservation of 20,000 ha of upland river catchment. SCaMP was created in response to the 'unfavourable and declining condition' of large areas within the catchment (30% of which is designated as Sites of Special Scientific Interest), partly attributed to overgrazing, upland drainage, historical pollution, inappropriate vegetation management and uncontrolled burning. Years of drainage of the UK uplands has caused 5,000 year old peat bogs to dry out and erode releasing colour and sediment into watercourses and millions of tonnes of carbon dioxide into the atmosphere contributing to climate change. Over the last thirty years there has been a substantial increase in the levels of colour in the water sources prior to treatment from many upland catchments. The removal of colour requires additional process plant, chemicals, power and waste handling to meet increasingly demanding drinking water quality standards. The SCaMP plans detail the environmental restoration required to improve habitats, the farm operation required to sustain the habitat, and the infrastructure improvements needed to allow the system to work and the hydrological functions of the habitat to operate. The main activities being undertaken to replace watershed services in SCaMP are (Natural England, 2009):

- Blocking drainage ditches to re-wet peat bogs that had been drained, creating new habitats for wildlife;
- Restoring areas of eroded and exposed peat and heather moorland;
- Establishing woodland by planting thousands of new trees and replacing existing coniferous trees with native broad-leaf species;
- Providing new waste management facilities to reduce run-off pollution of water courses, and
- Fencing to keep livestock away from areas such as rivers and streams and from special habitats.

See http://corporate.unitedutilities.com/scamp-index.aspx for more information on SCaMP.

Restoration cost

New York invested $1.5 billion in its Catskill watershed to restore the watershed functions provided by natural capital (NRC, 2004).
The Sustainable Catchment Management Plan (SCaMP) conserves 20,000ha of water catchment land in North West England. Investments included habitat restoration expenditure of £10.5m, and improvements to farm buildings and fencing of £2m (Natural England, 2009).

Replacement cost
Seattle Public Utilities purchased the forested Cedar River watershed in 1889 to filter water. As a result it has avoided the costs of construction ($200 million) and annual operating and maintenance ($3.6m) of a new water filtration plant (Cosman et al, 2011).

New York has saved between $6 and $10billion compared to the cost of a filtration plant plus the $400 million in annual maintenance and operation costs (NRC, 2004; UNEP, 2008). It is unclear whether this value includes the additional greenhouse gas sequestration, recreational and non-use values associated with conserving land.

Changes in ES flows
The nature of the SCaMP project means that it is difficult to measure annual changes in ES flows. It was more appropriate to appraise the benefits relative to a 'no-SCaMP' scenario over a relevant timeframe. **Table A2** shows the unit values of ES benefits from such a project, and the estimated annual benefits. The annual benefits of SCaMP are not a representation of value of the site as they do not take account of phased delivery or the impacts of discounting.

Table A2. Estimated unit value benefits of SCaMP (2008 prices) *(eftec, 2010a)*

Ecosystem Service	***Unit Value (2008)***	***Annual Value***
Greenhouse gas regulation	£25 - 50 per t CO_2/year (DECC, 2009)	£0.05 million
Water	n/a	n/a
Informal recreation	at least £1 per person per visit (Christie, 2000)	£0.5 million
Non-use values	£0.19 per year per household (eftec, 2006)	£0.5 million
Note these values give only partial coverage of the ES impacts of SCAMP.		

The adopted baseline for SCaMP is business as usual (BAU) without the project. This means, for example, the improvements to informal recreation from SCaMP are set relative to a non-SCaMP scenario. This is assumed to result in a 5-10% increase in the value derived from an informal recreation visit, giving an estimated value of £0.97-1.94 per person (Christie, 2000).

Stock value
A key unresolved issue in the eftec report on SCaMP (eftec, 2010a) is the water quality regulation benefits associated with the project. This means that the calculated NPV (£-4.8million over 50years and £0.4 million over 100years) is an underestimate. The report says that there are initial indications that SCaMP is stabilising water colour from the area – set against on-going increases in non-SCaMP areas – and water colour could potentially improve further in future. Although it is clear that water quality benefits could be very significant, there can at present be no certainty that such benefits will exist. Water quality monitoring is ongoing and better estimates of future cost savings may become available in time (eftec, 2010a).

Table A3 sets out the present value of ecosystem service benefits from the SCaMP project over a 50year and 100year timeframe.

Table A3. Estimated present value benefits (£million) of SCaMP *(eftec, 2010a) [NOTE, figures being checked and we will try to adjust to 25 yrs]*		
Ecosystem Service	***PV (50 year)***	***PV (100 year)***
Greenhouse gas regulation	£0.86m	£1.92m
Water	-	-
Informal recreation	£4.7m	£7.3m
Non-use values	£4.7m	£7.3m
Total Benefit (PVB)	£10.2m	£16.2m
Note these values give only partial coverage of the ES impacts of SCAMP.		

Watershed/forest information

A case study project that combines watershed and forest management is the 'Slowing the Flow' project, Pickering, North Yorkshire (Defra, 2011b), which planted 85ha of woodland and 150 large woody debris (LWD) dams in order to avoid investment in flood protection walls.

Figures A.1 and **A.2** are photographs showing two examples of what large woody debris dams are and how they help to increase flood storage by creating an upstream pool and reconnecting streams with their floodplain.

Image A1.

Image A2.

Forestry Commission (2013)

Changes in annual ES flows

Defra (2011b) estimated mean increase in ecosystem services to be worth £204,000 per year in the Pickering 'Slowing the Flow' project. The study drew on willingness to pay studies, damage costs (e.g. from flooding), opportunity costs (i.e. of lost agricultural production), and the costs of substitute capital (e.g. costs associated with replacing the watersheds' erosion regulation function with dredging).

The central NPV estimate of the project was £4.3m (over 100years), due mainly to benefits from habitat creation and climate regulation.

Table A4. Indicative annual ecosystem service present values (£k at 2011 prices) for the woodland creation (85 ha) and LWD dam (150 dams) measures (Defra, 2011b)	
	Mean (£/yr)
Habitat creation	£121,524 (eftec, 2010b; eftec, 2010c)
Flood regulation	£5,964 (Defra, 2010)
Climate regulation	£107,035 (DECC, 2010)
Erosion Regulation	£205 (Inman, 2006)
Education and knowledge	£14
Community development	£549 (used UK minimum wage)
Agricultural production	-£31,604 (McBain and Curry, 2010)
Net Present Value	£203,687

Stock value

Table A5 shows the estimated present values for the ‘Slowing the Flow’ project, which covers 85 ha. They illustrate the potential magnitude of benefits from combined forestry and watershed management in the UK.

Table A5. Estimated present value benefits (£million) of ‘Slowing the Flow’ *(eftec,2011)*	
Ecosystem Service	***PV (100 year)***
Habitat creation	£1.6m to £4.5m
Climate regulation	£0.9m to £5.5m
Flood protection	£0.09m and £0.3m

Some of the figures in Table A5 are estimates of the value associated with ecosystem services from this project based on a range of GB data obtained using non-market valuation techniques. Such techniques have a great deal of uncertainty associated with them, which is compounded when the evidence used is based on transferring values from other, similar cases. ES values, both market and non-market, will vary over space and time, adding further uncertainty to such value estimates. For these reasons, it should be recognised that the figures in Table A5 are only indicative of the societal value of this project and should be treated as such.

Furthermore, Defra note how their objective was not to estimate definitive values but to provide some conservative estimates to serve as the foundation for a more robust future valuation of ecosystem services.

It should be noted that the scale of woodland creation required (85 hectares) may not be feasible in practice. Many of the beneficial sites were to be found within designated areas (e.g. SSSI, Scheduled Monuments) and were not considered available for public interest reasons. As a result new planting was deemed acceptable at only 10% of riparian woodland targeted (eftec, 2011).

Forest information

Restoration costs

GHK (2011) estimate the present value cost of restoring woodland habitats (excluding land purchase) to be between £5,058 and £7,776 per ha over 100 years. These estimates reflect total costs – as well as capital expenditure, they include administration, regulatory and transaction costs. The UK Biodiversity Action Plan (BAP) set an objective for the UK to restore 50,300 ha of non-native plantations on ancient woodland sites (PAWS) to native woodland in the UK by 2015 (Woodland Trust, 2010). Costs to achieve BAP restoration target levels, are estimated to be £12million from 2010-2015 and £11million from 2015-2020 (GHK, 2006).

GHK (2011) estimate the present value cost of creating woodland (from agricultural land, excluding land purchase) to be between £3,404 and £7,436per ha over 100years. Social cost of carbon values provide an indication of the costs of replacing some of the lost ES from woodland. In addition, the UK BAP set an objective for the UK to create 135,000 ha of new woodland by 2015 (Woodland Trust, 2010), and costs to achieve these UK BAP woodland creation target levels are estimated to be £19million from 2010-2015 and £20.5million from 2015-2020 (GHK, 2006).

Replacement cost

The social cost of carbon values provide some indication of the cost of replacing sequestration benefits from woodland; current UK government guidance (DECC, 2011; DECC 2012) includes central estimates for 2013 of £5.98/tCO_2e for sectors covered by the EU ETS and £57/tCO_2e for non-ETS sectors, both rising over time to £212/tCO_2e (£733/tC) by 2050 at 2011 prices.

Changes in ES flows

Woodland provides a range of ecosystem services and as many of these should be accounted for as possible. Furthermore, woodlands are heterogeneous and this detail should be accounted for as much as possible (NCC, 2012).

Market value

85% of domestic demand for wood is met from imports, valued at £6bn/year. Average unit values range from £83 to £387 per cubic metre for imports in 2002 (FC, 2004). The average price for domestic timber was £70.5 per cubic metre in 2003 (FC, 2012). This suggests that substituting the domestic portion of the timber supply market with imported timber can be achieved at relatively low cost.

Non-market value

The estimated total annual non-market value of the benefits provided by woodland in Great Britain is approximately £1 billion per year Willis et al. (2003). These estimates were updated to account for inflation by the UKNEA as set out in **Table A6**:

Table A6. Estimated total non-market benefits of GB Forests per year (£)
(eftec, 2011)

Ecosystem Service	***Willis et al. (2003)***	***UKNEA (2011)***
Recreation	£392m	£484m
Biodiversity	£386m	£476m
Landscape	£150m	£185m
Carbon sequestration	£94m	£115m
Air pollution absorption	£0.4m	£0.5m

In Willis et al. (2003) the air pollution absorption (health benefits) of woodland was found to be relatively insignificant (£0.4 million per year) because of the low population numbers in close proximity to areas of woodland.

The figures in Table A6 are calculated by applying estimated unit values to areas of forests in Great Britain. **Table A7** shows unit value benefits of selected ecosystem services from forests in Great Britain. These are average unit values and the value associated with marginal changes in individual forests may be higher or lower than this average. Average values are nevertheless useful indications of marginal changes.

Table A7. Estimated unit value benefits of forests in Great Britain *(eftec, 2011)*	
Ecosystem Service	***Unit Value (2008)***
Recreation	£3 per person per visit (£1.66 in 2002 prices)
Landscape and aesthetic amenity	£200 - £500 per household/year for home with forest view; £155 - £330 per household/year for forest views whilst travelling
Biodiversity	£1-3 per household/year for increase in biodiversity as a result of increasing forest cover by 12,000 ha in a variety of forest types, rather than solely through remote coniferous forests.
Carbon sequestration	£6 - £70 per tonne of carbon
Air pollution absorption	£125,000 for each death avoided by 1 year due to PM10 and SO2; £602 for an 11 day hospital stay avoided due to reduced respiratory illness
Water supply and quality	£0.10 - £1.25 per m^3 where water not available for abstraction for potable uses. However, in most of Great Britain the marginal cost is zero due to guidelines on woodland planting
Protection of archaeological artefacts	£0 to £247/ha
Timber (GVA, domestic market this includes processing of imported timber)	£1.7 – £2.1 billion per year

Most of the figures in Table A7 are estimates of the value associated with ecosystem services from forests in Great Britain based on a range of non-market valuation techniques. Such techniques have a great deal of uncertainty associated with them, which is compounded when the evidence used is based on transferring values from other, similar cases. ES values, both market and non-market, will vary over space and time, adding further uncertainty to such value estimates. For these reasons, it should be recognised that the figures in Table A7 are only indicative of the societal value of GB forests and should be treated as such.

Stock value

The total area of the UK covered by woodland increased by 0.3 per cent in 2011, compared with 2010, to 3.08 million hectares, the highest since 1924.

Information is readily available on the market value of UK woodlands based on the Forestry Commissions land use valuation estimates. The total estimated market value of the UK woodlands was £9.0 billion in 2011, an increase of 69 per cent from £5.3 billion in 2008 (ONS, 2012). These are gross values, so do not take into account costs, such as the costs of harvesting timber.

To get an idea of the scale of the total stock of non-market benefits associated with woodland, we provide information on the estimated carbon sequestration value of future woodland planting in Great Britain. Future planting is assumed to be 13,400ha/year of broadleaf and 4,700ha/year of conifer over the next 200years in Great Britain and the value of carbon sequestration benefits alone is approximately £1.11-1.25 billion (Brainard, 2003). This is a net carbon value meaning that it does account for the carbon sequestration that would have occurred under the baseline (current) land use.

Note that the market values for woodland land use may capitalise future income from timber, but also reflect values of sporting licences or other recreation markets, or potentially from carbon offsets. However, it may not be possible to achieve this multiple values simultaneously from a woodland. Therefore, the carbon sequestration values set out by Brainard (2003) and the market value of woodland land use set out by ONS cannot be summed, either because there may be double counting of carbon sequestration benefits that have been capitalised into land values through the potential income from carbon offsets, or because realising carbon values has a trade-off with realising timber values.

6.3.8 Oil and gas reserve data

Restoration cost
It is not possible to restore oil and gas reserves due to their non-renewable nature.

Replacement cost
Given the fact that oil and gas are non-renewable reserves that will exist until used as well as the fact that energy markets are international in nature and that energy is provided through a mix of sources, asking what is the 'replacement cost' of oil and gas may not seem to be a particularly useful question.

However, whilst the marginal replacement cost for UK supplies is (currently) close to £0 as it is possible to import substitute energy sources, the cost of replacing all UK energy is dependent on the energy generation mix which (currently) includes oil and gas. The uptake of alternative energy sources (renewable or fossil fuel) is more costly and this additional cost of developing alternative UK energy supplies is reflected in subsidies. Currently the subsidy for wind generation is 4.8p/kWh (Collins, 2011). Theoretically, replacing the electricity produced by oil and gas, estimated to be 133.83tWh (DECC, 2013), with wind generation would cost approximately £6.42billion in subsidies. However, this scale of wind generation capacity is not physically feasible within the UK's territory.

Changes in flows
In 2010, there was extraction of 55 billion cubic metres of gas and 63 million tonnes of oil (ONS, 2012). The total income from domestic oil and gas extraction was an estimated £39.7 billion in 2008, with the industry as a whole accounting for an estimated £37 billion of GVA (UKMMAS, 2010).

Stock value
Gas: The upper range of the volume of the UK's total gas reserves was estimated to be 1,802 billion cubic metres at the end of 2010, 13 billion cubic metres higher than in 2009.

Oil: The upper range of the UK's total oil reserves was estimated to be 2.5 billion tonnes at the end of 2010, 121 million tonnes lower than in 2009.

The total value of the UK's oil & gas reserves at the end of 2010 was £139.7 billion; £43.2 billion lower than in 2009 (ONS, 2012).

The ONS uses an indirect valuation method to calculate the present value of the physical stocks of oil and gas assets. This measures the current value of the asset's future streams of income by discounting the expected future resource rent. The method relies on information about the size of resource rent, the number of years for which the rent is to be received and the social discount rate to be applied. For more information on how this is calculated, see the following link: Monetary Valuation of Oil and Gas Reserves .

Changes in flows and stock value (ONS, 2012)
For non-renewable resources, the market price reflects the value of the remaining stock and therefore takes into account annual extraction as well as the scarcity of the resource. The annual flow of extracted resources represents depreciation in the value of the stock and new discoveries of reserves represent an appreciation in the value of the stock.

The total value of the UK's oil & gas reserves fell 23.6% between 2009 and 2010. This could be attributed to a rise in unit costs lowering resource rents for producers, offsetting the rise in expected level of reserves in 2010, compared with 2009

Though the volume of the UK's oil & gas reserves were generally declining between 1990 and 2010, the value of these reserves shows an upward trend until 2007 when there is a decline. The value of the reserves has grown by £130.6 billion between 1990 and 2010.

The value of the stock responds to many things such as changes in unit costs of extraction, the behaviour of substitute resources, consumer and industry behaviour, policy decisions and speculation as well as depreciation due to extraction and appreciation due to resource discoveries. Therefore it is important to consider both the condition and extent of the stock as well as its market value which can be volatile and may obscure trends in the underlying condition and extent of the asset.

The rise in gas reserves between 2009 and 2010 was primarily due to an increase in the upper range of undiscovered reserves of 72 billion cubic metres to 1,021 billion cubic metres, partly offset by a fall in total discovered reserves by 59 billion cubic metres to 781 billion cubic metres.

The fall in oil reserves between 2009 and 2010 was due to a fall in the upper range of undiscovered reserves by 103 million tonnes to 1.4 billion tonnes, together with a fall in total discovered reserves by 18 million tonnes to 1.1 billion tonnes.'

Annex 2: Summary of natural capital asset checks

Summary of Pollinators natural capital asset check					
Asset	**Trends in natural asset integrity**	**Target performance**	**Criticalities**	**Sustainability of performance**	**Red Flags**
The pollination service provided by insects to crop plants across the UK. The main insect pollinators, bees (including bumblebees, honeybees and solitary bees) and hoverflies are considered. These pollinators are part of the wider network of pollinators across the UK, which also supports the sexual reproduction of wild plants.	Although honeybee numbers are increasing, the increase in number of colonies is made up of those kept by amateur beekeepers, mainly in suburban areas. Some crops and many wildflowers are not well pollinated by honeybees. However the condition of honeybees is well monitored and new policies in place will further safeguard honeybees. Wild bee diversity has declined and insect pollinated wild plant species richness continues to decline in some habitats. Monitoring efforts have so far detected losses of rare species, there are no systematic schemes for monitoring the abundance of common species so the trends are not clear. Pollination services to wild plants are at risk, particularly for specialised plant species, as the diversity of these have declined in parallel with pollinators with narrower niche breadth. Whether the asset as a whole is able to support crop pollination depends on the specific requirements of crops.	Insect pollination boosts the yield of crops, increasing the market value and allowing farmers to stay in production. The target performance varies from crop to crop (see table 2), as different crops require different stocking densities so that pollination does not limit production. In addition to the performance in relation to the producers, the pollinator assets should also sustain wild flower and plant pollination.	There are no agreed limits of change to the honeybee asset, although honeybee plans are now in place for “sustainable” pollination suggesting that resilience of the honeybee stock is a priority. There are no agreed limits of change to wild pollinators. A diverse mix of wild pollinators and honeybees will reduce the probability of collapse of pollinator services. Honeybees are vulnerable to acute shock such as diseases as pathogens can spread quickly between colonies. The integrity of the asset could decline in a non-linear way if there is a positive feedback between wild flower diversity loss and pollinator diversity.	The asset of honeybees is not currently able to pollinate all crops in the UK. There is a trend towards increased honeybee numbers but this will not lead to increased pollination services unless the colonies can be moved around the UK to meet pollination needs. This is unlikely given the amateur nature of new beekeepers, who may not keep with the activity in the long term. Wild pollinators do a large proportion of crop pollination across the UK, but may not be sufficiently abundant to meet increased pollinator needs, particular across large fields associated with oil seed rape production.	Overwintering rates are a suitable indicator of honeybee stress and should continue to be monitored. Overwintering rates in honeybees are not currently a cause for concern. Wild pollinator populations would benefit from systematic monitoring allowing populations to be tracked over time. Incidents of large scale pesticide poisonings have not increased in the UK. Hoverflies are not efficient pollinators but appear resist to land use changes which affect bees, they may therefore be vital to conserving pollination services into the future and should be monitored for population stress. The continued loss of wild flower diversity and pollinator diversity however, should be seen as a red flag. While short-tongued bumblebees and generalist populations do not seem in peril, those with a narrower habitat niche are in decline. New data showing decreasing rate of decline of flowering plant richness is encouraging and should continue to be monitored.

Level of Certainty	Established	Established but incomplete evidence	Competing Explanations	Established but incomplete evidence	Established but incomplete evidence

Summary of Arable Soils natural capital asset check

Asset	Trends in natural asset integrity	Target performance	Criticalities	Sustainability of performance	Red Flags
The asset is agricultural soils associated with arable crop production. The scale of the asset is approximately 4.4m ha of land in arable production in England and Scotland (98.6% of UK cropped area). This differs from the total UK croppable area including temporary grassland and uncultivated land which is up to 6.1m ha.	The ability of arable soils to produce crops has relied on the use of additional inputs to increase yield from historic levels. This intensive management has compromised the range of non-production ecosystem services. Recent trends in crop yields and input use are static (or declining for P and K), suggesting that productivity is being maintained. Indicators for other linked ecosystem services have been improving, notably percentage of river length classified in good condition and agricultural emissions of GHGs emissions (N_2O) and also ammonia. Recent trends suggest that the main provisioning function of the asset is being maintained whilst other linked ecosystem services are being improved.	• Maintain overall levels of crop production • Reduce agricultural GHG emissions • Maintain or increase stocks of soil carbon • Contribution to flood management (run-off) • Good Ecological Status of water bodies (abstraction and impoundment) • Disposal of sewage sludge • Halt loss of biodiversity by 2020	There are no broadly agreed standards or criticalities for soil quality, although limits can be applied to individual indicators: • Informal threshold for soil C concentration of 2%. • pH values above 7.5 are a potential limiting factor for plant growth. • Upper limits exist for soil metal concentrations	In the short term the asset should be able to respond to management in order to maintain or improve performance across the range of target ecosystem services.	Widespread failure to meet target performance is unlikely due to available management options; however, if soil C levels continue to decline following observed trends then a large proportion of arable soils would technically be failing GEAC cross-compliance requirements to maintain soil organic matter. Localised failures may occur, e.g. through excessive loss of soil carbon or increased pH.

Summary of Blue Carbon natural capital asset check					
Asset	**Trends in natural asset integrity**	**Target performance**	**Criticalities**	**Sustainability of performance**	**Red Flags**
Seagrasses and the climate regulation service provided via carbon sequestration and storage	*Globally* seagrasses have been disappearing at a rate of 110 km^2 yr^{-1} since 1980 and the rate of loss is increasing (Waycott et al., 2009). UK Seagrasses may have never fully recovered from a wasting disease in the 1930s (Short et al., 1987). Although the 2009 WWF Marine Health Check downgraded the status of seagrass from severe decline to degraded (Wilding et al., 2009) continued direct physical pressures on seagrass beds (outside of MPAs) are increasingly resulting in fragmentation and even losses of many beds (Rhodes et al., 2006; Goumenaki, 2006; Suonpää, 2009).	Seagrass beds are a priority habitat under UK (UK BAP) and a sub-feature under EU (Habitats Directive) conservation objectives. These objectives require the maintenance or restoration of seagrass to a favourable conservation status. Given current evidence is that seagrass has not yet recovered to its former extent following disease and continues to decline, there is a need to restore at certain locations. Seagrass extent is an indicator for GES under the WFD and GEnS under the MSFD.	MPAs, voluntary codes of practice and local fisheries byelaws protect against physical disturbance. Improvements in catchment management and sewage treatment are improving water clarity and nutrient loading to above critical thresholds for the seagrass. Meadows outside of protected areas and or catchment management plans continue to be degraded and seagrass is vulnerable to many exogenic unmanageable pressures. (e.g. through ocean acidification, sea level rise and climate change). Restoration of seagrasses is possible but loss of seagrass may change the local environment making it unsuitable for restoration. Restoring seagrass to levels of functional equivalency in terms of ES may take many decades if possible at all.	Although evidence on the extent and health of seagrass is mixed and there is not a consolidated effort to monitor seagrass extent in the UK. A 2009 review (Wilding et al., 2009) suggested that in general they are declining in the UK, but whilst highly likely there is insufficient evidence to be certain of this. Furthermore, as the extent of seagrass declines, its ability to sequester carbon is not only declining, but carbon will be being released to the system. Although the trend is slowing it is likely to continue until a point where all seagrass outside of protected areas is compromised. The implementation of the Habitats Directive and UK BAP targets through restoration has yet to be acted upon in the UK. Therefore we can conclude that seagrass is currently unable to give the target	It is probable that there is a critical threshold in fragmentation of seagrasses whereby the negative effects that seagrass loss initiates further accelerate losses at rates greater than the seagrass can recover. Current monitoring methods and timings may not be sensitive to these critical thresholds. In the 1930s the entire North Atlantic populations of *Zostera marina* were decimated by an epidemic of a wasting disease(Den Hartog, 1987). As of yet *Zostera* beds have not since regained their former distribution, so restoration is needed. As ecosystem engineers that influence their own growing environment, loss of seagrasses can lead to a significant shift in environmental conditions (water currents, sediment composition) which may inhibit restoration. Seagrass meadows growing at the upper or lower limits of its distributional range or environmental tolerances are more likely to be vulnerable to anthropogenic disturbance and less able to recover.

				performance.	

Summary of Saltmarsh-fisheries natural capital asset check					
Asset	**Trends in natural asset integrity**	**Target performance**	**Criticalities**	**Sustainability of performance**	**Red Flags**
Coastal Saltmarsh Habitat and the supporting services underlying commercial fish stocks	There is approximately 40,000ha of coastal saltmarsh in England and Wales (Environment Agency 2011). The extent of coastal saltmarsh is declining at a rate of around 100 ha/yr due to historical land claim from the sea, ongoing loss from coastal development and relative sea level rise, but has been slowed by managed realignment. The proportion of indicator fin-fish stocks being harvested sustainably was 10% 1990's and around 40% in 2007. The 2012 ICES benchmark assessment of bass in the North Sea, English Channel, Celtic Sea and Irish Sea (ICES subareas IV & VII, excluding south and west Ireland) shows a recent decline in spawning stock biomass and increasing fishing mortality (F) during the 2000's. Year classes since 2008 appear very weak, leading to an expectation of a continued decline in spawning stock biomass to the detriment of commercial and recreational fisheries. There is agreement over the continued loss in the extent of coastal saltmarsh in the UK, although there is uncertainty in recent data.	Coastal saltmarsh is a priority habitat under UK (UK BAP) and EU (Habitats Directive) conservation objectives. These require the maintenance or restoration of coastal saltmarsh to a favourable conservation status. Action is advocated by Natural England (2010) to ensure that 'wherever possible the creation of upper coastal saltmarsh should be facilitated by, for example, managed realignments of flood defences which restore natural tidal processes and reduce coastal squeeze'. Assessments of the health of sea bass stocks will be reflected in biological assessments, future Spawning Stock Biomass estimates and landings estimates.	Coastal saltmarsh plays key role in development of juvenile fish. Currently supply of coastal saltmarsh habitat is potentially insufficient to support demand for fish stocks (i.e. it could be a limiting factor). Non-linear declines in fish stocks will occur if the threshold for stock collapse is breached and this may be irreversible. Deteriorating coastal saltmarsh quality has impacts on other ES (e.g. flood hazard regulation, biodiversity and recreation), but this is partly because it depends on alternative land uses.	As the extent of coastal saltmarsh declines in the UK, its input to productive fisheries declines. Coastal saltmarsh is already understood to be a limiting factor in the sustainability of some commercial fish stocks (e.g. bass). The implementation of the Habitats Directive and UK BAP targets is reducing the decline in coastal saltmarsh habitat through managed realignment. The majority of fish stocks are continuing to decline and to be harvested unsustainably.	The extent and condition of coastal saltmarsh continues to decline and the majority of commercial fish stocks continue to be overexploited. The declining trend in fish stocks suggests that the current measures in place are not sufficient and pose a threat to the future of some commercial fish stocks in the UK. The risk that the coincidence of suitable nursery grounds with sufficient spawning stock biomass may decline leading to stock collapse results in a RED FLAG. However uncertainties remain around the resilience of the stock to saltmarsh nursery ground collapse. Whilst coastal saltmarsh can be recovered through managed realignment, the complexity of ecological food webs means that reintroducing habitat may not lead to resurgence in fish stocks. The impact on other ES from deteriorating saltmarsh and therefore the need for 'red flags' in these areas is unclear.

Summary of Urban Green Space natural capital asset check					
Asset	**Trends in natural asset integrity**	**Target performance**	**Criticalities**	**Sustainability of performance**	**Red Flags**
Urban green space, including formal parks and gardens, sports fields, urban woods/forests /wetlands, undeveloped land and agricultural land at the urban fringe. The scale of reporting is national. The scale of analysis is variable depending on data.	Broadly at a national level the ability of the asset to support ecosystem services is maintained or improved. At specific locations where there is a limited extent of urban green space and declining condition this is not the case.	The closest approximation to a performance target for urban green space are Natural England's standards for accessible green space, which are intended to provide guidance to the planning system. These standards comprise three elements: 1. An accessibility and quantity standard (Accessible Natural Greenspace Standards – ANGSt); 2. Service standards; 3. Quality standard (Green Flag Award scheme).	There is evidence that the use of services from urban green space declines rapidly and in a non-linear way with distance between the asset and its beneficiaries. This has important implications for the spatial allocation and performance of the asset. At local scales (which is the scale at which the asset delivers services) there is a high degree of variation in the extent and condition of the asset. There is a risk that the generally improving national condition of the asset masks the need to address specific local problems with the integrity of the asset.	Taking the ANGSt standard as the target performance, the asset is currently not able to meet this target performance. The first three ANGSt criteria were tested using spatial data on the extent and location of green urban space for five cities (Aberdeen, Bristol, Glasgow, Norwich and Sheffield). For these cities, which are considered to be representative of Great Britain (Perino et al, 2013), criterion 1 (at least one 2 ha patch of green space within 300 m) is met for between 30-48% of households; all cities meet criterion 2 with between 2.06-4.03 hectares of green space per 1,000 population; and criterion 3 (at least one 20 ha patch of green space within 2 km) is met for between 68-91% of households.	No prospect of general collapse but the provision of services is highly localised. At local scales the asset may be highly under-provided.

Summary of Tees Estuary natural capital asset check					
Asset	**Trends in natural asset integrity**	**Target performance**	**Criticalities**	**Sustainability of performance**	**Red Flags**
The estuarine ecosystem. Estuaries including intertidal mudflats, saltmarsh, sand dunes and open beaches, as well as associated individual assets. The asset check is at the site specific scale for the Tees Estuary, North East England.	The ability of the asset to support regulating services is compromised by current and expected changes in estuarine dynamics due to a range of natural and anthropogenic pressures. Improvements in water quality are benefitting migratory fish but there is not data available to assess the impacts on estuarine and marine fish stocks which contribute to the north sea net fishery. The ability of the asset to support recreational activities is increasing. The ability of the asset to support wild species diversity is mixed due to declines in waterbird populations but increases in seal numbers.	The habitats are designated as an SPA meaning they must be maintained or restored to favourable conservation status. Under the Water Framework Directive the estuary must reach good ecological and chemical status by 2015. Redcar Borough Council has a goal of increasing visitor numbers by 10,000 per annum by 2025. The estuary has a function in supporting the economic development of Teesside in terms of the port and process industries.	There is concern about the effects of opportunistic macroalgae on Seal Sands and the subsequent effects on the waterbird populations. There is a low risk of leeching of historical contamination from the mudflats due to dredging, estuary dynamics and sea level rise which could have negative effects on the ecological functioning of the estuary. Increasing recreational activities appear to be negatively affecting waterbird populations.	The intertidal habitats are not supporting the waterbirds the site was originally designated for. Water quality has improved in the estuary but achieving target performance will be hindered by further erosion of intertidal habitats containing historical pollution and the re-distribution into the water column. Opportunistic macroalgae on Seal Sands also restrict the estuary from reaching target performance. Future development and expansion of the industrial aspects of the estuary are likely to have negative impacts on the future sustainability of the natural capital asset.	The Tees estuary is a highly dynamic system which has buffered the effects of previous perturbations. The Tees is reaching a new equilibrium following historical changes and current underperformance could be addressed as the estuary reaches a new steady state over the next 10 – 20 years. The most pressing concerns at present are the effects opportunistic macroalgae, the impacts of the Tees Barrage and to a lesser extent increasing recreational activities. Future concerns will be the impacts of climate change, in particular sea level rise.

Summary of Lakes & Reservoirs natural capital asset check					
Asset	**Trends in natural asset integrity**	**Target performance**	**Criticalities**	**Sustainability of performance**	**Red Flags**

Lakes & Reservoirs Generally national or River Basin District-scale data Some well researched individual site examples	Integrity maintained in general for UK for water supply, hydropower and recreation, but climate (supply) and demographic (demand) changes are causing increasing strain on services in several regions of England, particularly the South-east. Widespread morphological degradation (modified banks & dammed/sluice outflows) undertaken for particular services (controlled water supply and energy production) have reduced some services (e.g. flood regulation and passage of migratory fish, such as salmon, sea trout and eels) – impacting both market and non-market goods and services (e.g. fisheries).	Quantity: EA maximum abstraction targets (or just for rivers?) Meet renewable energy obligations? Quality: quality targets for water supply (Nitrates Directive target) & recreation (Bathing Water quality (Faecal Indicator Organisms & cyanobacteria) Biodiversity: WFD Status & Habitats Directive targets, Angling performance targets?	WFD provide standards for the assets, but not for the services. Water quantity thresholds – drought. Water quality threshold – temp effects on nutrient release, climate/ nutrient thresholds for algal blooms Biodiversity – water level change thresholds for macrophytes, inverts and fish; environmental flows (flushing) threshold for cyanobacteria	Scotland: generally yes – both quantity and quality are generally high, so sustainable water supply, hydropower and recreational use. Central belt possibly shows some unsustainable services (water purification?) England: more regionally variable: North – sustainable, South – more at risk of being unsustainable given climate and demographic changes Wales – intermediate. Biodiversity targets (WFD & Habitats Directive): generally sustainable – particularly in NW England & Scotland.	The assets are delivering services adequately at present, but there is limited knowledge of climate change impacts, demand management and tipping points.

Annex 3: Natural Capital Asset Check Approach

October 2012

Introduction

This is the first elaborated version of the asset check approach being developed through a scoping study for Defra and the UKNEA follow-on WP1. Any comments on this are welcome and should be sent to the project manager, Ian Dickie: ian@eftec.co.uk

This proposed approach lays out a series of questions, the answers to which form the analysis in, and aim to provide conclusions from, a natural capital asset check.

The working definition of a 'natural capital asset check' is:

'An assessment of the current and future performance of natural capital assets, with performance measured in terms of their ability to support human well-being.'

Thus, the purpose of a natural capital asset check is to assess how changes in a natural capital asset affect human wellbeing. It incorporates concepts of integrity, performance, red flags and sustainability.

It is organised through a series of questions about the asset, set out under the following 5 steps:

1. The asset.
2. Integrity of the asset.
3. Performance of the asset.
4. Asset criticalities.
5. Asset check.

A summary table of these 5 steps is set out in the first section of the document but should be completed last.

The questions are set out under each step in coloured boxes. The boxes include guidance on *answering the questions in italics* that can be overwritten as the asset check is completed. There is some duplication in use of the evidence for different purposes, often as a result of the same evidence being a proxy to answer different questions (e.g. in question D on ecosystem services and H on ecosystem functions). In these cases answers may be cross-referred to previous responses.

Uncertainty in evidence can be described using the following scale, adopted from the UKNEA:

Well established: high agreement based on significant evidence
Established but incomplete evidence: high agreement based on limited evidence
Competing explanations: low agreement, albeit with significant evidence
Speculative: low agreement based on limited evidence

Summary

A summary of the asset check should reflect the uncertainties in the evidence available, conclusions on integrity and sustainability of the natural capital asset, and future sustainability of the asset is assessed in terms of whether it is expected to deliver the target performance, and the presence of red flags. Where these issues are quantified relevant data should be included.

Table: Summary of natural capital asset check

Asset	Trends in natural asset integrity	Target performance	Criticalities	Sustainability of performance	Red Flags	Uncertainties/ Evidence gaps
Questions A & B	*Question I*	*Question M*	*Key issues from part 4, particularly questions Q and R*	*Question Y*	*Question Z*	

1. Natural Capital Asset

It is useful to define these parameters for the analysis clearly at the outset. If a subset of a natural asset is being checked (e.g. peat bogs in Scotland are a subset of all peat bogs in the UK), then this can affect availability of data and interpretation of results.

Our approach in the scoping study for Defra assumes that an asset needs to have some physical measurement, and defines natural capital assets as:

…stock that can be managed or protected in order to have a positive economic or social value.

However, in further work looking at the definition of natural capital we have defined it as:

'…the configuration of natural resources and ecological processes, that contribute through their existence and/or in some combination, to human welfare'

Question	Guidance on Answer
A. Define Natural Capital asset being checked	*Specify natural capital asset, e.g. habitat type and/or ecosystem services (e.g. peat bogs, carbon sequestration in woodland, all carbon sequestration in habitats)*
B. What is the spatial scale for which the asset check is being conducted	*UK, England/ Scotland/ Wales, Regional, County, Local?*
C. Define the timescale for the asset check.	*Take into account rate of change in asset, decision-making timescales, and timescales over which services from the asset can change. Past timescales should avoid reference to historical periods (>50 years) unless they are relevant to decision-making. Different timescales may be appropriate for different services from a natural capital asset.*

D. What are the main ecosystem services the asset provides?	*List main ecosystem services the asset provides (or contributes to providing)*

2. Integrity of Natural Capital Asset

Together, extent and condition reflect the integrity of the stock of natural capital, which produces flows of ecosystem services.

Question	Guidance on Answer	Trends			
		Past trend	Current trend	Future Trend	Summary of Trends **(see key*)**
E. What is the extent of the natural capital asset?	*Can be area, volume, number*	*Describe/ quantify trend*	*Describe/ quantify trend*	*Describe expected future trend*	*Insert symbol*
F. What is the condition of the natural capital asset?	*Can be measured through different ecological data, e.g. conservation status, age structure, or proxies such as ecosystem processes*	*Describe/ quantify trend*	*Describe/ quantify trend*	*Describe expected future trend*	*Insert symbol*
Uncertainties/ Evidence gaps	*Give level of uncertainty in analysis* for D, E and F, and reasons for this. * Use Uncertainty scale described in introduction.*				

Key for trends				
	↑	increasing	↓	decreasing
	↔	evidence shows no trend	**O**	no evidence
	↑↓	both increasing and decreasing	(this could reflect ambiguous evidence and/or spatially differing trends)	

<table>
<tr><th colspan="2">Question</th><th>Guidance on Answer</th></tr>
<tr><td rowspan="6">G. Drivers of changes in extent and condition

(Note there may be different drivers of changes in stock and changes in condition)</td><td rowspan="2">List policy drivers</td><td>Policy drivers</td></tr>
<tr><td>Importance of policy drivers</td></tr>
<tr><td rowspan="2">List biophysical drivers</td><td>Biophysical Drivers</td></tr>
<tr><td>Importance of biophysical drivers</td></tr>
<tr><td rowspan="2">List socio-economic & other drivers</td><td>Socio-economic & other drivers</td></tr>
<tr><td>Importance of socio-economic and other drivers</td></tr>
<tr><td colspan="2">H. What are the asset’s main ecosystem functions?</td><td>List important ecosystem functions (or supporting and intermediate ecosystem services) that support the main final services from the asset. Supporting and intermediate services are defined in the UKNEA.
Note that supporting and intermediate services may originate from other assets that co-produce final services.</td></tr>
<tr><td colspan="2">I. Integrity Test: Is the ability of the asset to support ecosystem services being maintained?</td><td>Give details for different services (if relevant), consider the trends under questions E and F and the services from question D.
If no, what are drivers of decline (see question G)?</td></tr>
<tr><td colspan="3">Non-essential supporting information that can be useful for decision-makers includes:

- are the ecosystem services provided by the asset rival (i.e. consumption or use by one individual reduces the availability for others) or non-rival (i.e. consumption or use by one individual does not reduce the availability for others) goods?

- are the ecosystem services provided by the asset market (i.e. are they bought and sold in a market) or non-market (i.e. there is no market in which they are bought and sold) goods?

- To consider future trends in the asset in more detail, use can be made of the scenarios developed by the UKNEAFO (see Work Package 8 outputs)

- some main final services may rely on supporting and intermediate services from natural capital assets not considered in the asset check. Links to the status of these other assets may be an important factor for the asset check. It may be possible to consider their status/trend/management within the</td></tr>
</table>

asset check, but where the links become complex, such analysis may not be feasible. However, these interdependencies should be noted; furthermore the natural capital underpinning the final services in question may justify a separate asset check.

3. Performance of Natural Capital Asset

In this context 'performance' is fitness to carry out the role which is required of a capital asset. This is regarded as useful because defining the target performance of natural capital assets captures both the current and future quantity and quality of an asset. Human 'requirements' include basic human needs, but also reflect infinite wants, so the definition of performance is usually subjective.
A NCAC can help distinguish between policy targets which relate to the state of the natural capital asset (e.g. Water Framework Directive targets) and goals in terms of the performance of services (e.g. there are targets for atmospheric greenhouse gas concentrations, but not for the state biotic natural capital in terms of its capacity to store carbon i.e. we don't have a target for carbon storage in natural habitats).

Question	Guidance on Answer
J. Is there a measure of the current output of ecosystem services from the asset?	*Either a direct measure of levels of ecosystem services (see question D), or an indication of this based on the amount of the asset (stock) and its ability to provide the service (condition) (see question I)*
K. What goods and benefits do these ecosystem services support?	*Ecosystem services, goods and benefits are defined in the UKNEA: services support the provision of goods to people, for who they have economic, health and/or shared social values.*
L. What evidence exists on the monetary evidence on the value of some/all of these services?	*Valuation of evidence is useful to understand the order of magnitude of the value of ecosystem services and of the impacts of changes in levels of services. Interpretation of valuation evidence can be time-consuming where complex evidence needs to be reviewed from the literature. Best use of available valuation evidence may use value transfer (see guidelines at: http://archive.defra.gov.uk/environment/policy/natural-environ/using/valuation/documents/summary-steps.pdf) and effort should be proportionate to the importance of the evidence.*
M. What is the target performance from the asset?	*Summarise performance: the role that capital performs in providing beneficial services - see below for guidance on definition*

<table>
<tr><td>Uncertainties/Evidence gaps</td><td colspan="2">Give level of uncertainty* in answer to M and reasons for this.
* Use Uncertainty scale described in introduction.</td></tr>
<tr><td rowspan="5">Defining performance:

Answering these questions can help define performance, but not all questions can be answered for all assets</td><td>What policy targets are there for the asset?</td><td>(e.g. maximum sustainable yield for fish stocks, global concentrations of GHG)</td></tr>
<tr><td>What is the trend in the main services the asset provides?</td><td>See question d for services, and UKNEA synthesis report Figure 5 for trends.</td></tr>
<tr><td>What types of goods are supported by the asset?</td><td>(e.g. food, drinking water, pollution control) See UKNEA synthesis report Figure 10 for terminology</td></tr>
<tr><td>Who benefits from the goods?</td><td>Identify the number and location of beneficiaries</td></tr>
<tr><td>What wellbeing results from the goods?</td><td>Use measures of the levels and trends in wellbeing supported by the asset</td></tr>
<tr><td>N. Are any future changes in target performance expected?</td><td colspan="2">How is target performance expected to change? Consider exogenous factors like those associated with the drivers under question F, and the asset’s role in climate change adaptation.</td></tr>
<tr><td>O. Can future target performance be defined?</td><td colspan="2">What is the target level of future performance of the asset?
What are the drivers of this (see question G).</td></tr>
<tr><td colspan="3">Non-essential supporting information that can be useful for decision-makers includes:
- Has target performance changed over time? If so how?
- Distributional issues: what is the distribution of the beneficiaries of the goods supported by the ecosystem services from the asset?
- Do the goods provided by the ecosystem services from the asset have use and/or non-use values?</td></tr>
</table>

4. Natural Capital Asset Criticalities

Note that these answers may be very different for different spatial scales, so Question B gives important context, and appropriate scale of analysis may need to be reconsidered.

Question	Guidance on Answer
P. What is the trajectory of change for the asset?	*Specify if any linear or non-linear changes are known or anticipated (see trends from questions E and F)*
Q. Are there any standards or agreed limits of change to the asset?	*Specify if there are any relevant standards or limits for the condition of the asset (e.g. adult spawning stock biomass for fish) or the services from it (e.g. fish landing quota).*
R. Are there likely to be any threshold effects?	*State knowledge of any thresholds – thresholds can include where the integrity of an asset declines in a non-linear way, where the influence of feedbacks on an asset change, or where the ability of an asset to recover declines.*
S. What is the reversibility of changes to the asset?	*Can changes to the asset be reversed? (e.g. can the asset, and its functions, be restored or recreated?)*
T. What is the cumulative effect of impacts on the asset?	*What patterns of impacts result from past, current and future trends and drivers (see questions D, E and F)?*
U. What risks are associated with current trends in the asset integrity?	*Identify risks of significant detrimental impacts: see answers to questions O, and relate this to answers to questions Q – T.*
V. What substitutes exist for the main ecosystem services from the asset?	*For the services identified in G, are substitutes available? If so what supplies are available or potentially available?*
Uncertainties/Evidence gaps	*Give level of uncertainty* in analysis and reasons for this.* ** Use Uncertainty scale described in introduction.*

Non-essential supporting information that can be useful for decision-makers includes:

- What is the level of investment needed in the natural capital to maintain it above the limits/thresholds identified above?
- What are the distributional (social group/intergenerational) implications of the criticality identified?
- For question U, define on what basis the substitute(s) are identified (e.g. which ecosystem services the substitute provides).

5. Natural Capital Asset Criticalities

Question	Guidance on Answer
W. Tradeoffs?	*If one or more of the asset's key ecosystem services (see question D) are increased, does this lead to reductions in other services? (To consider tradeoffs in detail, use can be made of the scenarios developed by the UKNEAFO (see Work Package 8 outputs))*
X. Synergies?	*If one or more of the asset's key ecosystem services (see question D) are increased, does this lead to increases in other services?*
Uncertainties/Evidence gaps	*Give level of uncertainty* in analysis and reasons for this.* ** Use Uncertainty scale described in introduction.*
Y. Sustainability test: is the asset currently able to give the target performance?	*Compare integrity in question I and performance in question M.*
If yes - will this performance be sustained into the future?	*Relate changes from question P and criticalities from Q and R to future changes identified in questions N and O. Give timescale – from question C.*
If no – state why?	*Is this because target performance is unrealistic, or because integrity of asset is compromised, or both?*
Z. Red flags?	*This is a warning if future target performance is at risk, for example because:* *- the asset is underperforming (see question Y) and continuing to decline (see Question P), or* *- there is prospect of collapse (a limit or threshold – see questions Q and R) which could be irrecoverable (i.e. being irreversible, see question S, and with no substitute, see question U)*
Uncertainties/Evidence gaps	*Give level of uncertainty* in analysis and reasons for this.* *Use Uncertainty scale described in introduction.*

Reporting
If a formal report write-up of the asset check is required, it is suggested the information above is presented under these summary heading: o State of the asset (extent, condition) o Drivers/threats to asset o Services o Drivers influencing future services o Future services from the asset o Natural asset integrity test o Current and future target asset performance o Synergies o Thresholds o Cumulative impacts o Reversibility o Uncertainties (missing information) o Sustainability test.

Annex 4: Asset check case studies

The asset check case studies are provided in a separate document.