Environment Agency

Natural Capital Approach

The Natural Capital Register and Account Tool, Version 1.2 – Technical Report

Chief Scientist's Group report

July 2023

Project code: ENVWLB00460C

We are the Environment Agency. We protect and improve the environment.

We help people and wildlife adapt to climate change and reduce its impacts, including flooding, drought, sea level rise and coastal erosion.

We improve the quality of our water, land and air by tackling pollution. We work with businesses to help them comply with environmental regulations. A healthy and diverse environment enhances people's lives and contributes to economic growth.

We can't do this alone. We work as part of the Defra group (Department for Environment, Food & Rural Affairs), with the rest of government, local councils, businesses, civil society groups and local communities to create a better place for people and wildlife.

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This report is the result of research commissioned by the Environment Agency's Chief Scientist's Group.

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If you have any comments or questions about this report or the Environment Agency's other scientific work, please contact research@environment-agency.gov.uk.

Dr Robert Bradburne
Chief Scientist

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NCRAT includes:

- Environment Agency Natural Capital Register and Account Tool version 1.2, Workbook
- Environment Agency natural capital scorecard version 1.2
- Environment Agency Natural Capital Register and Account Tool version 1.2, Quick-Start Guide
- Environment Agency Natural Capital Register and Account Tool version 1.2, User Guide
- Environment Agency Natural Capital Register and Account Tool, version 1.2, Technical Report

NCRAT can be accessed at www.gov.uk/government/publications/natural-capital-register-and-account-tool or by email request from the Environment Agency Natural Capital Team at naturalcapital@environment-agency.gov.uk.

For Environment Agency and Defra group staff; NCRAT v1.2 is hosted on the Environment Agency Natural Capital Sharepoint site.

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Version history and change control

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v1.1	05 January 2022
v1.2	12 July 2023

Version	Changes to this document	Corresponding change to other NCRAT resources	Author	Date
v1.2	Pages, 2, 6 and 7 (amendments to authors, citation, and acknowledgments)	NCRAT User guide NCRAT Excel workbook	G. Kinsey	15 Jan 24

Executive summary

"Building nature into our plans and decisions has never been more important to achieve our ambitions in improving the environment and reaching net zero. Doing this robustly enables us to engage with the many people who will help us deliver these improvements on the ground. This update of the Environment Agency Natural Capital Register and Account Tool brings the evidence it accesses up to date and will allow users to engage more easily in the process of accounting for natural capital in their projects and to have confidence in the results. I look forward to seeing how we and others can use it to make better places for people and nature."

Dr Robert Bradburne - Environment Agency Chief Scientist

A natural capital register and account presents the value, quantity and quality of natural resources in a place. The outputs can change the way we see the environment and the value it gives to our lives and the economy, as well as helping to monitor net gain, or net loss, of natural assets.

This Technical Report and the associated User Guide provide an overview of version 1.2 of the Environment Agency Natural Capital Register and Account Tool (NCRAT), what it can be used for and a detailed explanation of its workings. Caveats, limitations and potential future developments are also discussed and a case study shows outputs and use of NCRAT.

In developing this latest version of NCRAT, the majority of the work has focused on updating the workbook to keep it current and to improve usability, the key areas are:

Asset register:

- Updated habitat classifications for asset quantity (habitat extent)
- Additional condition indicators (e.g., protected areas)

Process tabs and calculations:

- All processes and calculations reviewed and updated where appropriate
- Improved linking to streamline calculations
- Updated external data sources to reflect latest available evidence
- Addition of a Unit Value Look-up tab as a central point for reference data used within NCRAT

Other input and output tabs:

- Edits to improve the inputting of pressures on natural capital
- Output graphics refreshed in response to user feedback and the Natural Capital Risk Register revised to provide a more detailed output.

A fuller list of the changes made from version 1.1 to 1.2 is provided in the ‘Updates from version 1.1’ section of this report.

NCRAT can be used, without specialist economic knowledge, to create a strategic view of natural capital assets in a place (from Local Authority to River Basin District) and the value that they provide to the local economy.

Before the creation of NCRAT, a natural capital register and account took months to produce and thousands of pounds in specialists’ fees. With NCRAT, you can create an account yourself within days and for free. As far as we are aware, as a replicable, transferable, scalable and freely available tool, NCRAT remains the first of its kind.

The Environment Agency’s Natural Capital Team wants to empower staff and partners to take a natural capital approach in a robust, transparent and consistent way. To do this we are creating a suite of natural capital tools and products to help inform decisions and conversations about England’s natural assets. These tools will help us to design better outcomes for people and places, and collaborate with stakeholders on collective priorities, benefits and risks.

NCRAT provides a way to create place-based natural capital registers and accounts using built-in benefit and valuation data, and when used alongside the scorecard it is a ready-made engagement product. NCRAT is primarily for use in England, but aspects may be adapted for use in Wales, Scotland and Northern Ireland.

The Natural Capital Team will be actively collecting feedback from users of NCRAT to add to an evaluation of its performance and using this to develop the next iteration. If you would like to provide feedback, please contact us at NaturalCapital@environment-agency.gov.uk.

In releasing this tool, it is important to note that:

- A natural capital register and account will only ever reveal a partial value of nature. There are many services and functions of nature that are not valued in this tool (for example, noise regulation or pollination) and there are many ecosystem services that cannot be effectively valued in any account, for example the full value of biodiversity
- It is not a decision-making tool but will complement an evidence base for a place to help support place-based decisions
- NCRAT and its outputs are not designed for use in a regulatory context or for flood appraisals
- The values presented for the ecosystem services are intended to show a partial view of the irreplaceable services that nature provides to the local economy for free, or little input. It is not a price or a value for exchange. Previously natural resources have not been valued at all, leading to reduction or mismanagement of the asset.

There has been contention in some environmental circles, with economists and the government facing criticism for trying to put a “price tag” on nature. It is important to understand that this is not the intention of natural capital accounts. The intention is to communicate with audiences outside of the environment sector about how nature contributes to the local economy and wellbeing. Valuing the services that people receive from nature is a powerful way of doing this and can encourage more systematic and transparent thinking about the wider consequences of environmental decision-making.

Unless a quantity is attributed to a benefit that people get from nature, it may be unlikely to be recognised in the decision-making process. It is also helpful to then express benefits in monetary terms to be able to compare like-for-like (for example, costs in £ with benefits in £). Natural capital accounting encourages systematic and transparent thinking about the wider consequences of environmental decision making. We will only ever be able to present part of the natural capital story with quantity and monetary figures. The rest we must continue to describe in words and ensure these descriptions are given equal standing to any figures. This remains a challenge and one we will aim to meet in future iterations of NCRAT and its scorecard.

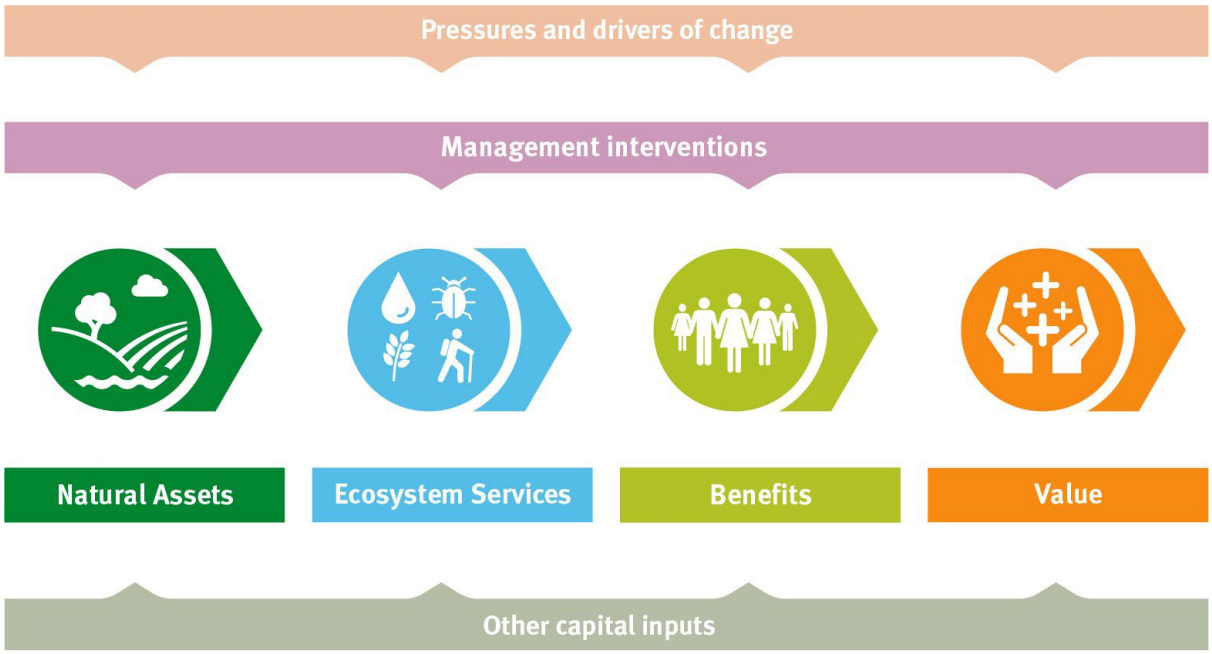
> “… making the moral case for protecting nature for its own sake, because it is beautiful and important, and we have no right to destroy it – the case campaigners have been making for half a century or more - has demonstrably failed. When nature is valued at nothing, when it is invisible in the economic system by which we live, that system invariably tosses it aside.”

Isabella Tree, Chapter 17, The Value of Nature, in ‘Wilding, the return of nature to a British farm’ (2018).

Introduction

Natural capital is our stock of natural assets such as forests, water, land, soil, air and minerals that provide valuable goods and services (benefits) to people such as providing clean air and water, food and recreation as well as supporting sustainable economic growth. Figure 1 shows the flow from natural capital (assets) to the benefits (value) people derive from it.

Figure 1. Natural capital assets, ecosystem services, benefits and values

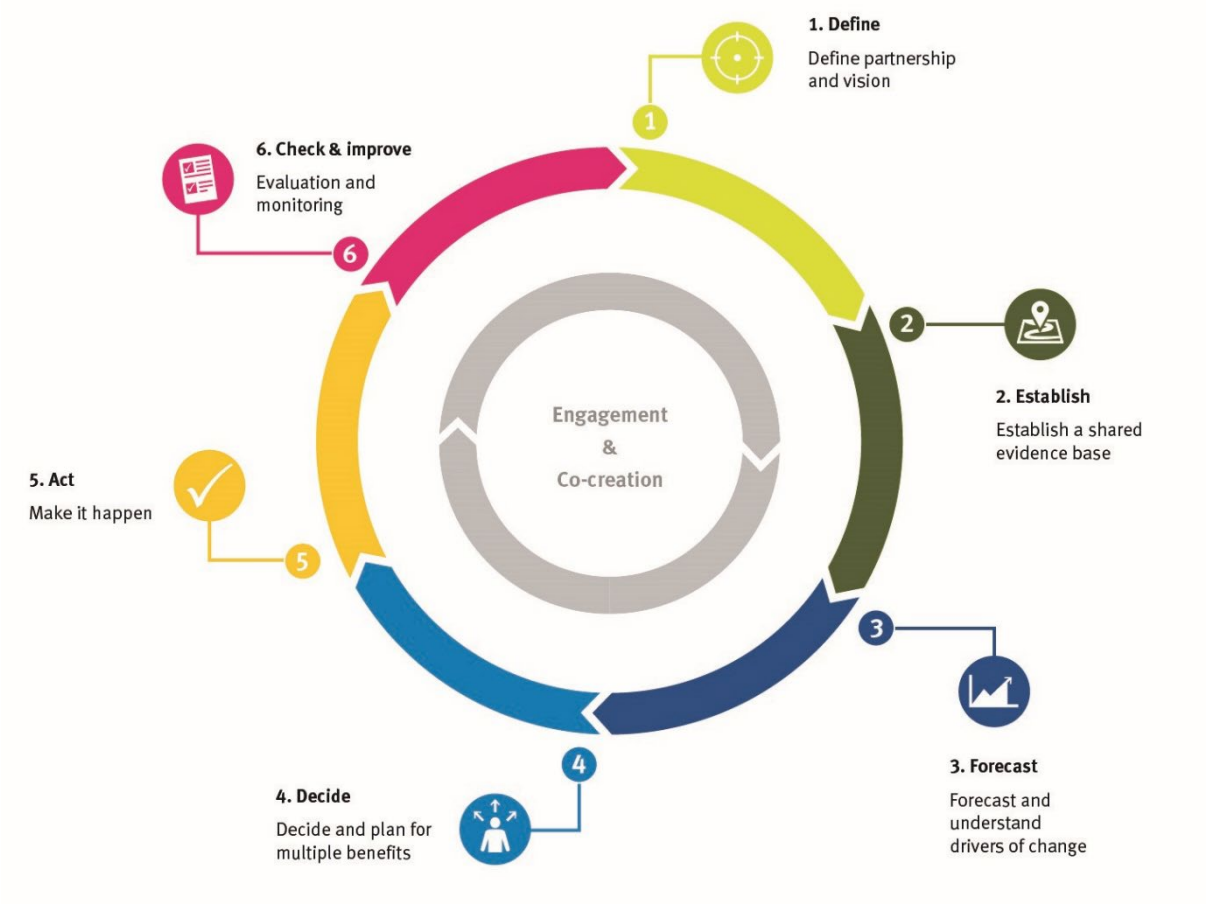


At the heart of a natural capital approach is the understanding that nature underpins human wealth, health, wellbeing and culture. Recognising the complex ways in which natural, social and economic systems interact enables us to use better evidence to support decisions that protect and enhance natural capital so that it can continue to deliver the services and benefits we need.

Human capital, manufactured capital and financial capital are routinely considered in financial and management decisions. The natural capital approach aims to include the value from the natural environment in economic decisions and acknowledge its role in underpinning all our economic activities and overall wellbeing.

A natural capital register and account is a way of presenting information about the natural environment and the value of the services it provides. The aim is to establish a framework within which organisations can account for natural capital, documenting assets in a format that extends traditional financial reporting while staying compatible with it. Figure 2 shows an environmental planning and delivery cycle; natural capital registers and accounts sit at ‘Step 2. Establish a shared evidence base’.

Figure 2. A place-based environmental planning and delivery cycle



A natural capital register and account tells the environmental story a new way; describing the value produced by natural assets within a place which in turn can start new conversations about the value of our natural environment with different audiences.

Value can be expressed in many ways including, in part, in monetary terms. By calculating (where possible) a monetary value to the benefits produced by natural assets, we become better able to understand what the local economy might lose should those natural assets come under threat. It may help businesses better understand the value that natural capital provides to the local area and how it supports the local economy.

A natural capital register and account can:

- Start new conversations about the value that the local natural environment provides to the local economy
- Help to establish an asset and values baseline for a place
- Support prioritisation and place-based planning.

Some of the benefits that nature provides are too intangible or bundled with other benefits to be able to place individual monetary values on. The impact of some benefits can also vary greatly from person to person depending on an individual's circumstances. This means that not all the natural capital of a place can be quantitatively described with

monetary figures, the rest we must describe qualitatively in words with the ongoing challenge of ensuring the narrative is given equal standing to any figures.

Progress is rapidly being made in the field of natural capital across organisations. Natural capital registers and accounts produced by the Environment Agency, Office of National Statistics, National Trust, Forestry Commission, Natural England, Economics for the Environment Consultancy, and Vivid Economics, to name a few, are among the first of their kind. The story that registers and accounts tell depends upon the scale at which they are based, the data sources that are being used and the specific ecosystem services that are analysed and highlighted. This cross-cutting work is testing the theory of a natural capital approach and working to improve best practice with common data standards.

Using NCRAT

This section provides an overview of the structure and principles for using NCRAT. For specific input instructions, please refer to the User Guide.

As defined by the Natural Capital Committee, a natural capital asset register is an inventory of the quantity and quality of natural assets in a place.

The Environment Agency has developed NCRAT to record quantity in terms of the extent of different types of habitats and their quality in terms of their condition as relevant to the delivery of ecosystem services.

It uses this information to estimate the flow of services from the assets and where practicable calculates monetary values (benefits). This is to provide decision makers with evidence to support place-based planning and investment.

With user input, NCRAT provides:

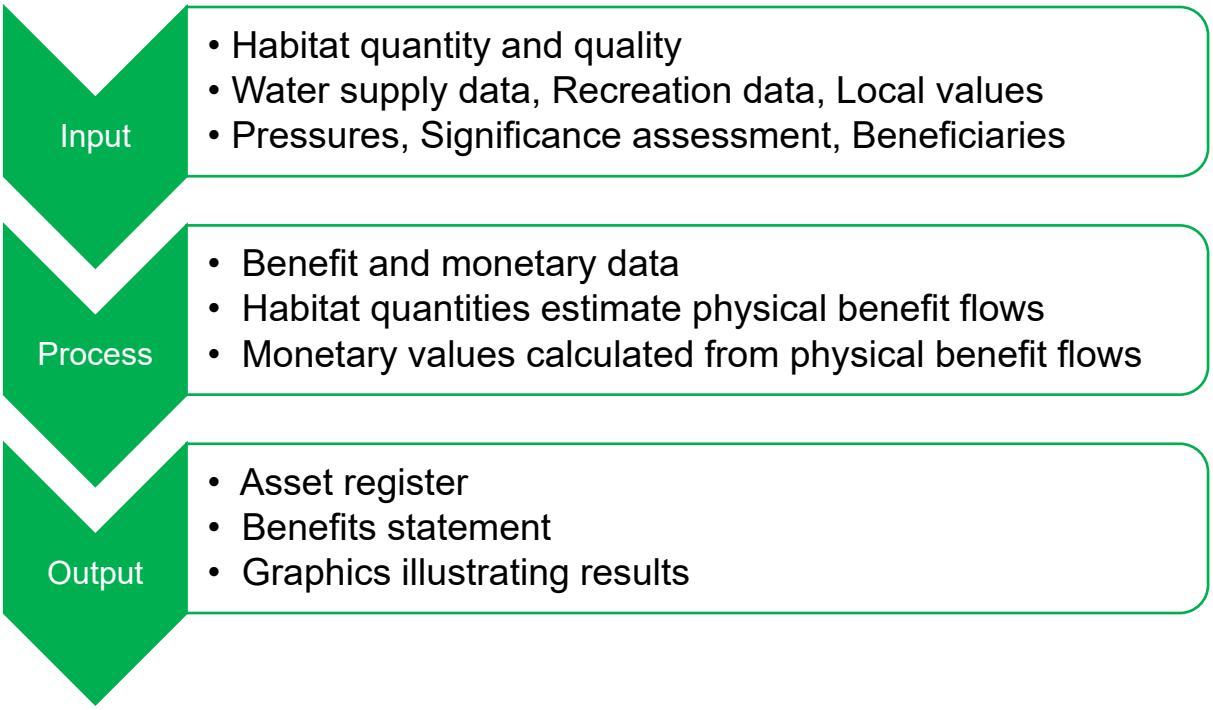
- A register of the quantity of natural capital assets (i.e., extent of habitats) in a specified place (the account boundary) and a summary of the quality (condition) of the assets
- A benefits statement showing the flows of ecosystem services from assets and the calculated monetary values of selected services including present value over time
- An assessment of the significance of the benefits
- A register of the pressures on ecosystem delivery
- An attribution of benefits to assets
- Automated graphics that illustrate the outputs for the benefits statement.

To support decision makers and their engagement with others, a natural capital scorecard template is also provided (separately) and can be completed after the register and account to summarise and present the graphics in a visually engaging way, see the scorecard section below. This should be used alongside an interpretive narrative.

Overview of structure

NCRAT is an Excel workbook and requires habitat extent and condition and other local data to be input by the user. It automatically runs calculations on these and uses built-in valuation data to generate estimated benefit flows and any associated monetary values. It provides a summary of this information in the form of a benefits statement. The flow chart in Figure 3 shows these steps.

Figure 3. NCRAT flow chart



Thirteen ecosystem services (sub-divided into twenty-two) are included in NCRAT. It includes information and values about ecosystem services for which we have been able to gather robust and reliable benefit and value information. These are shown in figure 4 and figure 5.

Figure 4. Icons for the ecosystem services quantified and valued in NCRAT

We aim to add more values for ecosystem services to the account in further development of the tool. Supporting services are not included, because, as they underpin cultural, provisioning and regulating services to introduce them would be to increase the risk of double-counting in the account.

Figure 5. Screen shot of the benefits statement showing ecosystem services quantified and valued in NCRAT

	Ecosystem service	Significance	Benefit valued	Benefit type	Beneficiaries: Local population	Beneficiaries: Wider Society	Beneficiaries: Public Sector	Beneficiaries: Private Sector	Physical flows: Measure (unit)	Physical flows: Avg unit / year	Monetary values: Valuation basis	Monetary values: Annual value (central) £m	Monetary values: Asset value (PV, 100 yr) (low) £m	Monetary values: Asset value (PV, 100 yr) (high) £m	Monetary values: Asset value (PV, 100 yr) (central) £m	Representation
Provisioning	Agriculture – Arable	+ +	Food	Market	●	●	◑	◑	Yield of arable production (tonnes/yr)	916,282	Gross margin	61.09	-	-	1,821.11	
	Agriculture – Livestock (dairy)	+ +	Food	Market	●	●	◑	◑	Yield of livestock (dairy) production (kL/yr)	554,407	Gross margin	83.16	-	-	2,479.24	
	Agriculture – Livestock (meat)	+ +	Food	Market	●	●	◑	◑	Yield of livestock (meat) production (tonnes/yr)	61,568	Gross margin	32.51	-	-	969.25	
	Fish and shellfish landings	+	Food	Market	●	●	◑	◑	Volume of fish and shellfish landings (tonnes/yr)	7	Net profit	0.00	-	-	0.05	
	Water supply (public)	+ +	Water supply	Market	●	○	◑	●	Abstracted raw water quantity (m3/yr)	355,273,793	Resource rent	418.29	-	-	12,470.32	
	Water supply (energy generation)	+ +	Water supply	Market	●	●	◑	●	Abstracted raw water quantity (m3/yr)	377,384,801	Not valued	-	-	-	-	
	Water supply (all other)	+ +	Water supply	Market	◑	◑	◑	●	Abstracted raw water quantity (m3/yr)	118,269,433	Marginal value	1,011.64	-	-	30,159.62	
	Timber	+	Timber	Market	◑	◑	◑	●	Volume of timber removals (m3/yr)	43,844	Stumpage price	1.64	-	-	48.92	
	Renewable energy	+	Renewable energy	Market	◑	◑	●	●	Renewable energy generation (MWh/yr)	383,817	Resource rent	5.31	-	-	158.35	
Regulating	Climate regulation	+	Climate	Non-market	◑	◑	◑	◑	Net CO2eq sequestered (tonnes/yr)*	129,255	Abatement cost	52.93	2,376.09	2,722.99	2,551.18	
	Air quality – PM2.5	+ +	Health	Non-market	◑	◑	◑	◑	PM2.5 removed (tonnes/yr)	131	Avoided cost (treatment and productivity) plus welfare value	7.11	-	-	262.12	
	Air quality – SO2	+ +	Health	Non-market	◑	◑	◑	◑	SO2 removed (tonnes/yr)	521	Avoided cost (treatment and productivity) plus welfare value	0.02	-	-	0.85	
	Air quality – NO2	+ +	Health	Non-market	◑	◑	◑	◑	NO2 removed (tonnes/yr)	385	Avoided cost (treatment and productivity) plus welfare value	1.39	-	-	11.49	
	Air quality – O3	+ +	Health	Non-market	◑	◑	◑	◑	O3 removed (tonnes/yr)	16,811	Avoided cost (treatment and productivity) plus welfare value	0.92	-	-	62.67	
	Hazard regulation	-	Flood risk reduction	Non-market	◑	◑	◑	◑	Annual volume of potential flood storage by woodlands (m3/yr	1,906,962	Not valued					
	Disease and pests	-			-	-	-	-								
	Pollination	-			-	-	-	-								
	Soil quality / erosion	-			-	-	-	-								
	Noise mitigation	-			-	-	-	-								
	Waste remediation	-			-	-	-	-								
Cultural	Recreation (adults)	+ +	Recreation	Non-market	●	●	◑	◑	No. visits to open spaces (visits/yr)	202,851,360	Welfare value	824.68	-	-	20,372.15	
	Recreation (children)	+ +	Recreation	Non-market	●	●	◑	◑	No. visits to open spaces (visits/yr)	51,452,469	Not valued	-	-	-	-	
	Physical Health	+	Health	Non-market	●	●	◑	◑	No. active visits to open spaces (visits/yr)	104,468,451	Avoided treatment cost	191.23	-	-	5,701.11	
	Education	+	Educational benefits	Non-market	●	●	◑	◑	No. educational visits (visits/yr)	100,000	Exchange value	2.81	65.63	102.04	83.83	
	Volunteering	+	Volunteering	Non-market	-	-	-	-	No. volunteering days (days/yr)	250,000	Opportunity cost	26.70	-	-	796.01	
	Amenity	-			-	-	-	-								
	Aesthetic / sense of place	-			-	-	-	-								
	Spiritual	-			-	-	-	-								
Bundled	Water quality – rivers	+ +	Various	Non-market	●	●	◑	◑	-	-	Welfare value of good water quality	15.42	376.77	542.49	459.63	
	Water quality – transitional, coastal waters and lakes	+	Various	Non-market	●	●	◑	◑	-	-	Welfare value of good water quality	0.07	1.80	2.59	2.20	
	Biodiversity	-			-	-	-	-								
	Total market benefit value (£m)											1,613.64			48,106.86	
	Total non-market benefit value (£m)											1,123.28			30,303.23	
	Total quantifiable value (£m)											**2,736.93**			**78,410.09**	

Key features

NCRAT records information about natural assets in a place. This information is used to estimate the benefit flows from natural assets in physical and monetary terms.

The valuations are for the flows of ecosystem services estimated to be produced by the stocks of natural capital assets within the accounts' boundaries. NCRAT is intended to support engagement with stakeholders and place-based decision-making and investment.

NCRAT's design emphasis is on the use of open-source, nationally available data that, once input by the user, feeds input to the (semi-)automated process components of NCRAT for recording data on natural assets and for calculating benefit flows. This is

intended to allow a broad spectrum of stakeholders to use NCRAT, both internal and external to the Environment Agency. Moreover, the aim is for NCRAT to provide a robust, replicable and transferable (place to place) approach to creating natural capital registers and accounts, the results of which different stakeholders will be able to interpret and understand in consistent terms.

In the main, NCRAT uses the quantity (recorded as extent) of natural capital assets to calculate benefits. There are some cases where the quality (condition) of an asset is also used to calculate benefits. For example, peatland condition which is used to calculate carbon emissions.

In general, asset condition data is recorded to provide a fuller picture of the state of natural capital assets and should inform the assessment of risks and pressures acting on natural capital asset. In most cases, if asset condition is not included, a default assumption is made that the asset is in average condition.

The key features of NCRAT are shown in table 1.

Table 1. Key features of NCRAT

Tool feature	Description
Transferable, automatable and replicable	Place-based, local authority scale to river basin district scale, input any source data, built-in valuation data and automation.
Natural capital quantity and quality data	Any data source can be used to populate the habitat quantity (extent) and quality (condition) sections of the asset register tab National, open-source data is preferred to enable collaboration with stakeholders,
Ecosystem service valuation data	Thirteen ecosystem services are valued in £

A common data standard or metric isn't currently provided for natural capital assets, hence the UK National Ecosystem Assessment (UKNEA) eight broad habitat types are used as a proxy, and these are likewise used to provide the high-level natural capital assets classification in NCRAT (table 2).

Table 2. Eight broad habitat types from the UK National Ecosystem Assessment

Broad Habitat Type
Coastal margins
Enclosed farmland
Freshwaters – open waters, wetlands and floodplains
Marine
Mountains, moorlands and heaths
Semi-natural grasslands
Urban
Woodlands

NCRAT is best applied at a scale above 10,000 hectares, up to a few million hectares, and the register is transferable to multiple scales to cover, for example:

- Local Authorities
- WFD catchments
- Local Enterprise Partnerships
- River Basin Districts

See the User Guide (section ‘Cell B17 input for Selected scale’) for more information on inputs at different scales.

Uncertainties and limitations

NCRAT and the accompanying scorecard form part of a suite of tools which are being created and trialled by the Environment Agency to apply a natural capital approach in a consistent and robust way.

Natural capital accounts typically assume assets (habitats) are in average condition to quantify the ecosystem service flow of benefits and monetary values. This assumption has been adopted in NCRAT.

NCRAT includes the option to record information about the condition of natural capital assets. Whilst in most cases it uses the quantity of natural capital assets to calculate benefits, there are some cases where the condition of an asset is also included in the calculation of benefits. For example, peatland condition is used to calculate carbon emissions.

NCRAT provides a section (the 'Input – NC risks' tab) in which to include current pressures on natural assets and risks to their condition in the future. Local, expert knowledge and judgement should be used to inform this assessment and ideally it should be considered during the environment planning and investment decision-making process.

Not all natural capital registers and accounts are comparable. Some may prioritise different stories for different places. For example, they can tell a different story depending on the scale they are created at and the values that are applied for different habitats.

A confidence score using a red-amber-green (RAG) colour-coding system has been applied to the monetary values in the tool's benefits statement. This signifies the confidence we have in the data i.e., use of assumptions, peer review and transferability. Specific assumptions that under-lie values in the account are detailed in the 'Interpreting the values' section below.

The number of ecosystem services and benefits provided by a place vary, and not all of them can be quantified. This means that not all services are currently represented within NCRAT although we are looking to improve this. For example, due to a lack of suitable data and method of calculation, the tool does not include an estimate of the mental health benefits derived by time spent in green-blue natural places even though this ecosystem service is very likely to be present within most place (account) boundaries and is likely to be very important to the people living in and using the place.

The following is important to remember when viewing NCRAT's outputs:

- A natural capital register and account will only ever reveal a partial value of nature. Hence, the monetary values presented in NCRAT show only a partial view of the irreplaceable services derived from nature by people, communities and businesses for free (or little) input. These monetary values are not prices, or values for

exchange. Previously, natural resources have not been valued at all, leading to reduction or mismanagement of the asset.

- There are some services and functions of nature that are not valued in NCRAT (for example noise regulation or pollination) and whilst some services that cannot be effectively valued in any account (for example the value of biodiversity) NCRAT aims to make ecosystem services that have not been valued explicit
- NCRAT and its outputs are not designed for use in a regulatory context or for flood appraisals
- NCRAT is not a decision-making tool but its outputs will compliment an evidence-base for a place and help to support place-based decisions
- Some monetary valuations are better than others (more widely accepted, based on more robust market values, peer reviewed etc). We have tried to highlight this in the account outputs with the RAG rating.
- In the absence of quantitative data, qualitative information about the condition of an asset or delivery of a service is just as important to include. Qualitative data is harder to present as it cannot be included directly in a numerical account and therefore presents an ongoing challenge to present on an equal standing with the monetary figures.

Case studies

During the course of its development, NCRAT has been trialled in different parts of the Environment Agency, including the Environment Agency operational areas, the OxCam project and the Environment Agency's own estate. These case studies are described below with weblinks to view the examples in more detail.

"Nature is far too complex to study through one lens alone. Natural capital accounting is a systematic way of bringing together environmental, financial and economic information. All parts of that information are useful and when considered together they start to show more interesting results – in particular, about how dependent economic activity is on nature. It is the process of going through accounting – linking assets to services to benefits – that's most useful for decision makers. This tool is designed to make that process more accessible. The evidence needs to be robust but that's not sufficient. Evidence is inevitably partial. Use this tool, to integrate natural capital thinking into decision making. That is the significant contribution you can achieve in England, the UK and beyond."

Ece Ozdemiroglu, Founder and CEO of eftec and Chair of British Standards Institute (BSI) committee SES/1/8 Assessing and Valuing Natural Capital.

Account for the Environment Agency estate

In the government's 25-year Environment Plan (published 2018), the use of natural capital accounting was highlighted as a key method to better understand the benefits provided by the natural environment. As a result, the Environment Agency has committed itself to embedding natural capital understanding and capability. Some of our recent analyses (to 2021-22) has revealed that an additional 6,000 tonnes of carbon dioxide equivalent will be removed from the atmosphere each year due to work to create and restore woodland, saltmarsh, and peatland habitats. This removal of greenhouse gases is worth £27 million over the next 40 years to our economy. On pages 12, and 34 to 35 of the Environment Agency Annual report and accounts for the financial year 2021 to 2022 you can find the natural capital account for the Environment Agency's land assets.

Accounts for Environment Agency Operational Areas

The Environment Agency delivers its work across England in sixteen Operational Areas. Many of the Areas have been using NCRAT to create a register and account to help illustrate the value of nature within their boundaries. NCRAT's outputs can or have been used as part of part of the evidence base for each Area's 'Local Outcome Plan'.

In the East Midlands, the Environment Agency Planning and Engagement Team used a prototype version of NCRAT to generate headline figures and information about the value of nature or local natural capital assets to the local economy. The scorecard was created by Environment Agency staff following discussion on the potential uses of NCRAT in relation to their local industrial strategies with two Local Enterprise Partnerships (LEPs), Leicestershire Local Enterprise Partnership and Derby, Derbyshire, Nottingham, Nottinghamshire (D2N2).

Where, previously, the environment and flood risk did not figure on the LEPs' agendas, this natural capital information has helped to get it squarely on table and position the Environment Agency as an enabler for sustainable growth. There is an increased chance that the natural environment and flood risk mitigation will be at the heart of investment decisions going forward. The Leicestershire LEP, along with their Natural Capital Group which includes Leicestershire County Council, also plan to use NCRAT as a step towards producing an environment investment plan. The D2N2 LEP and their Place Advisory Board also intend to use it in the same way. This should also increase chances of linking into growth and other funds with partners.

"Here in the East Midlands, we have shown the tool to local planners and they are really excited by it because it provides them with a clear means of seeing the value of their "patch" and planned activities. They can use it to see what benefits their plans have and it is an opportunity to really bolster business cases and ensure investment goes to the right places and into the right communities. Furthermore, this tool could be a massive opportunity in environmental land management schemes.

From a Local Outcome Plan perspective there are also huge opportunities! A simple objective to enhance natural capital – can now be set as a measurable outcome!"

Bryan Hemmings – Flood and Coastal Risk Manager, East Midlands, Environment Agency

In Greater Manchester the Urban Pioneer project, which helped develop the original NCRAT, used NCRAT and its outputs to demonstrate the economic significance of investing in natural assets.

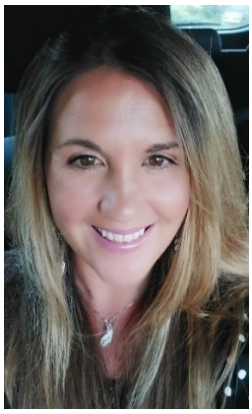
"[NCRAT gives the] *ability to link the benefits provided by natural capital to the policies, plans and goals of others in a measured and valued way. Using a natural capital account, we identified an additional 10% of monetary value created from the Warrington Flood Alleviation scheme that had previously been invisible to us. This is changing how we include natural capital improvements as part of future FCRM scheme designs."*

Adam Booth – Urban Pioneer Project Manager, Greater Manchester, Environment Agency

For internal users, more about how the Greater Manchester Team used natural capital accounting can be found on the Urban Pioneer SharePoint

An account for the OxCam Project

The Oxford-Cambridge pan-regional partnership (OxCam PRP), see BBC article (2023), is a multi-Authority initiative supporting economic planning and development to 2050 across Oxfordshire, Bedfordshire, Buckinghamshire, Cambridgeshire and Northamptonshire. The OxCam PRP has a Local Natural Capital Plan (LNCP) Team. The Team have been using NCRAT to create a balance sheet and valuation for some of the ecosystem services and benefits that nature provides in the OxCam arc.



"The OxCam LNCP account summary highlights the value of the benefits the Arc's natural capital provides to society – and all the interlinking and overlapping dependencies, but also shows the gaps in the evidence and understanding which are just as important. The information used to calculate many of the benefits in the account is from our baseline mapping work, and it was great to be able to test and help refine the Environment Agency accounting tool and create a picture of benefits and value. Our account is a way of quantitatively linking together the total benefits that flow from nature and tracing them back through the flows to the assets. This is important, if we only focus on the benefits and values in isolation, we miss that it's the assets we have to look after. The quality and quantity of these assets change over time due to pressures and drivers of change, such as growth and climate change - for this reason in our summary we also include information about the landscape, pressures and opportunities unique to the area to set that important context. The account provides a snapshot in time to support engagement around issues and opportunities and provides a base for future comparisons to be made."

Sarah Trouw, Project Director Oxford to Cambridge Arc, Environment Agency Team

More about the OxCam natural capital approach can be found on the OxCam LNCP website.

The natural capital scorecard

NCRAT is accompanied by a template to help users create a natural capital scorecard. Once completed, this is designed to provide a dashboard-style scorecard to share the outputs of NCRAT in an engaging way. The outputs and inbuilt graphics from NCRAT can be used to populate the scorecard template once all the user-input is completed.

Any user-generated narrative about the place (i.e., the area within the account boundary) and interpretation of the results should also be added to the scorecard.

Examples of the NCRAT outputs and graphics used in the scorecard are shown below (figures 6 to 12).

Figure 6. Scorecard example - valuing natural capital

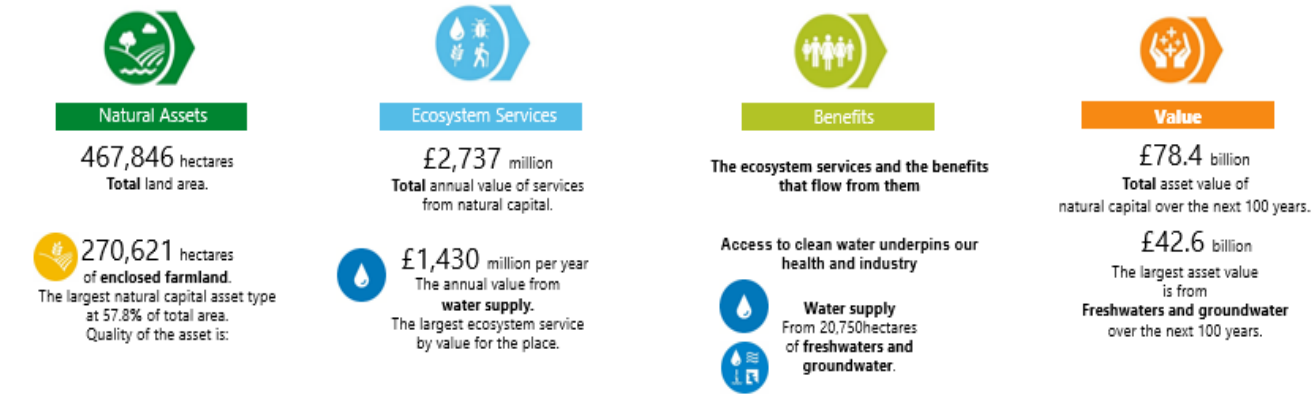


Figure 7. Scorecard example - Natural Assets

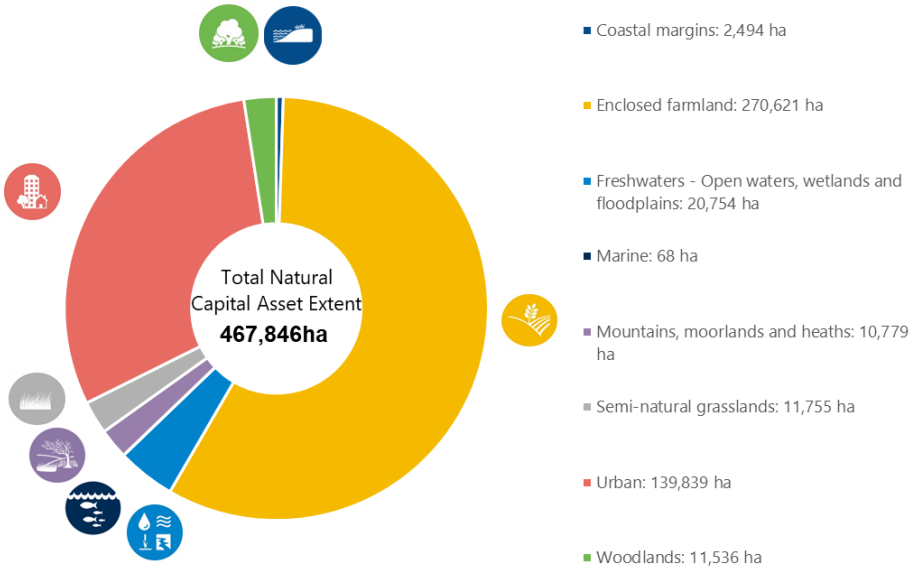


Figure 8. Scorecard example – Risk register

Level of pressure categories	Description
High	High likelihood the pressure will affect natural asset(s) and high risk of loss of ecosystem service.
Medium	Medium likelihood the pressure will affect natural asset(s) and medium risk of loss of ecosystem service.
Low	Low likelihood the pressure will affect natural asset(s) and low risk of loss of ecosystem service.
None	The pressure is not expected to affect the natural asset(s) nor ecosystem service.
No data	No data available to assess likelihood of pressure and affect on natural asset(s) nor ecosystem service.
Not assessed	Risk rating not completed
	No viable benefit-asset attribution

	Natural capital assets (NEA Broad habitat type)							
Ecosystem Services Group	Coastal margins	Enclosed farmland	Freshwaters - Open waters, wetlands and floodplains	Marine	Mountains, moorlands and heaths	Semi-natural grasslands	Urban	Woodlands
Agriculture		High			Medium	Medium		
Fish and shellfish landings	Medium			No data				
Water supply			High					
Timber								High
Renewable energy		High	High		Medium			
Climate regulation	Medium	High			Medium	Medium		High
Air quality	Medium	High	High		Medium	Medium		High
Hazard regulation								
Recreation	Medium	High	High		Medium	Medium	High	High
Physical Health	Medium	High	High		Medium	Medium	High	High
Education		High	High		Medium	Medium	High	High
Volunteering		High	High		Medium	Medium	High	High
Water quality		High	High		Medium	Medium	High	High

Prioritised drivers of change	Description
Example driver 1	0
Example driver 2	0
Example driver 3	0

Figure 9. Scorecard example - River length by ecological status

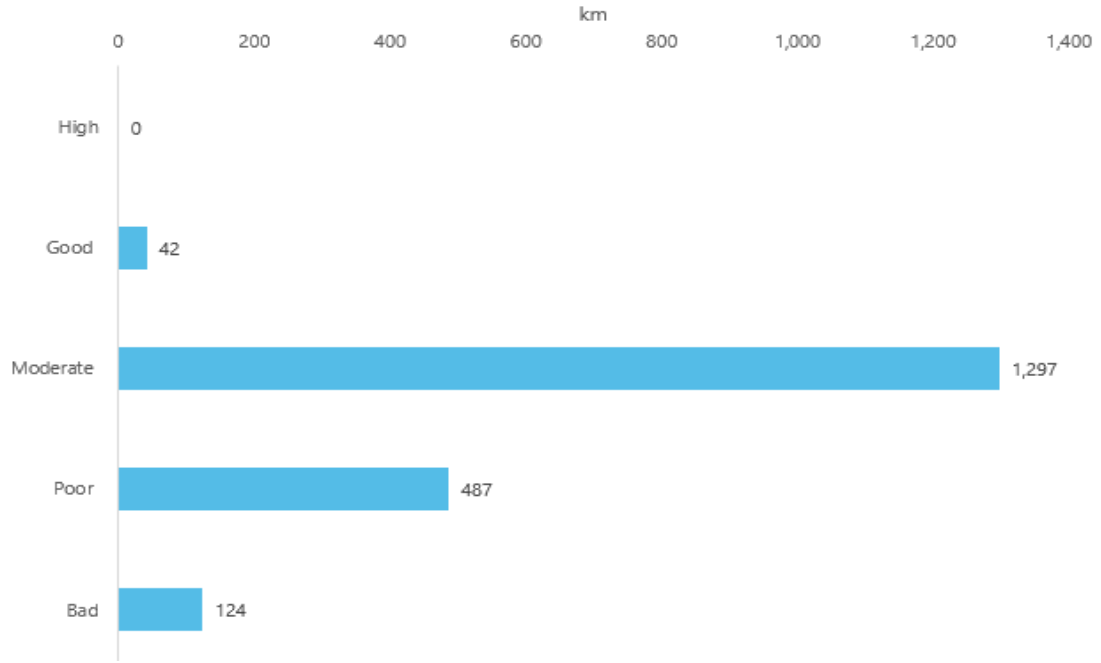


Figure 10. Scorecard example – ecosystem services

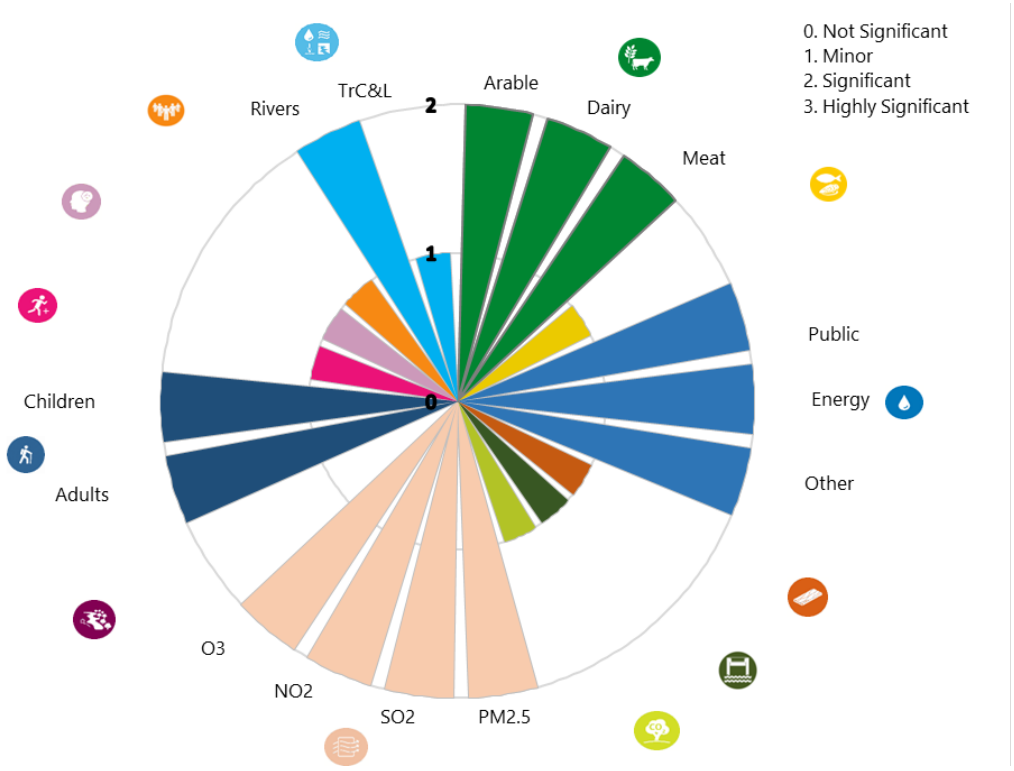


Figure 11. Scorecard example – Benefits

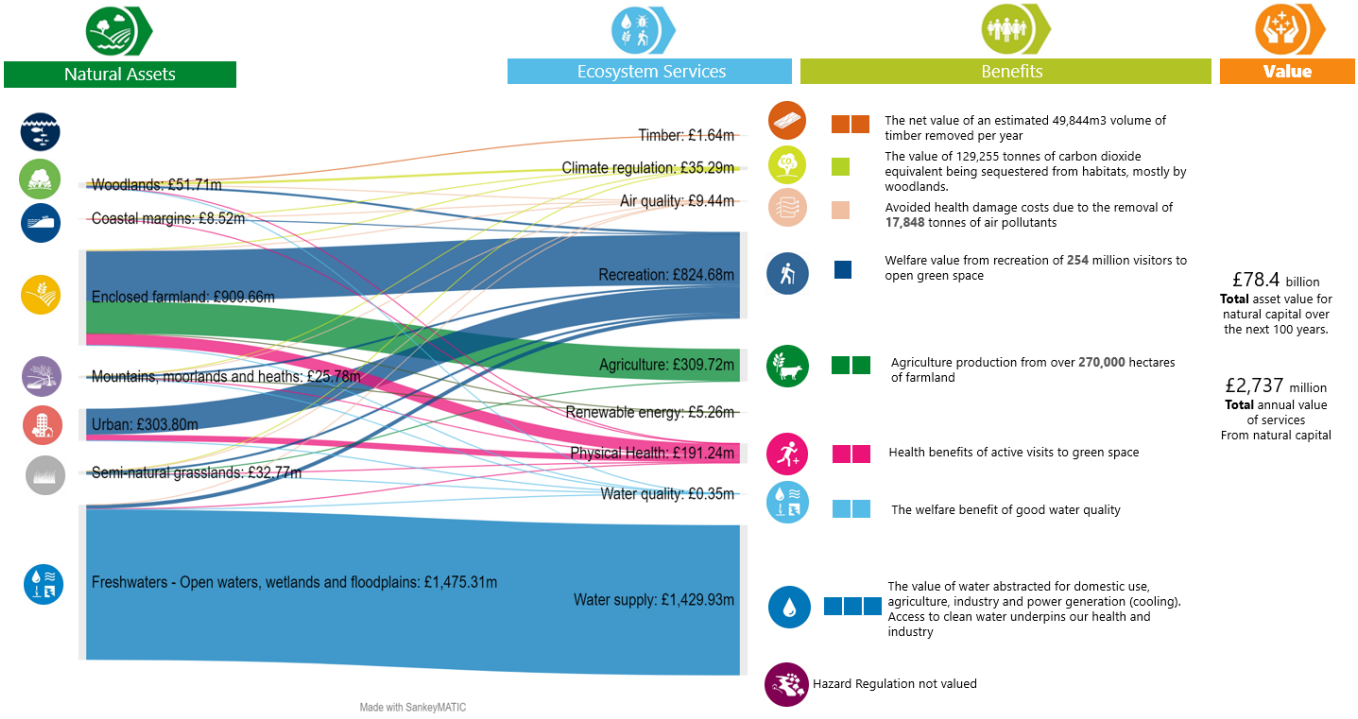
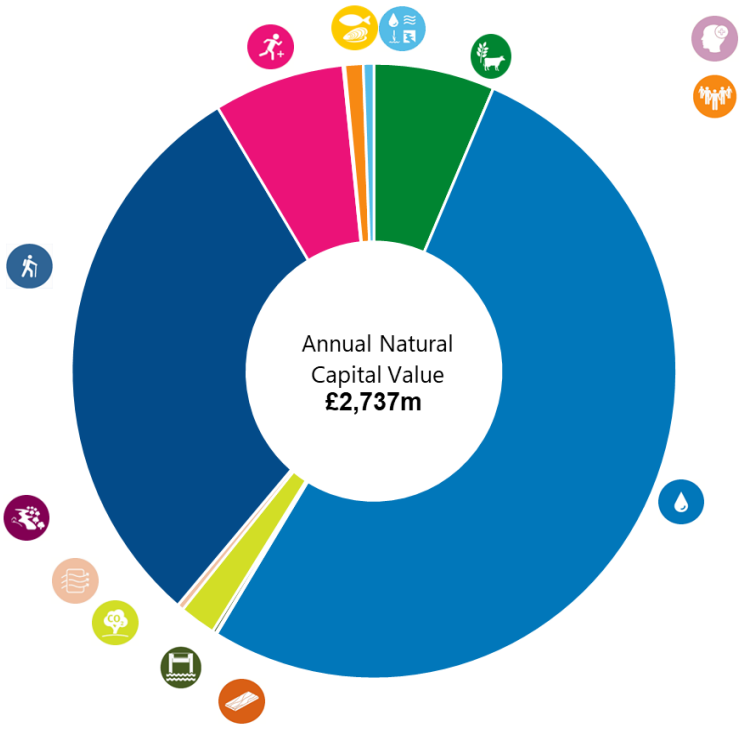


Figure 12. Scorecard example – Value of natural capital benefits



- Agriculture: £177m
- Fish and shellfish landings: £0m
- Water supply: £1,430m
- Timber: £2m
- Renewable energy: £5m
- Climate regulation: £53m
- Air quality: £9m
- Hazard regulation: £0m
- Recreation: £825m
- Physical Health: £191m
- Education: £3m
- Volunteering: £27m
- Water quality: £15m

Interpreting the values

This section provides details of the updates that been made from NCRAT version 1.1 and provides full descriptions of all metrics as now covered in the tool. The processes and calculations behind the outputs are laid out according to each of the ecosystem services covered by NCRAT. The Environment Agency wants NCRAT to be transparent with regards the reference values, data sources and methods used, and by doing so promote greater standardisation across the discipline.

You will find discussions on the feasibility of including other ecosystem services and benefit calculations, including recommendations for future revisions of NCRAT, in Annex 2 below. We welcome further contributions to these discussions and if you would like to provide feedback, please contact us at NaturalCapital@environment-agency.gov.uk.

Updates from Version 1.1

The updates included in this version of NCRAT (version 1.2) have been based on user feedback and recommendations from third party reviews commissioned by the Environment Agency in 2022 (unpublished). The changes made to the workbook include:

- Updating current values, references and methods
- Incorporating new metrics/methods
- Expanding the scope of the ecosystem services included

Any decision on whether to implement specific revisions in NCRAT has been made considering:

- User feedback on functionality
- The conceptual underpinnings of the natural capital approach and the logic chains for each ecosystem service calculation
- Preference for consistent data sources and quantification/valuation approaches within each ecosystem service category and sub-category
- Updating data sources to the latest available evidence and corresponding guidance.

A summary listing of the changes is shown in table 3 below.

Table 3. What has changed from version 1.1 to version 1.2

Element of NCRAT	Version 1.1	Version 1.2
Input tab – place description	Contains range of input cells for user to put in the essential information to define their place	Added a new input cell to allow users to set the price year for the account generated. This feeds through to the unit value look-up tab and inflates all monetary values to the selected price year across NCRAT.
Input tab - Asset Register – habitat classification and habitat data sources	Sets out UKNEA habitat classifications with suggestions for using a mixture of remote-sensed Corine Land Cover data and other habitat data sources	Retains UKNEA and adds UKHab classification system (for increased resolution). Retains option for using Corine Land Cover data and expands range of other habitat data sources. Provides option for asset register to include more detailed habitat data gained from ground-based survey methods.
Input tab - Asset Register – habitat condition	Provides for input of habitat condition data for peatland, woodland, waterbodies (including All surface waters, Rivers, TraC waters, lakes, and Groundwater), water availability and abstraction, bathing water status and SSSIs	‘Surface waters’ removed as wholly overlaps with the other waterbody data inputs. Additional options added to cover condition of statutory and non-statutory protected areas and blue green space.
Input and Output tabs – Natural Capital Risks	Provides for input of 6 ‘pressures and drivers for change’ against quantity and quality of each of the 8 UKNEA broad habitats. Output reported on ‘NC Assets’ tab as an aggregated pressure rating, one for quantity and one for quality, for each broad habitat	Input essentially unchanged but table transposed to align with Natural Capital Committee’s approach. User guidance clarified and ‘No data’ option added to distinguish from ‘None’ (i.e., no impact). Added a new option for user to input custom-defined drivers for change. A (hidden) process introduced to generate a more comprehensive risk register output table. Showing risks to each major ecosystem service for each broad habitat (where valid relationships exist).

		Provides a more detailed view of the risks and pressures. More closely aligns with Natural Capital Committee approach.
Input tab – local values	Provides for optional user override of default values for physical and monetary flows for ecosystem service 'measures'.	Added a new option for user input of shellfish landings. Added new options for user input for onshore wind power generation and solar power generation added.
Process tabs	18 Process tabs The process tabs are where the calculations are located. Each shows the logic chain for the calculation and includes embedded reference values.	All calculations and reference values reviewed and updated where appropriate: Food – crops and livestock - changed to now use 5-year average for gross margins (from Nix) due to wide fluctuation in values over time. Food – fish – updated with latest MMO and ONS values Food – shellfish – user input for landings added, ONS values now capture both fish and shellfish, hence now shown as combined in output. Water supply - public – updated resource rent unit value using latest ONS figures Water supply – energy generation – new process tab created but no significant changes to outputs; this anticipates further development in licence details to enable distinction of 'other' industrial uses of water from cooling uses. Timber – updated values from ONS (flow) and Forest Research (monetary). Renewable energy – hydropower, wind and solar - updated load factors and now using a 5-year average for the respective resource rent unit values. A space now added for PV calculation and added to logic chain. Climate regulation – no significant change. Embedded reference values moved to new 'unit

		value lookup' tab. Non-traded carbon look-up tab updated to use annual value for the selected price year, aligned with BEIS assumptions on forecasting values, and option offered to user to select central, low or high unit values. Hazard regulation – woodland - updated water storage values and moved to unit value look up tab. (placeholders added for arable, shrub and semi-natural grassland). Hazard regulation FC – [other habitats] – new tab created but not used – acting as a placeholder for inland wetlands and coastal wetlands in anticipation of gaining agreement Quality of water – no significant updates – awaiting release of 2022 WFD ecological and chemical status data. Will update these as soon as released. Quality of Air – reference values for PM2.5 removal updated and moved to unit value look-up tab. A new inflation calculator created to accommodate users being able to set account price year Recreation – embedded reference values moved to unit value look-up tab. Formulas amended to take account of user input of monetary values in respect of background inflation calculation (i.e., background inflation calc switch off for this process). Health – embedded reference values moved to unit value look-up tab. Proportion of recreation visits assumed to be 'active' amended from 43% to 51.5% to reflect White et al. 2016 as cited in ENCA Education – embedded reference values moved to unit value look-up tab

		Volunteering – embedded reference values moved to unit value look-up tab
Reference tabs and look-up tabs	8 ‘other data’ and reference tabs	Unit Value Lookup tab added as reference point – makes updating easier, reduces risks of systemic formula errors GDP deflator tab revised and updated with latest HMT GDP deflators. This is now used to calculate monetary values according to user-input price year.
Output tab – benefits statement	13 main ecosystem services covered, subdivided to 22, of which: 20 physical flows quantified (no physical flows for water quality of rivers or for ‘TraC and Lakes’) 20 monetary values calculated (no monetary valuation for water supply for energy generation or for recreation by children)	13 main ecosystem services covered, subdivided to 22, of which: 20 physical flows quantified. Same as v1.1 but note change of description of physical flow for flood risk reduction; now described as ‘annual volume of potential flood storage by woodlands’ 19 monetary values calculated. As per v1.1 but with removal of monetary valuation for flood risk reduction by woodland as replacement cost is contested.
Supporting documentation	User Guide created Technical Report created Scorecard template created	User Guide and Technical Report extensively updated to reflect technical updates and to meet requirements for publication on gov.uk. Quick Start Guide created to help new users get started.
Data support package	Refers EA users to National Once Data Package (not published) for water supply, hydropower and recreation data.	Updated data support package for EA users (not for publication). Semi-automatically generates water supply, hydropower and recreation data as well as place and place description data for any EA Area, catchment, local authority.

Agriculture

Agricultural production within a place (i.e., within an account's boundary) is from the natural assets of 'enclosed farmland', 'semi-natural grassland' and 'mountains, moorlands and heath'.

The physical flow of services is based on default assumptions from the John Nix Pocketbook for Farm Management on the average yield for five agricultural goods (feed wheat, milk, beef, lowland sheep, upland sheep) that are estimated to be produced from those natural assets (see table 4). Note: the John Nix Pocket book is updated annually and the 52nd edition was the current edition at the time of preparing NCRAT version 1.2.

The economic values are also based on the John Nix Pocketbook and the default gross margins take into account deductions of variable costs from the sales value. The final values exclude fixed costs (such as farm overheads) and allowances for unpaid farm labour and the use of fixed capital assets (e.g., farm machinery) and any subsidies. They also exclude the wider potential environmental costs of agriculture (for example, release of carbon through machinery used).

The values for agriculture are a default part of the account (table 4), generated when habitat quantity information (as extent in hectares) is entered into the natural capital asset register. The default calculations for agricultural land types and product flows and value can be manually altered (in 'Input – Local Values' tab) to make the valuations more bespoke for the user's defined place. In the output statement, values are given for yield of arable production of wheat, yield of dairy production (milk), and yield of livestock production (meat – beef and sheep).

Table 4: Example of habitat extent information to show default assumptions for agricultural outputs in NCRAT (note; this would equate to 'basic' level of data entry and could be overridden by input of 'Local Values')

UKNEA broad habitat	Area (ha)	% Split	Area (ha)	Split of output (%)				
				Wheat	Dairy	Beef	Sheep (lowland)	Sheep (less favoured area)
Enclosed Farmland	20	Arable 50%	10	100%	-	-	-	
		Pasture 50%	10		50%	50%	-	

Semi Natural Grassland	2		2		-	-	100%	-
Mountain, Moorland, Heath	1		1			-		100%

Agriculture metric details

- Description – Agricultural production wheat, milk, beef, lowland lamb, upland lamb from farmland
- Type of valuation - Annual gross margins (net sales revenue minus cost of goods sold)
- Quantity of asset input - Corine land cover data for the place:
    - Enclosed Farmland (ha) (default split of 50:50 into arable and modified grassland)
    - Semi-natural Grasslands (ha)
    - Mountains, Moorlands and Heaths (ha)

- Default assumptions for quantity/flow - Types of agricultural land:

    - Enclosed farmland – 50:50 split between arable and modified grassland
    - Arable – 100% wheat
    - Modified grassland – 50% Dairy, 50% Beef
    - Semi-natural grassland – Lowland sheep share (default 100%)
    - Mountains, Moorlands and Heaths – Upland sheep share (default 100%)

  2019-2022 Average annual yields per agricultural type:

    - Arable – Annual yield – Feed wheat (default: 8.6 tonnes/ha/yr)
    - Based on average yield for feed winter wheat
    - Modified grassland – Annual yield – Dairy cow (default: 17,000 litres/ha/yr)
    - Based on average of 2.1 cows/ha at a yield of 8,000 litres per cow
    - Modified grassland – Annual yield – Beef (default: 543 kg/ha/yr)
    - Based on 1.5 cows/ha (average of spring and autumn calving) at average sales weight of 325kg/calf.
    - Semi-natural grassland – Annual yield – Lowland Sheep (default: 390 kg/ha/yr)
    - Based on average for lowland spring lambing. 9.8ewes/ha at 40kg average sales live weight/lamb.

    - Mountains, Moorlands and Heaths – Annual yield – Upland Sheep (default: 142 kg/ha/yr)
    - Based on 4 ewes with lambs/ha sold at 35.5kg live weight sales/ewe.

- Can you use local quantity/flow data? - Yes

    - Override the default assumption of a 50:50 split between arable and modified grassland by entering detailed habitat breakdown in the 'Input – Asset Register' tab.
    - Override default assumptions for agricultural type (arable/modified grassland/semi-natural grasslands/mountains, moorlands and heaths)
    - Override default assumptions for area by output type (Feed wheat/dairy cow/beef/sheep) and corresponding annual yields, in combination with gross margins.

- Default assumptions for valuation - Physical and Monetary values remain constant over time

- Can you use local valuation data? - Yes

  Possible to override default assumptions for all gross margins, in combination with default assumptions for annual yield.

- Value/unit (2021 prices) - Gross margins for:
    - Feed wheat (default: 800 £/ha/yr)
    - Dairy cow (default: 2,003 £/ha/yr)
    - Beef (default: 131 £/ha/yr)
    - Lowland Sheep (default: 413 £/ha/yr)
    - Upland Sheep (default: -17 £/ha/yr)

- Source(s) - Quantity/flow

    - Yield per hectare: John Nix Pocketbook 49th edition
    - Gross margin per hectare: John Nix Pocketbook 48th to 52nd editions
    - Note: not open-source data, book requires purchase.

- Other studies using this monetary valuation approach - unknown

- Discount factor applied – using standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

In reviewing the method for estimating and valuing the food provision from agriculture, three aspects are significant:

- Availability and topicality of locally based land use data
- Data and methods for producing accurate estimates of physical output
- The method for valuing the contribution of natural capital to this service.

Farm output can vary significantly by area, and a drawback of the approach is the assumption of fixed percentages of output for a given land type (e.g., modified grassland is assumed 50% dairy and 50% beef). Defra publishes data on the Structure of the agriculture industry in England. This includes farmland use and livestock numbers by English local authority area which provides an opportunity to make more use of the locally based information. This data is regularly updated and should give a more accurate estimate of farm output by type for a selected place.

In consultation with the Environment Agency's technical steering group, it was decided that maintaining consistency of land area information with the Corine Land Cover (CLC) inventory data was a priority. In addition, the ability to over-ride default assumptions of agricultural output by land type has been built-in to reflect local information where available.

The annual John Nix Pocketbook (the 52nd edition was the latest available at the time of preparing NCRAT version 1.2) is a widely recognised farm management guide that includes low, medium and high estimates of output, income and costs for a wide range of farming activities presented on a per hectare basis. This facilitates the calculation of output for a place, based on input land area by type. It was also used as the source of gross margin information in the prototype tool. The drawback is that this is nationally based information. Spreads of output are typically in the range +/-15 to 20% around the average output values. Given this narrow range and the limits on accuracy of land use information, and to ensure NCRAT is practical, it was decided to use average values only[1] as a measure of agricultural output in this tool.

There are several possible approaches to calculating monetary values for food provision, and there are significant pros and cons with each. A key consideration is the attribution of value to natural capital compared to other capital inputs. Ideally the aim is to establish a value for the food provision service of agricultural land (i.e., its soil, water and minerals). A

[1] The exception was Mountain Moorland and Heath for which the low value of Least Favoured Area (LFA) grazing was used to reflect the low grazing value of this habitat.

further consideration is the compatibility of the selected approach with other methods such as the UK Office for National Statistics (ONS) natural capital accounts; the ONS accounts have generally favoured a resource rent approach for provisioning services.

The main approaches considered are discussed as follows:

- The resource rent approach calculates the value attributable to natural capital by taking gross farm sales and deducting costs of other capital inputs such as direct input costs (e.g., fertilisers), labour (including an allowance for unpaid farm labour) and manufactured capital (e.g., an expected return on farm assets such as harvesting machinery). Under the UK market conditions, this usually means that food production will most likely be assigned a negative overall value in an account. Based on the Farm Business Survey (FBS) data, typically only dairy has a positive residual value after subtracting all other input costs. This reflects the economic reality that most farm enterprises related to food production do not generate positive returns without public subsidy. One possible solution is to reconcile this is by simply reporting net zero value on the benefits statement. However, this ad-hoc adjustment is questionable since it is then a departure from the principles of the resource rent approach
- Gross margin is calculated by deducting variable costs from sales value, and hence excludes fixed costs (such as farm overheads) and allowances for paid and unpaid farm labour and the use of fixed capital assets (for example, farm machinery). This provides an indication of the value of farm output and avoids the case of negative values for natural capital. This is the method used in this tool.

Reporting negative values for natural capital benefit flows (or alternatively arbitrary allocations of zero value) will likely be unhelpful as it will not recognise the dependencies on natural capital assets and will be difficult to communicate for stakeholder engagement. If NCRAT is to be used for EA's conversations with farmers and other land managers, an approach that is more relevant to them will need to be adopted. Consequently, for reasons of pragmatism and engagement, it was decided to use the gross margin method to value the benefits of food provision in NCRAT.

Two possible sources of gross margin data were considered: the John Nix Pocket Book and the FBS[2]. FBS provides regional data for eight English regions and for nine farming

[2] There is a difference in the intended use of the John Nix Pocketbook and the FBS data. 'Nix' tends to be for consultants and is predictive in terms of the values it uses; it takes into account various sources of data, including FBS data, to estimate the likely values for the year of the pocketbook (the ABC Budgeting and Costing Book is an alternative source to Nix). By comparison, Defra's FBS data is financial survey of farm businesses that provides

types[3] based on annual survey data. One potential drawback with FBS regional data is that sample sizes can be small, sometimes only a handful of farms by type. It is possible to extract/create data at the national level (England level) either by (i) combining the regional reports and weighting the data according to the sample numbers to create a weighted average across all regions; (ii) requesting the data from the FBS (it is open-source data so this should be a formality); or (iii) using the tools provided by the FBS website to collect the gross margin data at the England level. However, it was accepted that at a national level, sample sizes are usually over a hundred farms which should provide more accurate results and the John Nix Pocketbook draws upon FBS data at a national level as well as other sources. As this information is consistent with physical estimates the decision was to use the John Nix Pocketbook gross margins in this tool, and as UK market prices can vary significantly from year to year, it was further decided that a five-year average of gross margins (for the years 2018-22) for the selected agricultural output categories would be used.

Overall, the approach taken to updating the agriculture benefit calculations is intended to make the inputs simple and easy to apply, the results sufficiently accurate for engagement with local stakeholders and the values possible to update annually.

Fish and shellfish landings

This is the estimated market value of marine fish and shellfish landings from local boats – a provisioning service by the marine asset within a place (table 6).

The physical flow for fish and shellfish landings is not a default part of the account. To create a flow and value for landings in the account, local data (tonnes of sea fish and/or shellfish landed) must be entered into the 'Input – Local Values' tab. The recommended source for fish/shellfish landings per port is: Marine Management Organisation (MMO) (2021) UK sea fisheries annual statistics report 2020 (and its updates).

For the economic value, NCRAT (v1.2) uses data from ONS (2022) natural capital account reports, averaging values from 2016 to 2020 of net profit for fish and shellfish landings across the UK. This gives the net average annual profit of £219/tonne landed in 2021 prices.

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a rich seam of data on different aspects of the farm in England for government statistics (Allan Butler, pers. comm. 2020).

[3] Farm types are; cereals, general cropping, horticulture, dairy, lowland grazing, less-favoured area (LFA) grazing, mixed, pigs and poultry.

From ONS natural capital accounts methodology guide (2022): “Valuations are calculated using net profit per tonne (landed) estimates, provided by [Seafish.org], for different demersal, pelagic and shellfish species. Net profit per tonne is calculated using [Seafish.org] economic estimates for fleet segments and 2013 to 2014 MMO data on landings by stocks (landed value and landed weight) and landings by stocks and species (in cases where species are not managed by total allowable catches). Annual net profit per tonne (landed weight) is multiplied by tonnes of fish captured (live weight) for a specific species. This data is aggregated for overall annual valuations of fish provisioning from the UK EEZ.”

The calculation here excludes: the value of fish farming and recreational fishing. In addition, the method uses landings data only from boats less than 10m length as these are the boats that fish locally. Larger vessels are likely to have caught fish from much further away and so would not reflect the value of natural capital in the place.

Fish and shellfish landings metric details

- Description - Fish and shellfish landings – Estimated market value of marine fish and shellfish landings from local boats (of less than 10 m in length)
- Type of valuation - Net profit
    - Net average annual profit from annual volume of fish and/or shellfish landings
    - A proxy for resource rent as it deducts fishing costs from sales value
- Quantity of asset input - For vessels less than 10m in length:
    - Sea fish landed (tonnes/year) and Shellfish landed (tonnes/year) within the place for which the account is prepared
- Default assumptions for quantity/flow - Physical flows remain constant over time
- Can you use local quantity/flow data? - Yes – default data not available. Suggested source; use the latest MMO (2021) UK sea fisheries annual statistics report 2020.
- Default assumptions for valuation - Monetary values remain constant over time
- Can you use local valuation data? - No – fixed value within the account
- Value/unit (2021 prices) - £219/tonne landed
- Source(s) - ONS (2022) UK natural capital accounts: 2022
- Other studies using this approach – ONS (as above)
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

For maritime areas, the interactions between the terrestrial catchment and the support it provides to marine fish stocks may be significant. However, given the other factors that affect fish stocks and fish catch, it is not possible to attribute the full value of marine fish landings to the value of spawning grounds within the place for which the account is prepared. For local fish landings, fish landed at any given port may be caught at a considerable distance from the local area. However, if the landings are from smaller UK vessels (under 10m) then they would more likely be from a smaller area of coastal waters, with a closer correlation to the support of terrestrial catchment. As a simple guidance rule, it is recommended that only catches to local ports from UK vessels under 10m are included in the account.

Therefore, provision has been made in NCRAT to input local fish landings to local ports. This tonnage is inputted by the user and is valued at the net average annual profit of £219/tonne in 2021 based on time series from ONS (2022) natural capital accounts.

Water supply

The water supply service within the account represents the provision of water by the natural assets (groundwater/rivers and streams). The quantity or flow of water is expressed as a proportion of the annual licensed abstraction of water within the place (the account boundary).

The account captures physical flow of water for public use and consumption (public water supply), for energy generation (hydropower), and for other uses including agriculture and industry (table 5).

Within NCRAT's calculations all the licensed quantities are adjusted for average *actual* abstraction. This adjustment is based on difference ratios from 2016-2018 using Defra water abstraction statistics (2022) for actual abstraction compared to licensed abstraction (table 5 below). The values for each type of water use are based on the unit value of water abstraction for production of public water supply (2021 prices).

Table 5. Water uses

Public water supply	0.62	Ratio	Average (2016 to 2018) actual abstraction 5,320Mm^3 divided by average (2016 to 2018) licensed abstraction 8,589Mm^3.

Hydropower generation	0.26	Ratio	Average (2016 to 2018) actual abstraction 8,016Mm^3 divided by average (2016 to 2018) licensed abstraction 30,334Mm^3.
All other water uses	0.19	Ratio	Average (2016 to 2018) actual abstraction 2,718Mm^3 divided by average (2016 to 2018) licensed abstraction 24,937Mm^3.

The quantity of water is not a default part of the account or linked to the asset register. To create a flow and value for water supply in the account, local data (amount of licensed water abstracted (m3/yr)) must be entered into the 'Input – Local Values' tab[4]. NCRAT then provides a value for water provision, based on the valuation criteria listed in the following section.

Water supply metric details

- Description - Water supply - The value of water abstracted for public supply and abstraction by agriculture and industry. Water supply used for hydropower generation (i.e., electricity generation) is estimated in physical terms, but not valued
- Type of valuation - Resource rent approach
- Quantity of asset input - Licensed abstraction within the place (m^3/yr)
- Default assumptions for quantity/flow
    - Volume of licensed water abstraction is sustainable and remains constant over time.
    - Abstractions <20m^3 do not need a licence.
    - National (England) ratio of actual abstraction to licensed water abstraction is representative of all catchments in England
- Can you use local quantity/flow data? - Yes – no default data provided. Abstraction licence data needs to be requested from the Environment Agency
- Default assumptions for valuation
    - Water abstracted in the place but 'exported' to beneficiaries outside should be included in the account.
    - Water abstracted outside but 'imported' to be used in the place should not be included in the account.

[4] Data for water abstractions by type of use for both ground and surface water abstractions has to be requested from the Environment Agency. Please refer to the User Guide.

    - Monetary values (i.e., unit resource rent value) remain constant
- Can you use local valuation data? - No, fixed valuation data is in the account
- Value/unit (2021 prices)
    - Average water supply resource rent value 0.67 £/m^3 for public water supply.
    - £1.52 (min £0.21 max £2.83) per m^3 for water abstraction for 'other' including industry.
    - No value applied to water abstraction for hydropower generation – a reliable value is difficult to determine due to significant changes in the electricity generation mix
- Source(s)
    - Public water supply - ONS (2022) UK natural capital accounts: 2022.
    - For 'other' uses including industry, Stantec (2019) 'A natural capital assessment of groundwater for the EA'. Appendix C 'Valuation of provisioning services' p.72.
    - Original source WS Atkins and Cranfield University (2000) published 2002, p.30-31. Optimum Use of Water for Industry and Agriculture Dependent on Direct Abstraction Best Practice Manual. WS Atkins Ltd & Cranfield University. R&D Technical Report W157
- Other studies using this approach – ONS (as above)
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

For the purposes of defining the account boundary of water supply, it is important to reflect on the approach to defining the geographical boundary of the place for which the account is prepared:

- Water abstracted within the place but 'exported' to beneficiaries outside should be accounted for (i.e., water transfer, or public water supply for the distribution network)
- Water abstracted outside the place but 'imported' to be used in the place should not be included in the account.

This follows the key rule of attribution also used in national accounts and hence accounts should not be used to show the 'water footprint' of the activities in the place (which may involve importing water).

In effect the default assumption in NCRAT is that the natural asset is located at the abstraction point. On average this may be a fair representation of the dependency on water availability and abstraction within the catchment, but this assumption must be

carefully considered. Local level insight may be needed in instances where abstraction points are located outside of the account boundary, but the resource (for example, surface water or groundwater) is predominantly situated within the boundary. This needs to be judged on a case-by-case basis and will require the user to make informed adjustments to data inputs.

The Environment Agency is the only source of nationally available data on water abstraction, and hence it remains the data input for version 1.2 of NCRAT. Publicly available reports using this data are too high-level for use in NCRAT, with annual abstraction estimates for England only disaggregated to EA regional charge areas by source and purpose (Defra water abstraction statistics). Data at a catchment level are not published given the sensitivity of potentially identifying individual large abstractors.

Evidence on the value of abstracted water for different sectors is varied. Research into the value of public water supply is extensive, whilst the reliability of estimates for other uses is questionable given the age of the source studies and their transferability to different local contexts. In principle, the value varies by use, location (e.g., the availability and quality of water supply), local factors (characteristics of abstractors), and time (e.g., dry or wet years).

There is a choice of valuation methods. The ONS (2022) Natural Capital Accounts use a resource rent method for estimating the value of water supply, whilst other evidence sources can be used to apply a replacement cost approach. There has been some critique (unsourced) of using resource rent value as not representing the true value of water as provided by nature as in reality it reflects the costs of water company actions.

The resource rent value from ONS UK natural capital accounts 2022 is used in NCRAT and is based on calculations for the water collection, treatment, and supply class (SIC 36). This captures water supply, “process of treating water and rents in industrial applications” as per ONS UK natural capital accounts 2022. In view of the critique noted above, the resource rent approach should be applied and interpreted with caution in regulated markets. This is because the observed market price may not reflect the genuine exchange value for the good and/or service in question. This would apply to regulated utility sectors in England, such as water. For further guidance on application of the resource rent approach see ONS (2022) technical guidance, UN SEEA (2021) or discussion in Obst, Hein and Edens (2016).

In England, the regulator (OFWAT) sets price caps on water company charges based on allowances for forecast operating costs, capital costs and allowable returns on financial capital employed. These price caps do not include an allowance for the benefits of natural assets. Hence the effective market price is set to recover the costs of financial resources used in water supply only, and not the benefit provided by natural assets. Consequently, the resource rent method which is based on a regulated market value (set to recover only costs and a return on financial capital employed) is likely to understate the benefits of water.

The approach used in this tool is to:

- Use the resource rent estimate from ONS (2022) to value public water supply
- Estimate water abstraction by the energy sector in physical terms but omit monetary value estimates for the present time since a reliable value is difficult to determine due to significant changes in the electricity generation mix. A qualitative assessment can be provided in the Significance Assessment for the role of electricity supply in the chosen place based on local knowledge; and
- Value usage of other sectors based on a reasonable range given the evidence available. Stantec (2019) reports a range of £0.21 to £2.83 per m^3 for different types of food production and agricultural use which in turn was based on the Environment Agency (2018) Groundwater Appraisal Guidance, WS Atkins and Cranfield University study (2000), and UK NEA (2011).

Timber

This value represents the provision of wood and its products (building materials, fuel, paper etc) in a place. Timber is assumed to be from softwood, typically coniferous trees, as opposed to hardwoods, typically broadleaved trees, which may differ in price.

The estimated quantity of timber is taken from the amount of woodland in the place. The total amount of timber removal in the UK[5] (13.7 million m^3) is divided by the total area of woodland in the UK[6] (3.19 million ha) and then multiplied by the area of woodland within the account's boundaries.

The physical flow and value of timber are default parts of the account that are calculated when the total quantity of woodland (extent in hectares) is entered into the asset register.

The value of the timber is calculated by multiplying the quantity by the price of overbark standing [7].

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[5] ONS woodland account: *https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/woodlandnaturalcapitalaccountsuk/2020*

[6] From Forest Research (2022) data - https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/forestry-statistics-2022/1-woodland-area-planting/

[7] Overbark is the volume of wood including the bark. Can be either standing volume or felled volume.

The price is taken from Table 2 of the Forest Research timber price indices and calculated as the average of the 2021 real price for the period March 2016 to September 2021. Note that this relates to the Coniferous Standing Sales Price Index for Great Britain and so applies to softwood/coniferous trees as opposed to broadleaves/hardwoods which may differ in price. The price is called 'stumpage' and is a proxy for resource rent as standing sales value reflects the contractors expected felling, distribution and selling costs.

Timber metric details

- Description - Timber - The net value of timber-based products from woodland
- Type of valuation - Stumpage price[8]. Proxy for resource rent as standing sales value reflects the contractors' expected felling, distribution and selling costs
- Quantity of asset input - Quantity based on woodland area (ha)
- Default assumptions for quantity/flow
    - Total volume of timber removals in the UK divided by the total area of woodland in the UK, then multiplied by the area of woodland in the account boundary
    - Physical flows remain constant over time
- Can you use local quantity/flow data? - No
- Default assumptions for valuation
    - Average price of overbark standing - The price of overbark standing relates to the Coniferous Standing Sales Price Index for Great Britain and so applies to softwood/coniferous trees as opposed to broadleaves/hardwoods which may differ in price.
    - Sustainable timber yields harvested - It is assumed that each year the level of timber harvesting is sustainable - that is, the other ecosystem services attributed to woodland (e.g., recreation) are not diminished by harvesting this level of timber and that all the ecosystem services estimated from the woodland in the area are calculated based on this level of timber harvest each year.
    - Monetary values remain constant over time
- Can you use local valuation data? - No
- Value/unit (2021 prices) - Average price of overbark standing - £30.5 £/m^3
- Source(s) - Timber value - Forest Research (2022). Timber Price Indices. Available at: https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/timber-statistics/timber-price-indices/

[8] Stumpage is the price a private firm pays for the right to harvest timber from a given land base. It is paid to the current owner of the land.

- Other studies using this approach - UK natural capital accounts: 2022 Office of National Statistics
- Discount factor applied - Standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

Total woodland output (in cubic metres) is calculated according to total volume of timber removals in the UK divided by the total area of woodland in the UK, then multiplied by the area of woodland in the account boundary.

NCRAT uses the standing sales figures (based on the average for the 6 years, 2016-22) from Forest Research (2022). The standing sales value reflects the contractors' expected felling, distribution and selling costs, hence it is a more appropriate proxy for resource rent for the production function of growing timber.

Renewable energy

The service 'renewable energy' is represented by the ability of streams and rivers to provide power and of terrestrial habitats (such as enclosed farmland or mountains, moorland and heath) to support onshore wind turbines and solar fields. This service represents the value of energy available from renewable energy sources already installed within a place. Note that solar panels installed on buildings (i.e., panels on roofs) should not be included in the natural capital assessment for a place.

The installed capacity of renewable generation by source within a place can be taken for each Local Authority from the BEIS Renewable electricity generation tables, (select the tab for the latest year available, and filter for 'hydropower', 'onshore wind' and 'solar').

NCRAT takes the figure for installed capacity and converts it into an annual quantity of energy generated (MWh/yr) by using national load factors for renewable generation by source (BEIS, 2022). The energy generated is valued at the ONS (2022) resource rent value used in the UK natural capital accounts[9].

[9] Electricity generated from hydropower is both measured and valued as part of the renewable energy ecosystem service as it represents the final good provided. Unlike water

The estimated quantity of renewable energy provision within a place is based on the number of installed hydro-generators, onshore wind turbines or solar fields and their total capacity in megawatts[10] as set out in the following section.

Renewable energy metric details

- Description - Renewable energy – Value of installed capacity for hydropower, onshore wind and solar power generation
- Type of valuation - Resource rent
- Quantity of asset input - Local installed capacity (latest available) (MW)
- Default assumptions for quantity/flow - Physical flows remain constant over time
- Can you use local quantity/flow data? - Yes
- Default assumptions for valuation
    - Annual renewable energy production: For a renewable energy source, the capacity installed in the place for which the account is prepared is multiplied by the UK average load factor and the number of hours in the year. Note that NCRAT estimates a 6-year average load factor which is assumed to remain constant over the accounting period.
    - Similarly, the UK average resource rent value (i.e., monetary value) is assumed to remain constant.
- Can you use local valuation data? - No
- Value/unit (2021 prices) - 12.6 - £/MWh
- Source(s)
    - Regional renewable energy installed capacity (2021) (MW)
    - Digest of UK Energy Statistics (DUKES): renewable sources of energy
- Other studies using this approach UK natural capital accounts: 2022 Office of National Statistics
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

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abstraction, where water abstracted for hydropower is an input to the megawatts generated.

[10] Data on renewable electricity by local authority is available here: https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes

Discussion

Renewable energy statistics are available from the Department of Business, Energy & Industrial Strategy (BEIS, 2022), and reflect the generation, installed capacity and load factors from renewable energy.

Climate regulation

The service 'climate regulation' is represented by the ability of habitats to regulate carbon dioxide or carbon dioxide equivalents (CO_2e) from the air, reducing impact on global warming. This method estimates the net tonnes of carbon dioxide sequestered per hectare per year by different habitats (natural capital assets) in a place. The estimated total amount of carbon dioxide sequestered across all the habitats in the place is then valued.

As well as carbon dioxide sequestration from across habitats, NCRAT calculates other greenhouse gas (GHG) sequestration and emissions (in carbon dioxide equivalent terms, CO_2e) by peatland habitat in different conditions. Peatland in near natural condition acts as a carbon dioxide sink and a methane source. Peatland which has been drained acts as a source of both carbon and methane emissions.

Any carbon dioxide equivalent emissions from peatland are offset against habitats that are net sequesters of carbon dioxide. Hence the overall physical carbon dioxide equivalent flux reported in the benefits statement and other outputs within NCRAT is an estimated net sequestration figure.

Climate regulation metric details

- Description - Climate regulation – carbon dioxide equivalent sequestration by habitats
- Type of valuation - Abatement cost (using non-traded carbon value)
- Quantity of asset input (see table 6 below)
- Default assumptions for quantity/flow - Physical flows remain constant over time
- Can you use local quantity/flow data? - No
- Default assumptions for valuation
    - Non-traded carbon value series inflated from 2020 prices to accounting price year set by user.
    - Central non-traded value is default series used in calculations.
    - BEIS (2021) non-traded carbon value series is forecasted to 2050.
    - For carbon values post-2050, follow BEIS (2021) guidance to apply a real annual growth rate of 1.5% each year.
- Can you use local valuation data? - No, but user can decide to apply high or low value series if appropriate.

- Value/unit (2021 prices) - £/tonne (non-traded price of carbon in 2021 prices) from BEIS 2021. Note: these values reflect 2021 price year for the purpose of this reporting
    - Low 123
    - Central 245 (default value used in NCRAT)
    - High 368
- Source(s)
    - BEIS (2021). Valuation of greenhouse gas emissions: for policy appraisal and evaluation. Annex 1: Carbon values in £2020 prices per tonne of CO_2. Available at: https://www.gov.uk/government/publications/valuing-greenhouse-gas-emissions-in-policy-appraisal/valuation-of-greenhouse-gas-emissions-for-policy-appraisal-and-evaluation
    - Gregg et al. (2021). Carbon storage and sequestration by habitat: a review of the evidence (second edition) Natural England Research Report NERR094. Natural England, York. Available at: http://publications.naturalengland.org.uk/publication/5419124441481216
    - Christie et al. (2011). Economic Valuation of the Benefits of Ecosystem Services delivered by the UK Biodiversity Action Plan. Available at: http://users.aber.ac.uk/mec/Publications/Reports/Value%20UK%20BAP%20FINAL%20published%20report%20v2.pdf
    - Original sources quoted in Christie et al. (2011) for woodland carbon sequestration values:
    - Brainard, J., Bateman, I.J., Lovett, A.A., 2008 (actually 2009). The social value of carbon sequestered in Great Britain's woodlands. Ecological Economics In Press, Doi:10.1016/j.ecolecon.2008.08.021.
    - Bateman, I.J. and Lovett, A.A. (2000). Estimating and valuing the carbon sequestered in softwood and hardwood trees, Timber products and forest soils in Wales. Journal of Environmental Management (2000) 60, 301–323. doi:10.1006/jema.2000.0388
    - ONS (2021). Semi-natural habitat natural capital accounts, UK: 2021. https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/seminaturalhabitatnaturalcapitalaccountsuk/2021
    - Forestry Commission (2017). Woodland Area, Planting and Publicly Funded Restocking. Available at: https://www.forestresearch.gov.uk/documents/3176/wapr2017.pdf
    - IUCN (2017). Peatland Code Field Protocol: Assessing Eligibility, Determining Baseline Condition Category and Monitoring Change. http://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/PC_Field_Protocol_v1.1.pdf
    - Original source quoted in IUCN (2017): Smyth, M.A., Taylor, E.S., Birnie, R.V., Artz, R.R.E., Dickie, I., Evans, C., Gray, A., Moxey, A., Prior, S., Littlewood, N. and Bonaventura, M. (2015) Developing Peatland Carbon Metrics and Financial Modelling to Inform the Pilot Phase UK Peatland Code. Report to Defra for Project NR0165, Crichton Carbon Centre, Dumfries.

    - http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=19063&FromSearch=Y&Publisher=1&SearchText=peatland&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description
- Other studies using this approach - ONS 2019 – saltmarsh carbon sequestration values
  ONS 2021 for semi-natural grasslands - woodland carbon sequestration values
  ONS 2019 – peatlands natural capital accounts
  https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapitalforpeatlands/naturalcapitalaccounts
- Discount factor applied - Standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Table 6. Quantity of asset input

Source	Habitat Type	Sequestration or Emission rate (tCO2e/ha/yr) *From literature*	Notes
N/A	Coastal margins	0.000	Assumes zero sequestration. This is consistent with ONS (2019)
Christie et al. (2011)	Enclosed farmland	0.107	Page 106. Table 43. Assumed equal to the "crop" value
N/A	Freshwaters – Open waters, wetlands and floodplains	0.000	Assumes zero sequestration. This is consistent with ONS (2019)
N/A	Marine	0.000	Assumes zero sequestration. This is consistent with ONS (2019)

Christie et al. (2011)	Mountains, moorlands and heaths (Central)	0.675	Page 106. Table 43. Assumed equal to the "bogs and heath" values
	Mountains, moorlands and heaths (Min)	0.450	
	Mountains, moorlands and heaths (Max)	0.900	
Christie et al. (2011)	Semi-natural grasslands	0.397	Page 106. Table 43. Assumed equal to the "grassland" value
N/A	Urban	0.000	Assumes zero sequestration. This is consistent with ONS (2019)
ONS (2021), Semi-natural Habitat natural capital accounts	Woodlands	6.7	National average of broadleaved woodland carbon sequestration calculated from national broadleaved area (1.5 million hectares) and aggregate sequestration (10.08 million tonnes CO_2)
Gregg e al. (2021)	Saltmarsh (Central)	5.190	Page 514. Gives central carbon sequestration rate of 1.4tC/ha/yr (Low 0.64tC/ha/yr, high 2.19tC/ha/yr). These values multiplied by 3.67 (1 tonne of C is equivalent to 1 x (44/12) = 3.67 tonnes of CO_2) as referenced in BEIS. (2019).
	Saltmarsh (Min)	2.350	
	Saltmarsh (Max)	8.030	
	Mudflats (Central)	1.980	Page 152

Natural England Report NERR094 (2021)	Mudflats (Min)	0.400	Page 152
	Mudflats (Max)	3.450	Page 152
IUCN Peatland Code Field (2017)	Actively eroding	-23.84	Page1
	Drained	-4.54	Page 2
	Modified	-2.54	Page 3
	Near natural	-1.08	Page 4

Discussion

The value placed on changes in greenhouse gas emissions has been reviewed by BEIS and updated values released July 2021. These values were added to NCRAT (v.1.1).

Air quality

The service 'air quality' is represented by the ability of habitats to remove pollutants from the atmosphere by absorbing them. The value of this service is based on the avoided costs of avoided health impacts due to the removal of air pollutants.

Jones et al. (2017): "Vegetation provides an air quality regulating service (UKNEA, 2011) by capturing airborne pollutants and removing them from the atmosphere through: (a) the internal absorption of pollutants via stomatal uptake; and (b) the deposition of pollutants on external surfaces such as leaves and bark (Bignal et al., 2004)".

This version of NCRAT values PM2.5 removal by:

i) PM2.5 removal rate and avoided health care cost by local authority (CEH and eftec, 2019)
ii) national average PM2.5 removal rate and avoided health care costs (Jones et al., 2017)

For method i) user of NCRAT can select up to three local authorities in the 'Input – Local Values' tab and use NCRAT's built-in results from an alternative interactive mapping tool, developed by the authors of Jones et al. (2017). Through additional modelling, NCRAT includes estimates of PM2.5 removal per hectare of woodland in each local authority in the

UK with estimated value of the health benefits. For a selection of local authorities, NCRAT multiplies the total woodland area by the relevant physical and monetary unit values.

For method ii) the user of NCRAT only needs to input data on the total woodland area in the 'Input – Asset Register' tab. NCRAT will then apply the national average removal rate per hectare and national average avoided health costs from Jones et al. (2017) to estimate the value of health benefits. This second method is the default approach for the following pollutants:

- Air quality - SO_2 absorbed (tonnes)
- Air quality - NO_2 absorbed (tonnes)
- Air quality - O_3 absorbed (tonnes)

The study (Jones et al., 2017) estimates avoided health costs (life years lost) due to reduced concentrations of air pollutants, where reduction is attributable to vegetation in the UK.

Air quality metric details

- Description - Air quality – Avoided health damage costs due to the removal of air pollutants from the atmosphere
- Type of valuation - Avoided health damage costs (life years lost)
- Quantity of asset input (see table 7 below)

Table 7. Quantity of asset input

Habitat	National default PM2.5 removal rate (tonnes/ha/yr)	SO_2 removal rate (tonnes/ha/yr)	NO_2 removal rate (tonnes/ha/yr)	O_3 removal rate (tonnes/ha/yr)
Coastal margins	0.00045	0.00225	0.00112	0.04067
Enclosed farmland	0.00018	0.00162	0.00130	0.05236
Freshwaters – Open waters, wetlands and floodplains	0.00021	0.00056	0.00021	0.03361
Marine	0.00000	0.00000	0.00000	0.00000

Mountains, moorlands and heaths	0.00023	0.00073	0.00031	0.04483
Semi-natural grasslands	0.00030	0.00119	0.00061	0.04310
Urban	0.00000	0.00000	0.00000	0.00000
Woodlands	0.00606	0.00381	0.00142	0.07390

Source: Jones et al. (2017). Volume of absorbed of each pollutant for each broad habitat type per hectare per year

- Default assumptions for quantity/flow - For each pollutant and based on Jones et al. (2017):
    - It is assumed that each hectare of habitat type abates the same level, at the same value across the catchment; rather than modelling the variable impact/value in different locations, the overall average for each type is used.
    - Removal is forecast to reduce over time as the concentration in the atmosphere falls.
    - For local PM2.5 removal (if local authorities have been selected in 'Input – Local Values' tab):
    - The average rate of PM2.5 removal per hectare of woodland is assumed constant across time and space.
    - The underlying modelling (eftec and CEH, 2019) assumes that removal rates decrease until 2030 to reflect decline in concentration over time. After 2030, removal rates are assumed to remain constant.
- Can you use local quantity/flow data? - For PM2.5: Yes – can use up to three Local Authorities (tab 'Input – Local Values'). Otherwise NCRAT uses the 'national default' from Jones et al. (2017).
  For other pollutants: No – fixed value within the account
- Default assumptions for valuation - The assumption on declining then constant future physical flows drives change in monetary unit values, for both average annual value and average asset value (PV100)
- Can you use local valuation data? - No
- Value/unit (2021 prices) (See table 8 below)

Table 8. Value/unit (2021 Prices)

Total asset value - removal per tonne*	Values** (£/tonne)

PM2.5 (national default)	1,850,632
SO_2	1,503
NO_2	27,566
O_3	3,449

* GDP inflator re-based from 2012 to 2021 (1.15). HM Treasury (2022).

** From Jones et al. (2017). Table S10. Pg. 16. 2015 value. 100-year present value. Includes savings from respiratory hospital admissions, cardiovascular hospital admissions and deaths.

Note that for local PM2.5 removal, average asset value (PV100) per hectare of woodland varies by local authority. Full unit look-up is available in the NCRAT workbook.

- Source(s) - Jones et al. (2017). Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts. Available at: http://nora.nerc.ac.uk/id/eprint/524081/7/N524081RE.pdf
  The values for absorbed PM2.5 are based on total volumes of pollutant capture for 2015 (Table 9 - pg.45) divided by total habitat extent in 2007 which is assumed to remain constant between the two years (Table 7 - pg. 42). Note this source does not provide values for marine or urban habitats.
  Local PM2.5: eftec and CEH (2019). Pollution removal by vegetation. Available at: https://shiny-apps.ceh.ac.uk/pollutionremoval/
- Other studies with valuations (see table 9 below)

Table 9. Other studies with valuations

From Defra ENCA, January 2020	
Jones et al. (2017) for ONS	Estimates avoided health costs (mainly life years lost) from reduced concentrations of air pollutants attributable to UK vegetation. Note that this is a corrected version published February 2019.

ONS (2018)	Builds on Jones et al. (2017) to explore how air pollution removal varies across the UK. Provides an interactive map to enable users to estimate the volume and value of pollution removed by vegetation from any selected region in 2015. Values are estimated as avoided health damage costs per resident, but because of the dynamic spatial nature of the model in some cases is possible that residents of one region may benefit from pollution absorbed in neighbouring regions.
CEH and Eftec (2019)	An alternative interactive mapping tool to ONS (2018) developed by the authors of Jones et al. (2017). Through additional modelling, this tool includes estimates of PM2.5 removal per hectare of woodland in each local authority in the UK with estimated value of the health benefits. Note that values are given in terms of 100-year asset values, rather than annual values. The two must not be confused as they are an order of magnitude different.

- Discount factor applied - for local PM2.5 removal modelling, the health discount rates are applied from HM Treasury (2022):
    - Discount Rate (0 – 30) 1.50%
    - Discount Rate (31 - 75) 1.29%
    - Discount Rate (76 - 100) 1.07%

  For national defaults (all pollutant types) standard social time preference rate (STPR) are applied, as this was the Green Book advice at the time:
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

Defra (2020a) recommends that damage costs are uplifted by 2% each year in real terms in line with average GDP growth. This reflects the assumption that willingness to pay for health outcomes will rise in line with GDP. This is equivalent to the discount rate for health effects being set at 1.5% as set out in the Green Book (p. 103).

Hazard regulation

Note: NCRAT and its outputs are not designed for use in a regulatory context or for flood appraisals.

The service 'hazard regulation' is measured as the potential additional water storage capacity of woodland following the method and results from a paper produced by Forest Research (Broadmeadow et al., 2018). This paper is included in the Defra ENCA service data book (2020).

Broadmeadow et al. (2018) provide average cubic metre per hectare (m^3/ha) unit values based on estimated flood water storage due to woodland water use and floodplain woodland hydraulic roughness. This represents the average potential storage capacity provided by woodland. The assessment scope is limited to woodland in Flood Risk Catchment areas (i.e., not all woodland). The paper assumes that water storage is the least cost alternative to flood damage prevention, and that reservoir construction are the most feasible replacement. However, this remains not monetised within NCRAT, as the flood water storage replacement cost[11] rationale used by Broadmeadow et al. (2018) is not considered robust to be applied across all woodland at scale.

Broadmeadow et al. (2018) sets out a number of limits to its methodology, virtually all of which suggest that its estimation is partial. Hydrological modelling is essential for any estimation of the service provided. In general, flood reduction benefits from this regulating service will vary spatially; in the case of urban stormwater reduced run-off, it is highly localised and dependent upon catchment characteristics. Efforts to improve knowledge of drainage and sewerage challenges are ongoing.

Hazard regulation metric details

- Description - Hazard regulation – Water Storage
- Type of valuation - Ecosystem service is not monetised.
- Quantity of asset input - Ha of woodland
- Default assumptions for quantity/flow
    - The Broadmeadow et al. (2018) Forest Research paper is based on a single study and model.
    - Assume we can use this as the basis for all woodland.
    - The method as a flow chart is on page 4 of the paper.
    - Caveats and assumptions are discussed throughout the paper.
- Can you use local quantity/flow data? - No – fixed within the account
- Default assumptions for valuation
    - Assumes all woodlands in flood risk catchments provide same flood water storage capacity nationally regardless of management.

[11] Reflects the replacement cost of building a reservoir to retain the same volume of water, which is not necessarily the least cost option.

- Can you use local valuation data? - Not applicable – monetary valuation not applied
- Value/unit (2021 prices) – woodlands – 165 m^3/ha/yr (Source: Broadmeadow et al., 2018)
- Source(s) - Valuing flood regulation services of existing forest cover to inform natural capital accounts. Broadmeadow et al. (2018). Forest Research. https://www.forestresearch.gov.uk/research/valuing-flood-regulation-services-existing-forest-cover-inform-natural-capital-accounts/
- Other studies using this approach
    - Unknown for accounts
    - Captured in Defra ENCA services data books' (tab 'flood regulation')

Discussion

The Broadmeadow et al. (2018) approach is described in the ENCA Services Databook (2021) as a "Novel methodology developed to provide indicative national estimates of water regulation services of woodland to inform natural capital accounts. Based on modelling to estimate the potential volume of flood water avoided by woodland ecosystems in flood risk catchments compared to grass cover. Provides spatial breakdown by country and by public / private forest" (Flood regulation tab, Defra, 2021).

For monetary valuation, Broadmeadow et al. (2018) is described (again by ENCA) as adopting "a replacement-cost (rather than [avoided] damage cost) approach to valuing the flood regulation service of woodland by applying annualised average capital and operating costs of flood reservoir storage that would be required in the absence of the ecosystem service. Provides spatial breakdown by county and by public/private forest. The estimates are experimental and indicative" (Defra, 2021).

The monetisation of the estimated water storage capacity, whilst previously included in NCRAT v1.1, is not included in NCRAT v1.2 because of the following limitations of the Broadmeadow et al. (2018) approach:

- It does not account for spatial factors and location of the woodland. The approach assumes uniform effectiveness across a catchment; however, the location of woodland is a crucial determinant of its effectiveness.
- The replacement cost method criteria are unlikely to be satisfied. These are that the replacement should be: (i) a full substitute for ecosystem service it is replacing; (ii) the least cost alternative solution; and (iii) expected to be adopted if the existing service is impaired or lost. Potential issues are that with regards to (i) the water storage function may play little or no role in mitigating flood damage, and with regards to (ii) a range of alternative measures need to be considered in order to establish least cost option for a given location. Both suggest that a replacement cost approach in this instance is likely to be an unreliable proxy for flood risk mitigation benefits.

- Other types of natural capital assets that regulate flow are not included. This is a limitation of the current tool.

Recreation

The value generated for recreation is the estimated welfare value from recreational day visits to accessible green spaces within a place (the boundary of the account).

The method uses the University of Exeter's Outdoor Recreation and Valuation (ORVal) Tool (Day and Smith, 2018), which is a recreation demand model, to estimate the number of visits and the estimated value of those visits. The figure represents the "monetised welfare loss experienced by individuals if they could no longer visit that greenspace"[12]. The supporting technical guidance of the ORVal tool can be found here: https://www.leep.exeter.ac.uk/orval/documents

The ORVal recreational demand model predicts visits based on the location of the recreation asset, surrounding population, habitat type(s) and local alternatives, but makes the assumption that accessible green space is in average condition for its type. Recreation visit behaviour is based on results from Natural England's survey 'Monitor of Engagement with the Natural Environment' (MENE), which captures UK adults (i.e., over the age of 16).

ORVal does not include visits by children under 16. NCRAT includes an estimate of the number of visits that children make to recreational spaces, using an assumed ratio of under 16 visits to the total number of adult visits. This ratio is based on national figures from MENE (Natural England, 2019b). The number of those visits is included in NCRAT but is not easy to establish the welfare value associated with a child's visit to greenspace, and there are some risks of double counting with the value that has been attributed to adult visits (e.g., trip costs). Hence this benefit has only been included as quantitative information within NCRAT's benefit statement and a welfare value is not calculated for visits by children under 16.

Recreation metric details

- Description - Recreation - The welfare value of recreational day visits to open green space
- Type of valuation - Consumer surplus (recreation demand model)

[12] ORVal User Guide, Box 3. P.13

- Quantity of asset input - Use the ORVal tool to select greenspace within the boundary of a place. ORVal estimates the number of visits, split by socio-economic grade, to the selected green spaces.
- Default assumptions for quantity/flow - Physical flows (i.e., visits) remain constant over time.
  ORVal assumes that accessible green space is in average condition for its type.
- Can you use local quantity/flow data? - User must select which green spaces are included within the boundary of their place.
- Default assumptions for valuation - Monetary flow (i.e., welfare value) remains constant over time.
- Can you use local valuation data? - User must select which green spaces are included within the boundary of their place.
- Value/unit (2021 prices)
  - The model is estimated from data collected in the Monitor of Engagement with the Natural Environment (MENE) survey.
  - The Recreation Demand Model that underpins the ORVal Tool is a statistical model that can be used to predict the number of visits that are made by adult residents of England and Wales to different greenspaces.
  - The welfare value from a trip is estimated using a travel cost method. The ORVal User Guide notes that the sum of 25p per km (2016 prices) travelled has been used (average variable car cost plus travel time). As such, ORVal welfare values entered in the 'Input – Local Values' tab are automatically inflated from 2016 prices to the accounting price year set by the user.
  - See https://www.leep.exeter.ac.uk/orval/documents for technical details of the ORVal model.
- Source(s) - Outdoor Recreation Valuation (ORVal), Version 2.0. February 2018. Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter.
- Other studies using this approach - ENCA Services Databook
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
  - Discount Rate (0 – 30) 3.50%
  - Discount Rate (31 - 75) 3.00%
  - Discount Rate (76 - 100) 2.50%

Discussion

The ORVal tool is referenced within government guidance for valuation of environmental impacts including Defra's ENCA (latest release 2022), and the HM Treasury Green Book (2022). NCRAT is also referenced within the UK's Environment Improvement Plan (Defra, 2023). As such, since its release and most recent update in 2018, ORVal remains the most comprehensive available source for predicting visits and associated welfare value to

accessible greenspaces within various spatial breakdowns (for example, single site, to local authority, to catchments).

The ORVal model captures all domestic day visits by adults, in line with MENE, where a recreation visit or a visit outdoors can range from 0-5 minutes to six hours or more. Note that tourism (i.e., overnight trips by non-UK or UK residents) is not included in ORVal and is beyond the scope of the MENE survey. Additionally, the MENE survey has been superseded by Natural England's People and Nature Survey (latest release December 2022). In addition, it should be noted that the data from ORVal takes into account the location of the recreation asset, surrounding population, habitat type(s) and local alternatives, but makes the assumption that accessible green space is in average condition for its type. Where this is not the case, green space with better/ worse condition than average will likely have higher/lower values for number and welfare value of visits.

It is worth noting that the land-use datasets (i.e., GIS data layers in ORVal) do not capture all accessible greenspace. This means that at a local level the natural capital associated with recreation may be under-represented as not all recreation assets are fully captured within the ORVal tool, however at the aggregate scale (e.g., scale for NCRAT) this is not a point of concern. Furthermore, the underlying datasets (spatial, MENE and monetary valuation) are representative of 2016 data, as the modelling inputs have not been updated since the launch of NCRAT. For more technical detail on the ORVal recreational demand model, determinants of predictions, refer to the ORVal supporting documentation.

Physical health

Physical health benefits provided by natural capital assets are valued from the estimated number of active day visits to green space within the account's boundary (table 14). Natural environments provide the context for a large proportion of England's recreational physical activity (White et al., 2016).

To estimate and then value the physical health benefits of active visits to green space NCRAT uses estimates of visits to green space from the University of Exeter Outdoor Recreation and Valuation (ORVal) Tool[13], as entered by the user to estimate recreation benefits. Of total recreation visits, 51.5% are estimated by White et al. (2016) to be 'active' visits with health benefits. Active visits are defined as those that meet the recommended daily physical activity guidelines either fully or partially during visits (i.e., result in 30 minutes of moderate-intense physical exercise).

[13] The link to the supporting technical guidance of the ORVal tool (data inputs and outputs) can be found here https://www.leep.exeter.ac.uk/orval/documents.

Active visits are valued to reflect improvements in 'quality of adjusted life years' (QALYs). Where one QALY is equal to 1 year of life in perfect health[14]. The benefit is valued to reflect the economic value of this health improvement in terms of the avoided treatment cost due to improvement in QALYs. Beale et al. (2007) estimated that regular exercise of moderate intensity, if undertaken 52 weeks a year, would be associated with 0.0106768 QALYs per individual per year[15].

The monetary unit value of a QALY improvement is based on Claxton et al. (2015) who estimate a cost-effectiveness threshold of a QALY to be roughly £12,900/QALY in 2008 prices. This figure is used as a proxy for health costs, reflecting the avoided healthcare costs when a QALY is improved by one unit[16]. The cost-effectiveness threshold per QALY is adjusted to reflect the avoided treatment cost per active visit using the assumed number of QALYs improved per individual per year from Beale et al. (2007). Based on this information, the avoided health cost is estimated as £3.39 per visit in 2021 prices.

Physical health metric details

- Description - Physical health - health benefits of active day visits to green space
- Type of valuation - Avoided treatment cost
- Quantity of asset input - Using the ORVAL tool to highlight greenspace within the boundaries of the account. NCRAT estimates of the number of visits, split by socio-economic grade, to the green spaces
- Default assumptions for quantity/flow
    - 51.5% of all recreational visits are 'active' visits
    - All active visits are defined as "made at least one, 30-minute active visit (equal to or more than 3 METs (Metabolic Equivalent of Task)) to natural environment in the previous week"
    - It is assumed:

        a) at the individual level that the visit described for the previous week is representative of average visits made by the individual to urban natural environments all the time

[14]From: https://www.nice.org.uk/glossary?letter=q

[15] An 'active visit' is defined as those who met the government recommended daily physical activity guidelines either fully, or partially, during visits.

[16] Note because health benefits are in terms of avoided treatment cost – rather than the welfare gain to individuals – there is no double-count with recreation benefits. See ENCA (2020) for further discussion.

b) that at the population level, last week is representative of all weeks in the year

- These assumptions are bolstered by
  a) the random selection of a visit in the last week (from all visits mentioned by the individual) to be described in detail
  b) data collection at the population level being during every week of the year

- Can you use local quantity/flow data? - User defines and selects which green spaces are included within the account in ORVal (i.e., those within the boundary of their place).
- Default assumptions for valuation
  - Based on analysis of Health Survey for England data; 30 min/week of moderate-intense physical activity, if undertaken 52 weeks a year, this would be associated with 0.0106768 QALYs avoided per individual, per year. Beale et al. (2007) also assume that the relationship between physical activity and QALYs is both cumulative and linear
  - Monetary unit value remains constant over time.
- Can you use local valuation data? - No
- Value/unit (2021 prices), see table 10 below.

Table 10. Value/unit (2021 prices)

Description	Source	Values
QALYs gained from sustained additional visits of physical activity (each week over the course of a year)	Beale et al. (2007)	0.0106768 QALY/visit
Number of weeks in a year	N/A	52.14
Cost effectiveness threshold of a QALY (2021 prices)	Claxton et al. (2015)	£16,540 /QALY
Resource value as cost of treatment avoided due to per visit (2021 prices)	Calculation	£3.39 /visit

- Source(s) –
  - Outdoor Recreation Valuation (ORVal), Version 2.0. February 2018. Land, Environment, Economics and Policy (LEEP) Institute, Business School, University of Exeter. https://www.leep.exeter.ac.uk/orval/documents.

    - White, M., Elliott, L., Taylor, T., Wheeler, B., Spencer, A., Bone, A., Depledge, M. and Fleming, L. (2016). Recreational physical activity in natural environments and implications for health: A population based cross-sectional study in England. Preventive Medicine, 91, p.383-388. https://www.sciencedirect.com/science/article/pii/S0091743516302298
    - Beale et al. (2007). An Economic Analysis of Environmental Interventions that Promote Physical Activity. https://www.nice.org.uk/guidance/ph8/documents/economics-modelling2
    - Claxton et al. (2015) Methods for the Estimation of the NICE Cost Effectiveness Threshold, Health Technology Assessment Volume: 19, Issue: 14, Published in February 2015. https://www.journalslibrary.nihr.ac.uk/hta/hta19140/#/abstract)
- Other studies using this approach - UK natural capital accounts: 2019 Office of National Statistics – should be noted that ONS have updated their approach to valuing recreation and physical health in the latest UK Natural Capital Account (2022).
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

Economic evidence that directly links natural assets with changes in level of physical activity is limited.

Physical health is evaluated on the basis of the improvements in quality adjusted life years (QALYs) of those whose recreational visits are physically active. A unit improvement in a QALY is valued as the avoided healthcare cost per unit. The advantage of this approach is that recreational input data already taken from ORVal can be used to estimate physical health benefits. As ‘estimates of active visits’ is apportioned from recreation visits based on ORVal estimates, the same caveats apply. This includes the scope of the ORVal tool, in particular that the visiting population refers to domestic day visits (i.e., overnight trips by non-UK or UK residents are not included). For discussion on ORVal see the section on ‘Recreation’ above.

The benefit is valued as the health benefits of active recreation (in terms of improvements in Quality Adjusted Life years – QALYs[17]) and the economic value of health improvement (in terms of the avoided health cost due to improvement in QALY). Claxton et al. 2015 estimate a cost-effectiveness threshold of a QALY to be roughly 12,900 per QALY. This value is used as a proxy for treatment costs, reflecting the avoided health costs when a QALY is improved by one unit (i.e., NHS resource adds one QALY to the life of an NHS patient).

Education

The value for 'education' is valued by "the costs incurred over and above those costs incurred in gaining knowledge that would be provided within a normal classroom environment" (Mourato et al*., 2*010*).* The value is not the estimated welfare value from educational visits to nature reserves.

For the example provided, the 51,725 children who visited RSPB nature reserves in 2009-2010, the total investment expended by schools ranged from just under £850,000 to just over £1.3 million. See table 11. NCRAT uses these figures as an indicative cost per student, per visit.

This method uses a transport cost (to parents) and time-cost (of students) and figures from Mourato et al. 2010 to estimate an opportunity cost for the educational visits. The costs of the trips to parents, the value of the time spent travelling and waiting to travel, are included in the total value. It is assumed that the benefits to the students undertaking the visit must be valued at least as much as these costs (otherwise the trip would not take place).

Table 11. Illustrative value of recorded school visits to RSPB Reserves in 2009/10. Adapted from Mourato et al. 2010.

	Total number of visits per group	Transport **Trip cost to parents**	Total **In-vehicle time**	Total **Excess time**	Sum of travel cost
Children	51,724	£400,861-£620,688	£93,276-£186,551	£279,829-£419,740	£851,364-£1,323,683

[17] QALY is a health measurement used widely in health and health economics research. QALY of zero denotes death, and 1 denotes full health.

Adults	5,747	--	--	£64,470-£96,704	

Education metric details

- Description - Education - Value of educational visits to nature
- Type of valuation - Opportunity cost
- Quantity of asset input - Number of educational visits by school children
- Default assumptions for quantity/flow
    - All trips are nature-related school trips by students outside the classroom
    - Physical flows (i.e., visits) remain constant over time
- Can you use local quantity/flow data? - Yes – no default data provided
- Default assumptions for valuation
    - Monetary values are based on school visits to RSPB reserves which are assumed representative of the value of all nature-based educational visits
    - Monetary unit value remains constant over time
- Can you use local valuation data? - No – fixed value within the account
- Value/unit (2021 prices)
    - Min: £20.36/student/visit
    - Central: £26.01/student/visit
    - Max: £31.66/student/visit
- Source(s) - Mourato et al. (2010). Economic Analysis of Cultural Services. http://uknea.unep-wcmc.org/LinkClick.aspx?fileticket=COKihFXhPpc%3d&tabid=82
- Other studies using this approach - See Natural England (2017) and (2018). The Mourato (2010) estimates are used to support corporate natural capital account of Three Hagges Wood Meadow in Yorkshire (eftec 2015), with the delivery costs to the estate deducted in order to derive minimum net benefits supplied by the estate.
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

This method is limited because it uses the cost of a visit as a proxy for benefits which cannot be estimated. It is also based on the example of visits to RSPB nature reserves. No consideration is given to including learning “outside the classroom but within (or around) school grounds” using local natural capital that does not have associated travel costs.

From Defra ENCA services data book (2020), tab ‘Education’: “Strictly speaking, the focus in natural capital accounting is to identify the contribution of the ecosystem to the benefit,

whereas a travel and time cost-based approach is seen as a proxy. Also, care should be taken not to double-count learning benefits with wider recreational or health benefits, which should be accounted for separately".

Volunteering

The value of volunteering in nature is calculated in NCRAT using the replacement cost of an average volunteer hour. NCRAT allows the user to input the total number of days of nature-based volunteering within the boundary of the place. The number of hours are then multiplied by the replacement cost of an average volunteer hour (Foster, 2013).

The value for the average volunteer hour is taken from the method in the Household Satellite Accounts (Foster 2013). This value is an estimate of the is the replacement cost valued using average wage rate. The value does not capture other benefits of volunteering, such as physical and mental health benefits to the volunteer and building social capital for the wider society. With inflation to 2021 prices the value is equal to £84.6/day.

Volunteering metric details

- Description - Volunteering - Value of nature-based volunteering time
- Type of valuation - Opportunity cost of time
- Quantity of asset input - Estimated number of hours of nature-based volunteering within the boundary of the place
- Default assumptions for quantity/flow
    - All hours included should relate to volunteering in nature only
    - A 'day' is equal to 7.5 hours
    - Physical flows (i.e., time spent) remain constant over time
- Can you use local quantity/flow data? - Yes – no default data provided
- Default assumptions for valuation
    - It is assumed that the private benefits of volunteering exceed the opportunity cost of their time, otherwise people would not volunteer
    - These private benefits may include health, educational and participating in social activities
    - Assumes the value of nature-based volunteering is the same as for volunteering in the UK in general
    - Monetary unit value remains constant over time
- Can you use local valuation data? - No – fixed value within the account
- Value/unit (2021 prices)
    - £11.27/hour
    - £84.55/day (7.5hours)
- Source(s) - Foster (2013). Household Satellite Accounts – Valuing Voluntary Activity in the UK, Office for National Statistics. Available at:

https://webarchive.nationalarchives.gov.uk/20160107021131/http://www.ons.gov.uk/ons/rel/wellbeing/household-satellite-accounts/valuing-voluntary-activity-in-the-uk/art--valuing-voluntary-activity-in-the-uk.html

- Other studies using this approach
    - Natural England (2019). Increases in and valuation of volunteering opportunities were a feature of the business case for the creation of the Canal and River Trust (see Defra 2012).
    - Sunderland et al. (2019). Accounting for National Nature Reserves: A natural capital account of the National Nature Reserves managed by Natural England. Natural England Research Report, Number 078. Available at: http://publications.naturalengland.org.uk/publication/4535403835293696
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2022)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

The benefits to an individual of volunteering are many and varied including, for example, physical and mental health benefits, as well as a sense of contribution to wider society. The various motivations individuals may have for volunteering mean it can be difficult to assign a representative benefit value. From Defra ENCA services data book (2021), tab 'Volunteering': "The treatment of volunteering in ecosystem accounting is yet to be addressed in the development of international guidance and there are few examples in practice. Conceptually, the challenge is identifying the contribution of the ecosystem / natural asset to the benefit of volunteering". Therefore, the scope is limited to reflect the number of volunteer hours that are nature-based and NCRAT workbook requires users to provide this input (i.e., no default dataset is available).

There are three possible approaches to valuing volunteering:

- Opportunity cost approach – value of volunteers' leisure time (i.e., use of their free time).
- Well-being approach – capturing positive change in personal well-being that associated with frequent voluntary activity.
- Replacement cost approach – what would it cost the recipient organisation if it had to pay (i.e., average wage rate) for these services?

ONS Household Satellite Accounts (Foster 2013) says, "Both the opportunity cost approach and the well-being approach value the gain to the contributor, rather than to the recipient of the output. They do not show the value of the output being produced, but the replacement cost approach shows how much the recipient would have to pay to replace the volunteering and therefore the cost that the volunteers are forgoing. This makes the

replacement cost method the best available method to value voluntary activity. The replacement cost approach has been recommended by the International Labour Office and is the most comparable to the National Accounts." (p.3).

This 'opportunity cost' approach uses the assumption that an individual must value an activity and its associated benefits at least as much as the next best alternative use of their time. Conventionally, the time given-up is valued at the individual's wage rate (or some proportion of it). So, a lower-bound proxy can be assumed based on the cost of the time that volunteers offer (i.e., what they are giving up to participate in the volunteering activity). The private benefits to the volunteer can be reasonably assumed to be at least the opportunity cost of their time, where the value of time can be assumed equal to wages forgone (for example, Foster (2013) in Natural England (2019)) or value of leisure time (for example, adjusted travel time).

Water quality

In this tool 'water quality' represents a "bundled ecosystem service" which covers a number of ecosystem services including supporting services (and their use/non-use values). The value represents the welfare benefit of good water quality for safety of recreation, clarity, flow, and thriving invertebrate, plant, and fish populations.

The National Water Environment Benefits Survey (NWEBS)[18], described in more detail in 'NWEBS briefing note' (Metcalfe, 2013) and 'An assessment of the non-market benefits of the Water Framework Directive for households in England and Wales' (Metcalfe et al., 2012[19]), is based on a national study funded by the Defra-led Collaborative Research Programme in 2007 which elicited willingness to pay (WTP) values from around 1,500 people for improvements in the water environment as a result of implementing the Water Framework Directive. NWEBS is used in other parts of the Environment Agency and Defra's decision-making, and therefore use in NCRAT ensures consistency with existing decision-making processes.

NWEBS provides values for improving the quality of waterbodies by Water Framework Directive (WFD) classification status (i.e., from bad to poor, poor to moderate, or moderate

[18] 2007, updated for the Environment Agency, 2013

[19] Metcalfe, P. J., W. Baker, K. Andrews, G. Atkinson, I. J. Bateman, S. Butler, R. T. Carson, J. East, Y. Guéron, R. Sheldon, and K. Train, (2012), An Assessment of the Non-market Benefit of the Water Framework Directive to Households in England and Wales, Water Resources Research, 48(3).

to good). These values are therefore linked to a change in the waterbody status rather than representing the value of given status. Given the lack of alternative evidence for values for water quality, the approach taken in this account was to include a monetary value only for those waterbodies in good condition (or higher) and to use the NWEBS value for a status change from moderate to good as an indication of the welfare benefit of maintaining the waterbody in good status or better (table 18).

In this tool, the quantity of water body length (in km) is automatically generated within the asset register of NCRAT once the information about 'Selected Scale' and 'Relevant River Basin District' and 'Management' or 'Operational' catchment(s) are entered in the 'Input – Place Description' tab. From the Water Quality look-up tables in NCRAT, each km is assigned an ecological status of 'high', 'good', moderate', 'poor', or 'bad' according to WFD classification results. The value per km is generated by using the £ per km from NWEBS. For transitional and coastal waters (TraC) and lakes, the user must look up the condition and area (in km^2) for water bodies (tab: 'Water Quality Look-up (TrC&L)') and input the required data directly into the 'Input - Asset Register'. Unlike rivers, these waterbody types have £ per ha values based on the river basin district that they sit within (rather than the management catchment). As already mentioned above, in this account only the values for water bodies at 'good' or 'high' status are assigned a monetary value.

In effect, the benefit flow is valued in terms of avoided deterioration in water quality. This is a central principle of the river basin planning process and the objective of maintaining current status as a minimum. Implicit within the assumption, however, is that appropriate actions and measures are being taken to sustain current quality levels and avoid deterioration.

For rivers, NCRAT includes a look-up table that auto-populates the asset register. The look up includes all river water bodies in England to summarise the count and length of waterbodies by status within the defined place to populate the asset register condition measures. The status data by length then links to the appropriate benefit valuation to calculate the benefit flow value.

If the User's defined place is across multiple catchments, then NCRAT takes a weighted average of NWEBS values based on the area of each catchment in study zone. This may be different to the length of river in good/high status in each catchment. This is not likely to be a serious issue as neighbouring catchments will have similar £/km values due to the NWEBS method.

Water quality metric details

- Description - Water quality of waterbodies
- Type of valuation - Welfare value of avoided deterioration in water quality

- Quantity of asset input - Count km of river or km^2 of TraC and lakes at good or high ecological status (auto-populated when management catchment or operational catchments within the account's boundaries are entered to tool's 'Input – place' tab)
- Default assumptions for quantity/flow - n/a – see NWEBS method
- Can you use local quantity/flow data? - N/A – quantity inputs are fixed and based on user selections in 'Input – Place Description'
- Default assumptions for valuation
    - Benefits values (from NWEBS, 2013) are applied to all stretches of rivers, TRaC waters and lakes within the accounting boundary
    - Water quality is valued as the welfare benefit from avoided deterioration in status from good (and high) to moderate
    - Only valuing the avoided deterioration from good (and high) water quality to moderate (and not moderate to poor/poor to bad) in order to be conservative
    - Five out of six NWEBS components of overall water quality are valued. This is to not double count 'safety for recreational' contact with recreation welfare values captured in ORVal (see Section on Recreation, above).
    - When the accounting boundary is across multiple catchments then NCRAT takes a weighted average of NWEBS values based on the area of each catchment in study zone. This may be different to the length of river in good/high status in each catchment.
    - This is not likely to be a serious issue as neighbouring catchments will have similar £/km values due to the NWEBS method
    - Monetary unit values (£/km or £/ha) remain constant over time.
- Can you use local valuation data? - Yes – NCRAT includes the ability for local teams to override the default assumption on how many of the NWEBS components (5 out of 6) to include ('Input – Local Values' tab)
- Value/unit (2021 prices) - Annual value of good or high-water quality per km (NWEBS values inflated for 2021). See 'Water Quality…' look up tables in NCRAT.
- Source(s) - National Water Environment Benefit Survey 2013 https://www.gov.uk/government/publications/updating-the-national-water-environment-benefit-survey-values-summary-of-the-peer-review
- Other studies using this approach
    - Cycle 2 WFD Disproportionate cost assessments (2015).
    - A consultation on the draft update to the river basin management plan, Part 3: Economic analysis
- Discount factor applied - standard social time preference rate (STPR), HM Treasury (2020)
    - Discount Rate (0 – 30) 3.50%
    - Discount Rate (31 - 75) 3.00%
    - Discount Rate (76 - 100) 2.50%

Discussion

Defra ENCA guidance (2021) considers the quality of rivers, lakes and coastal waters to be a bundled ecosystem service, in that it includes a variety of ecosystem services (such as aquatic biodiversity, aesthetic benefits of clear water, opportunities for safe recreation etc.) which are difficult to separate. This is the approach taken in NCRAT.

The quality of waterbodies is currently assessed by WFD status and this data is readily available and periodically updated. It was decided to report both the number and extent of waterbodies by WFD status as the major measure of waterbody condition. Specifically, this included:

- For rivers, the number and length (km) of waterbodies by ecological status (high, good, moderate, poor or bad)
- For lakes, the number and area (km^2) by ecological status
- For coastal and transitional waters, the number and area (km^2) by ecological status
- For groundwater, the number and area (km^2) by quantity and quality

The National Water Environment Benefits Survey (NWEBS) provides values for improving the quality of waterbodies by WFD status (i.e., from bad to poor, poor to moderate, or moderate to good). The values are available for rivers by management catchment (expressed as a value per km), or for lakes, coastal and transitional waters by river basin district (expressed as a value per km^2).

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Annex 1: Unit Value Lookup

NCRAT v1.2 introduced the use of a Unit Value Lookup (UVL) tab. The UVL tab supports NCRAT principles by:

- Improving the functionality of NCRAT (e.g., streamlining calculations within NCRAT)
- Building resilience (e.g., makes it easier to update evidence included within NCRAT in the future versions)
- Supporting transparency of evidence used within NCRAT (e.g., systematic evidence base).

The UVL contains unit values included in NCRAT v1.1, as well as updated values for version 1.2. A combination of exchange, market and welfare values are used across the 13 ecosystem services, albeit exchange values are more broadly used. Where available, annual values are averaged across years (currently reflecting data for 2016 to 2022). A multi-year average unit value is applied to counter the potential for a single-year value being unrepresentative or an outlier, for example, due to extreme weather or other uncommon events that impact either physical or monetary flows. However, some evidence is only available as single values (e.g., from one-off studies) and have therefore been maintained within NCRAT as they represent the best available evidence.

The UVL tab contains all the data used in the process tabs across NCRAT and linked to each tab with a SUMIFS formula. Calculations for transformation of input data (e.g., total renewable energy generation and total value of renewable energy) to estimate a unit value (e.g., £/MWh) are now carried out within the UVL tab and the original data sources are reported in the "Sources(s)" column.

All monetary values are inputted according to their original price year and inflated according to the accounting price year set by the user in the "Input – Place Description" tab. This supports the simplification of the ecosystem service process tabs and ensure inflation adjustments are applied consistently throughout NCRAT. Data across the UVL is categorised as follows:

Metrics	Description
Physical quantities	Physical flow quantity unit value linked to Process tab
Monetary flow	Monetary flow unit value linked to Process tab

Single value (blue or green)	No time series data for physical quantity or monetary flow
Other Look-up	Unit look-ups are stored in separate look-up tabs in the workbook.
Requires Asset Register data	No physical quantity here as users have to enter data into Asset Register
Requires 'Input - Local Values'	No look-up value here as users have to enter their own data
Input to physical quantity calculation	Inputs to calculate physical quantity unit value
Input to monetary flow calculation	Inputs to calculate monetary flow unit value

It should be noted that the UVL tab does not replace other Look-up tabs within NCRAT where unit values may vary by location (e.g., catchments for water quality) or year (e.g., non-traded carbon values).

Annex 2: Future Considerations

Agriculture

The John Nix Pocketbook is updated annually, and it is recommended that an average gross margin is calculated and maintained within NCRAT as an annual update.

To improve upon the existing methods, a future iteration of NCRAT could use:

- A weighted average for gross margins extracted from FBS that would enable regional approaches to be scaled up to a national level. In addition, it would enable a maximum/minimum based on regional differences
- Run a Monte Carlo simulation based on the FBS or John Nix Pocketbook data to create a more reliable estimate of data that could then be used in NCRAT.

The gross margin relating to sheep could also be reviewed with reference to sources other than the John Nix Pocketbook. For example, the FBS survey of Hill Farming in England by Harvey and Scott 2022 suggests different value ranges for upland flocks.

Gross margins are more indicators of the value-added of the farm business than the value of the ecosystem services. It is recommended that consideration be given to moving to a different method of monetary valuation, such as an exchange value monetary approach. Which, in terms of a better indicator of ecosystem contribution, could mean a resource rent approach (e.g., rents charged to tenants less the direct costs; see paragraph 8.23 on page 181 of UN SEEA Revision 2021). This would align with ENCA Services Databook and might be less susceptible to significant fluctuations than a whole farm income approach (ONS England natural capital accounts methodology: 2023).

Fish and shellfish landings

Future revisions are planned for the ONS fish landings method and updates to this tool can be made accordingly.

Water supply

For future iterations of NCRAT, an account may be linked to the estimated costs of alternative water supplies produced by the water companies under their Water Resource Management Plans. These values were included for the first time in submissions for the UK Spending Review in 2020 (SR20) and tended to produce much higher valuations of water because they are a replacement cost method rather than a resource rent one. However, this method may not be appropriate and the consequences of using it need to be reviewed. There may also be some difficulties with the restricted nature of the data.

Timber

Future iterations of NCRAT to be updated as per standing sales values.

Renewable energy

The resource rent value for this service (£/MWh) is on the residual value resource rent approach calculated from the SIC Group 35.1 Electric power generation, transmission and distribution, and apportioned using inputs from ONS Annual Business Survey and data on total energy generation by source from BEIS (ONS, 2022).

Note that the resource rent approach should be applied and interpreted with caution in regulated markets. This is because the observed market price may not reflect the genuine exchange value for the good and/or service in question. This would apply to regulated utility sectors in England, such as energy. For further guidance on application of the resource rent approach see ONS (2022) technical guidance, UN SEEA (2021) or discussion in Obst, Hein and Edens (2016). Energy markets are highly volatile, complex, and driven by many factors (for example the mix of energy sources used in overall energy supply). Attributing a value to any particular generating source is highly problematic (impossible) as sources are highly substitutable.

Given a homogenous market for energy supply, it is not possible to establish values that represent the different costs and benefits of various energy sources (e.g., the greenhouse gas dis-benefit of fossil fuel use verses renewable energy sources).

The national regulator sets price caps that focus on limiting prices for the consumer whilst recognising the unavoidable cost pressures of suppliers. There is no necessary linkage between these price caps (and hence prevailing market prices) and the level of benefit derived from natural energy generating sources. Consequently, the resource rent method which is based on a regulated market value (set to recover only costs and a return on financial capital employed) is likely to understate the benefits of renewable energy generation.

In conclusion, renewable energy supply is a rapidly evolving market space, and it is important that the valuation methods used in NCRAT are regularly reviewed in light of emerging methods and trends.

Climate regulation

When future versions of this tool are created, it may be possible to factor in the changes in carbon sequestration over time: different habitats sequester carbon in different rates over time and could reach a state where they cannot absorb anymore and may even leak carbon. This will depend on factors such as the type of species planted, geology, management of the woodland etc. There is also the potential in the future to link carbon sequestration quantities to the management techniques of different habitats.

This tool is published at a time when an increasing number of organisations are looking to natural assets to achieve their ‘net zero’ targets. As a result, we are seeing more research focused on carbon sequestration by different habitat types. Natural England and the Environment Agency published in 2021 findings from a review on carbon sequestration by different habitats. The unit values for carbon sequestration have been updated to reflect the latest evidence where relevant.

Air quality

As with climate regulation and valuations for non-traded carbon, air quality methods are rapidly advancing in natural capital accounting. In future iterations of this tool there are likely to be updates based on Defra and Green Book guidance.

Hazard regulation

In addition to overcoming the above limitations, the Environment Agency has an ambition to improve the method for evaluating the benefits of natural flood mitigation (NFM) for the following aspects:

- An assessment of the potential flood damages in a place, to properly capture the susceptibility of the local area to flood damage
- To account for the effectiveness of local natural flood management (NFM) features, recognising their location and role in managing flood risk

A further consideration is that the method should estimate values based on readily available data and be relatively simple to calculate which is a challenge, given the complexity of hydrological modelling.

This hazard regulation method solely focuses on fluvial flood risk. Future versions of NCRAT could include focus in on a wider range of natural flood management intervention types that provide volumetric flood storage. For example:

- Coastal/estuarine managed realignment
- Floodplain and wetland restoration
- Offline storage areas
- Runoff attenuation measures
- Sustainable Urban Drainage Systems (SUDS)

We may be able to draw out more evidence from other sources including Environment Agency NFM evidence directory (2017) and Environment Agency long-term investment scenarios (2019). The Defra ENCA project (2020) also offers data from Morris and Camino (2011) for wetlands; and JNCC and CEFAS (2019) for saltmarsh which we may be able to use in future versions.

Recreation

The recommendations for future iterations are to:

- Maintain a watching brief for alternative recreation models and values
- Ensure that the definition and valuation of recreation is kept separate from that for health. Note that in combination, recreational enjoyment, avoided physical ill-health and avoided mental ill-health give a broad picture of the values that access to green space provide to people.

Physical Health

The recommendations for future iterations are to:

- Maintain a watching brief for alternative recreation models and values (e.g., developments in ONS approach (2022))
- Ensure that the definition and valuation of ‘recreation’ is kept separate from that for ‘physical health’
- Review discount rates recommended by the Green Book in relation to health costs and benefits

- Keep up to date with Green Book guidance on health valuation and also with alternative sources of health valuation data.

Education

The next version of NCRAT could explore in greater depth and seek to gain more composite data by:

- Seeking data from other organizations or managed areas that support educational visits. For example, the National Trust, the Woodlands Trust, as well as privately owned land like areas around reservoirs
- Examine the value of the education component of visits to engage in citizen science, such as the RSPB's Schools' Birdwatch
- Explore the valuation of education outside the classroom in settings that involve natural capital but does not require travel costs.

Volunteering

The recommendation for future iterations is to keep up to date with Green Book guidance and also with alternative sources of volunteer valuation data.

Water quality

Valuation data sets for the benefits of water quality are limited and the NWEBS data set remains the go-to data for water valuation and the method we have used here is a derivative of that data set. The wider value of water is underplayed in this tool due to the current lack of evidence and methods to value it in a broader sense.

The Environment Agency are working with Defra to explore improvements to the way we value water quality; in particular, research into how people use local waterbodies and the value they place on local waterbody conditions.

Noise reduction

The UK Urban Natural Capital Account extension (eftec and CEH, 2018) used existing traffic noise maps, and modelled the influence of tree canopy in reducing how far this noise travels. Benefits of lower noise levels include reduced sleep disturbance and hence reduced mental stress and health problems. The value per property varies with background noise level in bands above 55dBA – higher levels of noise cause more disturbance of sleep, so reducing them has more value. This is not yet available to an account of this type.

Urban Cooling

An extension (eftec et al., 2018) to the UK Urban Natural Capital Account (eftec et al., 2017) modelled the influence of urban natural capital (parks and woodlands) on urban heat island effects. The modelling estimated that these features reduced average temperatures by 0.75^{o}C across the Manchester city-region during a heat wave. The cooling service is highly localised, depending on proximity to larger areas of woodland/parkland, where temperature reductions will be greater. The value of the heat regulation was estimated based on avoided costs to business: from not losing worktime in the construction industry; and from reduced air conditioning costs in commercial buildings. Whilst this modelling is possible, it requires detailed location specific modelling, which requires spatial inputs that are beyond the current scope of this tool.

Waste remediation - including water purification

The capacity of the natural environment to assimilate waste and process waste products to a degree that reduces potential harmful effects to human health and the wider environment is usually poorly defined in natural capital and ecosystem service frameworks and typically not assessed in physical or monetary terms.

The inclusion of the bundled water quality benefit flow in NCRAT reflects, to some extent, the capacity of surface and groundwaters to assimilate and process waste products. This is because water quality status is determined in part by pressures from a variety of organic or inorganic waste. Hence the method would also need to consider the 'unbundling' of the water quality ecosystem service in order to better differentiate the provisioning, regulating and cultural service elements.

However, there are multiple (and complex) sources of pollution (for example, bioremediation of industrial wastes by disposal on agricultural land, or retention of nitrogen and phosphorus from point and diffuse pollution sources in sediments). Hence there are multiple (and complex) processes taking place.

Scoping work is required to better define the *asset – flow – benefit - value* pathway(s) and specify the indicators and metrics that could be applied. Note that this requirement extends beyond NCRAT and relates more generally to uses of natural capital accounting at all levels (i.e., including national level). There are very few practical assessments that have sought to examine these[20].

[20] One example is the ecosystem account developed by La Notte et al.; (2012; 2017) for water purification services in the EU. They assess nitrogen retention in rivers as a proxy for water purification. This is based on the observation that excess nutrient loading is

Recreation - angling

There is a sizeable evidence base on the recreation value of freshwater angling, including recent research by the Environment Agency (2018b). However, data for where people fish is very limited. The main data held is rod licenses which does not inform on location or frequency of angling activity. Estimating the physical flow in this case (the number of angling trips in a place) will require local level data gathered on a case-by-case basis to assess the local importance of freshwater angling (e.g., engagement with local angling clubs).

There is also potential for double counting with the overall approach to estimating the physical flow for recreation, which is based on data from the MENE (Natural England, 2019b) via the ORVal tool. This captures reasons for visits and activities undertaken and includes fishing. Hence angling is implicitly included in this tool. Further iterations could review the MENE source data and inputs from local level engagement and estimate the proportion of total visits that could be attributed to angling.

Mental Health

Mental health is not included in this tool as the evidence base is currently insufficient to support quantification and valuation of the outcomes[21]. For the most part it remains highly context dependent and not reliably applied at the level of generalisation that the recent progress on physical health benefits of active visits has reached. Also, part of this benefit may already be captured within recreation values as recreational visits are likely to lead to mental health benefits.

Biodiversity

Benefits associated with biodiversity are not separately valued in NCRAT. Some proportion of the 'biodiversity value', however, is implicit within valuations of other benefits. This is due to the contribution that biodiversity has (as a supporting ecosystem service) to the production of final goods and services that individuals benefit from, such as timber, carbon sequestration, and recreation. In principle the more 'direct' value of biodiversity can

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typically the most prominent pressure for waterbodies in Europe due to a combination of diffuse (agricultural run-off) and point source (wastewater discharges) pollution. A replacement cost approach is applied to value nitrogen retention (constructed wetlands).

[21] Note: the one exception is for (avoided) mental health costs due to natural flood management measures, where there is specific guidance from Environment Agency partnership funding mental health guidance, 2020.

be included in an account addition to the other areas of benefits, such as values for wild species conservation, appreciation of the natural landscape, foraging/wild foods, and nature-based recreation (if separated from general recreation benefits). However, readily transferable valuation evidence that can be adapted to the specific context is limited. This includes both the quantification of physical flows and the associated values (for example the beneficiary population for aggregating nature conservation values)[22].

There is also a role that biodiversity has in the capacity of ecological functions and processes to recover from changes in environmental conditions due, for example, to management changes or external pressures. This is viewed as a form of 'resilience value' where greater levels ('stocks') of biodiversity can mean that different aspects of an ecosystem are more resilient to future shocks such as fire, drought, disease, invasive species and habitat loss[23]. If biodiversity is depleted the capacity to recover in the future can be diminished, even if there is no detectable change in the present day. At present, however, resilience and insurance values of biodiversity are not ordinarily accounted for in benefits assessments. This is a significant gap and more work is needed to improve understanding of these concepts and their materiality to decision-making before generalisable results can be provided. Such analysis should be able to show how the flow of values from a place varies over time under different future conditions (i.e., varying levels of water availability, changes in local climate variability, disease/pests that impact production).

[22] The ENCA Service Databook (Defra, 2020) summarises the main evidence sources, particularly for valuing biodiversity benefits. For the most part these relate to terrestrial habitats within the context of explicit policy goals (for example, SSSI conservation activities), rather than more broadly applicable evidence.

[23] Within this there can also be a distinct insurance value, where species diversity can reduce variability in financial returns for agricultural and forest products (for example, timber). The amount producers are willing to pay for the risk reduction that more diverse production systems offer is the insurance value of biodiversity.

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