ECONOMIC BENEFITS OF SALTMARSH CREATION FOR CARBON STORAGE

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Executive summary

This report presents a scoping analysis of the natural capital benefits of creating 25,000 ha of saltmarsh in the United Kingdom (UK) by 2050. Saltmarshes comprise the upper, vegetated portions of intertidal zones and are composed of a complex mosaic of intertidal vegetation (WWT, 2023). The creation of these habitats would have substantial biodiversity and ecosystem service benefits, whilst also incurring financial costs in the creation of these habitats.

WWT are calling for the creation of 100,000 hectares of new and restored wetlands in the UK by 2050, to make a real difference to nature recovery and to restore the critical ecosystem services and functions provided by wetlands.

The natural capital account (NCA) presented in this report is part of WWT's Roadmap to 100,000 hectares work, which aims to assess both the spatial and economic potential for large-scale wetland restoration targeted at tackling some of the key issues faced by UK society. The work has a particular focus on four themes where wetlands can provide solutions, namely (1) wetlands for carbon storage, specifically saltmarsh for blue carbon (detailed in this report), (2) wetlands for urban wellbeing (3) wetlands for flood resilience and (4) wetlands for water quality.

The NCA and accompanying reports have been developed separately for each of the four themes (focussing on 25,000 ha of wetland creation targeted at each theme). The accounts can also be aggregated to value the benefits provided by all 100,000 ha of wetlands in the WWT ambition. These aggregated benefits, together with a summary of all four accounts, are presented and discussed in the main project technical report, while detailed reports are provided separately for the individual accounts (such as this).

The analysis supporting the accounts ensures they can be aggregated with a low risk of double counting because (1) there is little overlap in the target wetland areas, (2) a wider potential wetland area providing similar benefits has been identified for each account, and (3) the approach taken in estimating costs and benefits are consistent across accounts. The account results do not show exactly where to create wetlands. They show the feasible returns to society from a realistic wetland creation strategy.

Only a selection of the potential benefits has been quantified and valued in this analysis, and further research is needed to increase the certainty of results and understand a wider range of benefits. Nevertheless, the results show substantial potential benefits from large scale intertidal habitat creation in the UK, as summarised in Table ES 1.

The analysis of these benefits has followed Defra's ENCA guidance, where relevant, and aligns to HM Treasury green book appraisal principles. The total net benefits (i.e. accounting for the costs of wetland creation) are estimated at £1.7 billion (assessed over 60 years in

present value terms). Some of these benefits are public goods, suitable for support through public policies (such as the Environmental Land Management scheme (ELMs) in England). Other benefits have potential market value, such as the value of carbon which could be traded under a future Saltmarsh Carbon code. Development of these funding approaches also requires further research.

Table ES 1: Natural capital asset valuation and liabilities associated with 25,000 ha UK saltmarsh creation, assessed over 60 years in present value terms). Red figures in brackets represent negative values (costs). All figures are in £m.

2024 prices	Valuation metric	Value to businesses	Value to the rest of society	Total
Asset values (monetised)				
Food provision	Total income from livestock	47	-	47
Carbon[1]	Value of CO_2e sequestered by saltmarsh	-	2,152	2,152
	Cost of CO2e emitted by livestock	-	(252)	(252)
Flood risk management	Value of additional coastal wetland area for flood control	-	531	531
Recreation & tourism	Welfare value uplift for created saltmarsh	-	235	235
Water quality	Value of Nitrogen removal	-	48	48
	Value of Phosphorous removal	-	18	18
Total gross asset value	**Mix of values**	**47**	**2,732**	**2,778**
Liabilities				
Production costs[2]		(1,081)	**-**	(1,081)
Total net asset values (monetised)		**(1,034)**	**2,732**	**1,697**
Total net asset values (non-monetised)				
Biodiversity	Total SSSI area: 4,295 ha			
Material non-monetised benefits				
Fishing (commercial), mental health.				

Table notes:
[1] Value of carbon emissions increase over time in line with BEIS (2018).
[2] Costs that are necessary to produce benefits (e.g. intertidal habitat creation costs).

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1 Introduction

1.1 Project objective

The project aims to support WWT's ambition to create 100,000 hectares of new and restored wetland habitat in the UK by 2050, to make a real difference to nature recovery and to restore the critical ecosystem services and functions provided by wetlands in the UK.

To achieve this 'Blue Recovery', WWT have published proposals for wetland solutions focussed on four key themes:

1. Wetlands for water quality
2. Wetlands for carbon storage
3. Wetlands for urban wellbeing
4. Wetlands for flood resilience

Each proposal details the partnerships and policy frameworks required to reach the 100,000 ha target, laying out the steps needed to move from small-scale, ad-hoc wetland creation to a strategic network of larger, connected wetlands that maximise benefits to society.

WWT's Roadmap to 100,000 hectares work aims to assess both the spatial and economic potential for large-scale targeted wetland restoration. Specifically, it involves:

- Mapping both the spatial demand for wetlands and suitable areas for wetlands designed to address these themes, for example, via natural flood management wetlands, constructed treatment wetlands, community urban wetlands, sustainable drainage systems or saltmarsh creation;
- Quantifying, through natural capital accounting, the scale of the potential benefits provided by large-scale, targeted wetland creation - benefits that are often underappreciated in considerations of wetland policy options; and
- Developing resources and engagement materials to demonstrate this potential.

Natural capital accounts (NCA) have been developed to estimate the multiple benefits of creating wetlands for each theme:

- **Wetlands for carbon storage (saltmarsh blue carbon).** This NCA focuses on the carbon sequestration benefit from the creation of saltmarshes in the UK.
- **Wetlands for urban wellbeing**. The NCA for urban wellbeing wetlands focuses on benefits, such as recreation, physical and mental health, and urban cooling, from the creation of freshwater wetlands near urban areas.

- **Wetlands for flood resilience**. The NCA for flood resilience wetlands focuses on benefits such as flood risk management, food provision, air quality regulation, carbon sequestration, recreation, and physical health.
- **Wetlands for water quality**. The NCA for water quality wetlands focuses on the water quality benefits provided by freshwater wetlands located in areas with particularly poor water quality. The benefits included are food provision, water quality, and recreation.

The remainder of this report provides evidence to demonstrate the value associated with creating saltmarsh for carbon storage. To do this, the NCA has been developed for a target area of potential saltmarsh creation in the UK. The account organises data on saltmarsh that would be created, the services they support, the value of the benefits they provide to people, and the distribution of those benefits across businesses and society into the future. These benefits are compared to the costs of saltmarsh creation in a balance sheet.

1.2 Project scope and consistency across accounts

In line with WWT's ambition to create 100,000 ha of wetland in the UK by 2050, the scope of this project is to estimate the multiple benefits of creating 25,000 ha of wetlands for each of the four themes. Although the natural capital accounts (NCA) and accompanying reports have been developed separately for each theme, these accounts can be aggregated to value the benefits provided by all 100,000 ha of wetland.

The analysis supporting the accounts ensures they can be aggregated with a very low risk of double counting, because:

- **Little overlap in target wetland areas**. The areas of wetland creation targeted in each account have been mapped according to criteria that identifies the areas most suitable to fulfilling the primary purpose of that wetland (i.e. flood resilience, urban wellbeing, water quality improvement, and saltmarsh). Although it is feasible that an area may be well suited to wetlands that provide both for example, flood resilience and an improvement in water quality, it has been found, by overlaying the target wetland areas in each account, that the areas targeted for these specific purposes do not overlap. This therefore reduces concerns of double counting the benefits of wetland creation across the accounts.
- **Wider potential wetland area providing similar benefits**. Each account has identified a larger potential wetland area than the 25,000 ha priority area actually covered by the account. Although benefits have been estimated for defined target wetlands, the benefit values applied are generally averaged at a regional or national scale rather than being spatially explicit at the site level. This means that the calculated benefits are not tied to specific locations within the target area, but rather represent a typical value that could be achieved at other wetland sites if the sites we have mapped to demonstrate the vision were not available. This includes if they were not available because they were used for a different wetland type. As a result, even if two accounts identify overlapping

target wetlands, there are alternative locations that could be used, so there is no double counting of the benefits. This is because the values used are not dependent on the exact site but reflect the typical benefits that could be realised in various potential locations. Therefore, if a wetland were moved from one location to another within the wider potential area, the values they generate would not be compromised. The account results do not prescribe specific locations for wetland creation; instead, they illustrate the potential societal returns from implementing a realistic wetland creation strategy across a broader landscape.

- **Consistency in approach**. The approach taken in estimating the costs and benefits are consistent across accounts, allowing for aggregation across accounts. The accounts have monetised costs and benefits based on a 2024 price year and have projected costs and benefits over 60 years. All accounts have assumed that an equal area of wetlands is created each year between 2024 and 2050 (i.e. the year in which the target area of wetland creation is achieved).

1.3 Report structure

This report documents the approach taken and the key results, including data gaps and uncertainties, for the wetlands for carbon storage natural capital account. The structure of the report is as follows:

- **Section 2: Approach** – provides an overview of the NCA and its application to intertidal wetland creation and restoration in the UK.
- **Section 3: Scope of the natural capital account** – defines the spatial boundary, asset register, benefits, and presentation of results.
- **Section 4: Summary of the analysis** – describes the analysis used to build the natural capital account.
- **Section 5: Results** – presents the UK intertidal wetland creation benefits results.
- **Section 6: Conclusions and recommendations** – summarises the results of the natural capital account and provides interpretation of the results and next steps.
- **Appendix 1: Benefit methodologies** – details the quantification and economic valuation methods used to produce the results reported.

2 Approach

This section provides a description of the natural capital analysis methods used to assess the benefits of creation of intertidal wetlands in the UK.

2.1 Natural Capital Accounting

Natural Capital is "the stock of renewable and non-renewable natural resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people"[1]. The natural capital approach involves distinguishing between stocks of natural capital assets and the flows of benefits they provide; projecting benefits into the future and linking the provision of benefits to the extent and condition of assets. The intention is to ensure that decisions prioritise maintaining the assets in order to secure all future benefits, and not to maximise one of the benefits at the expense of others or the natural capital asset itself.

Systematic and consistently generated evidence and repeated updates are what distinguish accounting from one-off assessments. Accounting offers comparability across space and time, bringing rigour to the presentation of data on natural capital assets, the services they provide, the benefits and hence value of those services, and the distribution of those benefits across society and into the future.

The approach to developing the UK intertidal wetland natural capital account is based on the Corporate Natural Capital Account (CNCA) framework for the Natural Capital Committee in 2015 (eftec, RSPB and PWC, 2015). This framework is also the basis of BSI:8632 on Natural Capital Accounting for Organizations[2]. Natural capital accounting aims to present information to the decision makers in a format they are familiar with so that the impacts and dependencies on natural capital are considered more explicitly and in conjunction with other forms of capital.

In this project, a **natural capital balance sheet** has been produced. This has two parts: asset values (of the benefits natural capital produce for businesses and wider society) and liabilities (on what needs to be spent to create and maintain natural capital). The balance sheet and its supporting schedules answer five key questions:

I. What assets do we own and/or manage?
II. What benefits do they provide and to whom?
III. What are these benefits worth?
IV. What does it cost to maintain the assets?
V. How do costs compare to benefits over time?

The following supporting schedules hold the information gathered to answer the above

[1] Source: Natural Capital Protocol *https://naturalcapitalcoalition.org/natural-capital-protocol/*
[2] Available at: *https://shop.bsigroup.com/products/natural-capital-accounting-for-organizations-specification?pid=000000000030401243*

questions:

- **Natural Capital Asset Register –** which records the stock of natural capital assets in terms of their extent, condition, and spatial configuration (e.g. size and status of designated sites). These indicators help determine the health of natural capital assets and their capacity to provide benefits[3].
- **Physical Flow Accounts –** which quantifies the benefits that the assets deliver in physical terms. The changes in the quantity / quality of the assets and their benefit provision over time are also shown.
- **Monetary Flow Accounts –** which estimates the economic value of the benefits in monetary terms and discounts the projected future flow of these benefits to provide the present value for the assets. This uses data from actual markets and other (non-market) values. The monetary flow account distinguishes private values from external values to the rest of society. These supporting schedules provide all the data required for the balance sheet.
- **Natural Capital Liabilities Account –** which details the costs of creating the intertidal habitats to provide the benefits analysed in the account.
- **Natural Capital Balance Sheet** – comparing the values of monetary flows and liabilities.

The monetary flow and cost accounts distinguish values to businesses from values to the rest of society. These supporting schedules provide all the data required for the balance sheet which compares the asset values to the costs of maintaining those values.

Where understanding and evidence allow, calculation of assets and liabilities can take account of expected changes to future costs and benefits of management, and external factors such as population growth or climate change. Otherwise, caution is needed when interpreting the bottom line of natural capital balance sheet – as BSI 8632 states, a positive net asset value is not necessarily an indication of sustainable asset management.

2.2 Preparing a natural capital balance sheet for saltmarsh creation

This analysis includes both a natural capital benefits account, which relates to Steps I – III above, and a natural capital liabilities account, which relates to Steps IV – V. The benefits and liabilities have been estimated for saltmarsh within the accounting boundary. The method used to define the accounting boundary is explained in Section 3.1.

The structure of the account allows calculations to link data on the extent of the assets identified in the asset register, to value data on flows of ecosystem services, through the process shown in Figure 2.1. The product of quantity and unit value gives an estimate of

[3] The natural capital asset register is also the basis for scoping the natural capital risk register, and for a materiality assessment (see Section 4) to determine the content of the flow and liabilities accounts.

annual value. Asset values are calculated by summing the expected future annual values of benefits over 60 years, discounted according to HM Treasury (2020) Green Book Guidance.

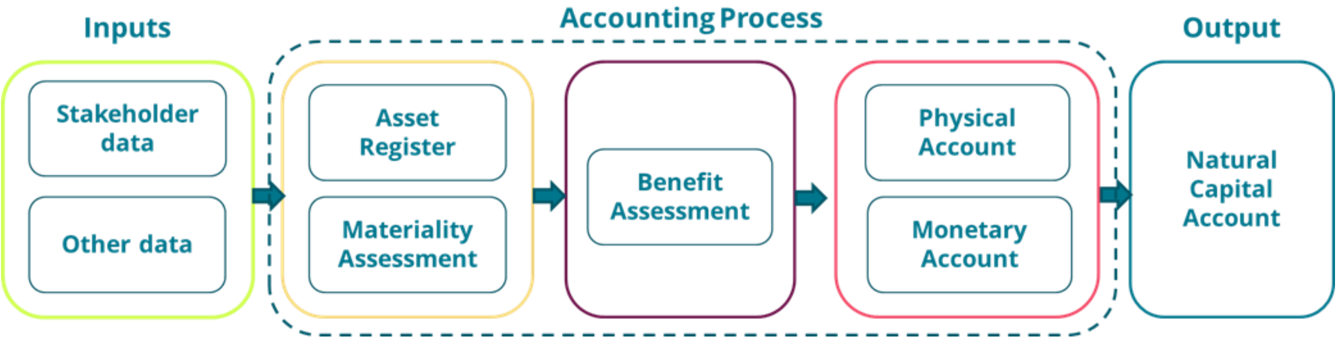

Figure 2.1: Outline of accounting process.

The balance sheets for the creation of saltmarsh are presented in Section 5. The assumptions and evidence used are provided in Appendix 1.

3 Scope of the natural capital account

Scoping of the account defines the spatial boundary of the account, the natural capital assets and the benefits covered and presentation of results.

3.1 Spatial boundaries and asset register

The spatial boundary of this account is the UK, which includes England, Wales, Scotland, and Northern Ireland. The natural capital assets are defined by the extent of areas suitable for creation of intertidal wetland areas - which primarily includes saltmarsh (and is hence referred to as saltmarsh in this report) - within the accounting boundary. Detailed mapping methods are available in the accompanying technical guidance document (Section 2; Appendix III). These assets make up the potential saltmarsh creation area in the UK (i.e. the accounting boundary) and are therefore part of the asset register.

The asset register includes the target area of saltmarsh creation, which is a subset of the total potential area for saltmarsh creation The target area represents a quarter of the overall area of wetland creation that meets WWT's 100,000 ha ambition.

The condition of these potential and target areas for saltmarsh creation are based on whether these not-yet existing intertidal wetlands would be within a designated Site of Special Scientific Interest (SSSI; (Natural Resources Wales, 2023; Natural England, 2023; NIEA, 2016)) and the overall Water Framework Directive (WFD) waterbody status for the coastal/transitional waterbody adjoining the potential saltmarsh parcel (Environment Agency, 2023; Natural Resources Wales, 2015; SEPA, 2023). See Section 4.1 for further details of the asset register.

3.2 Benefits

The list of potential benefits to assess reflects the list of individual benefits included in Defra's (2020) 'Enabling a Natural Capital Approach' (ENCA). This includes:

- Food provision
- Fishing (commercial)
- Timber
- Water supply
- Renewable energy
- Carbon sequestration
- Air quality regulation
- Flood risk management
- Noise reduction
- Temperature regulation
- Recreation
- Physical health
- Education
- Volunteering
- Amenity
- Biodiversity
- Soil
- Water quality
- Landscape
- Non-use values

Further to this list, minerals, other fibres and materials as well as mental health benefits are also considered.

A subset of these benefits have been included in this account, based on expert judgement on the material benefits provided by saltmarsh and on the availability of data. The methods used to assess these benefits for UK saltmarsh creation are described in Section 4.2.1 and Appendix 1. The calculations are linked to the location, extent and condition of natural capital assets, as identified in the asset register, described area in Section 4. Monetary valuations are prioritised in the accounts, and cover food, carbon sequestration, flood risk management, water quality, recreationz, and physical health benefits.

Monetary valuation is not possible for all the material benefits. The creation of saltmarsh in the UK could also have a material benefit for fisheries, biodiversity, and mental health, but these have not been quantified or monetised in this account. These material non-monetised benefits are listed as part of the account results.

The baseline year for the analysis is 2024. Monetary values published in earlier price years are inflated to 2024 values using the latest HM Treasury (2024) GDP deflators. Asset values are estimated using HM Treasury (2022) Greenbook guidance following a declining discount rate and a 60-year assessment period.

3.3 Presentation of results

Information inputted into and results from the account can be presented for different spatial areas and for different beneficiaries. Results can be disaggregated to the four countries, namely England, Scotland, Northern Ireland, and Wales, in the reporting boundary.

For this account benefits are divided across two main groups of beneficiaries: ‘Businesses’ (i.e. where the value identified is a financial return to a business) and ‘the rest of the society’ (i.e. public benefits to wider society). Businesses are represented by sectors (e.g. agriculture, fishing).

4 Summary of analysis

This section presents the data for the UK wetlands for carbon storage (saltmarsh creation) account, described in Section 2.2. The account uses data for the latest available year. It covers the natural capital assets within the accounting boundary. This reflects the areas of potential saltmarsh creation in the UK, as well as a proportionate subset of these potential areas to reflect the target saltmarsh areas that could be created.

4.1 Asset Register

The asset register is a registry of all natural capital assets within the boundary of the account. It forms the foundation of the account and records both the extent and condition of the assets. In this case, the account is divided between the potential saltmarsh creation area and the target saltmarsh creation area. The distinction between these is that the former includes the total area in the UK where saltmarsh could be created (see https://www.wwt.org.uk/wetland-potential) whilst the latter includes the target area that could be created. The potential creation area is used to provide context for the target creation area. As shown in Table 4.1, the proportions of potential saltmarsh in each country and for each saltmarsh type are applied to the target saltmarsh creation area, which has as its central value a total creation area of 25,000 ha.

The types of saltmarsh considered in this account include (1) middle marsh, lower marsh, and mudflat, (2) upper marsh, and (3) terrestrial, all of which are defined by the tide level and the vegetation established. Mudflats are characterised by mats of algae and *Zostera*, and typically lie below mean high water neaps (MHWN). Lower marsh is characterised by vegetation such as *Spartina*, *Salicornia*, and *Puccinellia*, and lie between MHWN and mean high water (MHW) levels. Middle marsh is dominated by vegetation such as Festuca and Juncus spp. and lies between the MHW and the mean high water spring tide (MHWS) levels. Upper marsh is typically characterised by vegetation such as *Elymus* and *Puccinellia* and lies between the MHWS and highest astronomical tide (HAT) levels (Davis et al., 2019). Terrestrial areas are those lying above HAT, which are made up of terrestrial rather than intertidal vegetation. Areas above HAT were largely excluded from the mapping process, as saltmarsh vegetation is unlikely to establish at such elevations (at current sea levels). Terrestrial vegetation therefore makes up only a small proportion (7%) of the potential creation area. Areas that remain tend to be small areas of higher elevation within larger areas of potential.

Information on the condition of the potential and target saltmarsh creation areas is provided in Table 4.2. The condition of the target creation area is estimated proportionally to the condition of the potential creation area. Condition in Table 4.2 is based on the proportion of the creation area that is within a designated SSSI. In addition, the WFD (overall) status of the coastal/transitional waterbody adjacent to saltmarsh potential locations was used to estimate the area of potential saltmarsh by assumed WFD waterbody status for each UK nation.

Table 4.1: Overview of Asset Register

Indicator		Potential creation area	Target creation area
Country	**Saltmarsh type**	**Area (ha)**	**Area (ha)**
England		**150,638**	**21,630**
	Terrestrial	10,743	1,543
	Upper marsh	54,029	7,758
	Middle marsh, lower marsh, and mudflat	85,866	12,330
Northern Ireland		**3,342**	**480**
	Terrestrial	238	34
	Upper marsh	1,199	172
	Middle marsh, lower marsh, and mudflat	1,905	274
Scotland		**6,716**	**964**
	Terrestrial	479	69
	Upper marsh	2,409	346
	Middle marsh, lower marsh, and mudflat	3,828	550
Wales		**13,411**	**1,926**
	Terrestrial	956	137
	Upper marsh	4,810	691
	Middle marsh, lower marsh, and mudflat	7,645	1,098
Total saltmarsh		**174,107**	**25,000**
	Terrestrial	12,417	1,783
	Upper marsh	62,446	8,967
	Middle marsh, lower marsh, and mudflat	99,244	14,250

Table 4.2: Condition data in Asset Register

Designated SSSIs		**Area (ha)**	**Area (ha)**
Area of SSSI within the saltmarsh potential area[4]		**29,910**	**4,295**
	England	21,864	3,139
	Northern Ireland	361	52
	Scotland	1,060	152
	Wales	6,625	951
		Proportion of total potential saltmarsh (%)	**Proportion of total potential saltmarsh (%)**
Area of SSSI within the saltmarsh potential area as % of total		**17%**	**17%**
	England	15%	15%
	Northern Ireland	11%	11%
	Scotland	16%	16%
	Wales	49%	49%

4.2 Natural Capital Asset Values

This section provides a summary of the methods used to estimate natural capital asset values for the creation of saltmarsh in the UK, with further details in Appendix 1. The account results represent a sum of the four countries in the UK. Where possible, the methods described in Table 4.3 are used for all reporting countries.

[4] Areal extent of each saltmarsh type was derived by reclassifying pixels of a digital elevation model (DEM; (NASA JPL, 2013) according to published average sea level data (Environment Agency, 2018a; Environment Agency, 2018b) local to each saltmarsh polygon, as follows: Middle marsh, lower marsh, and mudflat: elevations <MHWS; Upper marsh: elevations >= MHWS and <=HAT; Terrestrial elevations >HAT.

4.2.1 Methodology

Table 4.3 provides an overview of the benefits included in the accounts and the methods used to evaluate them. The distribution of benefits between private benefits (e.g. to farmers) and benefits to wider society, are also noted.

Table 4.3: Overview of benefits included in the account.

Benefit	Description	Annual Physical Flow Measure	Monetary Valuation Metric & Method	Beneficiary
Food provision	Estimated by the total area of saltmarsh with livestock grazing potential, the number of livestock that can graze on this area and the estimated premium price paid to farmers at the farm-gate for saltmarsh grazing livestock.	Number of livestock	Premium on saltmarsh grazing livestock	Farmer
Carbon	Estimated according to UK average carbon sequestration rate (tonnes CO_2 equivalent per hectare) based on saltmarsh age (i.e. years since creation or restoration of saltmarsh) and the non-traded price of carbon.	Carbon sequestered in saltmarsh (tCO_2e/yr)	Non-traded central carbon value DESNZ (2023) £/tCO_2e	Global society
	Estimated according to the number of cattle and sheep expected to graze on saltmarsh created and the non-traded price of carbon.	Carbon emitted by livestock (tCO_2e/yr)		
Flood risk management	Estimated according to the area of seaward facing saltmarsh that is exposed to wave power above a particular threshold and value of an additional hectare of flood control and storm buffering by coastal wetlands.	Area of seaward facing saltmarsh (ha)	Value of an additional hectare of flood control by coastal wetland (£/ha)	Local residents, government
Recreation	Estimated according to the number of new visits to a created saltmarsh based on the area of that saltmarsh and an estimate of the welfare value associated with each visit to agricultural land and agricultural land with seaside and/or estuary water margins.	Recreation visits to created saltmarsh (visits/yr)	Benefit to visitors evaluated as total welfare value from (ORVal) tool (Day & Smith, 2018).	Visitor population
Water quality	Estimated according to the nitrogen and phosphorus removal rate by saltmarsh, the proportion of intertidal area expected to be saltmarsh and the value of nutrient removal based on costs associated with the application of Catchment Sensitive Farming (CSF) measures.	g N and g P	Cost of applying Catchment Sensitive Farming (CSF) measures	Local residents; water treatment companies

4.2.2 UK Saltmarsh natural capital asset values

The estimated annual physical and monetary values, and present value of benefits over the 60 years for the UK saltmarsh creation account is summarised in Table 4.4.

The accounts identify a wide range of benefits from the creation of saltmarsh within the UK. They show significant values for regulating (e.g. flood risk management) and cultural (e.g. recreation) services.

The main values in the saltmarsh creation account (

Table **4.4**) are generated from the carbon sequestered by saltmarsh (77% of total asset value) and from the flood control provided by coastal saltmarsh (20% of total asset value). The high value associated with the carbon sequestration potential of saltmarsh is expected given the higher sequestration rate during the initial years after which a saltmarsh has been created, combined with the increasing monetary value per unit of carbon dioxide over time. The value associated with flood risk management is anticipated to be an underestimate given that the analysis does not allow for the predicted increases in flood risk over time caused by climate change.

Table 4.4 shows annual physical flow and monetary values in the reporting year (i.e. 2050), which is the year in which the target area of saltmarsh has been created. The amount of saltmarsh created annually increases cumulatively between 2024 and 2050. The annual monetary values reported have been discounted according to HM Treasury (2020) Green Book Guidance and are therefore lower than the values would be if all 25,000 ha of saltmarsh were created in the base year (i.e. 2024). Table 4.4 also shows the monetary 60-year present value (PV60) for each benefit. The PV60 represents the asset value, calculated by summing the expected future annual flow of benefits over 60 years, discounted according to HM Treasury (2020) Green Book Guidance to express in present value terms. The annual physical flows and monetary values are reported for 2050, which is the year in which the target area of saltmarsh is created.

Saltmarsh creation is expected to benefit commercial fishing, although it has not been possible to quantify and monetise this benefit (i.e. it is a material non-monetised benefit) due to uncertainties in the changes in fish populations as a consequence of saltmarsh creation. Vegetated coastal ecosystems — seagrass meadows, saltmarshes, tidal marshes, and mangrove forests — and other productive habitats (e.g. biogenic reefs) are widely cited as providing key ecosystem functions that underpin coastal fisheries production. These vegetated coastal ecosystems support fisheries production in several ways, including provision of nutrition (Jänes et al., 2020; Nagelkerken et al., 2008), provision of a nursery function for juvenile fish (Minello et al., 2003), and the predation and refuge function of these ecosystems (Beck et al., 2001; Hyman et al., 2022). Although it is clear that coastal habitats have an important role in supporting fisheries, in most cases it is not possible to quantify this role. It is not clear what the limiting factors of fish populations are and the way in which fisheries would respond to improvements in habitat size and quality. If a specific fish habitat is not strictly limiting population growth, a change in its availability does not lead to a change in stock sizes, provided that other regulating factors remain constant (Levin & Stunz, 2005). Relationships are not likely to be linear (Sundblad & Bergström, 2014), and are likely to be context dependent, including, for example, fisheries management regimes. Therefore, whilst the creation of saltmarsh is likely to increase fish stocks and, by consequence, increase fish catches and the total value of fish landed in UK ports, it is not possible to quantify the benefit.

Table 4.4: Summary of benefits values in the UK saltmarsh restoration account (see Table 4.5 for confidence ratings).

Annual overview	**Physical flow**					**Monetary value**					**PV 60 years (£m)**
Produced at: May 2024	**Physical indicator (Unit/yr)**	Businesses	Rest of society	**Reporting (2050)**	**Confidence**	**Valuation (£m/yr)**	Businesses	Rest of society	**Reporting (2050)**	**Confidence**	**Constant baseline***
Key monetised benefits											
Food provision	Total livestock grown on saltmarsh (no. heads)	44,600	-	44,600	🟢	Total income from livestock	1	-	1	🟢	47
Carbon	CO2e sequestered by saltmarsh (tCO2e)	-	304,167	304,167	🟡	Value of CO2e emissions sequestered /emitted	-	54	54	🟡	2,152
	CO2e emitted by livestock (tCO2e)	-	(32,073)	(32,073)	🟡		-	(6)	(6)	🟡	(252)
Flood risk management	Seaward facing saltmarsh area (ha)	-	9,270	9,270	🔴	Flood control	-	13	13	🔴	531
Recreation & tourism	Recreation visits to created saltmarsh (visits)	-	24,788,490	24,788,490	🟡	Increased welfare from visits to saltmarsh	-	6	6	🟡	235
Water quality	Volume of nitrogen and phosphorus burial (g)	-	2,100,000,000	2,100,000,000	🟡	Replacement cost for N removal	-	2	2	🟡	66
Material non-monetised benefits: fishing (commercial), biodiversity, mental health.						**Total value**			**71**		**2,778**

Table notes:
* PV estimates for carbon sequestration have trend assumptions included as part of valuation process.

The quality of the data used for physical and monetary estimates for each benefit is assessed using the rating described in Table 4.5.

Table 4.5: Assessment of confidence in physical and monetary benefit estimates.

Level of confidence	Symbol	Description of confidence
Low	● (red)	Evidence is partial and significant assumptions are made so that the data provides only order of magnitude estimates of value to inform decisions and spending choices.
Medium	● (yellow)	Science-based assumptions and published data are used but there is some uncertainty in combining them, resulting in reasonable confidence in using the data to guide decisions and spending choices.
High	● (green)	Evidence is peer reviewed or based on published guidance so there is good confidence in using the data to support specific decisions and spending choices.
No colour	● (grey)	Not assessed

4.3 Natural Capital Liabilities

The liabilities in the NCA reflect the expected costs of saltmarsh habitat creation. These costs were estimated in a study by eftec which looked at the average one-off capital costs (CAPEX) of UK intertidal habitat creation projects (eftec et al., 2015).

The costs for creating saltmarsh in the UK (via managed realignment) is estimated at approximately £65,275 per ha in 2024 prices. The study by eftec (2015) assumes that annual maintenance costs are incorporated into the cost of intertidal habitat creation. The target saltmarsh creation area in the asset register is 25,000 ha created over the next 27 years (i.e. between 2024 and 2050), which equates to 926 ha of saltmarsh created annually up to 2050. This amounts to a net cost of approximately £60.4 million per year up to 2050, after which no more wetland is created and hence no additional costs are incurred. The discounted annual cost in the reporting year (i.e. 2050) is £24.7 million and the present value of saltmarsh creation over 60 years is approximately £1 billion.

5 Account results

The asset values estimated are reported in the natural capital balance sheet. The asset values are separated into private benefits and benefits to wider society. Asset values are calculated by summing the expected future annual flow of benefits over 60 years. Where possible, future values take into account expected trends in the quantity and/or value of the benefit. Where this information is not available, benefits are assumed to be constant over time – this assumption increases the uncertainty of the results, the implications of which are reported in Section 6.

5.1 UK saltmarsh NCA balance sheet

Table 5.1 reflects the distribution of benefits and liabilities to businesses and wider society. Most of the benefits accrue to wider society through carbon sequestration, flood risk management and recreation, equating to around £2.8 billion in present value terms. These are however somewhat offset by the dis-benefits of greenhouse gas emissions from livestock, which equate to approximately £250 million over the assessment period. Therefore, the total net asset value to wider society is £2.7 billion in present value terms. A further £47 million accrues to businesses through livestock rearing. Overall, the total gross asset value of saltmarsh creation in the UK amounts to approximately £2.8 billion in present value terms.

In general, there is moderate confidence in both the physical and monetary flow estimates, with present value estimates having greater uncertainty due to assumptions on future trends. Key gaps and uncertainties for the accounting boundary include:

- The non-monetised and unquantified benefits listed in

- Table **5.1** are expected to be material, particularly the benefits to fishing through the creation of saltmarsh. Further work could include valuing these benefits.
- The maintenance costs and liabilities associated with natural capital and their distribution (e.g. saltmarsh maintenance) should be included in order to understand the relationship over time between spending on assets and the benefits they provide.

The liabilities associated with the cost of creating saltmarsh in the UK are estimated at approximately £1 billion over the next 60 years, which is approximately 39% of the value of the benefits. Accounting for these costs, the total net asset value of wetland creation in the UK is approximately £1.7 billion.

Table 5.1: UK saltmarsh creation natural capital asset valuation, PV60 £m.

2024 prices	Valuation metric	Value to businesses	Value to the rest of society	Total
Asset values (monetised)				
Food provision	Total income from livestock	47	-	47
Carbon[1]	Value of CO_2e sequestered by saltmarsh	-	2,152	2,152
	Cost of CO2e emitted by livestock	-	(252)	(252)
Flood risk management	Value of additional coastal wetland area for flood control	-	531	531
Recreation & tourism	Welfare value uplift for created saltmarsh	-	235	235
Water quality	Value of Nitrogen removal	-	48	48
	Value of Phosphorous removal	-	18	18
Total gross asset value	**Mix of values**	**47**	**2,732**	**2,778**
Liabilities				
Production costs[2]		(1,081)	**-**	(1,081)
Total net asset values (monetised)		**(1,034)**	**2,732**	**1,697**
Total net asset values (non-monetised)				
Biodiversity	Total SSSI area: 4,295 ha			
Material non-monetised benefits				
Fishing (commercial), mental health.				

Table notes:
[1] Value of carbon emissions increase over time in line with BEIS (2018).
[2] Costs that are necessary to produce benefits (e.g. intertidal habitat creation costs).

6 Conclusions and recommendations

The saltmarsh creation account can be used to (1) provide an evidence base for different groups and decision-makers to refer to on the size of the potential benefits provided by saltmarsh creation in the UK and (2) to provide useful information to help manage natural capital assets, but more information on site-specific opportunity costs and benefits of saltmarsh creation is needed.

As has been shown in the account results, saltmarsh has multiple benefits, but the predominant purpose of these wetlands is to sequester carbon dioxide, given the efficiency of saltmarsh in locking away carbon (WWT, 2023).

Improvements to the account:

The following suggestions are made to improve future analysis in the accounts.

- **Refine asset and benefit data:** More work could be undertaken to refine certain data, particularly the extent and condition of habitats (e.g. saltmarsh, mudflats, etc.) and the differing benefits associated with these habitats. More detailed modelling of the all the benefits covered in this account would increase the certainty of the results, but in particular:
    - The role of saltmarsh in mitigating flood risk is well understood, but the implications for flood risk management, particularly in the context of climate change, are poorly understood, and so the cost savings associated with his benefit remain uncertain.
    - The additionality and permanence of carbon storage in intertidal sediments is subject of research for the Saltmarsh Carbon Code. This may produce improved approaches for modelling this benefit from saltmarsh, and/or a basis for adjusting the value of the carbon sequestered to reflect risks of non-permanence (Groom & Venmans, 2023).
- **Assess the change in costs of maintaining natural capital assets, including in response to future pressures from climate change:** As described in Section 2, a complete natural capital account would include an assessment of current and planned spending on maintaining the extent and condition of the natural capital assets providing the benefits assessed. Maintenance can be understood in the broadest sense of including restoration, maintenance, and enhancement. This enables comparison of expected costs and benefits, and consideration of whether enough resources are being put into the right actions to ensure those benefits and the natural capital assets that provide them are sustained over time. However, at the UK scale considered in this account broad average costs would have to be used to estimate these costs.
- **Better understanding is needed of future trends in benefits from natural capital, including those caused by climate change:** The economic value of the benefits provided by natural capital assets is based on the assumption that the assets are

maintained to provide those benefits over time. Expected future changes in the quantity and/or value of benefits are reflected in the estimates where relevant data is available (such as factoring in the increasing value of mitigating carbon emissions – as reflected in the account workbook). However, there is insufficient data to represent some expected future changes (such as increased flooding caused by climate change) in the account. While management effort is made to maintain natural capital assets it is not certain that current maintenance costs will be sufficient to maintain the natural capital assets in the long term, particularly in the face of climate change.

- **Develop a natural capital risk register:** An assessment of future risks and pressures is suggested to identify what actions can be taken to address those and how much these actions will cost. This will help address the points above, going forward, as well as help identify potential sources of finance for different actions.

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Appendix 1 – Benefit methodologies

This appendix describes our approach to quantifying and valuing the benefits provided by restored saltmarsh in the UK accounting boundary. The analysis covers the physical and monetary flows of the benefits listed in Section 4.2.1.

A1.1 Food provision

Food provision comprises livestock outputs. The creation of saltmarsh in the UK provides an opportunity for livestock grazing on upper saltmarsh and associated terrestrial areas of higher elevation. The benefit is measured based on the marketed production from the sector at premium market prices. There is a distinction between business and societal benefits of food provision. Business benefits refer to net income to farmers, which can be proxied by gross margin. Societal benefits refer to the benefits of national food security. The societal benefits have not been estimated in this account.

The number of livestock that can be supported by grazing on saltmarshes was extrapolated from data provided by WWT on the stocking density of cattle on Steart Marshes, Somerset. The stocking density for sheep was estimated using the typical ratio of stocking density for sheep to cattle on grassland and applied to the stocking density of cattle on saltmarshes to estimate the stocking density for sheep on saltmarshes. Saltmarsh areas used for livestock grazing were assumed to be evenly split between cattle and sheep, with differing stocking densities used for each livestock. Livestock grazing was assumed to be possible only on upper and terrestrial saltmarshes.

For the monetary values of produce, the John Nix gross margins for livestock output has been collated to produce a five-year average estimate based on 2019 to 2023 figures (Redman, 2018, 2019, 2020, 2021, 2022). A rolling average figure is used to adjust for any potential volatility in agriculture markets. These average unit values were adjusted to account for the premium on saltmarsh grazing produce. To estimate livestock farm income, the adjusted gross margin unit value (£/head) is multiplied by the estimated livestock production figures (e.g. number of beef cattle) in each reporting area. The average unit gross margin figures are assumed to be constant over time.

A1.2 Carbon sequestration

A1.2.1 Carbon sequestered in saltmarshes.

Both natural and restored saltmarshes sequester carbon but at differing rates. Restored marshes become natural marshes 20 years after restoration, and hence the rate of carbon sequestration differs between marshes that were created less than 20 years ago and those that were created 20 or more years ago. The benefit is estimated using the sequestration rates (tonnes CO_2 equivalent per hectare) and the non-traded price of carbon.

Table A. 1: Saltmarsh sequestration rates.

Saltmarsh type	Sequestration rate	Source
Restored marshes (<20 years)	13.3 tCO_2e/ha/yr	(Mason et al., 2022)
Natural marshes (≥20 years)	8.2 tCO_2e/ha/yr	(Mason et al., 2022)

Table A. 1 shows the per hectare carbon sequestration rates for restored marshes that are used within this assessment. This sequestration rate is assumed for the first 20 years after the creation of a marsh, after which the sequestration rate decreases.

This assessment assumes that 926 ha of marsh are created each year up to 2050, at which point the targeted 25,000 ha of marsh would have been created. The sequestration rate therefore changes depending on the age of the saltmarsh.

The total amount of CO_2 equivalent sequestered is estimated by multiplying these per hectare rates with the total hectares of the respective saltmarsh type, based on the age of that saltmarsh at each point in time. The amount of CO_2e sequestered is then valued following the DESNZ (2023) for the non-traded central price, £269 per tonne of CO_2e in 2024. This is multiplied by the estimated tonnes of CO_2e sequestered. Future flows of carbon are valued using the DESNZ (2023) carbon values series until 2050. Following DESNZ (2023) advice, a real annual growth rate is then applied starting at the most recently published value for 2050 and into the future.

Carbon emitted by livestock

The account estimates the volume and cost of carbon emissions from livestock. Note that this calculation does not account for emissions from all farm operations (e.g. electricity, fuel from vehicles, fertiliser, and pesticide use) and is therefore an underestimate of the carbon emitted from farming activities.

Table A. 2 shows the per head carbon emission rates for cattle and sheep that are used within this account. The unit sequestration factors used have been estimated using the total carbon dioxide equivalent emitted by each livestock in the UK (Jones et al., n.d.) and the total number of heads for each livestock type (Defra, 2020b). Emission rates are assumed to remain constant over time. These emission rates are likely to be an overestimate of the emissions associated with saltmarsh grazing livestock given that these emission rates are the average emission rates across all grazing practices.

Table A. 2: Livestock emission rates.

Livestock type	Emission rate	Source
Cattle (other cattle)	-3.1 tCO_2e/head/yr.	(Defra, 2020b; Jones et al., n.d.)
Sheep	-0.2 tCO_2e/head/yr.	

The total amount of CO_2 equivalent emitted is estimated by multiplying the per head rate for a given livestock type by the corresponding number of heads grazing on saltmarshes. The number of cattle and sheep has been estimated as part of the 'Food Provision' benefit[5]. The amount of tCO_2e emitted is then valued following the same approach as for tCO_2e sequestered in habitats and in accordance with the DESNZ (2023) guidance.

A1.3 Flood risk management

Flood risk management is measured in terms of the area of seaward facing coastal saltmarshes exposed to wave power above a certain threshold and the value of an additional hectare of coastal wetland to protect against flooding.

The proportion of seaward facing saltmarsh is applied to the area of actual saltmarsh creation. The proportion of these seaward facing saltmarshes with a mean wave power[6] above a certain threshold is also applied to the area of actual saltmarsh creation. The area of actual saltmarsh created each year increases linearly to 2050, at which point the total target area for saltmarsh creation is met. The area of exposed seaward facing saltmarsh therefore increases each year up to 2050.

The flood risk management benefit is estimated by multiplying the relevant area of the saltmarsh by the estimated value of an additional hectare of flood control and storm buffering by coastal wetlands (Defra, 2020a).

A1.4 Recreation

Recreational benefit is measured in terms of number of additional visits to saltmarshes with seaside and/or estuary water margins that would be generated from the creation and restoration of saltmarshes in the UK, and the average welfare value associated with these visits.

The ORVal tool (Day & Smith, 2018) is used to estimate the number and welfare value of visits to the saltmarshes with seaside and/or estuary water margins in the account boundary. ORVal also breaks down the estimated number of visits and associated welfare value by socio-economic group. Estimates can be produced for various spatial breakdowns within England and Wales, but the data in ORVal is only provided for England and Wales.

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 saltmarshes with seaside and/or estuary water margins are in average condition for its type. Where this is not the case, areas with better/ worse condition than average will likely have higher/lower values for number and welfare value of visits. Similarly, as the model underlying ORVal is based on MENE data, it does not take into account visits by children or overseas visitors to the UK.

The welfare value per visit is estimated by extracting from ORVal the welfare values

[5] See A.1 – Food provision – livestock calculation.

[6] Mean Wave Power (Full Wave Field) is calculated in kilowatts per metre (kW/m) per horizontal metre of wave crest (ABPmer, 2008)

associated with areas of agriculture and areas of agriculture and water margins (Day & Smith, 2018). To estimate the welfare value of water margins, the welfare value of agricultural areas is subtracted from the value of agricultural areas and water margins. The estimated welfare value per visit of water margins is then multiplied by the estimated number of visits to saltmarshes with seaside and/or estuary water margins.

A1.5 Water quality

Maintaining the quality of water in the environment could have welfare benefits to the public as proxy for the many ecosystem services provided. The welfare benefits are linked to maintaining the current WFD quality status of the waterbodies.

The physical change is estimated by the average sequestration and burial rate of nitrogen (N) and phosphorus (P) in coastal saltmarshes (Watson et al., 2020). The sequestration of N and P per hectare of saltmarsh is multiplied by the saltmarsh area created each year. The monetary value of sequestering and burying N and P is estimated according to the replacement and abatement cost were the saltmarsh not providing the nutrient sequestration service. This is based on the cost of applying Catchment Sensitive Farming measures, such as the use of clover in place of N fertiliser, establishment of cover crops following winter wheat, regulatory controls on agricultural P and so on (Watson et al., 2020). The central value in the range of costs was multiplied by the amount of N and P sequestered by saltmarshes each year to estimate the monetary value of improving water quality.

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