Natural England Research Report NERR076

Natural Capital Indicators: for defining and measuring change in natural capital

www.gov.uk/natural-england

NATURAL ENGLAND

Natural England Research Report NERR076

Natural Capital Indicators: for defining and measuring change in natural capital

Jane Lusardi, Patricia Rice, Ruth Waters and Jenny Craven

Second edition 11th August 2020

First Published 26th September 2018

ISBN 978-1-78354-499-8

Project details

This report should be cited as LUSARDI, J., RICE, P. WATERS, R.D. AND CRAVEN J. (2018). *Natural Capital Indicators: for defining and measuring change in natural capital.* Natural England Research Report, Number 076

Project manager

Jane Lusardi
Murley Moss
Oxenholme Road
Kendal
LA9 7RL
Jane.lusardi@naturalengland.org.uk

Acknowledgements

We would like to express our thanks to all those who have contributed to the development of this work.

Natural England:
Isabel Alonso, Chris Bolton, Pete Brotherton, Eleanor Brown, Rob Cathcart, Tim Collins, Roger Covey, Humphrey Crick, Alistair Crowle, Nick Dales, Alison Darlow, Iain Diack, Jeff Edwards, Caroline Emmerson, Dawn Enright, Frances Fewster, Dave Glaves, Emma Goldberg, Ruth Gregg, Sarah Hammonds, Julie Holloway, Christine Hopwood-Lewis, Jane Houghton, Richard Jefferson, Dave Key, David Knight, Pippa Langford, Jonathan Larwood, Chris Mainstone, Amanda Mathews, Rachael Mills, Angela Moffat, Mike Morecroft, Margaret Nieke, Stuart Pasley, Leslie Pearman, Suzanne Perry, James Phillips, Clare Pinches, Colin Prosser, Zoe Russell, Margaret Street, Helen Trapp, Clare Warburton, Jon Webb, Nick White, Cheryl Willis, Mike Young, Susan Zappala.

Environment Agency:
Stuart Allen, Elly Andison, Paul Bryson, Lydia Burgess Gamble, Oli Burns, Dominic Coath, Jess Durkota, Kathryn Edwards, Judy England, Dave Forrow, Karl Fuller, Tora Hallatt, Nick Hardiman, Duncan Huggett, Ruth Jones, Kate Kipling, Rachel Lenane, Jamie Letts, John Murray Bligh, Harriet Orr, Tim Pickering, Jo-Anne Pitt, David Seccombe, Jo Shanahan, Katie Sumner, Paul Whitehouse, Mark Whiteman.

Forestry Commission:
Miranda Winram.

With special thanks to Natural England Deputy Chief Scientist Dave Stone for the quality assurance, Economists Tim Sunderland, Rebecca Clark and Thomas Harle, and Alice Lord for formatting the report.

We would especially like to acknowledge and thank Nicola Terrett, Environment Agency Data Manager, for all her work on the data sets, as well as organising and collating the input from the Environment Agency.

Executive Summary

All aspects of human well-being depend on the essential services that are provided by a healthy natural environment. These services include food, clean water and air, regulating climate and hazards such as flooding, thriving wildlife, as well as cultural and spiritual enrichment. A safe, clean, healthy and sustainable environment is necessary for the full enjoyment of a vast range of human rights. This includes the role that a healthy environment plays in sustaining human health.

Despite increasing knowledge about the importance of the environment to human well-being, we do not fully understand which properties of the natural environment are vital for the long-term sustainability of these well-being benefits. This report takes a new and systematic approach to identify these vital properties, and which of these can act as effective, early-warning, indicators of change.

Natural capital is an economic concept recognising that nature provides benefits and value to people. It considers natural capital (habitats, species, air, soil, water, oceans, minerals and natural processes) as a stock, from which ecosystem services flow, providing benefits and value. Using a natural capital framework, this project goes back to first principles, to generate indicators through understanding the links between natural capital assets and the ecosystem services they provide. This has not been done before and fills a major gap in the evidence base for a wide range of applications. Many assessments of natural capital focus on the economic value of benefits, without specific consideration of the ecological and environmental properties that underpin this value. To sustain the full range of well-being benefits, we need to understand the quantity, quality and location of natural capital assets to ensure the ongoing provision of benefits and value to society.

Rather than being driven by the available data, we take a fundamental step back, to identify the properties of the natural environment that are critical for ecosystem services. Data sets to measure the indicators are then identified, revealing that there are a lot gaps in the available data for the attributes we want to measure.

This project aims to be open and easily applied. It does not involve costly or complex modelling and aims to be transparent, useable and accessible to all. It can be applied at a range of scales and used in natural capital assessments, accounts, tools and plans, or to evaluate and monitor interventions. As an example it has already been used to inform condition indicators for the Office for National Statistics development of UK ecosystem accounts.

Importantly this study helps us to understand what good natural capital assets look like, for the future sustainable provision of multiple ecosystem services, and the well-being benefits they support.

The aims and objectives of this report are to define and identify:

- The ideal indicators for measuring change in natural capital
- The data that can be used to do this.
- The data gaps, where data has not been identified to measure the natural capital indicators.

The method has been based on a natural capital logic chain showing the links between natural capital assets (their quantity, quality and location) and the ecosystem services and benefits they provide.

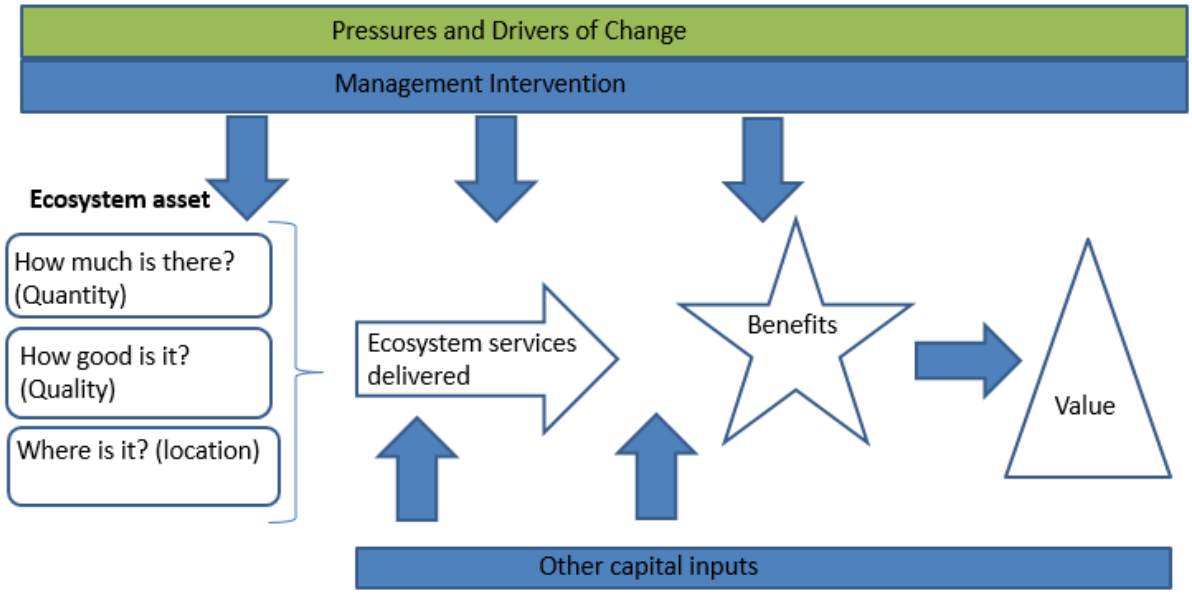

Figure 1 Natural England's natural capital logic chain

The ecosystem assets are based on the 8 broad habitats of the UK National Ecosystem Assessment. In addition geodiversity is recognised as an asset, underpinning both biotic and abiotic services. To show the links between assets, services and benefits, for individual ecosystem services, fifty one detailed bespoke logic chains have been created. These cover provisioning, regulating, cultural and abiotic services.

The logic chains have been initially populated based on evidence in the UK National Ecosystem Assessment (UKNEA 2011) and its Follow-on (2014). Expert opinion has then been used, through workshops and phone calls with over 80 specialists from Natural England and the Environment Agency. This input has been multi-disciplinary with specialisms ranging from landscape to geodiversity, and economics to flood protection, as well as habitats and species (to name a few). Through this input, and a quality assurance exercise by Natural England Deputy Chief Scientists, short and long list indicators for measuring change in natural capital have been identified. These have also been checked against a literature review, of abiotic and biotic attributes linked to ecosystem service provision (Smith et al 2017).

Although the UKNEA has been used as an evidence source, to define the broad habitat assets and identify the most importance services from these habitats, the Common International Classification of Ecosystem Services has been used as the framework to classify the services. This is to ensure consistency with the national ecosystem accounts being developed by the Office for National Statistics and other initiatives, both in England & globally. Due to the importance of catchments for the provision of water-based services, whole catchment logic chains have been developed for water quality, flood protection and water supply.

Only data sets which are regularly updated have been included in the outputs of this project. A review of data sets against a set of criteria (accessibility, frequency of update, relevant scale, coverage) is provided. Local data sets are not included. Data sets have been identified through: other sources using natural capital indicators (ONS, Scottish Natural Capital Asset Index, Local Ecosystem Accounts for Protected Areas); the input of Natural England and Environment Agency specialists and Data Managers; CEH work on data sources for the Natural Capital Committee State of Natural Capital second report. Gaps in data are also identified, where appropriate data sets have not been found to measure the short list indicators.

The results of this project are summarised in this report and made available in full as a series of annexes:

1. Detailed logic chains for: provisioning, regulating and cultural ecosystem services and abiotic services from geodiversity.
2. Summary notes for the eight broad habitats (three sides each)
3. Tables of short list and long list indicators for key ecosystem services in the 8 broad habitats
4. Natural Capital Indicators Excel spreadsheet, detailing the short and long list indicators, potential data sets to measure them and gaps where data has not currently been identified.

Short list indicators are identified for the quantity, quality and location of ecosystems. Ecosystem service indicators are measures of the service itself.

Short list indicators relevant to more than one ecosystem service in one broad habitat, are listed below. Other short list indicators, relevant to just one ecosystem service in one broad habitat, are detailed in the annexes.

Natural capital asset quantity short list indicators:

Extent of habitat e.g. blanket bog and other upland habitats, coastal & marine habitats, woodland, heath, semi-natural grassland, freshwaters, wetlands, urban blue and green space.

Natural capital asset quality short list indicators:
For regulating and provisioning ecosystem services, the quality indicators are based on natural processes underpinning the services:

- Hydrology and geomorphology: naturalness of water levels, flows, flooding, aquifer function, lake hydrological regime and extent of artificial drainage.
- Nutrient/chemical status - of water, soil and air/atmospheric deposition.
- Soil/sediment processes: carbon, biota, peat depth, coastal sediment supply.
- Species composition: naturalness of biological assemblage, absence of invasive non-native species, plant species diversity, presence and frequency of pollinator larval & adult food plant and marine net productivity, by species.
- Vegetation: ratio of vegetation to bare soil, plant growth rate, surface vegetation roughness, proportion of peat mass actively forming peat, vegetation structure/structural diversity, extent and condition of linear features & pockets of semi-natural vegetation (in farmland) and vegetation next to water courses.

- Cultural indicators in relation to:
    - Nature: visibility of wildlife, presence of flagship and/or rare species, species diversity, naturalness of watercourses, favourable condition of SSSIs and designated geosites.
    - Landscape: boundary features – type, length and condition; size of environmental space
    - Culture and history: designated historic environment assets.
    - Quietness: tranquillity.
    - Facilities: number of organised events, presence of clubs, schools, training centres.
    - Accessibility: perimeter access points, density of public rights of way / permissive paths.

- Geodiversity: favourable condition of designated geosites, active geomorphological processes.

Natural capital asset location short list indicators
For:

- Water quality: habitats in relation to sources, pathways and receptors of pollution.
- Air quality, local cooling and noise regulation: habitats & trees in relation to buildings & transport routes.
- Habitats and boundary features mitigating soil erosion and landslip risk.
- Flood protection: habitats in relation to settlements and infrastructure.
- Maintenance of habitats and species populations: proximity to other habitat patches, patch size/shape and naturalness of spatial configuration of habitats.
- Pollination: proximity of boundary features and semi-natural habitats to insect pollinator crops.
- Transition and connectivity of aquatic, terrestrial and marine habitats.
- Area for dynamic movement and development of coastal habitats.
- Cultural: % population who can access a minimum of 2ha accessible green space / blue space within 2 miles of home.

Ecosystem service flow short list indicators (specific to individual services):
Provisioning:

- Production of hay & other materials
- Amount of fish & other marine products
- Production of crops
- Production of timber, paper & other wood products
- Wood based fuel harvested
- Availability of water for abstraction
- Number of reared animals

Regulating:

- Water quality (chemical and biological, including pH viral & bacterial)
- Air pollutants removed
- Noise abatement
- Stabilisation of soil/sediment
- Regulation of flow regime for peak events/reduced inundation from coastal flooding
- Abundance, distribution & species richness of pollinators & seed dispersers
- Maintenance of sustainable ecosystems & life cycle stages
- Abundance & species richness of pest controlling species;
- Intact fungal networks to reduce infections in plants
- Carbon sequestered & greenhouse gases fixed;
- Local urban cooling

Cultural:

- Practices that relate to experiential and physical use (number of visits, duration of visits, range of activities undertaken and the number of people carrying out each activity, frequency and time spent) , scientific and educational use (number of research projects; PhD / Masters projects, number of school visits).

Benefits & values
Benefits are described for each ecosystem service and included in the detailed logic chains (Annex 1) but short and long list indicators have not been identified. Natural England economists reviewed values identified by the Office for National Statistics for the national ecosystem accounts. These values have been developed by ONS as a method for calculating the monetary value of benefits, which are applied after the benefit has been quantified. As these represent value methods rather than indicators they are not included in the logic chains. There is an increasing body of evidence on valuing ecosystem services, once they have been quantified. This covers methods rather than indicators and is beyond the scope of this report.

Data sets
The project identifies 73 regularly updated datasets for measuring the short and long list indicators. Very few of the data sets have been assigned a green RAG status for data availability, frequency of updates and coverage. For many indicators we identify data sets that are only partial, for example covering a limited number of sites across a broad habitat, or not frequently updated.

Data gaps (for short list indicators) relevant to more than one habitat or ecosystem service include:

- asset quality e.g.:
  - hydrology & geomorphology (extent of artificial drainage, naturalness of water level regime,);
  - soil & sediment properties (coastal/marine sediment properties)
  - vegetation (cover, roughness, plant growth rate).
- Location: although data sets exist that could be used for this, further analysis would be required.
- Naturalness of the biological assemblage (quality) and maintenance of sustainable ecosystems (ecosystem service), where no single data set measures these indicators. The numerous species data sources available for individual taxa could contribute to filling this gap.

Minor data gaps, only relevant to one ecosystem service and one broad habitat are also identified.

The discussion assesses the splitting of natural capital assets into broad habitats and catchments, in relation to functioning systems. It also considers the limitations of the logic chains as a simplification of complex natural/sociological systems. Despite this, the logic chains show the links between assets, ecosystem services and benefits in a clear and simple way.

The uncertainties in our understanding of the relationship between natural capital asset attributes and ecosystem services are considered, along with the need to review this work as further evidence becomes available.

The focus on natural capital assets rather than values is discussed. Focussing on assets helps to pick-up early signs of deterioration in natural capital and to inform potential management actions. Our ambition however is to provide indicators across the breadth of our logic chains, which will require further work in relation to indicators for the benefit values, both monetary and non-monetary.

Synergies and trade-offs between ecosystem services are not examined. Some ecosystem services, such as water abstraction, are also pressures and drivers of change on other ecosystem services. Decision making at both national and local levels needs to take account of both synergies and trade-offs, to ensure the sustainable provision of multiple ecosystem services.

A primary concern of this project is that cultural ecosystem services are fully integrated into the approach for practical application. The added complexity of developing indicators for cultural services is discussed, providing a rationale for the adaptations to the logic chain and indicators of quality adopted.

Data sets and gaps are discussed, including the use of local data sets to measure change in the short list indicators.

The Conclusions summarise that this project provides a systematic approach to defining indicators of natural capital. The use of logic chains enables the natural capital assets to be clearly linked to ecosystem services and benefits. It fills a number of major gaps in our understanding of natural capital in England, particularly in relation to natural capital asset quality (or condition), cultural services and the recognition of geodiversity as natural capital. We are looking to test application of these indicators at an England and local scale on land and sea.

Contents

List of tables

List of figures

1 Introduction

This report identifies indicators for measuring change in natural capital in England, at a range of spatial scales, from local to national. It links attributes of the state of natural capital, to the provision of key ecosystem services. As such it helps to inform how natural capital can be enhanced for the future sustainable provision of multiple ecosystem services.

Text Box 1. Definitions

Natural Capital is defined by the Natural Capital Committee as:

the elements of nature that directly or indirectly produce value for people, including ecosystems, species, freshwater, land, minerals, air and oceans, as well as natural processes and functions.

Definitions of other terms, as used in this report:

- **Attribute**: an environmental property.
- **Indicator**: non-quantitative measure of an environmental property.
- **Metric**: quantitative measure of an indicator, including the units used.
- **Ecosystem asset**: the stock of nature which provides ecosystem services and benefits to people. In this report broad habitats are used to define the ecosystem assets. Geodiversity is also considered as a natural asset supporting abiotic and ecosystem services.
- **Ecosystem service**: the components of nature that are directly enjoyed, consumed, or used in order to maintain or enhance human well-being.
- **Benefit**: the benefits to people that are obtained from ecosystem services.
- **Value**: the value that people place on the well-being benefits obtained from ecosystem services, which can be expressed in both monetary and non-monetary terms.
- **Flow**: the links and provision from ecosystem assets to ecosystem services, benefits and value.
- **Logic chain:** also known as a causal model, demonstrating the links in a process to deliver a particular outcome. In this report, the logic chains depict the links between ecosystem assets, services, benefits and values and the factors affecting them.

Since the publication of the Millennium Ecosystem Assessment (MEA 2005) there has been ever increasing interest in ecosystem services and natural capital. This has included evidence, such as the UK National Ecosystem Assessment (UKNEA 2011) and numerous academic papers, as well as the development of policy and strategy through the reports of the Natural Capital Committee, Natural England's Conservation Strategy 21 (Natural England 2016) and the government's 25 Year Environment Plan (Defra 2018). Globally, there is recognition that a safe, clean, healthy and sustainable environment is necessary for a vast range of human rights (Human Rights Council 2018). This includes recognising the link between a healthy environment and human health (World Health Organization and Secretariat of the Convention on Biological Diversity 2015).

As we move from evidence and policy to implementation, with the ambition to enhance the state of our natural capital, we need to know:

- How do we enhance natural capital for the sustainable provision of multiple ecosystem services, now and into the future?
- How do we measure change in the state of our natural capital as we implement policies and strategies?

These two questions also lead us to consideration of how management actions affect natural capital and its provision of ecosystem services. Although not directly the focus of this report, consideration of how we enhance natural capital, helps us to think about the land management that will contribute to this. The Ecosystem Services Transfer Toolkit - NECR159 produced by Natural England and York University (Waters and others 2016) provides a searchable literature review of how land management actions affect the provision of ecosystem services, which complements this current report.

A number of existing initiatives identify indicators for measuring change in natural capital, including: Office for National Statistic (ONS) work on UK ecosystem accounts (ONS 2017); Defra local ecosystem accounts for protected areas (White and others 2015); Scottish Natural Heritage's Scottish Natural Capital Asset Index (SNH 2011-2017). There is also an Elsevier Ecological Indicators journal special edition on ecosystem, service indicators, including papers on experience from other countries (Hauck and others 2016).

Many of the reports and initiatives identify indicators based on the existing data that is available. This report takes a step back from the data that is currently available, to identify what attributes of natural capital are required to sustain multiple ecosystem services. It then assesses what data we have to measure these indicators and what are the current gaps in data.

Importantly this work links the natural capital indicators to the provision of individual services, for example, what attributes of natural capital are needed to help to regulate/mediate water quality. This is then put together to address multiple ecosystem services.

This identification of natural capital indicators has been developed from a practical perspective, with the ambition, to both enhance the state of our natural capital, and be able to measure it as it changes. It has considered indicators for the state of natural capital assets, ecosystem services, values and benefits to people. The outputs aim to be transparent and available to all, without the need for complex modelling or data input.

There is a particular focus on the state of natural capital assets, in terms of their quantity, quality and location. There can be a time lag between changes in the state of natural capital, for example, soil or habitat conditions, and subsequent changes in ecosystem services and benefits. Indicators for the state of natural capital assets therefore act as an early warning system for action. James Hutton Institute in their review of the indicators in the Scottish Natural Capital Asset Index for Scottish Natural Heritage (Albon and others 2014), identified the need to focus on the state of ecosystem assets, which support the natural processes and functions underpinning ecosystem services. This focus also helps to inform the land management needed to enhance our natural capital.

This report is aimed at anyone who is looking to measure changes in the state of natural capital in England, at a range of scales from local to national. This includes those working on natural capital assessments, plans, accounting and tools, as well as practitioners providing advice on actions to enhance natural capital.

2 Aims and objectives

The aims and objectives of this report are to define and identify:

- The ideal indicators for measuring change in natural capital
- The data that can be used to do this.
- The data gaps, where data has not been identified to measure the natural capital indicators.

3 Method

3.1 What makes a good indicator?

What does good look like for natural capital? Indicators, developed and deployed well, will show how well a system is working and, if there is a problem, an indicator can help determine what action to take to address the issue. To identify good indicators we have taken account of a series of principles to ensure that they are fit for purpose (text box 2).

Text box 2

Principles for defining robust indicators

1. Transparent

The basic rationale for an indicator should be open and understandable. It should be clear how the indicator is derived from basic concepts (see 3 below): what it comprises; the data used to compile the indicator; and the limitations of and assumptions included within the indicator. The indicator should be intuitive in the sense that it is obvious what the indicator is measuring.

2. Relevant

The indicator should tell you something about the system that you want to know. It should relate as directly as possible to the issue of interest and be able to describe the state of, and changes in, a system. The indicator must be suitably sensitive to change, with a change in the indicator reflecting change in the state of the system at the required spatial and temporal scales (see 6 below). In complex systems, using proxies or a 'basket' of indicators might be necessary to describe the system state and changes.

3. Meaningful

The indicator should represent the state of and changes within the system in ways that are readily understood by users and audiences. This should then reflect a clear, evidence-based logic-chain that demonstrates how changes in the state of the system link to changes in the indicator. The frequency of monitoring should reflect the pace of system change with minimal time-lag between the collection and reporting of data.

4. Knowable

The indicator should be based on robust data capable of being either measured or modelled. The data assembled to compile and report on the indicator should be readily available; using methodologically sound monitoring or modelling methods that are clearly set out and subject to audit and review. It may be necessary to use traditional indicators while new indicators are developed and new data are collected.

5. Actionable

An indicator should be 'practically applicable' within the contexts and decision processes in which it is to be used. It should provide information that informs actions relating to the system, should these be required.

6. Scalable

The indicator must be applicable at the range of spatial and temporal scales required for evaluating the relevant issue. Spatial scale could range from local to global and temporal scale from near to long-term. Where necessary, the temporal scale could span past, present and anticipated future states of the system.

Gary Kass, Natural England Deputy Chief Scientist

3.2 Identifying Natural Capital Assets

3.2.1 Broad Habitats and boundaries

The eight broad habitat types identified by the UK National Ecosystem Assessment (UKNEA 2011) have been used for the division of natural capital assets. This approach is consistent with the Office for National Statistics UK ecosystem accounts (ONS 2017) and Scottish Natural Heritage's Scottish Natural Capital Asset Index (SCNCAI SNH 2011-7). We have mainly followed the boundaries defined for broad habitats in the UKNEA, adapting these where necessary to avoid duplication and overlap (text box 3). In recognition of the role of geology in underpinning both abiotic (non-living) and ecosystem services, geodiversity is also treated as a natural capital asset in this work.

Text box 3: Boundaries of Broad Habitat Assets
(based on UKNEA, *unless indicated in italics):*

- **Mountains, Moorlands and Heaths:** *All land above the Moorland line* plus lowland heath.
- **Semi-natural grassland:** all grassland that is not improved, *below the Moorland line* and outside of urban and coastal areas.
- **Enclosed farmland:** cropped and improved grassland fields (outside of urban (areas), plus hedges, ditches and small woodlands interspersed among them.
- **Woodland:** vegetation dominated by trees>5m in height when mature; >20% canopy cover. Coniferous woodland plus broad-leaved, mixed and yew woodland, *below the Moorland line* and outside of urban areas and small farm woodlands in enclosed farmland.
- **Freshwaters – Openwaters, Wetlands and Floodplains**: rivers, lakes, ponds, wetlands, groundwaters, as well artificial freshwaters (reservoirs, canals, gravel pits) *below the Moorland Line.*
- **Urban:** urban and sub-urban contiguous areas with populations >10,000 people.
- **Coastal:** sand dunes; shingle; salt marsh; sea cliffs, coastal lagoons *and intertidal sediment (beach and mud)*.
- **Marine:** all English areas covered permanently by sea water or inundated with saline water at some stage in the tidal cycle, *excluding those habitats covered by coastal.*

3.2.2 Approach to Freshwater Catchments

Due to the importance of freshwater catchments for water related ecosystem services (water supply, water quality and flood protection), these services have been considered at a terrestrial freshwater catchment level, rather than the freshwater broad habitat boundary. These catchments therefore encompass enclosed farmland, semi-natural grassland, woodland, urban, mountains, moorlands & heaths, as well as freshwaters. The only services that have been considered for the freshwater broad habitat, rather than at a catchment level, are maintaining nursery populations and habitats, climate regulation and the cultural services. In recognition of the importance of upper catchments and headwaters for water quality, water supply and flood protection, these have also been considered separately for the mountains, moorlands and heaths broad habitat.

3.3 Ecosystem Services framework

The ecosystem service categories have been based on the Common International Classification of Ecosystem Services (CICES v. 4.3), again to ensure consistency with ONS, SNCAI and international approaches. CICES does not include supporting ecosystem services but defines "*ecosystem function*" as underpinning the provision of ecosystem services. The key ecosystem services on which to focus, were based on those identified for broad habitats in the UKNEA (2011).

3.4 Natural Capital Logic Chains

Natural England has used a natural capital logic chain approach to consider key attributes for natural capital assets, ecosystem services, benefits and values. The use of logic chains simplifies a complex natural and human system and helps to identify the links across the chain. Gaps exist in our full understanding of how natural capital provides benefits to people, across these logic chains. They have therefore been based on existing evidence (particularly UKNEA 2011 and its follow on report 2014), supplemented by expert opinion. Consistency and quality assurance have been provided through Natural England's Deputy Chief Scientists and a final check against an evidence review of links between natural capital assets and ecosystem services (Smith and others 2017).

3.4.1 Natural Capital Logic Chain framework

We have developed a logic chain framework (Figure 1) that shows how ecosystem assets underpin the provision of ecosystem services and benefits to people, and that all parts of this chain are affected by management interventions, pressures and drivers of change. Other capital inputs are often needed for people to obtain the benefits from ecosystem services (a simple example is the processing of trees to produce wood products). The quantity, quality and location of natural capital assets affect the ecosystem services and benefits that it provides.

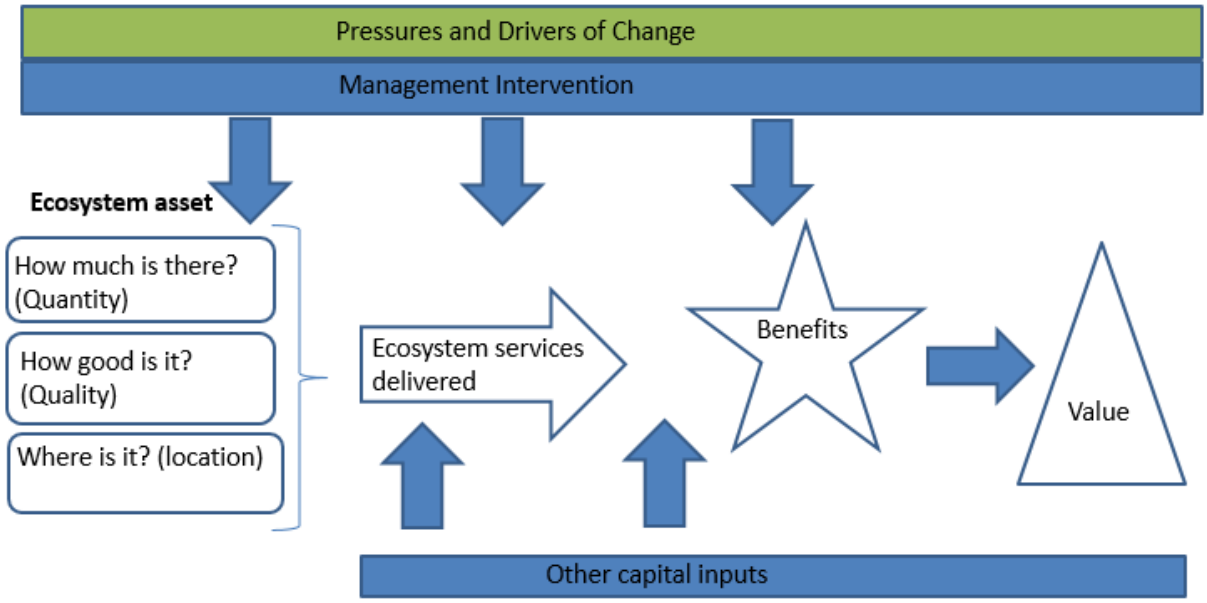

Figure 1 Natural England's natural capital logic chain

Figure 1 is a simple logic chain which has formed the basis of more detailed bespoke logic chains. Across the broad habitats, we have produced 42 detailed logic chains for provisioning and regulating services, eight cultural services logic chains, one for each broad habitat, and a geodiversity logic chain, covering all habitats and services (Table 1).

Table 1 The ecosystem services and broad habitats for which detailed logic chains have been produced

Broad Habitat	Materials from plants, algae & animals for agricultural use	Wild plants, animals, algae & their outputs	Aquaculture	Plant-based energy	Cultivated crops	Water supply for drinking and non-drinking purposes	Reared animals & outputs	Mediation of waste, toxics and other nuisances by ecosystems and Biota			Mass stabilisation & control of erosion rates	Flood protection	Pollination & seed dispersal	Maintaining nursery populations and habitats	Pest & disease control	Global, micro & regional climate regulation	Cultural ecosystem services	Geodiversity services
								Water quality	Air quality	Noise regulation								
Coastal Margins											X	X		X		X	X	Abiotic services from geodiversity, covering all broad habitats
Marine		X	X					X						X		X	X	
Urban						x		x	X	X		x		X		X	X	
Enclosed Farmland					X	x	X	x			X	x	X	X	X	X	X	
Semi-natural Grasslands	X					x	X	x				x	X	X		X	X	
Freshwaters						x		x				x		X		X	X	
Woodlands	X			X		x		x	X			x		X		X	X	
Mountain, Moorlands & Heaths						**X**	X	**X**			X	**X**		X		X	X	

X=logic chain for this broad habitat; x=catchment logic chain covering this broad habitat; **X**=logic chain for this broad habitat and covered by catchment logic chain.

Even these more detailed logic chains are a simplification of a much more complex and interacting natural and human system. We have not attempted to show these more complex interactions.

3.4.2 Development of logic chain templates

To develop the detailed logic chains, eight templates were first produced, one for each broad habitat, based on evidence in the UKNEA (2011), and UKNEA Follow-on work (2014) for cultural ecosystem services and marine indicators. This approach was developed through initial work with Natural England upland specialists. The templates include sections on asset quantity, quality and location, ecosystem service flow, benefits, management interventions and other drivers of change.

3.4.2.1 Provisioning and regulating services logic chains

The project aimed to identify indicators that reflected the flow of services from the ecosystem/geodiversity asset through to the benefits. We focussed on identifying indicators, based on the attributes of the natural assets that are most important to enable a sustainable flow of services. Indicators of the asset itself are also important as there is often a lag in change from the asset to the ecosystem service flow and benefits. For example, it is possible to still be receiving benefits even though the asset itself is declining. Changes in the indicators of the asset, therefore act as an early warning system. Understanding of these asset indicators is also needed to inform land management actions to enhance the provision of ecosystem services.

As well as identifying indicators for the extent and location of ecosystem assets, the quality, or condition of assets is also critical. For regulating and provisioning services, quality attributes were based on natural processes: hydrology & geomorphology; nutrient & chemical status; soil/sediment processes; species composition and vegetation. Natural processes underpin the provision of ecosystem services and this approach is consistent with that taken by Natural England's integrated biodiversity advice project (Mainstone and others 2018).

3.4.2.2 Cultural ecosystem services logic chains

The availability and quality of the natural environment, as well as what is undertaken in it, can form the basis of measurements (Tratalos and others 2016). To identify natural capital indicators for cultural ecosystem services, the logic chain (Figure 1) was adapted to capture the distinction between the places where we engage with the natural environment, the things we do while we are there and the benefits we get from those interactions. This was based on work undertaken for the UKNEA Follow-on (2014) and recognises that the availability and quality of the natural environment, as well as what is undertaken in it, can form the basis of measurements. Additional asset attributes have been added to capture the quality of a place, for each broad habitat. The cultural practices, or what people are doing in a place, are covered in the ecosystem services. The benefits to well-being are received through the interactions between the practices and the place. Whilst building on this useful UKNEA Follow-on framework, it was also important for this project to keep the cultural services aligned with the CICES ecosystem services framework adopted. This was achieved by identifying the practices related to the CICES cultural services listed in Figure 2.

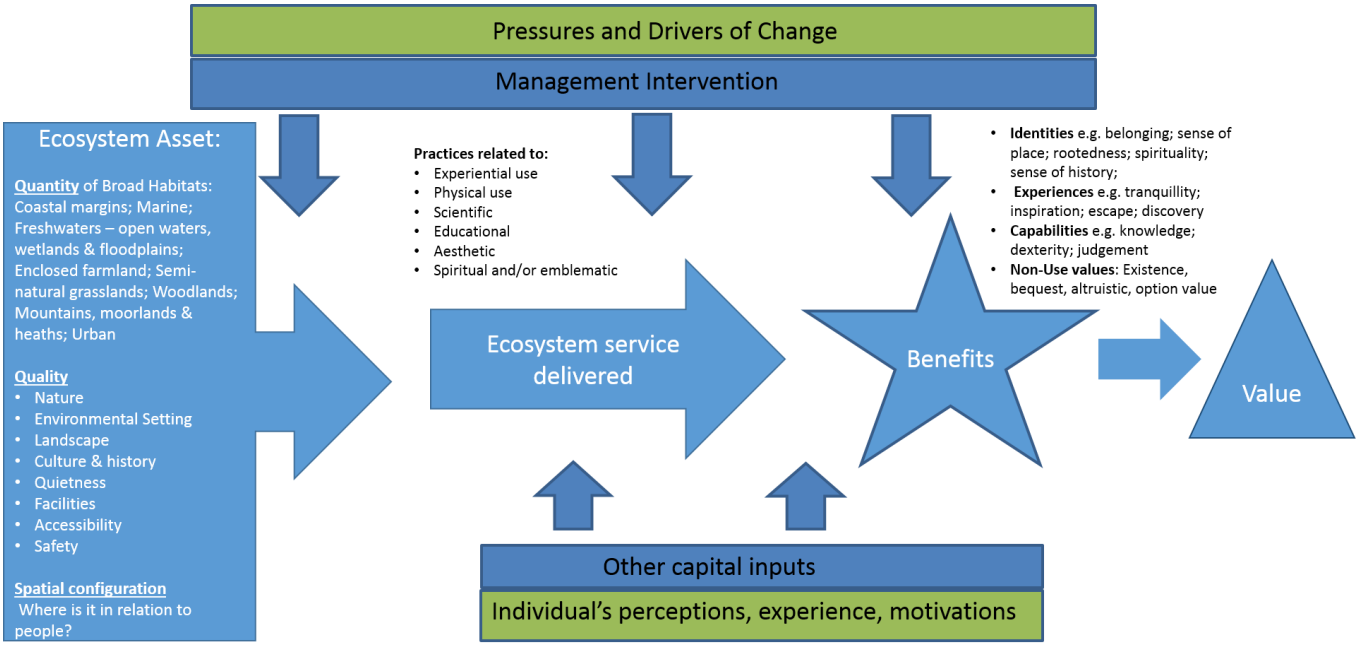

Figure 2 Natural England's natural capital logic chain for cultural ecosystem services

Using this approach a single logic chain for the range of cultural ecosystem services was produced for each of the eight broad habitats. These include additional quality and location attributes relating to nature, landscape, culture and history, quietness, facilities, accessibility, safety and location in relation to people. Indicators for practices relate to experiential and physical use, scientific and educational use, aesthetic and spiritual/emblematic practices. Benefit attributes for aspects of wellbeing relate to identities, experiences and capabilities (as identified by the UKNEA Follow-on 2014). Non-use values such as existence and bequest have been added to retain consistency with CICES and to recognise their importance for some people in the context of cultural services and benefits.

As stated in section 3.4.1 all parts of the logic chain are affected by management interventions, pressures and drivers of change. The cultural logic chain also recognises that each individual's perceptions, motivations and experiences will influence not only what they do (practices) but also the benefits they get from their personal interaction with the natural environment. Other capital inputs are often needed for people to obtain the benefits from ecosystem services. In the cultural logic chain some of the quality attributes for facilities and accessibility (such as car parks, provision of access points etc.) are essentially other capital inputs (built capital). Because these can be important for the provision of cultural ecosystem services, they have been included as quality attributes, in line with the UKNEA Follow-on (2014).

3.4.2.3 Geodiversity logic chain

Geodiversity is critical in its underpinning of ecosystem and abiotic services: provisioning, regulating and cultural. The geodiversity logic chain therefore considers geodiversity as an additional natural capital asset, on top of the broad habitat types. This logic chain covers all services from geodiversity. The template for the geodiversity logic chain was based initially on evidence in *Geodiversity: Valuing and Conserving Abiotic Nature* (Gray 2013). The attributes of the quality of geodiversity assets, that are important for underpinning services, were grouped under geophysical; geochemical; formative geological processes, palaeontology and minerals. As geodiversity is important for the provision of cultural services, attributes identified in the cultural services logic chain were incorporated into the geodiversity one.

3.4.3 Attributes for benefits and value

Attributes for benefits were described in the logic chains. Natural England economists reviewed the Office for National Statistics UK Ecosystem Accounts (ONS 2017) and associated scoping studies, to identify potential natural capital indicators for the monetary values of benefits. The ONS work, along with an increasing body of evidence from other sources, develops methods for calculating monetary values for benefits, of both market and non-market goods. These are methods for calculating a monetary value, once a benefit has been measured. Beyond market goods such as food and timber, there is a lack of regularly updated data sets that report on the monetary values of benefits. This economics work was quality assured by the Natural England Principal Economist. The lack of indicators for values and benefits results in the key indicators focussing on attributes of the natural capital asset and ecosystem services flow. Further work will develop the indicators for benefits and values.

3.5 Identification of key indicators (short and long list) from logic chains

The logic chain approach was used to ensure that the selection of indicators was transparent and showed clearly how an indicator is relevant and meaningful, relating to changes in the system (Text box 1). Indicators were only identified where they could be practically used to inform management action (Text box 1). For example, climate affects the provision of ecosystem services but indicators were not identified for climate, as it was not considered to be actionable, that is, not directly affected by management interventions. Indicators were also not identified by this project for management interventions, drivers of change, or individual perceptions, motivations and experiences in the case of cultural services.

From the eight broad habitat templates, the bespoke detailed logic chains were developed by adding-in attributes specific to a service and broad habitat, such as location, ecosystem service flow and benefits. Any attribute that was completely irrelevant to a particular logic chain was removed.

To identify the key indicators, two workshops were run, one with Natural England and one with Environment Agency specialists. A further Natural England workshop was run for cultural services.

In total fifty nine Natural England and twenty nine Environment Agency staff contributed to the project, with specialisms that included habitats, ecology, species, geomorphology, geology, water quality, flood regulation, fisheries, climate change, air quality, landscape, access and engagement, green infrastructure, historic environment, natural capital, social science, economics and data management.

In the workshops, specialists used their expert opinion to highlight on the detailed logic chains, those attributes which they considered to be key indicators for measuring change in natural capital. They also deleted any further attributes that were considered to be irrelevant for a specific logic chain. If an attribute was considered to be relevant but not a key attribute, it remained on the detailed logic chain but was not highlighted. The logic chain outputs were circulated to participants and other specialists, following the workshop to seek further input.

To ensure consistency across all the logic chains, a quality assurance (QA) exercise was undertaken by two Natural England Deputy Chief Scientists. As part of the QA, short and long list key indicators were identified. A good indicator conveys information about more than just itself. As such, the short list indicators aimed to provide a succinct but comprehensive suite, to measure across the full range of services and habitats through a limited number of indicators. Recognising that data might not be available to measure all the short list indicators, a longer list was also retained. Long list indicators were considered to be important for measuring change in natural capital but were judged to be covered by the short list indicators. Only short-list indicators were identified during the QA of the cultural logic chains.

Complex natural processes underpin the provision of ecosystem services and there is a lack of full understanding of the relationship between the biotic and abiotic attributes of natural capital assets and the ecosystem services they support (Maseyk and others 2017). Smith and others (2017), building on the work of Harrison and others (2014), have undertaken a systematic literature review of the evidence for biotic and abiotic attributes of natural capital underpinning ecosystem services. The short and long list indicators, for provisioning and regulating and cultural services, have been checked against Smith and others (2017).

3.6 Data Sources

3.6.1 Identification of data sources

Data sources, for measuring change in the long and short list indicators, were initially identified from Office for National Statistics work on national ecosystem accounts (ONS 2017), Defra local ecosystem accounts (White and others 2015) and the Scottish Natural Capital Asset Index (Scottish Natural Heritage 2011-7) . Data sets were also identified by the eighty eight Natural England and Environment Agency staff involved in the project. Work reviewing data sets by Centre for Ecology and Hydrology (CEH) for the Natural Capital Committee Second State of Natural Capital Report (Maskell 2014), was also used to identify robust data sets. Environment Agency and Natural England Data Managers also identified data sets and reviewed those identified by others.

Data sets were only included if they are regularly updated; one-off surveys or methods for measuring change (including for economic valuation) were not included. Local data sets were also not included within the scope of this current project; however local data sets may be important for filling some of the data gaps identified (see 4.6.3).

3.6.2 Review of data sources against criteria

Data sets were reviewed against a series of criteria and assigned a Red, Amber, Green (RAG) status (Table 2).

Table 2 Criteria for reviewing data sources

Criteria for review of data source	**Green**	**Amber**	**Red**
Data availability	Free access	Under licence	Restricted or supplementary charge
Frequency of updates	1-5 years	6-10 years	10+ years
Coverage	Whole of England	Partial	Site specific

As the project also aims to identify indicators and data sets for measuring change at a range of scales, an additional criteria was added on relevant scale. This was not assigned a RAG status as some data sets are useful at local and others at a national scale. The following criteria were used for relevant scale: Local: < Lower Super Output Area (LSOA); Mappable at a scale > Lower Super Output Area (LSOA); National level statistic: not mappable; Point survey (for point or sample surveys).

3.6.3 Data gaps

Where a data set could not be identified to measure change in a short list attribute, this was recorded as a gap in data. Two levels of data gaps were identified for short list indicators: data gaps relevant to more than one habitat or ecosystem service, and minor data gaps, only relevant to one ecosystem service in one broad habitat.

3.6.4 Natural Capital Indicators Excel Spreadsheet tool

In addition to the fifty one detailed logic chains (fifty for broad habitats and one for geodiversity), the project findings have been captured in an Excel Spreadsheet Tool. Text Box 4 shows the content of the Excel Spreadsheet.

Text Box 4 Natural Capital Indicators Excel Spreadsheet Tool component sheets:

1. **Priority attributes** – identifying short and long list indicators, showing which part of the logic chain they are relevant to, which broad habitats, which ecosystem services and including an identification number for data sets that are relevant to the indicator.

2. **Data sources** - reviewing data sources against the criteria of: data availability, frequency of updates, coverage and relevant scale, and identifying a RAG status for the first three of these criteria. An identification number for each data set is used to link to the priority attributes. The name and a web-link for data sources are also provided.

3. **Indicator tables** - for each broad habitat showing short and long list indicators against key ecosystem services.

4. **Data gaps** - data gaps (for short list indicators) relevant to more than one habitat or ecosystem service.

5. **Minor data gaps** - only relevant to one ecosystem service in one broad habitat.

4 Results

The detailed logic chains for provisioning, regulating and cultural ecosystem services, and services from geodiversity are provided in Annex 1. Annex 2 provides brief summaries of the results by broad habitat. Tables of short and long list indicators by broad habitat are provided in Annex 3. Annex 4 is the Excel spreadsheet (see Text Box 3 for contents). The results section of this report summarises short list indicators. Overall short list indicators are included in these results if they apply to more than one ecosystem service in one broad habitat. The following short list indicators of change in natural capital have been identified:

4.1 Ecosystem asset: quantity short list indicators

Extent of a range of habitats are short list indicators for regulating, provisioning and cultural ecosystem services: for example, blanket bog and other upland habitats, coastal & marine habitats, woodland, heath, semi-natural grassland, freshwaters, wetlands, farmland habitats, urban blue and green space. Table 3 provides further details of habitat extents.

Table 3 Ecosystem asset quantity - short list indicators (relevant to more than one ecosystem services in one broad habitat)

	Ecosystem services (In terrestrial habitats * relates to indicators for freshwater catchments)																
Indicator	Materials from plants, animals and algae	Wild animals, plants and algae and their outputs	Plant -based energy	Aquaculture	Cultivated crops	Water suppply *	Reared animals & their outputs	Water quality *	Air quality *	Noise regulation	Mass stabilisation	Flood protection *	Pollination & seed dispersal	Maintenance of nursery pops & habs	Pest & disease control	Climate regulation	Cultural services
Coastal & floodplain grazing marsh												X		X			X
Coastal lagoons														X			X
Intertidal sediment (beach and mud)											X	X		X		X	X
Coastal salt marsh											X	X		X		X	X
Coastal sand dunes											X	X		X		X	X
Coastal cliff														X			X
Coastal shingle											X	X		X			X
Farmland arable & orchards					X												X
Farmland pasture							X										X
Lakes & standing waters						X								X			X
Lowland fens														X		X	X
Lowland raised bog														X		X	X
Modified waters eg reservoirs & canals						X											X
Ponds														X			X
Reedbeds														X		X	X
Rivers						X								X			X
Hay meadows	X						X						X	X		X	X
Semi-natural grasslands							X				X		X	X		X	X
Marine intertidal rock		X												X			
Marine maerl beds		X												X			
Marine reefs		X						X						X		X	X
Marine sea grass beds		X						X						X		X	X
Marine shallow subtidal sediment		X												X		X	
Marine shelf subtidal sediment		X												X		X	
Marine subtidal rock		X												X			
Upland blanket bog						X		X			X	X		X		X	X
Dwarf shrub heath							X				X	X		X		X	X
Inland rock, scree and pavement														X			X
Mountain heath and willow scrub														X		X	X
Upland flushes fens and swamps														X		X	X
Wood pasture														X			X
Urban blue space - open water: ponds, lakes, reservoirs rivers, canals, streams, SUDs and associated vegetation														X		X	X
Urban green space: not semi-natural										X				X		X	X
Urban semi-natural habitats									X	X				X		X	X
Urban/street trees, canopy cover									X	X						X	X
Woodland, scrub and hedge									X Urban	X Urban				X		X	X
Broadleaved, mixed & yew woodland	X		X						X					X		X	X
Coniferous woodland	X		X						X							X	X
Individual trees/ veteran trees														X			X
Woodland priority habitats														X			X

For geodiversity natural capital assets, the quantity of assets is identified as: geological strata/bedrock type; unconsolidated deposits; minerals, aggregates and fossil fuels. These have not been identified as short list indicators.

4.2 Ecosystem asset quality: short list indicators

Short list indicators for natural capital asset quality, for regulating and provisioning services, are based on natural processes as follows:

- Hydrology and Geomorphology: naturalness of water levels, flows, flooding, aquifer function lake hydrological regime and extent of artificial drainage.
- Nutrient/chemical status - of water bodies, soil/sediment, atmospheric deposition and marine pH.
- Soil/sediment: carbon, biota, peat depth, coastal sediment supply.
- Species composition: naturalness of biological assemblage, absence of invasive non-native species, plant species diversity, presence and frequency of pollinator larval & adult food plant and marine net productivity, by species.
- Vegetation: ratio of vegetation to bare soil, plant growth rate, surface vegetation roughness, proportion of peat mass actively forming peat, vegetation structure/structural diversity, extent and condition of linear features & pockets of semi-natural vegetation (in farmland) and vegetation next to water courses.

Quality short list indicators for the cultural ecosystem services and geodiversity services are:

- Cultural indicators in relation to: nature; landscape, seascape and urban green space; culture and history; quietness; facilities; accessibility.
- Geodiversity: favourable condition of designated geosites; active geomorphological processes, terrestrial, coastal & marine.

Table 4a Natural Capital Asset Quality: short list indicators for regulating and provisioning services (relevant to more than one ecosystem service in one broad habitat)

Provisioning and Regulating Services		**Ecosystem services * relates to indicators for freshwater catchments**															
Indicator category	**Indicator**	Materials from plants, animals & algae	Wild animals, plants and algae and their outputs	Aquaculture	Cultivated crops	Plant -based energy	Water supply *	Reared animals & outputs	Water quality *	Air quality	Noise regulation	Mass stabilisation	Flood protection *	Pollination & seed dispersal	Maintenance of nursery pops & habs	Pest & disease control	Climate regulation
Hydrology & geomorphology:	Extent of artificial drainage						X		X				X		X		X
Hydrology & geomorphology:	Natural aquifer function: recharge & discharge						X										
Hydrology & geomorphology:	Naturalness of flooding regime												X		X		X
Hydrology & geomorphology:	Naturalness of flow regime						X						X		X		
Hydrology & geomorphology:	Naturalness of lake hydrological regime												X		X		
Hydrology & geomorphology:	Naturalness of water level regime						X		X						X		X
Nutrient (& chemical) status:	Atmospheric deposition: exceedance of critical loads														X		
Nutrient (& chemical) status:	Biological/chemical status of water (including viral & bacterial)		X	X					X						X		
Nutrient (& chemical) status:	Marine pH of sea water		X												X		
Nutrient (& chemical) status:	Soil/sediment nutrient status		X		X			X	X						X		X
Soil/sediment processes:	Coastal sediment supply/availability (including type, grain size)											X	X		X		
Soil/sediment processes:	Peat depth								X								X
Soil/sediment processes:	Soil or sediment carbon/organic matter content								X			X			X		X
Soil/sediment processes:	Soil/sediment biota		X												X		X
Species Composition:	Invasive non-native species														X		
Species composition:	Marine net productivity by species (kcal/ha/yr)		X														X
Species composition:	Naturalness of biological assemblage: number of trophic levels & community composition in each level		X												X		
Species Composition:	Plant species diversity													X	X		
Vegetation	Farmland: extent & condition of linear vegetation features and pockets of semi natural vegetation											X		X	X	X	
Vegetation	Plant growth rate	X			X	X		X									X
Vegetation	Presence & frequency of pollinator larval & adult food plants													X			
Vegetation	Proportion of peat mass actively forming peat						X		X						X		X
Vegetation	Surface/vegetation roughness								X			X	X				
Vegetation	Vegetation cover/bare soil						X		X	X	X	X	X		X		X
Vegetation	Vegetation next to water bodies								X				X		X		
Vegetation	Vegetation structure/structural diversity														X		

Table 4b Natural Capital Asset Quality: short list indicators for cultural and geodiversity services (relevant to more than one broad habitat)

Cultural & Geodiversity: Quality		**Ecosystem Services**	
Indicator category	**Indicator**	Cultural Services	Geodiversity services
Nature	Visibility of wildlife	X	
Nature	Presence of flagship species	X	
Nature	Presence of rare (red list) species	X	
Nature	Species diversity	X	
Nature	Naturalness of watercourses	X	
Nature	Favourable condition of SSSIs	X	
Nature	Favourable condition of designated geosites	X	X
Landscape, seascape & urban green space	Size of environmental space (ha)	X	
Landscape, seascape & urban green space	Boundary features – type, length & condition	X	
Culture & history	Designated Historic Environment Assets (World Heritage Sites, Scheduled monuments (% at risk), Historic Parks & Gardens, Listed Buildings, Conservation Area, registered battlefields)	X	
Quietness	Tranquility	X	
Accessibility	Mean number of perimeter access points per km	X	
Accessibility	Public Rights of Way / permissive paths; footpaths, bridleways, byway – length, density (km/ha)	X	
Accessibility	Presence of paths accessible to all – e.g. wheelchairs, pushchairs - length, density (km/ha)	X	
Facilities	Number of organised events	X	
Facilities	Presence of clubs, schools, training centres	X	
Formative geological processes	Active geomorphological processes; terrestrial, coastal & marine		X

4.3 Ecosystem asset: location (spatial configuration)

The location, or spatial configuration, of ecosystem assets influences the ability of an asset to provide a range of ecosystem services. The importance of location varies between different ecosystem services. For ecosystem services such as crops, reared animals, water supply and global climate regulation, the spatial location was not identified as a short list indicator. For these services the quantity and quality of the natural capital assets are the critical factors, rather than their spatial location.

Location is identified as a short list indicator for the following ecosystem services:

- **Flood regulation**: the distribution (and width for coastal habitats) of flood mitigating land and features in relation to infrastructure & settlements
- **Water quality**: distribution in relation to water pollution sources, pathways and receptors.

- **Mass stabilisation and erosion control**: the location of habitats and boundary features in relation to soil erosion and landslip risk, and for coastal habitats their width, area and location to allow dynamic movement e.g. of dunes and saltmarsh.
- **Air quality** and **Noise regulation**: distribution of habitats and trees in relation to buildings and transport routes.
- **Local climate regulation:** position of habitats and trees to provide cooling to buildings.
- **Pollination:** proximity to other semi-natural habitats and insect pollinated crops.
- **Nursery populations and habitats:** naturalness of habitat distributions allowing for dynamic movement of habitats (including transitions from marine to terrestrial); patch size, shape and edge; proximity to other semi-natural habitats.
- **Cultural services**: the proximity and accessibility of green space and blue space in relation to people.

4.4 Ecosystem services

For regulating and provisioning services short list indicators for ecosystem services are a measure of the flow of the services. These are detailed in Table 5.

For cultural services the flow of ecosystem services are represented by the interactions people have with the natural environment (practices). The short-list indicators for practices are as follows:

- Experiential and physical use: Number of visits, duration of visits, range of activities undertaken and the number of people carrying out each activity, frequency and time spent.
- Scientific and educational use: Number of research projects, PhD/Masters projects, number of school visits.

Table 5 Provisioning and regulating ecosystem services, short list indicators and descriptions of benefits

Ecosystem service	Short list indicators for ecosystem service flow	Description of benefits
Materials from plants, animals & algae	production of hay & other materials production of timber, paper and other wood products	Materials e.g. hay, grass for fodder Timber, paper and other products from wood
Wild animals, plants, algae, & their outputs (marine)	amount of fish & other marine products	Products from the sea e.g. fish, shellfish & seaweed for food, fertiliser, angling bait, medicines
Plant-based energy	wood-based fuel harvested	Energy from wood
Aquaculture	amount of fish & other marine products	Products from aquaculture e.g. fish, shellfish & seaweed for food, fertiliser, angling bait, medicines
Cultivated crops	production of crops	Food from crops e.g. cereals, vegetables, fruit
Water supply	availability of water for abstraction	Plentiful water e.g. water for drinking, domestic use, irrigation, livestock, industrial use including cooling, wildlife
Reared animals & their outputs	number of reared animals	Products from animals e.g. meat, dairy products, honey
Water quality	water quality (chemical and biological, including viral & bacterial)	Clean water, also underpinning e.g. water supply, sustainable ecosystems, cultural services, health benefits.
Air quality	air pollutants removed by vegetation	Clean air, also underpinning health benefits and sustainable ecosystems
Noise regulation	noise abatement	Health benefits e.g. reduced stress, hypertension, hearing impairment; benefits to sustainable ecosystems through reduction in disturbance; reduced impacts on educational & work performance
Mass stabilisation and control of erosion rates	stabilisation of soil/sediment	Erosion control e.g. soil/land retention, lack of transport disruption, protection of housing, businesses & infrastructure, reduced health & safety risk, reduced flood risk
Flood protection	regulation of flow regime for peak events/reduced inundation from coastal flooding	Reduced flood risk, affecting e.g. reduced health & safety risk, protection of housing, businesses & infrastructure, lack of transport disruption
Pollination & seed dispersal	abundance, distribution & species richness of pollinators & seed dispersers	Pollination underpinning cultivated crops dependent on insect pollination e.g. field beans, apples, plums, pears, cucumbers, plums, strawberries, oil seed rape
Maintenance of nursery populations & habitats	maintenance of sustainable ecosystems & life cycle stages	Biodiversity, in of itself, and underpinning all other services such as recreation (including wildlife watching), tourism, research and education, food from wild populations & aquaculture, flood protection (sea grass beds, dunes), climate regulation
Pest & disease control	abundance & species richness of pest controlling species; intact fungal networks to reduce infections in plants	Natural control of agricultural pest species and diseases
Global, regional & local climate regulation	carbon sequestered & greenhouse gases fixed; local urban cooling	Equitable climate e.g. reduced risk of drought, flood & extreme weather events, lower summer temperatures, reduced health & safety risks, reduced flood risk, protection of infrastructure/lack of transport disruption

4.5 Benefits and values

Short and long list indicators have not been identified for benefits and values. Benefits have been described for each ecosystem service and are included in the detailed logic chains (Annex 1). Table 5 provides the descriptions of benefits for provisioning and regulating services. The ONS values (ONS 2017 and scoping studies) reviewed by this project are not included in the logic chains, or the short and long list indicators, as they are a robust method for calculating monetary value, rather than a measure of the benefit.

Cultural benefits are identified on the logic chains as generic aspects of wellbeing that can be associated with the interactions between people and the natural environment. Non-use values such as existence and bequest have been added to retain consistency with CICES and to recognise their importance for some people in the context of cultural services and benefits. Cultural benefits are described as follows:

Identities e.g. belonging; sense of place; rootedness; spirituality; sense of history;

Experiences e.g. tranquillity; inspiration; escape; discovery

Capabilities e.g. knowledge; health; dexterity; judgement

Non-use values: existence, bequest, altruistic; option

4.6 Management interventions and pressures/drivers of changes

Indicators were not identified for management interventions, pressures or drivers of change affecting natural capital assets, ecosystem services and benefits. These can be specific to individual locations. As expert opinion was that all of these factors could be important, these are listed in full as text boxes on the detailed logic chains for provisioning and regulating services (Annex 1).

4.7 Data sources

Seventy three data sources have been identified to potentially measure the short list and long list indicators. These are shown on the second sheet of the Excel spreadsheet (Annex 4). On this spreadsheet, each data source is given an identification number; the identification number is also indicated on the first sheet, against the indicators that the data source could measure.

Very few of the data sets have been assigned a green RAG status for data availability, frequency of updates and coverage. For many indicators we identified data sets that were only partial, for example covering a limited number of sites across a broad habitat. An example of this is Common Standards Monitoring data, which measures a number of the short list indicators but only for Sites of Special Scientific Interest. These data sets are identified in the spreadsheet with a Red RAG status.

4.8 Data gaps

Data gaps (for short list indicators) relevant to more than one habitat or ecosystem service are identified on the fourth sheet of the Excel spreadsheet (Annex 4) and summarised for provisioning and regulating services in Table 6.

Data gaps identified include those for asset quality e.g. hydrology & geomorphology (extent of artificial drainage, naturalness of water level regime), soil & sediment properties (coastal/marine sediment properties) and vegetation (cover, roughness, proportion of peat mass forming peat). No single data set exists to measure the naturalness of the biological assemblage (quality) or to measure maintenance of sustainable ecosystems (ecosystem service) indicators. The numerous species data sources available for individual taxa could contribute to filling this gap.

Under asset quality for cultural services, there are data gaps for: size of the environmental space; numbers of perimeter access points; access paths accessible to all; rare species; presence of flagship species; visibility of wildlife and for marine, numbers of organised events and presence of clubs, schools, training centres. Data gaps for the flow of cultural ecosystem services are numbers of both research projects and school visits. For services from geodiversity, a data gap has been identified for active geomorphological processes.

Location, or spatial configuration, are listed as data gaps; although data sets exist that could be used for this, further analysis would be required. Minor data gaps, only relevant to one ecosystem service and one broad habitat are listed on the fifth sheet of the Excel spreadsheet (Annex 4).

Table 6 Data gaps (for short list indicators) relevant to more than one habitat or ecosystem service

Aspect	Indicator category	Short list attribute
Quality	Hydrology & geomorphology:	Amount of surface water run-off/overland flow
		Naturalness of water level regime
		Extent of artificial drainage
		Sediment properties including stability
	Species Composition:	Naturalness of biological assemblage: number of trophic levels & community composition in each level
	Vegetation	Surface/vegetation roughness
		Extent of permanent vegetation cover
		Plant growth rate - biomass
		Vegetation cover/bare soil
		Proportion of peat mass actively forming peat
		Vegetation cover/bare soil/concrete or tarmac
	Cultural: Accessibility	Mean number of perimeter access points per km
		Presence of paths accessible to all – e.g. wheelchairs, pushchairs - length, density (km/ha)
	Cultural: Landscape, seascape & urban green space	Size of environmental space (ha)
	Cultural: Nature	Presence of flagship species
		Presence of rare (red list) species
		Visibility of wildlife
	Formative geological processes	Active geomorphological processes; terrestrial, coastal & marine
Spatial Configuration	Spatial Configuration	Distribution of flood mitigating land in relation to infrastructure & settlements
		Width/area/location for dynamic movement and development of coastal habitats e.g. saltmarsh and sand dunes
		Distribution of habitats, other vegetation and boundary features mitigating soil erosion and landslip risk.
		Proximity to other semi-natural grasslands & habitats
		Transition and connectivity from subtidal to coastal and terrestrial habitats
		Distribution of habitats, in relation to water quality source-pathway-receptor
		Distribution of habitats & trees in relation to buildings & transport routes
		Patch size, shape and edge
Ecosystem service flow		Carbon sequestered & green house gases fixed
		Maintenance of sustainable ecosystems/life cycle stages
	Cultural: Scientific/ educational	Number of research projects; PhD / Masters projects
		Number of school visits

4.9 Potential uses with examples

The natural capital indicators project has been designed to be wide reaching in its applications. The aim is that it can be of use in any instance where the objective is to measure change in natural capital. The premise of the project is that of taking a step back from the data to identify the critical attributes of natural capital that underpin a range of ecosystem services. As such it can also be used to help define “what good looks” like in terms of natural capital supporting the sustainable future provision of multiple ecosystem services. This can in turn help to inform decisions on management interventions to enhance natural capital. Text box 4 provides examples of potential uses of the work, where the outputs from the project have been provided or used to inform other projects and initiatives.

Text box 4: Examples of uses to date of the natural capital indicators

Project outputs have been provided for use in the following:

- Office for National Statistics condition indicators for national ecosystem accounts.
- 25 Year Environment Plan metrics and evidence annex.
- Defining Natural England's attributes of resilience, for resilient landscapes and seas.
- Defra Pioneer projects.
- Lake District National Park State of the Park report.
- Natural England's Favourable Conservation Status strategies.
- Water Companies' business planning & performance commitments.
- A literature review by York University (based on the logic chains).
- Review of the Monitor of Engagement with the Natural Environment (MENE) survey.
- An evaluation of the impact of agri-environment schemes on natural capital.

5 Discussion

5.1 Defining natural capital assets

This projects splits natural capital down into broad habitat assets. This is to enable consistency with the work on national ecosystem accounts by the Office for National Statistics (ONS 2017) and Scottish Natural Heritage in their Natural Capital Asset Index (SNH 2011-7). It follows the approach taken in the UKNEA (2011), facilitating the use of the evidence amassed in that assessment. Using assets based on broad habitats also fits with nature conservation, centred on habitats and species, as well as place-based working. However, it is not always logical for all ecosystem services, for example the cultural services (discussed in section 5.4.1) and water based ecosystem services (discussed below).

Other typologies of assets exist and the 25 Year Environment Plan (Defra 2018) considers an asset list that includes ecosystems, species, freshwater, land, soils, minerals, air and seas. As the Environment Agency find catchments to be a useful asset definition for management/decision purposes, we took this approach in this study. The compromise was that logic chains for the water services of water supply, water quality and flood regulation were not done for the other broad habitat assets (apart from Mountains Moorlands and Heaths). In effect, they had been lifted out. We reinserted the results from the catchment work back into all the broad habitat summaries for completeness. In acknowledgement of the important role of upper catchments, logic chains for the water-based services were produced for Mountains, Moorland and Heaths).

The use of broad habitats as assets includes all of the component parts, such as soil, ecosystems, species, air and natural processes. This fits with a systems approach and avoids overlap between the assets (and double counting for accounting purposes). To avoid further spatial overlaps between broad habitats, minor deviations have been applied from the UKNEA (see text box 2). Any split of adjacent ecosystems into separate assets will have its drawbacks. This is especially true of Coastal and Marine habitats. We have included mudflats with Coastal habitats, rather than Marine.

Where broad habitats assets are fragmented (e.g. Semi-Natural Grasslands) a number of different assets may need to be considered together for a place-based approach. In contrast, the uplands support the largest continuous areas of semi-natural habitats in England. Rather than splitting out woodland, freshwater or semi-natural grasslands from other upland mosaic habitats, the boundary of the Mountain, Moorland and Heath broad habitat was taken to be all land above the Moorland Line, plus lowland heath.

Cultural services reflect people's interactions with places rather than individual broad habitats. The logic chain approach adopted ensures key qualities of place are incorporated as indicators whilst retaining the consistency of approach with broad habitats.

In recognition of the important role of geodiversity in the provision of ecosystem services (Gray 2013), a separate logic chain has been produced for all services. Covering all the broad habitats, this approach was taken to enable the inclusion of abiotic services, not dependent on ecosystems, such as the provision of minerals and fossil fuels, as well as cultural services from geodiversity.

5.2 Logic chains: simplification of a complex natural/sociological system

The use of logic chains is a simplification of extremely complex natural/sociological systems. Rather than chains, the attributes of natural capital are linked through a complex interacting network of relationships. This could be portrayed as intricate three dimensional web diagrams. Through the use

of logic chains we are aiming to show the links between assets, ecosystem services and benefits in a clear and simple way. Despite its limitations, the use of logic chains achieves this. However the complexities of the systems they aim to portray does need to be acknowledged.

Attributes can also appear in different parts of a logic chain. For example, water quality can be considered as either an asset quality attribute (for aquaculture or nursery populations) or as an ecosystem service. This is again a factor of attempting to capture a complex system on paper. This is not problematic as long as we are aware that the logic chains are merely a framework; they help us to show the factors influencing the provision of individual ecosystem services.

5.3 Available evidence

Gaps exist in our full understanding of how the attributes of natural capital assets influence their capacity to supply different ecosystem services (Maseyk and others 2017). Smith and others (2017), building on Harrison and others. (2014), provides an evidence review of links between natural capital assets and ecosystem services. The short list indicators for regulating, provisioning and cultural services were checked against the review by Smith and others (2017). This review is a count of numbers of papers identifying links between biotic and abiotic natural capital attributes and ecosystem services. It does not assess the strength of those links. Where there are no links identified, this indicates a lack of evidence, rather than a lack of a link.

The use of expert opinion, across a wide range of disciplines in Natural England and the Environment Agency, has been used in this work to interpret the existing evidence and address uncertainty. With increasing research interest in natural capital, and the development of further evidence, there will be a need to continually review this work. The outputs provided are therefore considered to be a beta version, subject to further refinement and review.

5.4 Focus on natural capital assets

In applying the natural capital concept, there is often a strong focus on monetary valuation. However values can potentially go up even if the quality of the asset is falling. Our focus on the ecosystem and geodiversity natural capital assets ensures that we are able to pick up changes in the underlying asset that will affect its capacity to provide services and benefits. There is often a time lag between impacts on ecosystem attributes and impacts on services, benefits and value. Indicators of the ecosystem assets act as an early-warning system, detecting deterioration in the natural environment that will affect the future provision of benefits to people.

Focussing on the health of the environment, for a wide range of ecosystem services, also ensures that it is not only the ecosystem services and benefits which can be valued in monetary terms that are measured. This is also consistent with the human rights focus on a clean, healthy and sustainable environment (Human Rights Council 2018).

Defining the indicators of ecosystems and geodiversity that underpin ecosystem services is also vital for us to influence land management to enhance natural capital. This work helps us to define what good looks like for natural capital assets. Importantly, assessing the state of assets helps in decisions about how to enhance them, in terms of what, where and how. In this respect this work complements the previous Natural England commissioned literature review of how land management interventions, in different broad habitats affect the provision of ecosystem services (Waters and others 2016), published as a searchable tool: Ecosystem Services Transfer Toolkit - NECR159

As outlined in the methods and results (sections 3.4.3 and 4.5) our review by economists of the ONS national ecosystem accounts, identified methods for monetary valuation of benefits rather than regularly updated data sets. As such they have not been included in the results of this project. Our

ambition however is to provide indicators across the breadth of our logic chains. We are therefore looking to undertake further work with our economists in relation to indicators for the value of benefits, both monetary and non-monetary.

5.5 Ecosystem service synergies and trade-offs

This project has identified a number of synergies between ecosystem services where indicators of natural capital assets support multiple ecosystem services. However although the indicators may be the same, the levels that will enhance an individual service may differ. This is evident when comparing a number of the provisioning and regulating services. For example soil nutrient status to enhance ecosystem services, would be low for water quality, climate regulation and maintaining nursery populations and habitats but high for crops and reared animals.

Some ecosystem services, such as water abstraction, are also pressures and drivers of change on other ecosystem services. At the same time the extent of different natural capital assets will affect the range and level of ecosystem services that are provided. This project aims to identify indicators for the long-term sustainable provision of multiple ecosystem services. However, how this can be achieved will be the subject of both national and local decision making.

5.6 Approach to cultural services

Within the ecosystem services framework, cultural ecosystem services (CES) are those that represent the many ways our interactions with the natural environment enrich our lives. These ultimately contribute to our health and wellbeing, for example through outdoor activities, creativity, learning or our personal connection with the places and spaces we frequent. Because they essentially stem from our individual relationship with the natural environment, CES are typically intangible and this has made them particularly difficult to define, articulate and measure using indicators (Fish and others 2016; Bryce and others 2016; Tratalos and others 2016). As cultural services cannot be measured in the same way as biotic indicators, a different approach has been needed.

This project has focussed on identifying a tangible set of robust indicators for CES that reflect the asset state in its ability to provide cultural ecosystem services and benefits for people, in terms of their interactions with the natural environment. The conceptual framework for CES in the NEA Follow-on (2014) defines this in terms of the interactions between the physical places, which they refer to as environmental spaces, and the cultural practices that occur within them, a distinction that underpinned the development of the CES logic chain for this project. Tratalos and others (2016) identified that this distinction can help the development of CES indicators because the availability and quality of the natural environment, as well as what is undertaken in it, can form the basis of measurements. This is the approach facilitated by the logic chain adopted.

There is no single typology of environmental spaces for CES and the rationale for adopting broad habitats for this project has been established. It is, however, more challenging to specifically link CES to individual broad habitats than for some provisioning and regulating services. This can be because of the individual motivations and perceptions people bring to the experience but also because they typically experience the natural environment as part of a journey that takes in a range of environmental features, or other habitats observed from afar influence their experience (Tratalos and others 2016). Recognising that the approach adopted is a simplification of a very complex system and set of interactions, this project has added additional quality indicators to each broad habitat that reflect the wider geographical or place-based context. Retaining broad habitats and adapting the

logic chain in this way ensures indicators for cultural services are fully integrated with provisioning and regulating services in the practical approach this project seeks to deliver.

5.7 Data and data gaps

The data sets identified and reviewed for this work are nationally available ones. Local data sets were beyond the scope of this project, due to both the resources required to find them and potential uncertainties in their robustness. Robust local data sets will however be extremely useful for local assessments of natural capital. By basing this project on identifying short list indicators for assessing natural capital, the aim is that this will help in the identification of local data sets, for example to measure vegetation cover, that can supplement the national data sets.

Identification of data sets has been through data managers at Natural England and the Environment Agency, the workshops with specialists and from work (Maskell 2014) for the second state of natural capital report for the Natural Capital Committee (2014). Data sets are only included if they are regularly updated, and can therefore be used to measure change. In the course of the project a number of one-off surveys and methods for measuring short list indicators were identified that are outside the scope of this project. Methods for calculating the value of non-market goods were excluded for this reason.

Where a data set has not been identified to measure a short-list attribute, this is identified as a data gap. This provides the opportunity to identify new methods for capturing data on natural capital, such as through earth observation. Norton and others (2018), propose a combined method of earth observation verified by ground sample survey.

However substantial limitations also exist in the data sets that have been listed. For example CEH's Countryside Survey data covers a number of the short list indicators but it has not been updated since 2007. Similarly two data sets which also measure a number of the indicators, the Water Framework Directive and Common Standards Monitoring, do not have complete spatial coverage, with the former not covering the smallest water bodies and the latter restricted to Sites of Special Scientific Interest.

Other data sets to measure the short list indicators may exist that have not been identified by this project to date. As with the evidence base, the aim is to continually review and update the data sources list.

Links are provided to the data sources, however their applicability and ease of use have not been tested. In terms of practical application, we are looking to test this at an England and local scale, through the development of natural capital baseline assessments.

6 Conclusions

This project provides a systematic approach to defining indicators of natural capital. The use of logic chains enables the natural capital assets to be clearly linked to ecosystem services and benefits. It is also driven by the principle of first identifying the key indicators of natural capital to measure, to ensure the future sustainable provision of multiple ecosystem services. Data sets are then identified for these key indicators. This has enabled the highlighting of gaps, where suitable data sets for measuring the indicators have not been identified. Recognising gaps in data for measuring change in natural capital, can help with potentially seeking ways of filling them, e.g. through the development of new technologies such as earth observation, or the use of local data sets for local projects.

Indicators have been categorised across the logic chains, where possible. Importantly though, we focus on natural capital assets as an early warning system. Drawing attention to the state of natural capital assets is essential to ensure that we are not missing factors that could be affecting the long-term provision of ecosystem services. It is also needed to effectively influence land management, to enhance natural capital through, for example, environmental land management schemes.

This work fills a number of major gaps in our understanding of natural capital in England. This includes the emphasis on asset quality (or condition), with the usefulness of the work already recognised by the Office for National Statistics for their development of national natural capital accounts (ONS 2017). The indicators for cultural ecosystem services are also particularly important. Cultural services are frequently overlooked or considered to be too difficult, with measures solely focussing on numbers of visitors or photos taken. The methodical approach used in this project has brought together key learning from the UKNEA Follow-on work (2014) with the Common International Classification of Ecosystem Services. Using expert opinion we have defined a robust suite of indicators for cultural services. Another aspect of natural capital that is often ignored is geodiversity. Notably this project defines indicators for ecosystem and abiotic services from geodiversity assets.

This work is targeted at anyone who is looking to understand or measure the state of our natural capital. As it concentrates on the properties of the natural environment required for the long-term sustainability of human well-being, its potential uses are wide-reaching. This breadth of application ranges from local to national, and from natural capital accounting to decisions on land management to enhance natural capital. The short list indicators could be applicable to any such project. Local natural capital assessments or plans, could use the indicators to assess the state of natural capital, to inform planning. This includes supporting the identification of locally available data sets to measure the indicators and potentially fill data gaps. Whilst from a broader perspective, the potential uses of this work also extend beyond natural capital to measurements of the environment in relation to well-being, human rights and social injustice (Lakerveld and others 2015, Mullin and others 2018).

Although we focus on the characteristics of natural capital assets, ideally we would identify short list indicators across the breadth of our logic chains. To achieve this, further work is needed on values and benefits. This project has been based on the available evidence, supplemented by expert opinion. Natural capital is an ever growing field for academic research and indicators will be reviewed as further evidence becomes available. Ultimately the proof of the pudding will be in the eating, we are looking to test the application of these indicators at an England and local scale.

7 References

Albon S, Balana B, Brooker R & Eastwood A. 2014. A systematic evaluation of Scotland's Natural Capital Asset Index. Scottish Natural Heritage Commissioned Report No. 751.

Bryce R., Irvine K.N., Church A., Fish R., Ranger S. and Kenter J.O. 2016. Subjective well-being indicators for large-scale assessment of cultural ecosystem services. Ecosystem Services. 21, pp 258-269.

Defra. 2018. A Green Future: Our 25 Year Plan to Improve the Environment.

Fish, R., Church A. and Winter, M. 2016. Conceptualising cultural ecosystem services: A novel framework for research and critical engagement. Ecosystem Services. 21, pp 208-217.

Gray, J.M. 2013. Geodiversity: Valuing and Conserving Abiotic Nature. 2nd Edition, Wiley.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R and Turkelboom, F. 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. *Ecosystem Services* **9**, pp. 191-203.

Hauck J, Albert C, Furst C, Geneletti D, La Rosa D, Lorz C, Spyra M (editors). 2016. Developing and Applying Ecosystem Services Indicators in Decision-Support at Various Scales. Ecological Indicators Special Edition. 61-1, 1-148.

Human Rights Council. 2018. Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment. Human Rights Council Thirty-seventh session 26 February–23 March 2018 Agenda item 3.

Lakerveld RP, Lele S, Crane TA, Fortuin, KPJ, & Springate-Baginski, O. 2015. The social distribution of provisioning forest ecosystem services: Evidence and insights from Odisha, India. Ecosystem Services, 14, 56–66. http://dx.doi.org/10.1016/j.ecoser.2015.04.001.

Mainstone, C.P., Jefferson, R., Diack, I, Alonso, I, Crowle, A., Rees, S., Goldberg, E., Webb, J., Drewitt, A., Taylor, I., Cox, J., Edgar, P., Walsh, K. 2018. Generating more integrated biodiversity objectives – rationale, principles and practice. Natural England Research Report 071NERR071

Maseyk, F.J.F., Mackay, A.D., Possingham, H.P., Dominati, E.J., Buckley, Y.M., 2017. Managing natural capital stocks for the provision of ecosystem services. Conserv, Lett. 1

Maskell, L., Pearce, B., Jones, L., Garbutt, A., Wood, C. 2014. Review of monitoring data for reporting on Natural Capital. Report to the Natural Capital Committee.

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC.

Mullin, K, Mitchell, G, Nawaz, NR, Waters, RD. 2018. Natural capital and the poor in England: Towards an environmental justice analysis of ecosystem services in a high income country. Landscape and Urban Planning 176 (2018) 10–21.

Natural Capital Committee (2014) The State of Natural Capital Second Report: Restoring our Natural Assets.

Natural England. 2016. Conservation 21 Natural England's Conservation Strategy for the 21st Century

Norton LR, Smart SM, Maskell LC, Henrys PA, Wood CM, Keith AM, Emmett BA, Cosby BJ, Thomas A, Scholefield PA, Greene S, Morton RD, Rowland CS. 2018. Identifying effective approaches for monitoring national natural capital for policy use. Ecosystem Services 30, 98–106

Office for National Statistics. 2017. UK natural capital: ecosystem accounts for freshwater, farmland and woodland.

Scottish Natural Heritage. 2011-7. Scottish Natural Capital Asset Index.

Smith AC, Harrison PA, Pérez Sobac M, Archaux F, Blicharskae M, Egohg,BN, Erősi T, Fabrega Domenech N, Györgyi AI, Haines-Young R, Lia S, Lommelen E, Meiresonne, L. Miguel Ayala, Mononen L, Simpson, G, Stange E, Turkelboom F, Uiterwijk M, Veerkamp CJ, and Wyllie de Echeverria V. 2017. How natural capital delivers ecosystem services: a typology derived from a systematic review. Ecosystem Services. 26, A, 111-126. https://doi.org/10.1016/j.ecoser.2017.06.006.

Tratalos J.A., Haines-Young R., Potschin M., Fish R. and Church A. 2016. Cultural ecosystem services in the UK: Lessons on designing indicators to inform management and policy. Ecological Indicators. 61, pp 63-73.

UK National Ecosystem Assessment. 2011. The UK National Ecosystem Assessment: Technical Report. UNEP-WCMC, Cambridge.

UK National Ecosystem Assessment Follow-on. 2014. The UK National Ecosystem Assessment Follow-on: Synthesis of the Key Findings. UNEP-WCMC, LWEC, UK.

Waters D, Austin Z, White P, Lusardi J and Waters R, 2016. Ecosystem Services Transfer Toolkit: Users Guide. Natural England Commissioned Report NECR159.

White C, Dunscombe R, Dvarskas A, Eves C, Finisdore J, Kieboom E, Maclean I, Obst C, Rowcroft P & Silcock P. 2015. Developing ecosystem accounts for protected areas in England and Scotland: Main Report. Department for Food, Environment & Rural Affairs/The Scottish Government.

World Health Organization and Secretariat of the Convention on Biological Diversity, 2015. Connecting global priorities: biodiversity and human health: a state of knowledge review. ISBN 978 92 4 150853 7

Natural England works for people, places and nature to conserve and enhance biodiversity, landscapes and wildlife in rural, urban, coastal and marine areas.

www.gov.uk/natural-england