The Role of Nature's Kidneys in Carbon Sequestration and Habitat Creation

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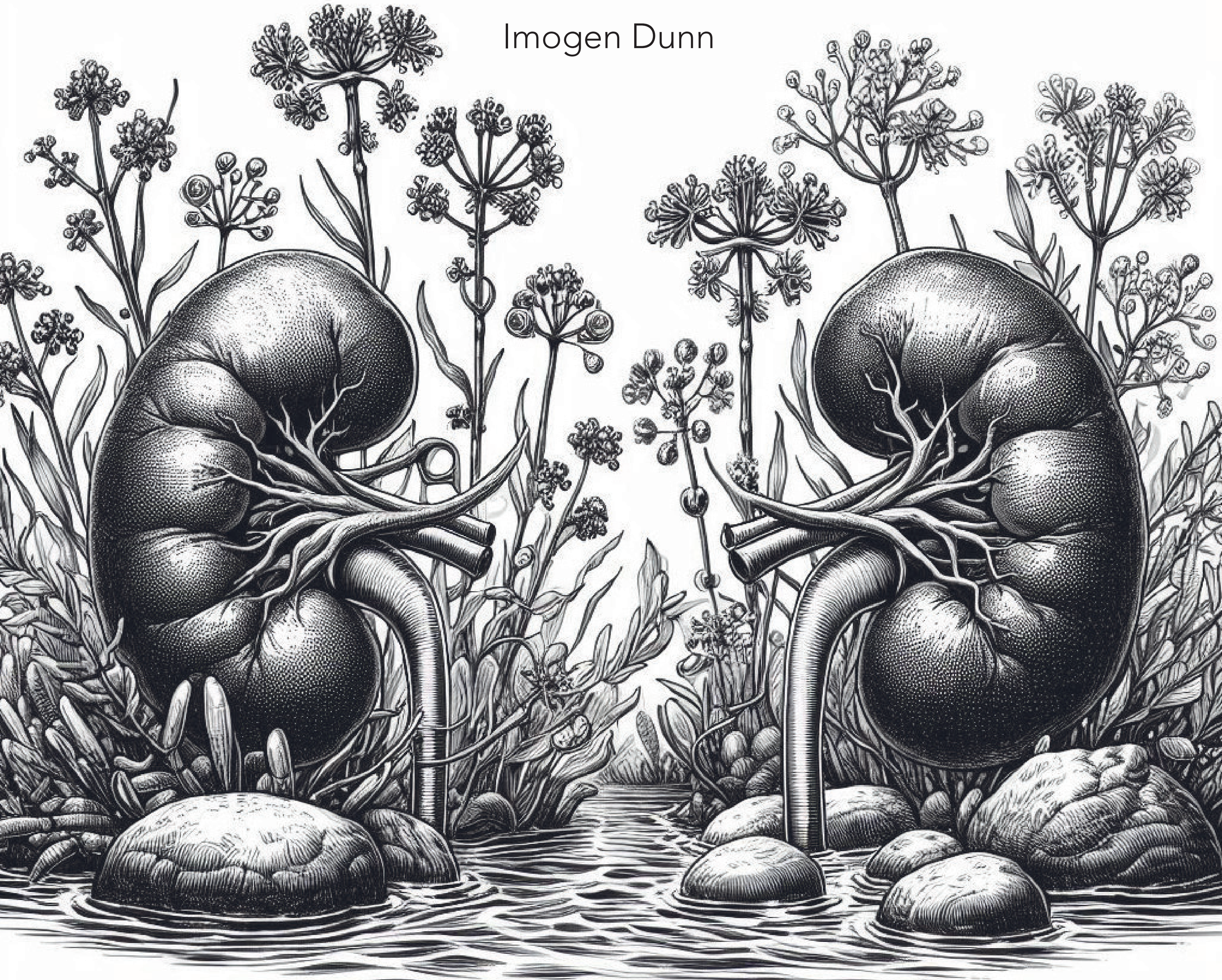

Contents

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Abstract

With the United Kingdom currently not on track to meet the goals that have been set regarding carbon sequestration and wildlife conservation, it is imperative that we continue to search for solutions that can boost its progress. By looking into the types of flora and fauna that various types of coastal wetlands support, their efficiency in sequestering and storing carbon, and the ecosystem services that they provide, this dissertation presents recommendations for the types of coastal wetlands that we need to focus on preserving and those that could be replicated on a large scale in the UK to aid the progress to its carbon sequestration and conservation targets.

List of figures

Figure 10. Fen wood-rush (Luzula pallescens), retrieved from: https://www.inaturalist.org/taxa/515215-Luzula-pallescens

Figure 11. Eurasian curlew (Numenius arquata), A. Sven-Erik (2017) retrieved from: https://www.alamy.com/eurasian-curlew-numenius-arquata-foraging-in-grassland-image158714252.html *

Figure 12. Brent goose (Branta bernicla) (2007), retrieved from: https://www.birdguides.com/articles/identification/brent-geese-photo-id-guide/

Figure 13. Bearded Stonewort (Chara canescens), retrieved from: https://www.inaturalist.org/taxa/486259-Chara-canescens

Figure 14. Pied avocet (Recurvirostra avosetta), M.S. Herrero (2020) retrieved from: https://birdsoftheworld.org/bow/species/pieavo1/cur/introduction

Figure 16. Map of potential saltmarsh creation for carbon sequestration, I.Dunn (2024) adapted from: https://wetland-data-explorer.wwt.org.uk/datasets/WWT-uk::wwt-wetlands-for-carbon-storage-potential/explore?location=54.244836%2C-2.693500%2C5.93

Figure 17. Chesil Beach and the Fleet Lagoon, Dorset, C. Wheeler (2018)

Figure 18. Mute Swan (Cygnus olor) colony, Abbotsbury Swannery, I. Dunn (2024)

Figure 19. Wallasea Islands, Essex Marina, RSPB, retrieved from https://www.rewildingbritain.org.uk/rewilding-projects/wallasea-island

Figure 20. Wallasea Islands in 2015 before wetland restoration, RSPB (2015) retrieved from: https://panorama.solutions/en/solution/wallasea-island-wild-coast-project-landmark-conservation-and-engineering-scheme

Figure 21. Imogen Dunn holding a mute swan (Cygnus olor) at Abbotsbury Swannery, Dorset (2023)

Introduction

The United Kingdom (UK) is home to a variety of coastal wetlands, including estuaries, fens, floodplains, mudflats, saline lagoons, saltmarshes, and seagrass beds. These are areas of land that are either permanently or seasonally inundated with water, each offering its own unique ecosystem supporting a wide range of biodiversity. Wetlands are commonly referred to as "nature's kidneys" due to their ability to filter water, but they also hugely beneficial for humans, plants, and other organisms, providing essential habitats for both flora and fauna, storing vast amounts of carbon, greenhouse gases and other pollutants, and acting as natural flood and erosion.

Since the 1970s, the UK has seen a steady decline in biodiversity and habitat loss, with increasing industrialisation and growth in agriculture (Alkemade et al., 2022) and many coastal wetland habitats have been lost during drainage for land development and agricultural use. As a result, around 1 in 6 species are now at risk of becoming extinct in the UK (Burns et al., 2023). The UK government have set out various goals to address the situation of wildlife decline. These include protecting and conserving more than 30% of land and sea for biodiversity by 2030 (Stephenson, 2022); creating or restoring 500,000 hectares of wildlife-rich habitats (Defra 2023); reducing the risk of species extinction by 2042 compared to 2022 levels (HM Government, 2023); implementing initiatives focused on creating and restoring wildlife-rich habitats (Defra, 2022); and halting and reversing biodiversity loss by 2030 (Stephenson, 2022). The UK government has put legislation (Environment Act, 2021) in place to set out an environmental improvement plan with priories focused on air quality, water, and biodiversity. This includes a goal of increasing species abundance by 10% and reducing the risk of species extinction by 2042. Also under this act, mandatory biodiversity net gain has been introduced for new developments, requiring developers to provide 10% more or better-quality natural habitat than what was present before development (Wentworth, 2024). Conservation covenants also secure long-term protection for natural areas under this legislation (Environment Act, 2021), as well as local nature recovery strategies. Environmental land management schemes also reward farmers for managing their land for nature (Defra, 2023).

To achieve net zero emissions by 2050, the UK has set out carbon sequestration initiatives, focusing on carbon removal technologies and carbon capture from industrial sources. Key initiatives include creating Carbon Capture, Usage and Storage (CCUS) clusters with government funding expanding capture methods, enabling captured carbon to be transported by ship, road, rail and pipelines for injection into deep geological formations for permanent storage (Reid and Flora, 2023); and funding research for direct air capture technology and other greenhouse gas removal technologies (HM Government, 2020). The UK has also committed to reducing emissions by 68% by 2030 compared to 1990 levels as part of its nationally determined contribution to the Paris Agreement. Although the UK has made significant reductions in its carbon emissions, even with these initiatives, it is not on track to meet its net zero target by 2050 (Richardson et al., 2024).

The focus of this dissertation is an assessment of different types of UK coastal wetlands in terms of their capacity for habitat creation and carbon sequestration. Using an analysis of research reports, data, and journal articles, this dissertation presents recommendations on the most efficient and beneficial types of coastal wetlands for replication on a large scale in the UK to incite progress towards its carbon sequestration and conservation targets.

Chapter 1 starts by looking at the coastal wetland types in the UK, giving a summary of key points about each type. Chapter 2 investigates the flora and flora supported in each type of coastal wetland, both above and below the water level. Chapter 3 explores the cultural, supporting and regulating ecosystems services of coastal wetlands. Chapter 4 examines the ability of different coastal wetland types to sequester carbon and store it as blue carbon. Chapter 5 presents a case study of a natural coastal wetland looking at the Chesil and Fleet Nature Reserve in Dorset, consisting of a saline lagoon with reedbeds and eelgrass beds. Chapter 6 offers a different perspective looking at a case study of the coastal wetland restoration project at RSBP Wallasea Islands in Essex Marina, consisting of lagoons, mudflats, saltmarshes, and grasslands.

Estuaries
Saltmarshes
Seagrass beds

Chapter 1: Coastal wetland types in the UK

Historically, wetlands have been viewed as unproductive wastelands that provide more value when drained for other uses such as agriculture or urban development (Sinthumule, 2021). It is estimated that coastal wetlands once covered 4% of England and Wales, compared to 0.2% coverage today (Burden and Clilverd, 2022, p.5). Despite this decline, there is a variety of coastal wetland types throughout the UK, each providing a unique habitat and supporting a range of wildlife and with over 17,381km of coastline, the UK supports internationally important coastal and marine ecosystems (Masselink et al., 2020).

Figure 1 – Map of UK Estuaries, saltmarshes and seagrass beds

1.1. Estuaries

Estuaries are found on the coast where a body of water is partially enclosed, receiving water from rivers and streams, but also permanently or periodically open to the sea. Fresh water from the rivers and streams mixes with saltwater brought in by the tide from the sea to form a brackish body of water, with varying salinity along its length (Potter et al., 2010).

Throughout history, estuaries have served many functions in the UK, including transport routes for trade and travel, providing habitats for wildlife and supporting diverse ecosystems, providing a food source by supporting local fish populations, serving as natural flood defences that protect coastal regions from storm surges by absorbing excess water, providing erosion control, improving water quality by filtering out pollution and excess nutrients, sequestering and storing carbon, and providing space for recreation and leisure purposes (Barbier, 2011).

Approximately 2,500km² of intertidal habitat has been lost from estuaries in England and Wales since 1843 due to human activity of development and land reclamation (Stamp et al., 2022). This has put a strain on the wildlife and the ecosystem services supported by estuaries.

Figure 2 - Fowey Estuary, Cornwall

1.2. Fens

Peatlands cover 12% of land in the UK and fens as a type of peatland, are defined as peat-forming freshwater wetlands with a layer of peat soil thicker than 40cm, being fed by surface water run-off, groundwater, streams, and rainwater (UK Centre for Ecology and Hydrology, n.d; Verhoeven, 1986). These types of habitats support low-productive, nutrient-limited vegetation and are dominated by sedge (*Cyperacae*) and moss (*Bryophyta*) (Hàjek et al., 2006).

Fens can be classified as poor and rich fens. Poor fens are typically species-poor, minerotrophic mires dominated by peat moss (*Sphagnum*). Rich fens on the other hand, are much more species-rich, supporting a variety of calcicole (lime-loving) species but less sphagnum species (Hàjek et al., 2006). The salt from seawater input in low-lying coastal fens determes what vegetation can survive, levels of greenhouse gas emissions that they emit, and the exporting of nutrients via submarine groundwater, which influences biogeochemical processes within the shallow coastal sediments (Toro et al., 2022).

Coastal fens have long been used for grazing livestock, fishing, wildfowling, and peat extraction (Historic England, 2020) but they also make up some of the most carbon-rich ecosystems in the world, provide a net cooling effect on climate change, reduce flood risks in coastal areas, and support biodiversity (UK Centre for Ecology and Hydrology, n.d).

Figure 3 – Burwell Fen

1.3. Floodplains

A floodplain is defined as an alluvial (loose clay, silt, sand, or gravel based) landform adjacent to a channel separated by banks, formed from transported sediment (Nanson and Croke, 1992). Floodplains form around river channels by erosion, with soil worn away by movement of water, and by deposition, with silt being deposited on coarser ground at either side of the river during floods. They can also contain peat soil around upwelling areas and fringes that receive water from springs (Gregg et al., 2021).

Throughout history, floodplains have been exploited for agricultural use and livestock grazing due to the seasonal deposition of nutrients that they receive, but have also acted as crucial flood defences, storing excess water during floods (Gregg et al., 2021).

Figure 4 – Old Wolverton Floodplain Nature Reserve

1.4. Mudflats

Mudflats form at the edges of tidal estuaries and in coastal areas sheltered from waves, as slow-moving tides gently lap over a flat expanse of fine mud or silt and are covered at high tide but exposed during low tide. Intertidal mudflats can be defined as lower tidal, middle, and upper flats (Dyer, Christie, and Wright, 2000).

Lower tidal flats are formed from sandy muds, occurring between the mean low water neap and mean low water spring tide levels, often experiencing stronger tidal currents. Middle flats are formed from fine silts, occurring between the mean low water neap and mean high water neap. The upper flats, which are only submerged during high spring tides are formed from fine-grained sediments such as coarse clay, occurring between the mean high-water neap and mean high water springs (Dyer, Christie, and Wright, 2000).

Figure 5 - Wadden Sea Mudflats

1.5. Saline lagoons

There are 177 saline lagoons in England, covering approximately 1,300 hectares (Natural England and RSPB, 2019). These habitats are defined as coastal areas of shallow, brackish, or saltwater that are either wholly or partially separated from the sea by banks of sand, shingle, pebbles, or rocks. Lagoons vary in salinity, with some saltier than others due to evaporation and some more fresh due to input from freshwater streams. Because of this variety in salinity, the flora and fauna communities that each lagoon supports varies from one to the next (English Nature, 1999).

Figure 6 - Cemlyn Bay, Anglesey

1.6. Saltmarshes

Saltmarshes form where intertidal sand and mudflats become raised above tide level and receive input from both terrestrial and marine carbon sources. Saltmarsh habitats act as net carbon sinks with high carbon sequestration and storage potential, though because of their exposure to natural coastal processes and rising sea levels, these habitats are susceptible to erosion and loss (Gregg et al., 2021).

Figure 7 - Scalasaig saltmarshes, Isle of Colonsay

1.7. Seagrass beds

Seagrass (*Zostera*) beds develop in intertidal and shallow subtidal areas on sands and muds. Although nationally scarce, they may be found in marine inlets, bays, lagoons and channels that are sheltered from significant wave action (Defra, 2008b).

Figure 8 - Eelgrass bed, Nova Scotia

Chapter 2: Cultural, supporting and regulating ecosystem services

Coastal wetlands play a part in cultural ecosystem services, providing non-material benefits to human societies and culture. They provide spaces for recreation and tourism with opportunities for activities such as photography, fishing, and birdwatching. They also create spaces for inspiration of art, music, literature, and poetry, and can provide areas for education and learning – particularly with nature reserves providing opportunities to learn about ecology, biodiversity, and sustainability. Coastal wetlands also promote well-being, providing space for improving physical and emotional well-being through meditation and exercise, and scenic landscapes contribute to mental well-being (Barbier, 2011).

Coastal wetlands also play a role in supporting ecosystem services, maintaining the fundamental processes of an ecosystem. They provide important habitats and niches for organisms to survive, supporting biodiversity and genetic variation, which can be particularly beneficial for habitat creation. They also carry out nutrient cycling by recycling carbon, nitrogen, phosphorus, and sulphur among living organisms (Barbier, 2011). The process of phytoremediation is an important process in this, naturally occurring in wetlands. This bioremediation technique uses plants and soil microbes so reduce hazardous contaminants in the environment and has been successfully exploited to filter metals, contaminants, salt leachate, sewage and other conventional wastes (McCutcheon and Jørgensen, 2008).

Coastal wetlands also provide regulating ecosystem services. They help with climate regulation, by absorbing carbon dioxide (acting as a carbon sink) and other greenhouse gases, which would otherwise contribute to global warming. Wetlands are also important in water and air purification, filtering out pollutants and excess nutrients from water and plants absorbing pollutants such as sulphur dioxide, nitrogen oxides and particulate matter from the air. This improves the environment for both humans and animal species. They are also important in flood and erosion control, as well as water regulation. Coastal wetlands such as saltmarshes provide natural hazard regulation, by acting as a buffer between extreme weather events and natural disaster such as floods, landslides, and droughts. They can regulate water flow and act as a buffer between the sea and coastal regions, through wave attenuation (slowing water flow) and in turn reduce risk of flooding (Sarika and Zikos, 2021). Floodplains also act as a natural buffer, absorbing floodwater during periods of high water-flow and help mitigate the risk of downstream flooding (Gunnell, et al., 2019). Coastal wetlands can also reduce risk of flash floods, acting like sponges, absorbing excess rainwater, and releasing it slowly during droughts. Vegetation stabilises the soil, reducing erosion caused by wind and water, maintaining land productivity, and protecting water quality by preventing sediment from eroded soil polluting waterways. Wetlands also provide biodiverse ecosystems that support predators, parasites and pathogens that naturally control pest populations, reducing the need for chemical pesticides. This can also regulate disease by maintaining a balanced ecosystem, where certain diseases are less likely to spread (Barbier, 2011).

Chapter 3 – Flora and fauna

With increasing industrialisation and agriculture in the 1970s, the UK started to see significant biodiversity and habitat loss (Ares and Wentworth, 2024). Wetlands cover about 4% of England, and have very high biodiversity, providing essential habitats for a variety of flora and fauna, both above and below water, playing a huge role in supporting a significant number of internationally important species. Because of this, 47% of UK wetlands are now under SSSI protection (UK National Ecosystem Assessment, 2011).

Coastal wetlands, aside from providing habitats for roosting, breeding, and feeding, provide a safe space for aquatic birds to moult and breed. Waterfowl become vulnerable as they go through their 6-8-week moult, losing old and growing new feathers, becoming flightless for 3-5 weeks during this. As a result, they need to find a large body of water that will enable them to escape any predators while they are unable to fly (Ringelman, 1990).

3.1. Estuaries

Estuaries provide essential habitats, spawning areas, nurseries, and migration routes for a variety of both commercially and ecologically important fish species in the UK. Fish such as European bass (*Dicentrarchus labrax*), sole (*Solea solea*), Whiting (*Merlangius merlangus*), Cod (*Gadus morhua*), Pollack (*Pollachius pollachius*), Dab (*Limanda limanda*), and most abundantly Herring (*Clupea harengus*) use estuaries as nursery habitats, with European bass and herring also using estuaries as feeding grounds (Stamp et al., 2022).

Estuarine habitats are also home to a variety of other organisms. The benthic communities living at the bottom of the body of water include annelid polychaete worms such as ragworm (*Hediste diversicolor*), sandworm (*Nereis virens*), sandmason worm (*Lanice chocilega*), gallery worm (*Capitella capitata*), molluscs such as the Baltic tellin (*Macoma balthica*), common cockle (*Cerastoderma edule*), soft-shell clam (*Mya arenaria*) and peppery furrow shell (*Scrobicularia plana*) that live within the sediment and feed by filtering the estuary water and suck up surface detritus. The epifaunal communities living on the surface of the substrate include blue mussel (*Mytilus edulis*), mud snail (*Hydrobia ulvae*), and European mud scud (*Corophium volutator*) provide rich feeding grounds for waders and ducks. Estuarine habitats also contain many amphipod crustaceans, invertebrates, algae, filter feeders, detritus feeders, phytoplankton, zooplankton, and microbial decomposers (Davidson et al., 1991).

Figure 9 - Atlantic Herring (Clupea harengus)

3.2. Fens

Coastal fens support plants such as cuckooflower (*Cardamine pratensis*), common birds'-foot trefoil (*Lotus corniculatus*), purple loosestrife (*Lythrum salicaria*), yellow iris (*Iris pseudacorus*) and water mint (*Mentha aquatica*), but also provide habitats for other wildlife such as water voles and swallowtail butterflies (Wildlife Trust, n.d).

Species regionally restricted to fens, include fen wood-rush (*Luzula pallidula*), fen ragwort (*Senecio paludosus*), heath dog-violet (*Viola canina* subsp. *Montana*), and insects such as the planthopper bug (*Eurysula lurida*) rove beetle (*Gryophaena pseudonana*), feather-winged beetle (*Microptilium palustre*), eyed longhorn beetle (*Ptilium affine*), plume moth (*Emmelina argoteles*), Cambridge groundling moth (*Scrobipalpa pauperella*), long-legged fly (*Dolichopus plumitarsis*) and dance-fly (*Platypalpus pallidiseta*) (Mossman, Panter and Dolman, 2012).

Species largely restricted to fens include bearded stonewort (*Chara canescens*), dwarf stonewort (*Nitella tenuissima*), ribbon-leaved water plantain (*Alisma gramineum*), early marsh-orchid (*Dactylorhiza incarnata* subsp. *Ochroleuca*), fringed water-lily (*Nymphoides peltata*), fen violet (*Viola persicifolia*), Cambridge milk-parsley (*Selinum carvifolia*), water germander (*Teucrium scordium*), wolf spider (*Pardosa paludicola*), marsh moth (*Athetis pallustris*), thick-headed fly (*Myopa polystigma*), silver barred moth (*Deltote bankiana*), marsh carpet moth (*Perizoma sagittata*), scarce pug moth (*Eupithecia extensaria* subsp. *Occidua*) and reed leopard (*Phragmataecia castaneae*) (Mossman, Panter and Dolman, 2012).

Figure 10 - Fen wood-rush (Luzula pallescens)

3.3. Floodplains

Floodplains support a range of plants including nationally scarce species such as snakeshead fritillary (*Fritillaria meleagris*), downy-fruited sedge (*Carex filiformis*), narrow-leaved water dropwort (*Oenanthe silaifolia*), and several dandelion (*Taraxacum*) microspecies. They also provide a large seasonal source of pollen and nectar that acts as a crucial food source for a variety of invertebrate species such as bumblebees (*Bombus*), sawfly (*Symphata*), hoverfly (*Syrphidae*) and beetle (*Coleoptera*) (Rothero and Lake, 2016).

During summer, floodplains provide breeding grounds for wading birds such as the Eurasian curlew *(Numenius arquata*), lapwing (*Vanellus vanellus*), common redshank (*Tringa totanus*), and black-tailed godwit, as well as skylark (*Alauda arvensis*), and yellow wagtail (*Motacilla flava*). Floodplains also provide feeding grounds during winter and times of flooding for wildfowl and waders such as whooper swan (*Cygnus cygnus*), Bewick's swan (*Cygnus columbianus bewickii*), European wigeon (*Mareca penelope*), Eurasian teal (*Anas crecca*), Northern shoveler (*Spatula clypeata*), golden plover (*Pluvialis apricaria*) and common snipe (*Gallinago gallinago*) and for passerines such as common starling (*Sturnus vulgaris*), redwing (*Turdus iliacus*) and fieldfare (*Turdus pilaris*) (Rothero and Lake, 2016).

Figure 11 - Eurasian curlew (Numenius arquata)

3.4. Mudflats

Mudflats consist of algae (*Phycophyta*), seagrass (*Zostera*) and sediment and although diversity of fauna within mudflats is relatively low, they support vast populations of the species that do occur. These species include the common cockle (*Cerastoderma edule*), sandhopper (*Corophium volutator*), laver spire shell (*Hydrobia ulvae*) and ragworm (*Hediste diversicolor*). In mudflats with a higher sand content, polychaetes such as catworm (*Nephtys hombergi*) and lugworm (*Arenicola marina*) can occur (Defra, 2008a).

Since the volume of small organisms living within the sediment is so high, intertidal mudflats provide vital food, nesting, and roosting habitats for wintering birds such as the barnacle goose (*Branta leucopsis*), brent goose (*Branta bernicla*), and internationally important numbers of turnstone (*Arenaria interpres*), knot (*Calidris canutus*) and redshank (*Tringa tetanus*) (Foster et al., 2013; Holt et al., 2010).

Figure 12 - Brent goose (Branta bernicla)

3.5. Saline lagoons

Saline lagoons provide important feeding, nesting and roosting grounds for birds, as well as habitats for algae, seagrass beds (*Zostera marina, Zostera angustifolia and Zostera noltii*), sea anemone (*Actiniaria*) and stalked jellyfish (*Haliclystus auricula*), while the soft sediment surrounding the roots is home to molluscs, tiny amphipods, polychaete worms and echinoderms (Langston et al., 2003; Natural England and RSPB, 2019)

There are also several species with distribution limited to saline lagoons, protected under the Wildlife and Countryside Act (1981). These include lagoon sand shrimp (*Gammarus insensibilis*), starlet sea anemone (*Nematostella vectensis*), tentacled lagoon worm (*Alkmaria romijni*), trembling sea-mat (*Victorella pavida*), foxtail stonewort (*Lamprothamnium papulosum*) and bearded stonewort (*Chara canescens*) (Natural England and RSPB, 2019).

Figure 13 - Bearded stonewort (Chara canescens

3.6. Saltmarshes

Saltmarshes are first vegetated with glasswort (*Sarcocornia perennis*) and then with cord-grasses (*Spartina anglica*), sea purslane (*Halimione portulacoides*), sea aster (*Tripolium pannonicum*), saltmarsh rush (*Juncus gerardii*) sand sea lavender (*Limonium sinuatum*) as the mud becomes drier (Adnit, et al., 2007). They also support species such as starlet sea anemone (*Nematostella vectensis*), mud snails (*Hydrobia* sp. and *H. neglecta*), lagoon cockle (*Cerastoderma glaucum*), lagoon sand shrimp (*Gammarus insensibilis*) and pied avocet (*Recurvirostra avosetta*) (Department of Energy & Climate Change, 2016).

Figure 14 - Pied avocet (Recurvirostra avosetta)

3.7. Seagrass beds

Three species of seagrass (*Zostera*) occur in the UK and are all considered scarce; Dwarf eelgrass (*Zostera noltii*), narrow-leaved eelgrass (*Zostera angustifolia*) and eelgrass (*Zostera marina*). These seagrasses stabilise the sediment, creating habitats and feeding grounds for a variety of species (Defra, 2008b).

Brent geese (*Branta bernicla*), mute swans (*Cygnus olor*), and Eurasian widgeon (*Mareca penelope*) feed on eelgrass itself, while other species will feed on the variety of benthic fauna it supports such as amphipods (*Amphipoda*), polychaete worms (*Polychaeta*), bivalves (*Bivalvia*), and echinoderms (*Echinodermata*) (Defra, 2008b). The seagrass (*Zostera marina*) meadows in Studland Bay, Dorset for example, support two species of seahorse; the spiny seahorse (*Hippocampus histrix*) and the short-snouted seahorse (*Hippocampus hippocampus*) (Garrick-Maidement et al., 2010).

Seagrass beds also provide vital habitats for fish such as pollack (*Pollachius pollachius*), two-spotted goby (*Gobiusculus flavescens*), and wrasse (*Labridae*), as well as two species of pipefish that are restricted to seagrass beds: snake pipefish (*Entelurus aequoraeus*) and broadnosed pipefish (*Syngnathus typhie*) (Defra, 2008b).

Figure 15 - Common eelgrass (Zostera marina)

Chapter 4: Blue carbon and carbon sequestration

Globally, 55% of biological carbon captured is done so by marine organisms (Nellemann et al., 2009). This organic carbon captured and stored by coastal marine ecosystems such as saltmarshes and eelgrass beds is referred to as blue carbon (Macreadie et al., 2019). With the UK's coastal vegetated blue carbon habitats sequestering approximately 271,000 tonnes of carbon per year, it is estimated that more than 244.1 million tonnes of organic carbon is stored within the UK's marine habitats (Burrows, et al., 2024).

Carbon sequestration is the process of capturing and storing CO_2, reducing the amount of carbon in the atmosphere and limiting climate change. This is split into three processes; biological carbon sequestration, where CO_2 is stored in the natural environment, such as in forests; geological, where carbon is captured from industrial facilities and power plants, or removed directly from the atmosphere and stored in geological formations; and ocean fertilisation, where nutrients such as iron, phosphorous and nitrogen are introduced in the ocean, causing phytoplankton to grow rapidly and absorb large amounts of CO_2. The heavier phytoplankton then sink to the bottom of the ocean and deposit the CO_2 (Nayak, Mehrotra and Mehrotra, 2022).

Grasslands, wetlands, and oceans act as carbon sinks, reducing greenhouse gas concentrations in the air by sequestering CO_2 from the atmosphere via photosynthesis and storing carbon in vegetation and soils. If burned or drained however, wetlands transform from carbon sinks to carbon stores, releasing centuries of stored carbon back into the atmosphere (Ramsar, 2019). This means that although creation and restoration of wetlands would provide huge benefits and progression towards the UK's carbon capture goals, the conservation and protection of existing wetlands is just as important to prevent large stores of carbon from being released back into the environment.

4.1. Estuaries

Estuary sediment is 10 times more efficient in storing carbon than sediment in forests and if left undisturbed, can store carbon below the seabed for thousands of years. (Bogeberg, 2024). Although the ability of carbon sequestration in estuaries is dependent on location and present vegetation, formation of saltmarshes and their ability to support seagrass beds significantly increases their potential for carbon sequestration and storage. It is important that these habitats are protected due to the vast stocks of carbon that they already store (Smeaton and Garrett, 2024). Disruption of these habitats could lead to huge amounts of carbon being released back into the environment.

4.2. Fens

Although peatlands such as fens sequester carbon at a relatively slow rate compared to other habitats, they can do so indefinitely (Gregg, et al., 2021). A variety of peatland types covers 3% of the planet, storing approximately 30% of land-based carbon, making them the largest carbon storing habitat. Although this makes fens crucial in carbon sequestration and carbon storage, they pose a huge threat to the environment if they are drained for agricultural use or burned either purposely or accidentally. They become large carbon sources, releasing centuries worth of sequestered and stored carbon back into the atmosphere. This has a catastrophic effect, as seen in 2019 with draining and burning of peatlands made up 10% of all global annual fossil fuel emissions (Ramsar, 2019).

4.3. Floodplains

Covering 16,000km² of the UK, floodplains provide vital spaces where rivers and streams can transport and deposit carbon-rich materials and act as large carbon stores. Research has shown that although floodplains initially accumulate organic carbon at much higher rates than other habitats, this starts to decline at around 300-600 years after soil formation. Floodplains will still however provide crucial carbon storage after this time. Human modifications to floodplains such as drainage, flood defences and stream diversion, however, limit the ability for a floodplain to act as a natural carbon sink, releasing carbon dioxide back into the environment (Gregg et al., 2021).

4.4. Mudflats

Intertidal mudflats, although not particularly efficient in sequestering carbon due to their lack of vegetation, do act as carbon sinks. This is possible, as they receive carbon input from both terrestrial and marine environments. The sediment particle size of intertidal habitats plays a role in their ability to store carbon, with the finer silt in mudflats being able to store more carbon than coarse and sandy sediments (Gregg et al., 2021).

4.5. Saline lagoons

Since saline lagoons only make up a small percentage of UK coastline, there is not much research on their ability to sequester and store carbon (Gregg et al., 2021). Sheltered environments however, mean that seagrass can commonly be found in saline lagoons, which has a huge impact on carbon sequestration and storage within these habitats (Burrows, et al., 2024).

4.6. Saltmarshes

Saltmarshes reduce rates of greenhouse gas emissions (Magenheimer et al., 1996) with a higher carbon sequestration capacity per unit area than other wetland systems (Bridgham et al., 2006), with the potential to sequester carbon continuously over thousands of years (Brevik and Houmburg, 2004; Caçador et al., 2016). Existing restored saltmarshes in the UK store an estimated average of 13.3 tonnes of carbon per hectare per year, while naturally occurring saltmarshes store and average of 8.2 tonnes (Fewins, 2022). This proves that saltmarshes are crucial in storing carbon and the restoration of them can be used to dramatically increase the UK's carbon storage.

The Wildfowl and Wetlands Trust (WWT) have identified spaces that could be used for creation and restoration of saltmarshes for sequestering and storing carbon as shown in figure 16.

Figure 16 - Map of potential saltmarsh creation for carbon storage

Existing saltmarshes
Potential spaces for saltmarsh creation

4.7. Seagrass beds

Of the 1 million tonnes of organic carbon in long-term stores found within coastal vegetated blue carbon habitats, 6% is stored in seagrass bed sediment. Seagrass beds have great potential to store large quantities of carbon within their sediments if undisturbed. Their vegetation is also able to sequester significant amounts of carbon in situ, as well as being able to trap and store carbon released from elsewhere (Gregg et al., 2021).

Chapter 5: Case study of a natural coastal wetland – Chesil and Fleet Nature Reserve, Dorset

Covering 480 hectares, the Chesil and Fleet Nature Reserve offers a unique ecosystem, with a 14km-long saline lagoon (the Fleet Lagoon), a shingle/pebble bank creating a barrier from the sea, and acres of reedbeds and eelgrass beds (Perrins and Ogilvie, 1981). It provides a sanctuary for breeding colonies of birds such as mute swan (*Cygnus olor*), cormorant (*Phalacrocorax carbo*), common tern (*Sterna hirundo*) and black-headed gull (*Chroicocephalus ridibundus*). It also provides a safe environment for aquatic bird species to carry out their annual moult in summer, and a place of rest for wintering birds such as whooper swan (*Cygnus cygnus*) and brent goose (*Branta bernicla*) (English Nature, 1999).

Due to its significance in providing internationally important habitats and supporting a wide range of rare species, as well as its location in Dorset, which is a centre for tourism and recreation, Chesil beach and the Fleet Lagoon as part of the Heritage Coast (on the Jurassic Coast) have been designated as an Area of Outstanding Natural Beauty (AONB), Special Area of Conservation (SAC), a Special Protection Area (SPA), a RAMSAR site (wetland of international importance), a Site of Special Scientific Interest (SSSI), a marine protected area, and is also a designated bass nursery area (Weber, O'Sullivan and Brassley, 2006; Energy & Climate Change, 2016).

Over the years, the Chesil and Fleet Nature Reserve has provided vital habitats for a vast array of wildlife. Intertidal sandy sediments at the eastern end of the lagoon supports

Figure 17 - Chesil Beach and the Fleet Lagoon, Dorset

two species of eelgrass (*Zostera marina* var. a*ngustifolia and Zostera noltii*), providing mute swans (*Cygnus olor*) with a plentiful source of food throughout winter and reeds (*Phragmites*) providing food for visiting canada geese (*Branta canadensis*). The lagoon has also supported a variety of nationally rare species such as the protected saline lagoon sandworm (*Armandia cirrhosa*), lagoon shrimp (*Gammarus insensibilis*), starlet sea anemone (*Nematostella vectensis*) and DeFolin's lagoon snail (*Caecum armoricum*) which is not known to be found anywhere else in the UK (English Nature, 1999).

At the west end of the lagoon, the reserve supports the largest resident population of breeding and non-breeding mute swans in Britain, considered a nationally important population (English Nature, 1999). Mute swans typically claim large territories of up to 10 acres on a pond or lake (Ivory, 2022), as they must find a large expanse of fresh water with enough food for the year, with mating and nesting occurring in March to April, hatching in May to June, and fledging in October. At Abbotsbury Swannery however, the Mute Swans have adapted to forgo their aggressive and territorial behaviour with towards humans and each other, to live in a habitat where they can successfully breed and moult safely, with plenty of food for all (Perrins and Ogilvie, 1981). This is made possible as the western end of the 14km Fleet Lagoon provides fresh water, with streams running through the site from the South Dorset Ridgeway, where nesting pairs can breed. Once the cygnets (offspring) have developed their desalination glands and can tolerate the salty water, they can swim towards the middle of the fleet and eat the eelgrass (*Zostera* sp.), which grows abundantly in the brackish water during the winter (Wheeler, 2021).

Figure 17 - Mute swan (Cygnus olor) colony at Abbotsbury Swannery, Dorset

The rare foxtail stonewort (*Lamprothamnium papulosum*) can also be spotted growing along the shore of the Chesil bank and the lagoon is also an essential space for fish populations, with over 25 species recorded (Perrins and Ogilvie, 1981). Fish species found in the lagoon include bass (*Dicentrarchus labrax*), black bream (*Acanthopagrus butcheri*), sand smelt (*Atherina presbyter*), mullet (*Mullus surmuletus*), goby (*Pomatoschistus microps*), and oysters (*Ostrea edulis*) are farmed commercially at the eastern end of the lagoon for local restaurants. Birds that can often be spotted on the reserve include little terns (*Sternula alibfrons*), European wigeon (*Mareca penelope*), common pochard (*Aytha farina*), Eurasian coot (*Fulica atra*) and osprey (*Pandion haliaetus*) (Dorset MPAs, n,d).

Although there have been no research projects investigating the carbon sequestration and storage potential of the Fleet Lagoon, the vast beds of eelgrass (*Zostera marina*) that it supports play a significant role in this.

Chapter 6: Case study of a coastal wetland restoration project – RSPB Wallasea Islands, Essex Marina

RSPB Wallasea Islands in Essex Marina is the largest restored wetland in Europe (Nugent, 2019). Forming 670 hectares of intertidal habitat, saline lagoons and coastal grassland, this restored wetland has been created to support a wide variety of wildlife including nationally and internationally important bird species. The creation and restoration of these wetlands has also dramatically increased the site's capacity to sequester carbon (Watts, 2020), with its mudflats and saltmarshes currently burying 1,200 tonnes of carbon dioxide each year (Nugent, 2019).

Wallasea Island now sits within a Special Protection Area (SPA) and Ramsar site within Essex Marina. Over several years, 3 million tonnes of soil was brought by ship, from the excavation of the tunnels of the Elizabeth underground line to raise land levels and create a 115 hectare area of saltmarsh, inlands and mudflats known as Jubilee Marsh (Burns, et al., 2023). This site provides a vital habitat for migratory birds and tens of thousands of birds visit each year, with highlights including short-eared owls (*Asio flammeus*), marsh harriers (*Circus aeruginosus*), dark-bellied brent geese (*Branta bernicla*) and pied avocets (*Recurvirosta avosetta*). Common seals have also been spotted here (RSPB, n.d).

Previously forming a large expanse of farming land, the restored wetlands now span 740 hectares, providing a space for human activity and recreation, with 6 walking trails and 2 shelters to encourage interaction and immersion with the environment and the abundance

Figure 18 - Wallasea Islands, Essex Marina

of wildlife it supports, with large numbers of wintering waterbirds on its extensive estuaries and saltmarsh (RSPB, n.d). With climate change in mind, the restoration of Wallasea Islands has also been engineered so that as sea levels rise, the water can creep up the long shallow slopes, allowing saltmarshes to expand and protect the coastline from erosion and flooding (Nugent, 2019).

Figure 20 - Wallasea Islands in 2015 before wetland restoration

Conclusion

Given that the UK is not on track to capture enough carbon annually before 2050 to meet the goal of achieving net zero emissions, and the amount of carbon that coastal wetlands can capture and store as blue carbon, the creation of more coastal wetlands could be used to support these goals. With wetlands providing the largest terrestrial carbon stores, restoration of degraded and creation of new wetlands provides a potentially important mechanism for climate change mitigation (Burden et al., 2013).

Considering the vast variety of wildlife that coastal wetlands support, the unique ecosystems and habitats that each type provides, and the fact that they boost diversity and lock away more carbon from the atmosphere than forests (Rawat, n.d.), it is clear that the creation of more of these spaces could also be used to the UK's advantage in its efforts to halt the biodiversity and habitat lost it has seen over the last 50 Years.

Looking at their efficiency in storing carbon, as well as their importance in providing habitats for fish and benthic communities, estuarine habitats should be protected. Due to risk of burning and draining causing carbon to be released back into the environment, existing coastal fens should be protected rather than being created. This is important, as they support rare and regionally restricted species and although sequestering carbon relatively slowly, are huge carbon stores. Floodplains are crucial in supporting a range of nationally scarce species of plants, but also provide breeding and feeding grounds for wading birds, wildfowl, and passerines. With this and their ability to sequester carbon at higher rates than other habitats for 300-600 years and then act as carbon stores, restoration and creation of more floodplains could prove particularly beneficial in the UK's aim for carbon sequestration and biodiversity improvement. Mudflats, though lacking in floral biodiversity not very efficient in carbon sequestration, can store large volumes of carbon within sediments and support large populations of benthic communities which act as an essential food source for wintering birds. These habitats should be protected for their existing carbon stocks. Saline lagoons are home to various protected species, but also provide nesting, roosting, and feeding grounds with a variety of benthic species within their sediment, as well as providing space for seagrass beds to grow, which are very efficient in carbon sequestration. Saltmarshes support a diverse range of plant, echinoderm, invertebrate, and bird species. With this and their higher capacity to sequester and store carbon than other habitats, they could also be used to push the UK towards reaching its carbon sequestration and biodiversity goals. Seagrass beds, although nationally scarce, support large populations of fish and benthic species, and provide essential feeding grounds for bird species. Their potential to sequester significant amounts of carbon and store it within their sediments and existing stocks makes them good candidates for reaching carbon sequestration and biodiversity goals.

It is clear that the UK could use wetlands to progress toward its carbon sequestration and biodiversity goals. It seems that floodplains, saltmarshes, and seagrass beds would be the most beneficial for restoration and creation for their potential and efficiency in sequestering carbon, as well as the support they provide to wildlife. The conservation of existing wetlands, however, is just as important, to prevent them from becoming carbon becoming carbon sources and to protect the often rare wildlife within them.

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Figure 21 - Imogen Dunn holding a mute swan (Cygnus olor) at Abbotsbury Swannery, Dorset