Turning the Tide

Systems thinking for a sustainable ocean

April 2025

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

The Institution of Environmental Sciences

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This publication reflects the overall balance of views expressed by participants in the Turning the Tide project and do not necessarily reflect the views of the individuals and affiliated organisations listed above.

About the Institution of Environmental Sciences

The Institution of Environmental Sciences (the IES) is at the forefront of uniting the environmental sciences around a shared goal: to work with speed, vision and expertise to solve the world's most pressing environmental challenges, together. As the global professional membership body for environmental scientists, we support a diverse network of professionals all over the world – and at every stage of their education and careers – to connect, develop, progress and inspire.

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Introducing Turning the Tide

At the start of 2023, we launched ‘Turning the Tide: systems thinking for a sustainable ocean’. To mark the end of this project, we will share four publications covering each of the project themes. This publication will summarise the key points included in the first theme: ‘Bridging the gap between land and sea’.

Turning the Tide: Systems Thinking for a Sustainable Ocean was a long-term project covering four key themes in marine and coastal science from a systems thinking perspective: ‘Bridging the gap between land and sea’; ‘Blue carbon’; ‘Blue economy’; and ‘Marine conservation and restoration’.

‘Bridging the gap between land and sea’, and Turning the Tide as a whole, opened with a webinar exploring the ways in which human activities affect the marine and coastal environment,[1] which was followed up by a forum on ocean literacy,[2] giving attendees a chance to learn more about understanding and communicating humanity’s relationship to the marine environment. As our ‘Bridging the gap’ content was being shared, a Treaty to protect the High Seas was agreed upon by the United Nations.[3] We shared a guest-authored blog on this historic development,[4] reflecting on how it had been achieved and what might happen next.

We hosted an event titled ‘Examining the land-sea interface: Coastal management approaches’, which focused on the application of Integrated Coastal Zone Management.[5] Finally, we collaborated with Ocean and Coastal Futures (OCF) to facilitate a roundtable discussion which sought to place the land-sea interface within the wider context of marine sustainability, wrapping up 'Bridging the gap between land and sea' and providing a foundation for the following project themes. Turning the Tide generated a variety of live events along with blogs and articles delving into each theme. To revisit any of the project outputs, follow the links in ‘What next?’, the final section of each Turning the Tide publication.

The land-sea interface

Foreword

Bridging the gap between land and sea necessitates an understanding of, and engagement with, terrestrial processes. Interdisciplinarity and systems thinking is key to our work, and that of the environmental science sector as a whole. The Foundation for Water Research (FWR) is part of the IES Communities ecosystem, and is an independent community of professionals from across the water sector and related scientific specialisms. The community comes together for deliberative discussion to support the development of interdisciplinary solutions to water challenges. FWR member and IES Vice President Mark Everard reflects below on the interconnectedness of marine and freshwater environments and processes, and the challenges and opportunities this poses.

"The land-ocean interface spans not only boundaries between major habitat types and the ecotones between them, but also multiple jurisdictions, regulatory frameworks and cultural associations. For many aquatic organisms, particularly diadromous species such as eels and salmon, free access between fully saline and fresh water is essential for the completion of life cycles, and the diverse, distinctive and productive estuarine ecosystems (or 'transitional waters') where these waters meet and blend creates vital recruitment, nursery and feeding habitat for many more animals and plants. Whilst the interface between land, fresh waters and the marine environment is hypothetically a place of great mixing – for ecology, folklore, biogeochemistry, physical processes and livelihoods – often in practice it presents a conceptual and legislative gap. This meeting of habitats is, in reality, more of a continuum than a hard division, providing a wealth of deeply interconnected ecosystem services that are widely exploited: for food production, tourism and recreation and aggregate extraction, as trade routes, and for many more purposes besides. It is also a space where humanity exerts profound influence, fragmenting inherently contiguous environmental processes. It does so directly through port, residential, industrial and agricultural development, fisheries and navigation, from barrages and other obstructions, and due to hard coastal defences. Many more diffuse impacts also arise from remote sources, such as disruption of sediment flows from rivers and elsewhere in the coastal zone contributing to erosion, and saline intrusion also results from over-abstraction of coastal groundwater. This is critical not just for the integrity of the ecosystems themselves, but also as environmental processes at this interface support diverse livelihoods, nutritional needs, cultures and economies throughout the world. Development of a symbiotic relationship that seeks to conserve vital ecosystem integrity and functioning through sustainable resource use is a goal requiring systemic understanding informing policy formulation and action. There have been some welcome breakthroughs, such as the United Nations Treaty to Protect the High Seas (Biodiversity Beyond National Jurisdiction, or 'BBNJ'), the explicit inclusion of 'Life below water' as Sustainable Development Goal 14 and 'life on land' (which includes fresh waters) as SDG13, increasing uptake of Integrated Coastal Zone Management (ICZM) and, in the UK, progress towards Marine Biodiversity Net Gain (BNG) as well as terrestrial BNG. However, these initiatives are just the start of a wider societal reorientation to recognise the values of ecosystems of all types both for their inherent values as well as foundational resources underpinning continuing human wellbeing, including the resilience of the land-ocean interface. Taking a systems approach to knowledge creation informing policy formulation and management practices is vital to ensure that good intentions do not fall between the cracks at the land-ocean interface."

– Professor Mark Everard

Marine and terrestrial ecosystems are strongly linked through their biogeochemical and socioeconomic processes and therefore, for effective management of both, it is essential that there is a strong understanding of the interconnections and feedback loops between them. However, regulation and management of these environments is often siloed, leading to negative impacts, unintended consequences and a failure to implement solutions to environmental challenges with multiple benefits for people and nature.

The importance of the connection between marine and terrestrial environments is most apparent at the land-sea interface, where the impacts are often more readily seen and felt by local communities. It is therefore crucial to interrogate the interconnections between land and sea, and thereby support well-informed, sustainable decision-making that supports the protection and restoration of both.

Management of areas within a coastal zone or area of the ocean generally comes from a desire to protect a valued resource or ecosystem service. However, due to jurisdictional boundaries and existing governance frameworks, which are often arbitrary and not aligned with environmental features, management approaches can be fragmented and may not consider the wider ecosystem. With recognition that valued resources and ecosystem services cannot be isolated from the environment in which they sit, it is imperative that any kind of management plan considers the effects that will spill out of its assigned zone, and not simply account for those within it. Similarly, due to the complex nature of the land-sea interface, it is important that governance is joined-up and transcends borders to act for the global good.[6] Regulations and management placed on one area of the marine and coastal environment will inevitably impact the wider system; therefore, efforts must be made by policy- and decision-makers to collaborate and ensure sustainability across this interface.[7]

To support such decision-making, it is essential that communities and other stakeholders are treated as experts in their local area and solutions are co-designed with those who will be impacted. Through lived experience local communities will have access to invaluable insights that can inform the most appropriate solution to an issue and can act as natural stewards long after an intervention or new approach is implemented. However, it is necessary to connect people with the marine environment to support this. Ocean literacy, along with mutually supportive concepts like marine citizenship,[8] represent a clear priority for improvement if marine and coastal scientists are to engage coastal communities – and those further inland – in essential conservation and restoration work. Those who inhabit and visit the coast are undeniably one of the strongest actors in the complex system presented by the land-sea interface.

A key element of ensuring the land-sea interface operates as a resistant, resilient and sustainable system is moving away from extractive blue economy models, and towards those posited by organisations such as the World Bank that specify sustainable management of resources.[9] There are many economically-driven activities that take place in coastal zones, ranging from fishing to tourism to renewable energy developments. It is important to note that the blue economy model is led by the wider economy, and as such also needs to support the move towards a circular economy that protects and restores marine and coastal environments and properly values the ecosystem services that they provide. The topic of blue economy will be discussed in more detail in the third Turning the Tide publication.

Though each of the above topics warrants in-depth exploration, it is essential that they are all considered as part of the same complex socio-ecological system made up by the land-sea interface. The marine environment cannot be tackled in isolation from its coasts: bridging the gap between land and sea has never been more important.

How can we manage the impact of land use on marine environments?

The nature of the land-sea interface means that decisions about land use will inevitably impact the marine environment. For example, nutrient runoff from agricultural land can cause chemical imbalances in coastal waters, leading to effects such as algal blooms, which in turn disturb the delicate balance of existing ecosystems by releasing toxins into the marine environment.[10] Sediment runoff can also occur from agricultural land if soil structure becomes compromised due to over-working, over time altering the geomorphology of coastal zones and disrupting habitats.

In addition, many UK news reports over the last 18 months have covered the topic of wastewater discharges into the sea, with the English Environment Agency revealing that 2023 represented a 54% increase in the number of sewage spills compared to 2022, and a 13% increase compared to 2020.[11] This was partially explained by the high levels of rainfall in 2023; this is a weather pattern which may become more frequent or extreme as the climate changes and, as such, something wastewater systems must be able to cope with. Discharges on this scale contaminate coastlines and beyond, rendering waters unsafe to swim in, and negatively impacting coastal ecosystems.

Understanding the land-sea interface as a complex system is a necessity. In the context of management plans, this can seem complicated: how do you define a management zone but avoid viewing it in isolation from the wider system it is a part of? However, there are ways to define the parameters of a zone while acknowledging it exists in a larger system: for example, indicating exogenic pressures (consequences are managed in the defined zone but the causes require global action) versus endogenic pressures (both causes and consequences are managed within the defined zone). This can bring clarity to which stocks (the quantity of any given resources in a system at one time) and flows (the movement of resources) are based within the limits of a management zone, and which may be out of its direct jurisdiction and require further intervention.

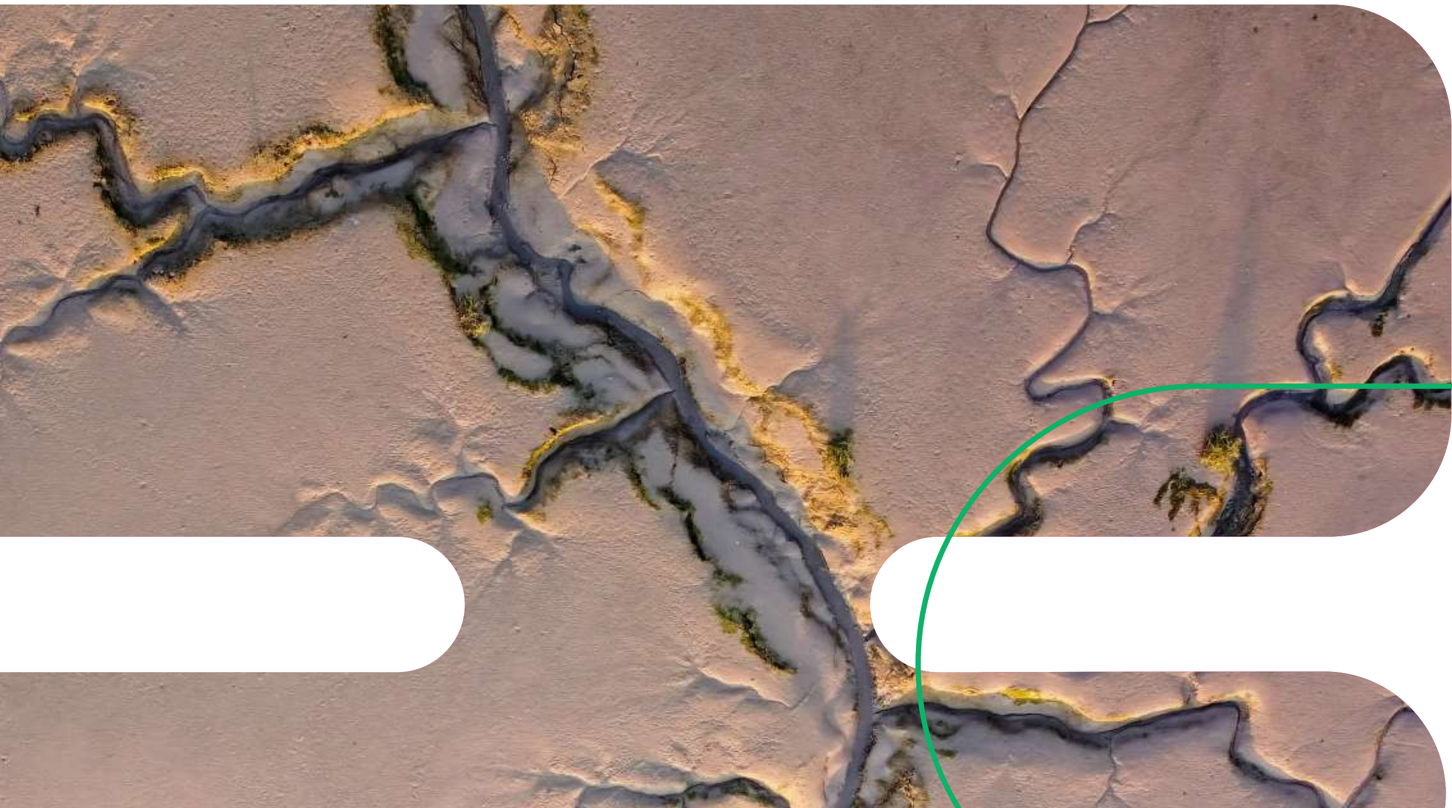
Management zones are their own smaller-scale systems. As such, it is important to ask where problems and solutions may be occurring – land or sea – and how they may interact. Since pressures can be naturally occurring or anthropogenic, they may have different potential mitigation strategies. In turn, interventions may lead to knock-on effects within the zone's system and further afield. To ensure the efficacy of management measures, understanding the nature of discrete yet interlinked factors is crucial.

Elliott et al (2020) separate these factors into activity, pressure and effect footprints: all marine activities have an activity-footprint (defined as the area in which the human activities take place), which result in pressures-footprints and effects-footprints. Pressures-footprints are the area covered by the pressures (defined in this context as mechanisms of change) generated by the human activities on the prevailing habitats and species; effects-footprints are the areas over which any adverse effects occur – this includes effects on the natural system and on ecosystem services from which goods and benefits are extracted.[12]

Management plans are generally instigated when something we have assigned value is affected by a hazard. Once this happens, the hazard is defined as a risk and subject to management strategies in an attempt to protect the valued resource. In the marine and coastal environment, risks are generally due to one (or more) of the 'Triple Whammy' issues: increased industrialisation and urbanisation; increased use of physical and biological resources; decreased resistance and resilience to climate change.[13]

However, knowing there is a risk is not enough on its own, as there are many factors that influence whether a management strategy will be sufficient – and actually approved in the first place. Barnard and Elliott[14] describe 10 tenets of environmental management plans that must be met to improve the likelihood of creating a successful, supported strategy. The tenets span social, environmental and fiscal concerns, referencing the fact that there are many layers of law, finance and public opinion that are as essential in a plan's adoption as its environmental merits and sustainability. Prioritising issues where we see the most direct effect from land-sea interactions, such as discharges or agricultural runoff affecting water quality, is crucial.

Alongside identifying problems, it is also vital to make clear what strategies could be put in place to solve them.



Coastal management approaches

There are a range of different management approaches when considering the land-sea interface. From a systems perspective, some have particular strengths and weaknesses in their ability to avoid an insular perspective and consider a zone's impact on its wider environment. Ultimately this is essential to ensuring the consequences of any interventions do not cause unintended consequences, either spatially beyond the zone's boundaries or temporally after a management scheme comes to an end. As such, systems thinking is the lens through which the following approaches are evaluated.

Integrated coastal zone management (ICZM)

Integrated Coastal Zone Management (ICZM) is, at its core, a tool for the conservation and sustainable management of marine, coastal and freshwater biodiversity. It is also a decision-making process and should begin with issue identification involving all stakeholders in an affected area. The more clearly the problem can be defined, the more likely it is that solutions will be appropriate and effective. Engaging varied stakeholders has the added benefit of contextualising issues in terms of a wide range of perspectives, thus ensuring solutions can take these into account. ICZM takes a systems-based approach to coastal management, identifying numerous interlinked yet distinct factors that need to be accounted for when managing, and planning for the future of, an area. Combining expertise from environmental science, law, education and economics, it attempts to tackle problems through an interdisciplinary lens to avoid siloed thinking.

Ecosystem-based management (EBM)

Another approach is ecosystem-based management (EBM). Haugen et al (2024) describe it as "the best practice for managing multiple ocean-use sectors, explicitly addressing trade-offs among them" but acknowledge "implementation is perceived as challenging and often slow".[15] To advocate for an approach that applies the principles of systems thinking the perceived challenges will also have to be addressed. Haugen et al identify a range of cross-sectoral barriers including governance, stakeholder engagement, and a lack of support for the approach. They propose a variety of solutions to tackle these issues, with improved communication, capacity building, the creation of certification schemes, and promoting the business case for ecosystem-based management (EBM) hailed as the four most important interventions.

There are practical steps being taken to advance ecosystem-based approaches: in the case of offshore wind development, for example. In the UK, there is pressure to increase power generation from offshore wind farms to meet decarbonisation targets with the National Energy System Operator suggesting in 2024 that the UK must “contract as much offshore wind capacity in the coming one to two years as in the last six combined”[16] to achieve Net Zero by 2030. However, there is concern around the damage offshore wind farms can inflict on marine ecosystems, meaning there must be balance between fulfilling clean energy demand and protecting already-threatened habitats.

Strategies like the implementation of regional ecosystem-based monitoring programmes (REMPs) can help to make these decisions and support the implementation of EBM. This has been successfully carried out in UK marine environments, such as the Bristol Channel, with dredging work (to harvest gravel and sand from approved sites) subject to a form of REMP – a Regional Seabed Monitoring Plan (RSMP). This involved collecting baseline information about seabed habitats and monitoring them, and reporting took place to “identifying conditions which should remain favourable for faunal recolonisation”, enabling habitat restoration to take place more effectively post-dredging.[17] Though avoiding activities such as offshore wind farm construction, or dredging, altogether, would avoid impacting habitats, this may not be practical – especially in terms of a green energy transition. As such, it is important to balance any harmful activities with a deep understanding of the ecosystem they are affecting so that decisions can be made to minimise the long-term impacts by having the data to restore affected areas back to baseline levels. Monitoring is an important part of any management approach, identifying what is needed to support a given area and evaluating whether the approach is working over time compared to identified baselines.

Shoreline management plans (SMPs)

Shoreline Management Plans (SMPs) are a method of protecting coastlines, in which the coastline is divided into sections and the most appropriate protective measures identified for each part. SMPs are ideally developed in liaison with local communities. The broad categories that can make up an area’s SMP are: ‘hold the line’ – maintain or upgrade protection from flooding or erosion by holding the shoreline in broadly the same position; ‘no active intervention’ – maintain or encourage a more natural coastline, which may involve discussing adaptation to the risk from flooding or erosion; ‘managed realignment’ – change the position of the shoreline in a controlled way, such as by slowing erosion or creating areas of habitat to help manage flooding; or ‘advance the line’ – actively move shoreline defences significantly seawards.[18] However, these options are very focused on the terrestrial space, focusing on how to limit the land’s impact on the sea rather than the inverse.

Adaptation pathways coastal management

Another approach to managing the land-sea interface currently favoured in the UK is Adaptation Pathways Coastal Management (APCM). This strategy takes a long-term view of a chosen zone, recognising the locked-in effects of climate change, such as rising sea levels, as well as other interlinked consequences like erosion. APCM plans recognise that there is uncertainty in terms of the exact effects of these factors but ensure they are taken into account, ultimately choosing an appropriate 'pathway' for the management of an area. However, these 'pathways' are iterative, meaning that decisions are checked and altered should circumstances change in the future. This allows for those involved in resourcing plans to have an idea of the costs involved along a projected pathway, to help investment remain consistent throughout, but does not lock a coastal zone into a single approach that may be insufficient should circumstances change: something which all stakeholders are made aware of throughout.[19] The English Environment Agency's Humber Strategy 2100+ takes this iterative approach – it was created due to the risks climate change could pose to the "half a million people, 14,000 businesses, and more than 120,000 hectares of agricultural land" already at risk around the Humber,[20] and will implement agile strategies from now until 2100 and beyond to ensure that the most appropriate interventions are in place.

Ultimately, there is no one-size-fits-all option, as approaches must be chosen based on the needs of the location, its communities and its environmental condition. However, key factors to prioritise are systems thinking, to ensure management zones are not viewed in isolation from the rest of the land-sea interface; stakeholder engagement, to ensure that those most affected have a say in plans; and the ability to iterate, to ensure that there is agility when dealing with inevitable uncertainty.

Governance and regulation

The boundaries of governance are often blurred when considering the marine and coastal environment. There is a real risk of different departments not working in a coordinated way or a lack of prioritisation for coastal environments. This presents a risk far beyond Westminster, as activities in one part of the marine environment will inevitably impact others, potentially on a global scale: joined up policy- and decision-making is desperately needed.

There is a complex system of international and national governance that applies to marine environments. In England and Wales, marine and coastal environments are primarily governed through the Marine and Coastal Access Act 2009 (MCAA), through a system of marine licensing, conservation zoning and the management of marine fisheries. The regulator for the MCAA is the Marine Management Organisation, responsible for making decisions around these three areas. There are also a number of policy targets relevant to the marine environment, such as those laid out in the Environmental Improvement Plan.[21]

There is a Defra-led cross-governmental Coast and Ocean Applied Systems Thinking Committee (COAST), which brings together chief scientific advisors from different government departments and the devolved administrations to address challenges facing the marine and coastal environment in the UK using systems thinking approaches, which is a positive step towards taking in integrated approach to environmental challenges. However, the UK Government has recently been criticised for slow progress on environmental issues – including in the marine and coastal environment. The Office for Environmental Protection has requested a review on the existing Environmental Improvement Plan (EIP), with the Chair of the Office for Environmental Protection for England and Northern Ireland pointing out that the Government is “largely off track” in terms of meeting its targets as set out in the EIP.[22]

Five priorities have been identified, with two (‘Speed up action in marine environments’ and ‘Set out clear mechanisms for reconciling competing demands for use of land and seas’) explicitly referencing the marine and coastal environment. Though this brings into focus a lack of action thus far, it may represent a pivotal moment in terms of the Government’s future environmental priorities.

In decision-making, focus is often on the land, with marine environments left to absorb the negative externalities of terrestrial policies. Key to changing this is framing the sea as vital to human health and wellbeing, highlighting the ecosystem services and societal goods and benefits it provides and supporting people to understand that it needs to be something to protect and restore. Supporting communities in understanding the role of the marine and coastal environment in human wellbeing can help to create connections between communities and the sea.

Ocean literacy

Ocean literacy is an evolving concept. It is deeply personal, as it is increasingly taken to encompass not only our understanding of the marine environment but our connection with it. This means it is an ever-changing and adapting area of discussion with endless individual interpretations.

The 10 Dimensions of Ocean Literacy[23] is a framework which identifies the key drivers behind improved ocean literacy. Included in this are 'Emoceans' (our emotions about the ocean); Access and Experience; and Knowledge. The mixture of pedagogical, subjective and experiential framings is intentional and aims to capture a wide range of perspectives about marine and coastal spaces, as well as suggesting gaps in connection which can be developed to improve overall ocean literacy.

Another approach involves thinking in layers and supporting communities to increase their sense of belonging in coastal environments by dissecting their own locale's relationship to it. Plover Rovers identify four key layers: communicating the science; using art to convey emotion; activism; and heritage and storytelling.[2] Progressing through the layers may be relatively straightforward for seaside communities, where the ocean is visible and tangible, and there is a more obvious connection between inhabitants and the coast. For those further inland it may take more work, but can likewise be achieved by illuminating links between an area's industrial past and the seaports that enabled it, or the effect that management of a local river may have by the time it meets the sea: regardless, the importance is in emphasising that we are all intrinsically linked to the marine environment.

Key is instilling the belief that anyone, anywhere, can contribute to marine stewardship and be part of the solution. Concepts such as marine citizenship, which extends beyond personal pro-environmental behaviours to include "public and political acts of collectivism and public engagement", can mutually support ocean literacy by helping citizens to understand their political and civic rights to participate in marine decision-making.[8]

One of the Ocean Decade Project's challenges is to 'Change humanity's relationship with the ocean', but in 2024 a White Paper[24] recommended that the wording should be changed to "Restore society's relationship with the ocean". This makes clear that the link between people

and marine environment is something that has been disrupted, and that connection is the natural state – something we need to return to rather than develop anew. It is of paramount importance that this reconnection includes diverse communities who are currently under-represented in marine and coastal fields: 'society' must include varied perspectives and lived experiences, otherwise it is another exclusionary term.

It should be noted that there is a lack of diversity in the marine and coastal sector, particularly in terms of the amount of people of colour represented – something that is reflected across the environmental sciences. Ocean and Coastal Futures' (OCF) report 'Ethnic diversity in the UK Marine and Coastal Sector: Accelerating Change', posits four reasons for this: 1. Inequality of access to blue spaces; 2. Pre-sector and school issues; 3. Higher education issues; and 4. Within sector issues. Though they are discrete problems, they are also a cumulative collection of barriers that will affect someone throughout their life course and reduce their likelihood of entering into the marine and coastal sector. Focusing on the former, as access to blue spaces is a key factor in the development of an interest in them, OCF's report suggests a range of reasons as to why this is currently so unequal in the UK, including the proximity of the ocean to where people of colour are living (disproportionately in urban centres further from the coast); financial barriers; and a lack of representation in media depicting coastal pursuits such as walking, surfing or swimming.[25]

In a study looking into the associations between connection to green and blue spaces and mental health,[26] 18 countries were ranked in terms of their population's sense of nature connection. The UK placed 16th (with 1st being most connected).

UK residents were also found to be visiting coastal blue spaces significantly less than many of their European counterparts in locations such as Spain, Portugal, Italy and Greece. On average, people surveyed in these countries were visiting a coastal blue space upwards of 8 times per four-week period, compared to under four times in the UK. Unsurprisingly, Spain, Portugal, Italy and Greece all ranked higher than the UK in terms of nature connection. As such, it seems the barrier to ocean literacy in the UK is twofold in comparison with our European neighbours: we are not visiting our coasts as often, nor do we feel as much connection to them. Though there are a variety of factors that may influence someone choosing to spend time in a green or blue space, such as more favourable weather in many European locations, or ease of travel, it is important that UK residents are encouraged to make the most of their coastlines to develop a closer connection with them – come rain or shine!

Systems thinking

As discussed throughout, the marine and coastal environment is an interlinked, transitional space, and as a result needs to be viewed as a complex system rather than as its component parts. The application of systems thinking is crucial.

Progress has been made through the creation of a marine horrendogram[27] which illustrates the complex nature of the legislation currently being used to manage and protect our transitional waters, coastal and marine environments. However, no terrestrial counterpart currently exists, and a combined map of the sea and the land is called for to ensure that their interconnectedness is widely understood.

Using systems approaches is important in making better decisions, understanding trade-offs, and protecting coastal areas. They are a great way of communicating the importance of certain coastal ecosystems and the multiple layers of ecosystem services and societal goods and benefits they provide. Systems thinking is fundamental to understanding the interactions between land and sea and ensuring that environmental scientists are equipped with the knowledge to understand the impact of their work on the wider environment and to implement multifunctional solutions.

What's next?

The work done by the Marine and Coastal Community to develop and deliver Turning the Tide is reflected in the IES' updated Message to Government.[28] This document puts forward the key priorities identified by our Communities to ensure that the climate crisis is addressed with clear direction and urgency.

We will be releasing summary publications for the other three themes covered in Turning the Tide: Blue Carbon; Blue Economy; and Marine Conservation and Restoration.

The next theme, Blue Carbon, examines the crucial role played in climate mitigation and carbon storage by three key vegetative coastal ecosystems: seagrass; saltmarshes; and mangroves. Their conservation and restoration is crucial, as is research to better understand the carbon storage properties of other marine life such as kelp. Threats are posed to blue carbon ecosystems by a range of anthropogenic pressures, such as coastal aquaculture and the effects of climate change on ocean temperatures.

If you haven't already joined, why not become part of the IES' Marine and Coastal Sciences Community? You can also request to join our Marine and Coastal Science LinkedIn group to connect with like-minded peers working, or interested in, the sector.

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Blue carbon

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Turning the Tide: Systems thinking for a sustainable ocean

March 2025

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Contents

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This publication reflects the overall balance of views expressed by participants in the Turning the Tide project and does not necessarily reflect the views of the individuals and affiliated organisations listed above.

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Blue carbon

Supporting vegetative coastal ecosystems will be an integral part of developing ocean-based solutions to the climate crisis. The Blue Carbon Initiative defines blue carbon as 'the carbon stored in marine and coastal ecosystems'.[1] This definition will be used throughout this publication, though there is no globally-agreed definition of blue carbon. Usually included in definitions of blue carbon are the coastal ecosystems of saltmarshes, seagrass meadows, and mangroves. Saltmarshes and seagrass prevent carbon from entering the atmosphere as it becomes buried in the seabed beneath them, while mangroves hold carbon within their own structures. All are referred to as 'blue carbon ecosystems' throughout this publication due to their abilities to store carbon. It has been argued that blue carbon discussions should be expanded to include other ecosystems, such as kelps and other seaweeds; more research is needed to understand their potential role in climate mitigation. However, the mounting pressures on all marine and coastal ecosystems mean we must act to protect them now, rather than pausing conservation efforts while we learn more.

Framing the benefits of seagrass meadows, mangroves, salrmarshes (and any other ecosystems the definition grows to include) beyond climate change mitigation will be key: their state affects affects both marine and terrestrial environments, and thus the return on investment from protecting them may be larger than many outside the sector are aware of. Communicating their vital role within the complex system that is the land-sea interface will be central to continuing to conserve, restore and research their carbon sequestration abilities.

The United Nations have described the ocean as 'the world's greatest ally against climate change', referencing its role as generator of 50% of atmospheric oxygen, and absorber of 25% of all carbon dioxide emissions along with 90% of the excess heat generated by these emissions.[2] However, the amount of carbon dioxide emitted by anthropogenic activities, which is then absorbed by seawater, means the ocean is slowly warming and becoming more acidic. This puts marine ecosystems at risk, as they cannot adapt quickly enough to the changing conditions of their habitat, particularly increases in temperature. In the case of blue carbon habitats such as seagrass, saltmarshes and mangroves, unsuitable growing conditions also hamper their ability to store carbon.

The impact of blue carbon ecosystems

Vegetative coastal ecosystems are highly important, with three often given particular focus: mangroves, saltmarshes and seagrass meadows. All three perform important functions, such as reducing coastal erosion by binding sediment together with their root structures; protecting coastlines by dampening waves and currents; and providing protective habitats for smaller sea creatures to thrive away from predators and conditions in the open ocean.

In addition, mangroves, saltmarshes and seagrass meadows also act as carbon sinks, trapping and storing carbon in the seabed. As both the above- and below-ground vegetation dies, a proportion of the carbon it holds is incorporated into and buried in the sediment it grows from – this is termed autochthonous carbon. Suspended sediments and organic matter from marine and terrestrial sources are filtered and stored in the same way. If this has come from outside the ecosystem any carbon contained as a result is termed allochthonous. As the sediment is waterlogged, oxidation and decomposition of the carbon cannot readily occur and the carbon stays stored in the sediment for decades to millennia. It is important to ensure this carbon stays buried by protecting and maintaining vegetative coastal ecosystems – or else they risk becoming carbon sources instead of sinks.

Other marine life, such as the macroalgae kelp, may also lead to the long-term storage of carbon. However, there are significant unknowns as the carbon produced by kelp is not buried on the rocky shores where it grows: we also don't currently know exactly where in the marine environment kelp deposition occurs. It is possible that deposition would take place across national boundaries and potentially a significant distance from the area in which the kelp originated – as opposed to mangroves, saltmarshes and seagrass meadows where carbon is incorporated and buried in the sediment in which they grow. Additionally, it is not known yet how much, if any, of the deposited kelp carbon is oxidised, decomposed or buried. As a result, there will be further challenges when attempting to quantify how much kelp carbon is stored, which nation(s) can be accredited with removal of carbon, where the kelp grows or where its carbon is buried.

In addition to the effects of a changing climate, there are anthropogenic risks to these vital ecosystems. Mangroves are being cut down to be used as fuel or building materials or to make space for more financially profitable coastal vegetation like palm trees and aquaculture such as shrimp farming. Similarly, saltmarshes have historically been drained to make space for agri- or aqua-cultural ventures and salt harvesting, and those that remain are polluted via nutrient runoff from industries like sewage and farming. The same is true for seagrass: nutrients used on terrestrial crops can cause overgrowth of marine species such as algae, which clouds the water and limits the light that seagrass relies on. Other marine activities such as aquaculture, or the anchoring of boats, can also disturb the root systems and growth of seagrass and other vegetation. Given the multiple benefits that these ecosystems can provide for biodiversity and climate mitigation and adaptation, it is essential that they are protected and restored.

Blue carbon around the world

There are a range of approaches to managing blue carbon habitats. It is important that they are considered as part of a wider system to realise their multiple benefits. Equally however, they should have tailored management that reflects their locale and the unique pressures upon them, and as such there is a fine balance to be struck between many interlinked yet distinct factors. There is no single approach that works for every blue carbon habitat and its associated stakeholders, so understanding the potential applications, strengths and weaknesses of a range of strategies is key to developing bespoke management approaches that account for as many factors as possible.

Special Areas of Conservation in the UK

Seagrass meadows are recognised as a vital carbon sink and habitat in UK waters, though they are currently under threat from pollution, disease and physical damage caused by human activity. To protect seagrass from these pressures and restore degraded areas, Natural England, working with the Ocean Conservation Trust, designated five Special Areas of Conservation (SACs) on England's southern coastline. Two of these are Plymouth Sound and the Solent Maritime area. In 2019, these areas were found to be degraded, with seagrass struggling to flourish. Through a combination of protection and reseeding, around 8 hectares of seagrass have been replanted as of 2024.[3]

Two reseeding techniques were trialled during the project: seed broadcasting and seed translocation. Broadcasting utilised both seeds planted in hessian bags and dropped onto the seabed, and a novel injection device (HMS OCToPUS) to directly plant and distribute seeds across the restoration site; translocation was carried out through the use of coir mats to grow plants from seed in the aquarium and subsequently placed in preselected areas by divers. Early indications suggest that combining these approaches has been successful in beginning to restore seagrass in the SACs.

The team faced a unique challenge when collecting seagrass seeds for both methods. These precious seeds only appear annually and must be hand-picked by divers, meaning that they needed to be stored if they were to be used year-round as planned. To enable this, researchers designed a new storage system able to keep the seeds in a state of dormancy using recirculated, chilled salt water. This increased average germination rates by 28% over the course of the project, impressing the need for innovative approaches to conservation and restoration. The impact their learnings could have on seagrass restoration globally is significant.

Spotlight on Australia

In Australia, ongoing work is focusing on re-establishing coastal wetlands to take advantage of their carbon sequestration properties.[4] A significant amount of Australian coastal land has historically been drained to enable activities like agriculture to take place, meaning the land is now degraded and unable to act as a carbon sink. The Australian Blue Carbon Method has been developed to remedy this: tidal gates are installed in place of bunds and other impassable defences, allowing for the controlled flooding of the land. As a result, emissions from agricultural land are reduced and carbon sequestration increases as the blue carbon ecosystems re-establish. Incentivising farmers to allow these transitions to take place on their land is essential, so the Australian Government pays them in Australian Carbon Credit Units, which are calculated per tonne of carbon dioxide equivalents and available to anyone eligible to take part in the country's Voluntary Carbon Market scheme. The tool 'BlueCAM' was developed to support this, calculating net abatement (carbon sequestered + avoided greenhouse gas emissions – ecosystem transition emissions – fuel emissions) occurring in newly-flooded land. BlueCAM is a free tool that was developed to model blue carbon projects in Australia and is able to estimate net abatement for a variety of Australian ecosystems. Because all the data underpinning the model is from Australia, this tool is not calibrated to blue carbon ecosystems in other countries. However, the tool does greatly simplify blue carbon accounting and could be adapted to different locations. This approach to carbon accounting – both accurate and easily available to landowners is crucial to encouraging sustainable initiatives globally, prioritising learning and improvement rather than risking wasted resources through duplication.

Engineering solutions in China

Coastal engineering can represent an agile coastal management approach, identifying weaknesses in an ecosystem's self-sufficiency and creating the conditions to mitigate this. Though care must be taken to recognise the impacts physical interventions could have across a wider system (for example cutting off marine migration routes or changing the makeup of an established habitat). In areas where the benefits outweigh the risks there can be positive outcomes. In North Hangzhou Bay, Shanghai, there were historically naturally occurring saltmarshes and a beach that was well-used by local people. When sea defences were built to protect coastal developments from projected sea level rise, this caused the bay to be altered to a lagoon and degraded the naturally occurring saltmarshes that had once been the primary feature of the bay, and as a result multiple species were in decline.[5] In addition, the stagnancy of the water had allowed sediment and pollutants to build up, making it unsafe for bathing.

After research identified that the constrained ecosystem had altered the bay's biodiversity, a management strategy was developed that involved engineering both islands and submerged areas to allow for improved water flow through the saltmarsh. This flow helped to purify the main body of water behind the sea wall, enabling it to be safely used for bathing once more. Its increased usability supported the connection felt by local people to the beach, improving the likelihood that they act as stewards and protect the new ecosystem. This engagement will likely be crucial: a second step in the efforts was to focus on revegetation, encouraging the wildlife which had previously lived in the area to return. This was particularly successful with bird populations, which have re-settled and are beginning to thrive. They will, however, have to be monitored and protected, both by researchers and the wider community of North Hangzhou Bay.

Designating Marine Protected Areas (MPAs) is an approach that supports the long-term conservation and protection of blue carbon ecosystems by ensuring that extractive, or otherwise damaging, activities are not carried out within agreed zones. Though it is true that the interconnectedness of the marine system means causes and effects transcend any static area, this approach can have significant positive impacts when protecting specific species that are known to remain broadly in one place. This benefit can be compounded if the functions they perform support the wider ecosystem. For example, it has been found that kelp forests guarded by sea otters are more productive, and able to incorporate carbon into their structures 12 times more effectively than unguarded forests due to the role played by the otters in managing sea urchin populations — which, if left unchecked, can consume vast amounts of marine vegetation.[6] If, or when, the role of kelp in climate change mitigation is proven, designating known kelp-rich sea otter habitats as MPAs could therefore potentially support kelp carbon burial in sediments through the reduction of anthropogenic pressures, allowing the otters to continue instinctively stewarding blue carbon stores.

Unlocking the potential of blue carbon ecosystems

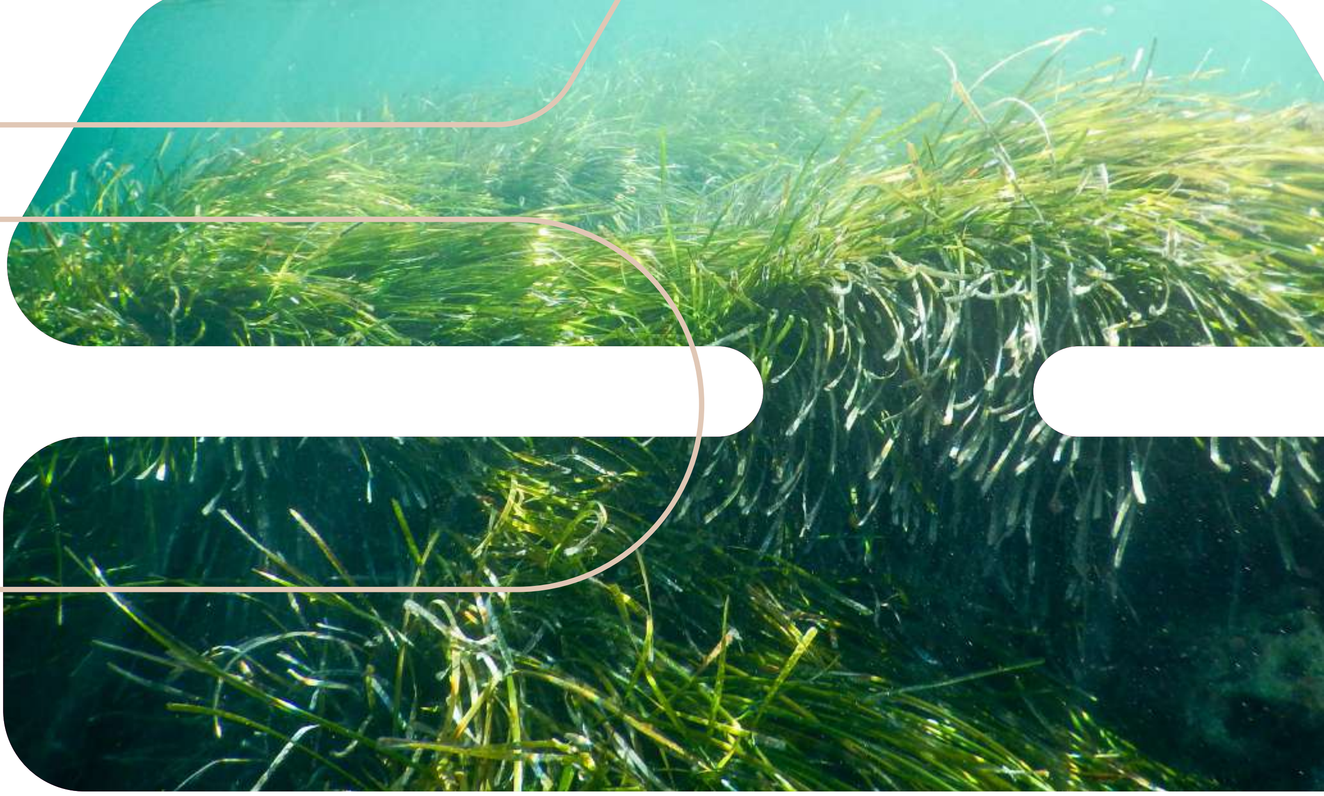
In June 2023, the UK Blue Carbon Evidence Partnership published its Evidence Needs Statement, which outlined five key areas where further evidence is needed to support UK blue carbon objectives:[7]

- Working towards the potential inclusion of saltmarsh and seagrass in the UK Greenhouse Gas Inventory;
- Encouraging and enabling investment in blue carbon habitats;
- Reducing the impacts of human and environmental pressures, including climate change risks, on blue carbon habitats;
- Managing coastal and marine habitats on a seascape scale, with consideration of land and marine connectivity; and
- Achieving climate change mitigation, adaptation and biodiversity benefits from blue carbon habitats as nature-based solutions.

These represent an important step towards a governance landscape that supports blue carbon environments. It is also a call to action for researchers and funders, a topic that is discussed in more detail in the next section.

It is essential that these Evidence Needs are acted upon quickly: if saltmarshes' importance can be quantified in the UK Greenhouse Gas Inventory, for example, there may be additional political will to protect these environments, which are threatened by sea level rise and could thus represent an additional incentive to contribute to global work to mitigate this well into the future.

In terms of having impact in the governance space, it is crucial that researchers and lobbyists communicate the socioeconomic benefits of action on climate change, and where applicable make those in decision-making positions aware of the potential returns associated with supporting initiatives in blue carbon habitats. As much as the ecological benefits may be of paramount importance to those in the environmental sciences, it must be recognised that different organisations have different priorities and selecting sector-relevant benefits to highlight is key to garnering support. Additionally, when addressing problems that will require behaviour change or other disruption to the norm, it is vital that the net positive outcome is made clear to all stakeholders to increase buy-in. Moreover, articulating the multiple benefits that blue carbon habitats can provide may improve buy-in



from different stakeholders. For example, blue carbon habitats do not only play a role in climate change mitigation but can also support biodiversity, climate adaptation and water quality. However, awareness of the benefits alone is unlikely to prompt the investment needed from coastal landowners to restore and manage these habitats without incentives attached. In the UK, organisations led by the UK Centre for Ecology and Hydrology are currently developing and piloting a Saltmarsh Code, which, if successful, would allow for the valuation and purchase of saltmarsh carbon.[8]

Interdisciplinary engagement is also integral to the success of any blue carbon projects. If scientists and local practitioners are given the platform to communicate with decision-makers, who in turn can ask questions and avoid being intimidated by the scale and technical complexities of the marine environment, it is more likely that decisions will be both scientifically sound and implemented sooner.

Collaboration is needed at the international level to unlock the benefits of blue carbon. Progress is being made in this space; COP29 played host to an Ocean Pavilion, during which partner organisations presented the Baku Ocean Declaration.[9] This outlined priorities for the marine environment, including investment into observation, research and mapping to achieve goals on climate, biodiversity and other UN targets. These include priorities to:

- Expand international collaboration to achieve progress in addressing the Earth's climate, biodiversity, and freshwater crisis;
- Enhance public and private funding to scale-up and diversify support of long-term ocean observation, research, and innovation for decision-making;
- Build capacity and access, particularly in small-island developing states, low-lying coastal regions, and other under-represented people and places to further develop ocean data, knowledge, and innovation; and
- Improve awareness of the ocean's role in planetary systems and the need for its preservation as a vital step towards mobilising decision-makers to prioritise ocean protection and restoration.

Mapping unknowns and encouraging pioneers

Blue carbon ecosystems have been, and in some cases still are, under researched, and gaps in our understanding can create barriers to protection and maintenance. One example of this is mapping the current extent of these ecosystems to measure their change due to degradation or positive interventions. In the case of mangrove ecosystems, which mostly occur in the tropics, it is relatively easy to understand their extent as they rise above the water and are therefore visible in satellite imagery. In the case of mangrove ecosystems, which mostly occur in the tropics, it is relatively easy to understand their extent as they are easier to identify through satellite imagery. Seagrass and saltmarshes can be trickier to quantify as they cannot always be identified from above.

Another key unknown is how vegetation may respond to the effects of climate change and their resilience in the face of a changing environment, for example rising sea levels or warmer temperatures. As such, any long-term conservation or restoration schemes must accept that adaptation is likely to be necessary and plans will have to be agile. In the same vein, science may not be able to provide all the answers needed to futureproof marine environments in time for perfect action to take place. This means that some efforts to support blue carbon environments may come up against unexpected barriers or consequences.

However, it is crucial that the research community views any such hurdles as learning experiences rather than reasons to stop action.

Despite challenges in exact quantification, it is imperative that these ecosystems are protected and restored. Given the timescales involved for effective climate action, we must move forward with projects in lieu of perfect evidence and take an adaptive approach to managing these habitats, informed by learning that we gain through the process. We will understand more about their functions over time, and until then they will continue to store carbon if properly managed and restored. If they are irreversibly damaged this opportunity will be lost entirely. As such, the marine and coastal sector needs to accept that work surrounding these ecosystems will have to be truly pioneering, as without certainty there will need to be courage (and enablement by funders) to try, fail, learn, and try again.

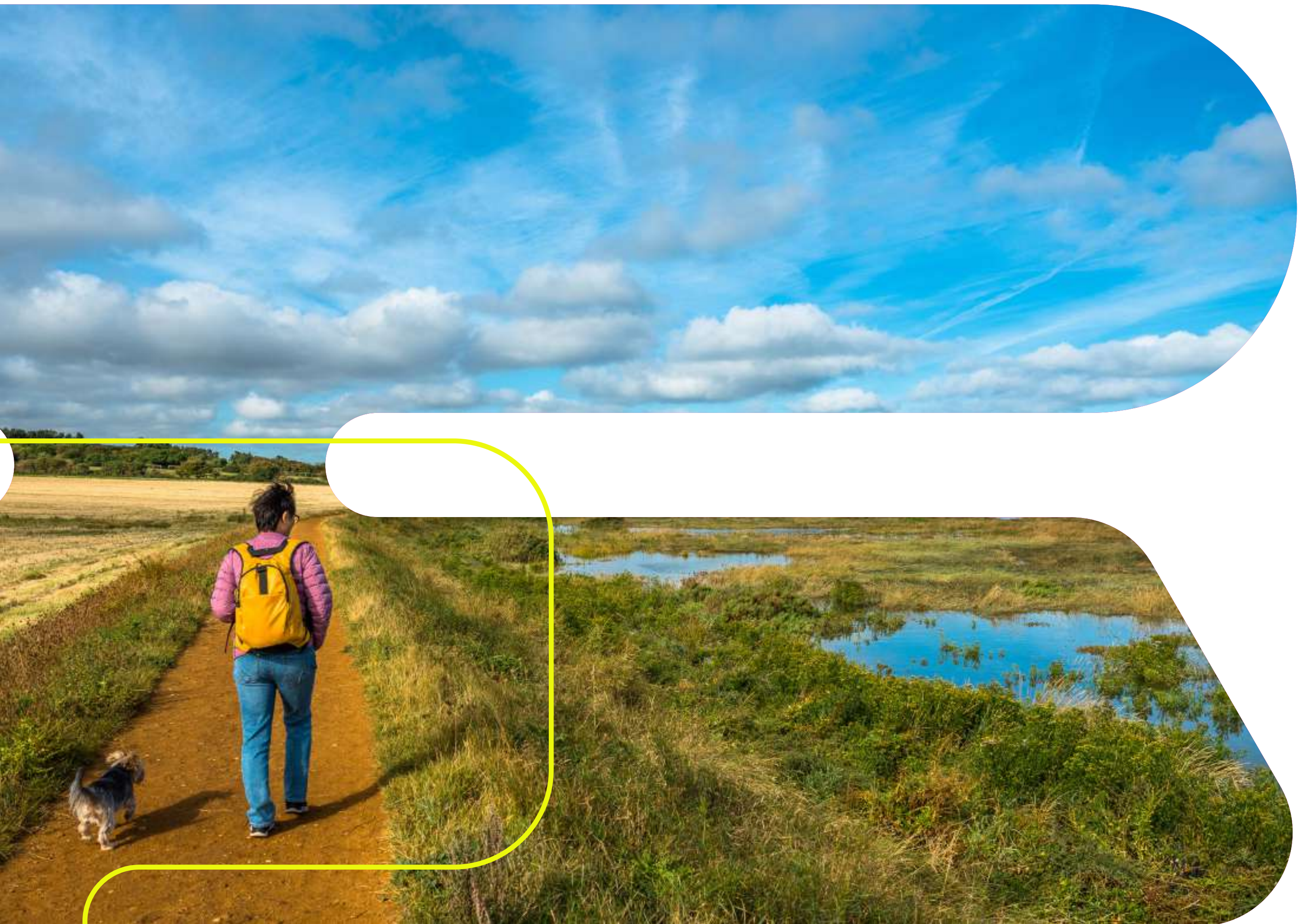
Blue economy

This topic will be discussed in more depth in our upcoming publication on the blue economy-specific theme of Turning the Tide – regardless, it is an area with clear links to blue carbon so should be considered within this theme.

There is discussion about the semantics of the term 'blue economy' in the context of blue carbon ecosystems. When looking to capture the interest of potential financiers, holistic phrases like 'nature credits' may work most effectively, as those outside of the marine and coastal sector may not understand the interconnectedness of marine and terrestrial ecosystems, and may overlook blue carbon projects when looking to invest for offsetting purposes, for example. This could also attract investment from those who may not have a specific interest in the marine environment but are looking to support wide-reaching interventions. As marine net gain continues to gain traction there is also the likelihood that habitat banks for the marine environment could lead to opportunities for credit stacking for biodiversity and carbon credits.

Language is important more broadly, too – a lot of definitions and buzzwords can be intimidating for someone outside the environmental science sector. Those with the finance to support blue carbon markets would likely benefit from more conversation with experts to understand where their investments would be most impactful. Alongside jargon-busting, it may be beneficial for environmental scientists to consider how investment in the stewardship of blue carbon environments could provide returns for investors. This may take the form of a quantifiable carbon offset, and where possible (and genuinely beneficial for the ecosystem in question) scientists may consider producing cost-benefit analyses in this vein if attempting to attract investment.

In October 2024, Natural England published their first State of Natural Capital Report for England,[10] which includes a list of 11 priority actions it feels the Government must act on to meet Net Zero targets and adapt to the realities of climate change while maintaining economic resilience. Several of these explicitly relate to blue carbon environments: 1. Use sea and land-use planning measures to ensure the protection and enhancement of ecosystem assets; 2. Minimise damage to the seabed through good fishery management; 3. Ensure space and sediment supply for saltmarshes and sand dunes with sea level rise; and 8. Create, protect and conserve natural carbon sinks and stores. Research estimates that blue carbon environments such as saltmarshes and other subtidal ecosystems play a part in sequestering carbon worth between £742 million and £4,259 million (in 2019 prices), so it is clear to see the fiscal value of protection and restoration along with the environmental benefits.[11] Put simply in Natural England's report, 'We need to invest in natural capital now, to reduce risks and reap rewards. Acting quickly to prevent and address the degradation of nature makes economic sense. It secures and enhances the benefits we depend on, now and for the future, meaning it will be cheaper and more effective in the long run'. This echoes the pioneering approach needed in marine and coastal research: even if the returns are not explicitly quantifiable, the investment will be beneficial and needs to be made now. Moreover, not investing would be to gamble the known storage properties of these ecosystems, and run the risk of degradation being irreversible when they have a vital role to play in slowing the effects of climate change.



Systems thinking

Blue carbon environments are a perfect example of the importance of systems thinking and approaches. Though it is possible to indicate the boundaries of a seagrass meadow, for instance, the fate of the seagrass within that boundary is significantly influenced by factors entirely outside of it. This takes place on both a local and global scale and involves both terrestrial and marine environments – as such, the need for collaboration between a large range of stakeholders is central. Similarly, the beneficial effects produced by that seagrass extend far beyond its growing range.

The benefits of blue carbon environments are not limited to carbon storage. The vegetation cover along coastlines by mangroves and seagrass provides habitats for a plethora of species who could not survive in open water or exposed areas; the intertidal zone of saltmarshes provides a perfect scavenging ground for many breeds of seabird. The roots of mangroves protect the coastlines of many tropical regions from the worst effects of extreme weather and related erosion by shielding otherwise exposed areas. Similarly, the root systems of seagrass bind sediment to the seabed, making it more resilient to strong currents and tidal erosion.

When engaging with decision makers, it is necessary to remain aware of the many layers of interconnected systems at play. It is impossible to separate people and ocean when thinking about the barriers to, and opportunities for, sustainable blue carbon habitats. Recognising this is essential to working within the system – holistic, interdisciplinary thinking must be applied.

Finally, it is also important to consider blue carbon habitats as systems of their own: they perform many functions aside from carbon storage, such as providing habitats for a wide range of organisms and should be recognised for their importance outside of the context of this theme. Their other functions and interactions directly impact their carbon storage abilities and are thus directly relevant from a systems perspective.

What's next?

The work done by the Marine and Coastal Community to develop and deliver Turning the Tide is reflected in the IES' updated Message to Government.[12] This document puts forward the key priorities identified by our Communities to ensure that the climate crisis is addressed with clear direction and urgency.

To supplement this publication, and its predecessor 'Bridging the gap between land and sea', we will be releasing summary publications for the other two themes covered in Turning the Tide: Blue economy; and Turning the Tide: Marine conservation and restoration.

The next theme, blue economy, is intrinsically linked to the future of blue carbon ecosystems. To ensure that marine and coastal areas are managed for the benefit of ecosystems and communities ahead of economic interest, it is important that there is cohesion in governance to ensure only sustainable, responsible development takes place. As with blue carbon, there are clashing definitions of a blue economy, ranging from sustainable to focused on extractive activities, and as such it is an evolving space with many stakeholders.

If you haven't already joined, why not become part of the IES' Marine and Coastal Sciences Community? You can also request to join our Marine and Coastal Science LinkedIn group to connect with like-minded peers working, or interested in, the sector.

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Blue economy

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Defining the blue economy

The concept of the blue economy is generally taken to cover all resource-focused activity taking place in the coastal and marine environment, including fisheries and aquaculture, maritime transport, renewable energy (such as offshore wind and tidal), tourism, seabed mining, marine biotechnology, and oil and gas. Given the range of activities, the term takes many forms and can describe resources that hold value outside of a financial perspective.

Ideally, there needs to be consensus on what constitutes the blue economy – and this needs to be sustainable. The UN Environment Programme[1] defines a sustainable blue economy as “the sustainable use of the ocean and coastal resources which generates equitable and inclusively distributed benefits for people, protects and restores healthy ocean ecosystems, and contributes to the delivery of global ambitions for a sustainable future”. A sustainable blue economy would inherently recognise the ocean as a complex system, meaning any activities taking place would have to be considered in terms of the effects they produce across the system rather than just in their locale. This would favour regenerative practices over extractive or polluting ones. As such, a sustainable blue economy would rely on balance and follow a circular model.

Challenges facing the blue economy

Extractive activities taking place in the marine environment are often not conducive to a sustainable blue economy. However, not all definitions of the blue economy take into consideration the long-term effects on ecosystems, and instead include any activities that align with traditional economic principles of profit and loss. A key criticism of this outlook is that extractive activities cannot take place indefinitely, as resources will either be used up or degraded, often leaving irreparable damage to the areas they have taken place in.

Oil and gas extraction is a clear example of this. Not only does the use of these finite resources directly contribute to anthropogenic climate change, which has myriad impacts on the marine and coastal environment, there are also direct impacts on the marine environment during the scoping and extraction process. The construction, drilling and extraction process causes significant noise and light pollution, disrupting entire ecosystems. This can lead to direct habitat damage as well as changes to animal behaviour, for example the hunting and breeding patterns of marine species can be affected. Once a rig is constructed and extraction is in process, they emit volatile organic compounds (VOCs), which can have a range of negative impacts on marine life and human health.[2] In addition, there is a risk of oil spills, which can cause untold damage to life in the vicinity of the extraction site but also much further afield.

Deep-sea mining is an extractive activity used to obtain minerals like nickel, cobalt and manganese, and is generally employed because of declining levels of these minerals in terrestrial mines. As on land, mining at sea has many negative impacts on the ecosystems situated near drilling and blast zones, through noise, chemical and particulate pollution. Organisations such as WWF have called for a global moratorium on any deep-sea mining until the associated risks are fully understood and all alternatives have been considered, stating that "Without this knowledge base, we cannot possibly design adequate safeguards to protect the marine environment and human well-being".[3]

However, there is tension between the damage caused and the need to procure these materials for use in transitioning to renewable energy. Electric cars, for example, require these minerals for use in

lithium-ion batteries, which are currently relied upon as the most viable alternative to internal combustion engines and the greenhouse gases they produce.

After controversially deciding in January 2024 to begin issuing permits for exploration of its seabed, with the view of permitting deep-sea mining, the Norwegian government paused the project in December 2024 without issuing a single permit. It would have been the first country in the world to embark on such a scheme, with many others imposing bans on similar projects in their own waters.

There are non-extractive options to source these minerals: in 2024 Mercedes-Benz opened the first battery recycling plant in Europe to enable it to extract and reuse them for its own electric vehicles. Part-funded by the German Federal Ministry for Economic Affairs and Climate Action, the plant will also host researchers from three German universities, who will aim to analyse the entire process and its potential for scaling.[4] This could represent a circular alternative to extractive practices, on land or at sea, currently used to source vital minerals.

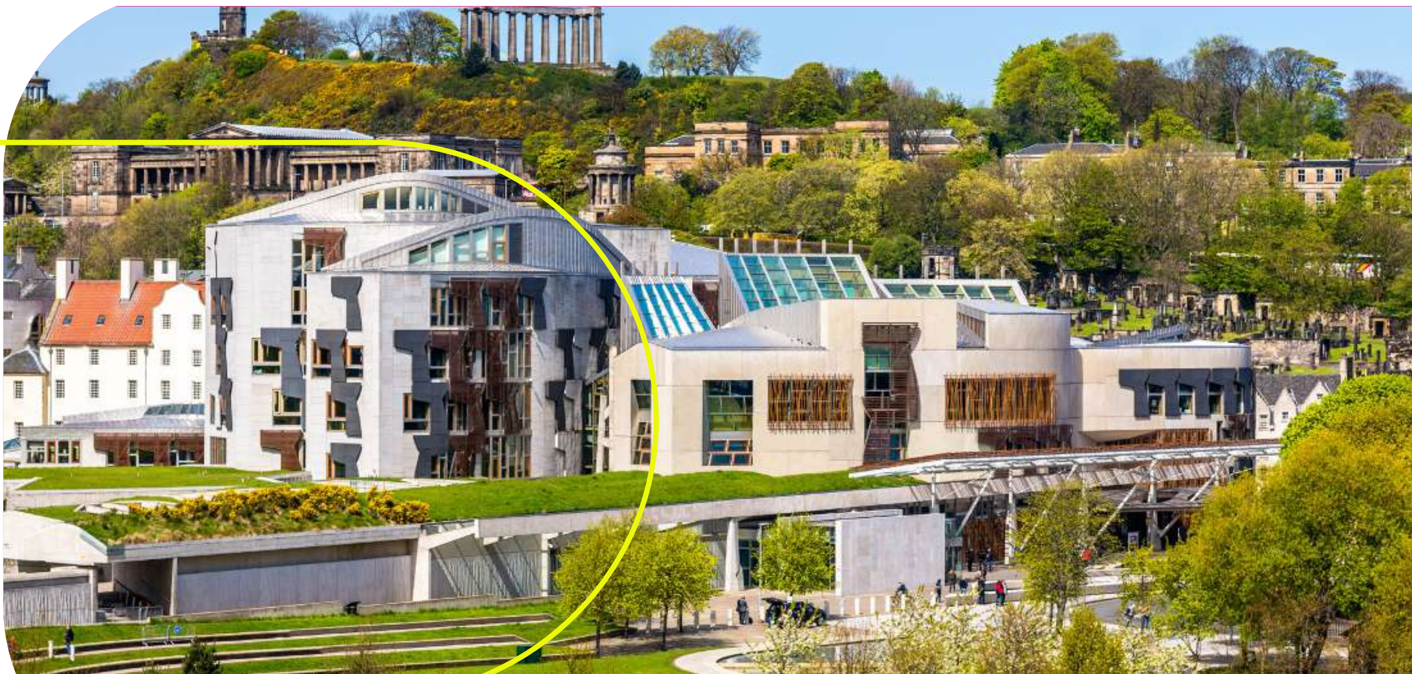
To explore the topic of deep-sea mining in more detail, you can read our article 'Examining the impact of deep-sea mining',[5] published as part of Turning the Tide and based on research by the iAtlantic programme.

Developing a supportive regulatory environment

There are changes needed – starting with governance – to move from business-as-usual to a system aligned with the UN's definition of a sustainable blue economy. Central to this shift will be the adoption of specific plans for the marine and coastal environment at a national level: Scotland and Portugal have done this but many other countries, including the UK as a whole, are lagging behind.

This is especially pertinent to the UK given that it is an island with multiple devolved administrations who all interact with the ocean independently and together. The adoption of the principles in Scotland's Marine Plan by central Government would be a useful first step. The Plan explicitly "promotes an ecosystem approach, putting the marine environment at the heart of the planning process to promote ecosystem health, resilience to human induced change and the ability to support sustainable development and use" and "adopts the guiding principles of sustainable development, which also ensures that any individual policy, plan or activity is carried out within environmental limits".[6]

Centring an ecosystem approach and addressing the fact that the ocean's resources are finite sets a strong precedent for governance of Scottish waters and could be replicated more broadly across the UK.



Investing in the blue economy

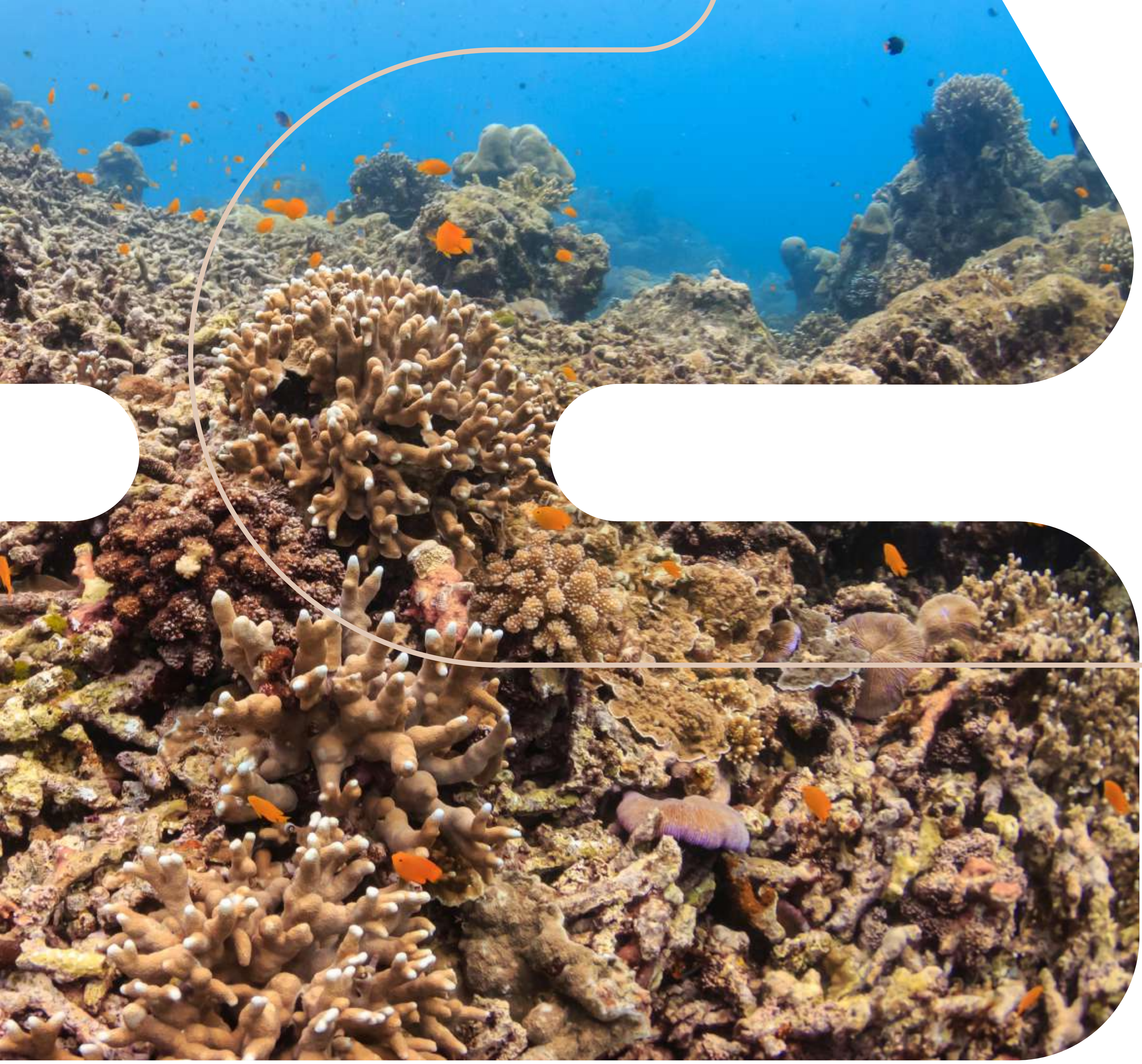
To drive the concept of a blue economy towards a sustainable definition, it is important to consider those who have so far profited from extractive practices, and how the activities causing damage can be transitioned to sustainable alternatives.

A sustainable and healthy marine environment is beneficial to a range of economic activities: for example, more people are likely to visit coastlines for tourism and leisure in areas with good water quality which are safe to swim in, and water free from pollutants benefits the species living in it supporting sustainable fish stocks. Reframing resources such as unpolluted seawater as valuable natural capital assets is key to driving an understanding of their value to those more familiar with financial sustainability than environmental. Considering how we value marine ecoysystems is important, and we should seek to identify the wider value that healthy marine ecosystems can provide beyond financial value.

Other types of theoretically infinite capital can be exchanged in and around the marine environment; knowledge is an example of this. Valuing these resources more holistically would support more regenerative and sustainable practices in marine and coastal environments. Emphasising that investment into the sustainability of the marine and coastal environment is an opportunity is crucial and can also support organisations to demonstrate progress towards both ESG goals and financial goals.

As well as presenting the opportunity associated with investment, it is essential to ensure that financiers understand the long-term risks associated with business-as-usual. Various coastal activities may become untenable in the future due to changes in legislation, rising sea levels and a changing landscape, or biodiversity loss resulting in fewer visitors for example. This is already becoming clear in some parts of the financial sector such as insurance, as companies are unable to cover the costs caused by the impacts of climate change such as extreme flooding. Other extreme events like Marine Heatwaves (MHW) are projected to increase, The incidence and severity of other extreme events, like Marine Heatwaves (MHW), are projected to increase. Globally these have already had negative consequences on marine ecosystems and associated economic activities.[7]

Should these happen more frequently in the UK as projected, we would stand to lose income from industries like fishing and incur longer-term costs associated with erosion and flooding should the protection afforded to our coastlines by blue carbon



ecosystems like saltmarshes and seagrass be diminished. The fact that much marine degradation cannot be easily observed from land is a barrier, as the risk is not currently as palpable as it might be in a terrestrial setting – so putting numbers to the costs potentially incurred by inaction will be useful. The scientific community can help through improved communication of challenges and solutions in the public domain.

If investment is made in a sustainable blue economy alongside climate mitigation measures, there will be far less risk to coastal and marine capital in the future. Supporting resilience of marine and coastal ecosystems will need to be a key part of the sustainable blue economy in the face of the interlinked crises of climate change, biodiversity loss and pollution.

Ultimately, it is important that financiers start to redirect mainstream finance towards more sustainable blue economy pathways and recognise the value of investing in the environment, which will not come at the expense of other socioeconomic goals, and instead will be beneficial to securing a sustainable blue economy that works for people and nature. Significant progress could be made simply by shifting investment away from destructive and extractive activities.

Innovation and technology

Innovation and technology are needed to support the transition to a sustainable blue economy in a number of key areas. Advancements in data collection and monitoring are needed to provide increased understanding of marine and coastal ecosystems as well as the impact of pressures on their functioning. Solutions are also needed to support practices that not only limit damage but actually support regeneration of marine and coastal environments. Innovate approaches that integrate technology and nature-based solutions are needed to build resilience and deliver multiple benefits. Given the breadth and depth of challenges facing these environments, it is essential that innovation and technology is scalable and that research is translated to practice rapidly and iteratively to support change at the timescales needed.

There are many ways in which innovation and technology can support more sustainable practice. For example, artificial Intelligence (AI) can help fishing trawlers to target species, reduce bycatch and minimise environmental impact. 'Smartrawl' is a robotic device that uses cameras to identify the size and species of anything caught in trawling nets, releasing anything it deems unintended.[8] Technology can also support a reduction in 'ghost fishing': researchers at the Scottish Association for Marine Science have demonstrated the efficacy of using a sonar scanning system to locate lost creels, a type of baited fishing pot, off the coast of Argyll.[9] This equipment can pose risks to marine species, who become trapped as nets and other items continue 'ghost fishing' unsupervised. Being able to locate lost creels means researchers can begin to work on techniques to remove them from the sea but also develop a greater understanding of currents and other factors that may influence where the equipment is deposited. This will allow for the identification of areas which are most highly impacted, and their subsequent monitoring. Once the long-term effects of lost creels are better understood, researchers may be able to develop techniques to remove them with minimal disruption to ecosystems.

It is likely that this research will be replicable in other locations, and similar initiatives are being trialled around the world, with organisations like the WWF encouraging the use of the 'GhostDiver' app to track sonar-identified ghost nets. Once located and logged in the app, WWF urge governments to embark on removal projects to protect marine life.[10] Though the exact amount of ghost fishing gear present in marine environments globally is unknown, a 2020 report suggested that between 500,000 and 1,000,000 tonnes of fishing gear are lost in the ocean every year – meaning it makes up at least 10% of all marine litter.[11]

Case study: Sustainable shipping

Innovation and technology will also be key to supporting a sustainable blue economy in the shipping industry, which is currently estimated to be responsible for between 2-3% of all anthropogenic greenhouse gas emissions globally,[12] and is undoubtedly a lynchpin of the blue economy. In the EU, voyages are subject to an Emissions Trading System, meaning that carbon dioxide, methane and nitrous oxide emissions must be paid for by shipping companies operating within the EU – even if only for part of a journey.

Initially, the system will only apply to carbon dioxide, and only to a percentage of total emissions, but will be scaled up to include the full scope of carbon emissions, plus methane and nitrous oxide, by 2027. It is hoped that this will act as an incentive for shipping companies to invest in more sustainable fleets and thus reduce their emissions and responsibility to pay tariffs.

One approach recommended by the European Maritime Safety Agency (EMSA) is the use of Exhaust Gas Cleaning Systems (EGCSs) – often referred to as 'scrubbers'.[13] These systems remove sulphur dioxide from the exhaust gases emitted by ships along with some particulate matter. However, this strategy is more of a sticking plaster than a solution, as it simply filters out a known pollutant as fuel is burned rather than creating a less-polluting alternative. If it fails or operates inefficiently, sulphur dioxide will still end up in the ocean and atmosphere.

'Slow steaming', or a reduction in a ship's speed, is a straightforward way to reduce greenhouse gas emissions across a voyage by simply reducing fuel consumption – it has been reported that a 20% reduction in speed can reduce a ship's emissions by 24-34%.[14] Using traditional maritime knowledge to optimise routes based on ocean currents, weather conditions and wind speeds can support this approach. The required innovation associated with slow steaming is not the method itself but how it could be applied in a modern world reliant on fast, predictable shipping.

Innovation would need to focus on engineering a shift in expectations on how long shipping should reasonably take, challenging cognitive dissonance regarding the journey goods have to take to arrive from overseas. Investment would be necessary in this scenario to mitigate losses incurred by slower, reduced trade.

Wind-powered shipping has already seen an increase in investment, with the International Windship Association (IWSA)

designating 2020-30 the 'Decade to Deliver' on wind propulsion in shipping, with 48 large ocean-going vessels already sporting modern wind-assist systems to reduce their fuel reliance.[15] The UK Clean Maritime Plan forecasts that, by 2050, wind propulsion technologies will be worth over £2 billion annually – more than either hydrogen or battery power.[16] Such growth presents an enticing investment opportunity, as well as an opportunity to reduce the emissions associated with shipping.

Interdisciplinarity and stakeholder engagement

Interdisciplinary collaboration across environments scientists, social scientists, industry and policymakers will be key to unlocking a sustainable blue economy. Innovative approaches to marine and coastal management and restoration which embed interdisciplinarity must happen alongside technological innovation. Interdisciplinarity can lead to benefits for multiple stakeholders, therefore the potential of innovation should not be looked at solely from the perspective of marine industries.

Interdisciplinary collaboration in the marine and coastal sector has already yielded groundbreaking results in other fields. Medical researchers have been able to isolate the chemical trabectedin from *Ecteinascidia turibnata* (more commonly known as the mangrove turbinate). Since 2010, trabectedin has been approved in the EU for use in the treatment of soft tissue sarcoma and some ovarian cancers.[17] This innovation could not have happened without collaboration between the marine and medical sector, and along with the benefits of interdisciplinarity it highlights the importance of conserving marine ecosystems like mangroves to safeguard future researchers' abilities to make similar discoveries. Using interdisciplinary examples like this to emphasise the fact that the ocean provides essential ecosystem services, some of which may not yet be fully understood or even discovered – and that we are all consequently stakeholders in its wellbeing – is a useful tool to advocate for a sustainable blue economy.

Stakeholder engagement must reach outside of scientific disciplines, outside of industry and finance, and into communities. Those who live in coastal regions often have rich knowledge about their local area. When making plans for coastal areas, their views must be taken into account and solutions co-designed. In addition to their knowledge, coastal communities are also poised to suffer most from the effects of climate change with sea level rise, high incidence of extreme weather events and pollution among the risks they may be exposed to. Many communities self-organise to tackle problems they have not caused, cleaning beaches and lobbying against pollutants being pumped into the ocean. They are currently being made disproportionately responsible for a resource that impacts the whole planet without enough support, due only to their proximity – and connection – to the coast.

This is particularly true when it comes to Small Island Developing States (SIDS), who often have ways of life entirely reliant on the ocean and are significantly impacted by climate change and associated severe weather events. Protecting their continued ability to access ocean ecosystem services, like seafood, is integral to SIDS local blue economies. Countries in the global north could learn from approaches used in SIDS where they have developed more sustainable approaches to blue economy activities

However, SIDS may not be well-equipped to deal with the effects of climate change. It is important to recognise that in many cases, the UK and other global powers have historically perpetuated this imbalance through colonialism. Much of the UK's power on the global stage has stemmed from its relationship with the ocean. Our blue economy has historically been extractive, and this is a model that has spread globally at the expense of many SIDS who now struggle to implement sustainable practices due to the declining health of the ocean.

In the context of the Commonwealth, a collection of countries formed through colonialism enacted over the ocean, the UK is uniquely placed to act as advocate, learning from and platforming sustainable practices, and taking the wellbeing of SIDS into account in its own interactions with the ocean system.

Additionally, research expertise based in the UK can – and should – be utilised to work urgently towards innovative solutions to the most pressing challenges facing the ocean, and investment must keep pace with the need for new technologies in the face of a changing climate. Collaboration and stakeholder engagement are therefore needed on a number of levels, spanning collaboration between disciplines, between coastal and marine stakeholders, and across regions.

Lessons can be learned from indigenous ocean stewardship that focuses on maintaining a balance of resources and treating humanity as part of the complex land-sea system rather than separate from it. Efforts have been made to recentre indigenous communities in planning for the marine environment, with the launch of Ocean Panel's 2024 Blue Paper, Co-producing Sustainable Ocean Plans with Indigenous and traditional knowledge holders, just one example. Launched at COP16, it provides insight into the ways in which policymakers can and should engage with indigenous communities to ensure their lived experiences and generations of knowledge are captured in marine management plans.

Systems thinking

Extractive industries and unsustainable practices in the marine and coastal environments have led to the widespread degradation of ecosystems, on both local and global scales. Viewing finite resources and delicately balanced ecosystems as individual entities which can be drawn from with no consequences outside of their own depletion is a dangerous practice. Degrading one component of the wider marine and coastal environment will have far-reaching impacts, whether in the short- or long-term.

Systems thinking approaches that recognise the interconnected nature of marine and coastal environments and their interaction with socioeconomic systems are needed to support a move towards practices that are aligned with a sustainable blue economy. Understanding the connections and dependencies across environmental, social and economic systems will support us in better understanding and quantifying the value that healthy marine and coastal ecosystems provide beyond traditional economic approaches and will support development of approaches that have multiple benefits across the systems involved.

What next?

The work done by the Marine and Coastal Community to develop and deliver Turning the Tide is reflected in the IES' updated Message to Government.[19] This document puts forward the key priorities identified by our Communities to ensure that the climate crisis is addressed with clear direction and urgency.

We will be releasing a summary publication for the final of the four themes covered in Turning the Tide, Marine conservation and restoration, which will cover the challenges and opportunities for conservation and restoration efforts in the context of the triple crisis of pollution, climate change and biodiversity loss. This will wrap up the project and explore what must be done to protect the marine and coastal environment for generations to come.

If you haven't already joined, why not become part of the IES' Marine and Coastal Sciences Community? You can also request to join our Marine and Coastal Science LinkedIn group to connect with likeminded peers working, or interested in, the sector.

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Marine conservation and restoration

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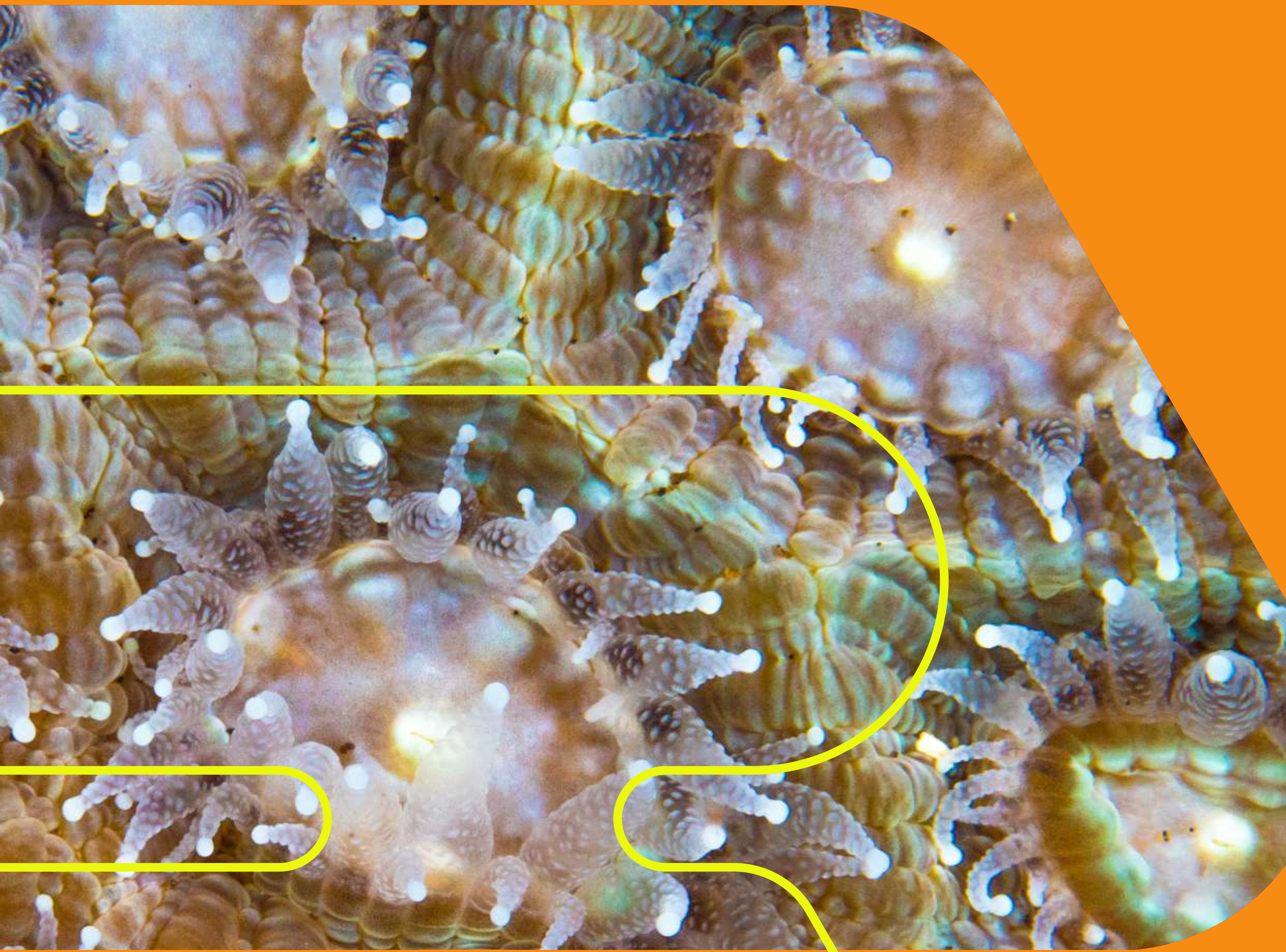
Turning the Tide: Systems thinking for a sustainable ocean

March 2025



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About the Institution of Environmental Sciences

The Institution of Environmental Sciences (the IES) is at the forefront of uniting the environmental sciences around a shared goal: to work with speed, vision and expertise to solve the world's most pressing environmental challenges, together. As the global professional membership body for environmental scientists, we support a diverse network of professionals all over the world – and at every stage of their education and careers – to connect, develop, progress and inspire.

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Risks to the marine environment

There are growing pressures on the marine environment from a range of anthropogenic sources, including climate change, pollution, overexploitation, and destructive fishing practices leading to biodiversity loss. Conservation and restoration of marine environments presents a complex challenge due to the complicated nature of ocean governance and the interconnectedness of marine and coastal habitats across jurisdictional boundaries. Moreover, as the ocean is a complex system, issues present in one location can have knock-on effects globally, and as such can compound and interact to cause unexpected consequences. The interconnected nature of the marine environment can therefore impact the effectiveness of conservation and restoration initiatives. Collaborative action is needed at the appropriate scale to drive change that can support a healthy, sustainable ocean.

As explored in the first theme of the Turning the Tide project, Bridging the gap between land and sea, marine environments are also strongly impacted by land use and human activity in terrestrial systems and the triple crisis of pollution, climate change and biodiversity loss.

Pollution

There are a range of potential marine pollutants in addition to the sewage that has made headlines in recent years: nutrient runoff from agriculture; emerging contaminants like PFAS, discarded 'ghost' fishing equipment; plastic pollution; chemical and oil spills; and light and noise from anthropogenic sources. These all have different impacts but their effects can compound and extend far from the original source.

It is important to consider the whole ocean system when seeking to understand the impacts of a type of pollution. For example, the presence of manmade chemicals in one part of an ecosystem's food web should not be considered in isolation, or solely in terms of its anthropogenic impacts, but investigated throughout the system. In Scotland, routine monitoring of fish and shellfish takes place to check for levels of polychlorinated biphenyls (PCBs), which are a type of persistent chemical generally found in electrical equipment. However, grey seals are not routinely monitored for PCB levels despite it being understood that these chemicals accumulate more readily in the tissues of marine mammals. The lack of monitoring is due to grey seals falling outside of the scope of a combined Defra and Cefas programme. As a result of this and other factors, the effects of PCBs on grey seals are not well-researched, and existing data is limited.[1] Should PCBs prove to be harmful to the long-term health of grey seal populations, effects would be felt throughout the ecosystems they populate. They favour kelp forests as a place to seek shelter and hunt for smaller prey: without this function, the kelp forest may become imbalanced due to increased numbers of grazing species which would normally be consumed by seals. This would, in turn, have devastating effects for the many organisms that rely on kelp for shelter and sustenance, and for the marine system more generally as carbon stored by the kelp would be released back into the ocean. As illustrated by this example, it is crucial that the full effects of pollutants – plus the further related consequences – are understood to avoid unforeseen long-term impacts.

Unfortunately, the longer-term impacts of pollution are already being felt in the marine environment. Phosphorus flows into the ocean, generally from agricultural land, have far exceeded safe levels as defined by Rockstrom et al's planetary boundaries model. Similarly, due to carbon absorption, ocean acidification is on the brink of exceeding its safe operating space in the same model.[2] Ocean acidification "harms calcifying organisms, impacting marine ecosystems, and reduces the ocean's efficiency in acting as a carbon sink". Once a boundary is breached, the risk of irreversible damage or reaching a 'tipping point' is stark. In the case of phosphorus, overabundance can cause plants like algae to grow rapidly and deplete oxygen levels.

Climate change

Climate change is responsible for a variety of pressures on the marine environment. Rising global temperatures impact the ocean both through heating its surface and by causing sea level rise through increased influx of freshwater caused by melting sea and sheet ice. These changes are happening at a pace too rapid for marine life to adapt to, and as a result the impacts of climate change extend throughout the whole ocean system.

In 2023, ocean heat content reached its highest level since records began. Inextricably linked to this was sea level rise, with global mean sea levels also at a record high.[3] An increasingly warm (and elevated) ocean surface has contributed to higher incidence and increased severity of extreme weather events like flooding and tropical storms. These will become more intense with the Intergovernmental Panel on Climate Change (IPCC) estimating that the proportion of tropical cyclones reaching categories four and five could increase by up to 20% should we experience up to 4°C of global warming.[4] In 2024, the UN reported that, if greenhouse gas emissions are not urgently reduced, the world could be on track for up to 3.1°C warming[5] – increasing the risk of climate-related impacts.

In the UK, the Health Security Agency reports that, due to sea level rise, the number of people in the UK significantly at risk of flooding is projected to increase 61% by 2050 under a modest warming scenario (2°C) and 118% in a high warming scenario (4°C).[6] Either scenario would necessitate permanent relocation of coastal communities along with damage to coastal ecosystems and infrastructure, generating both financial and cultural costs. Some level of adaptation may be possible but this must be proactive rather than reactive.

Biodiversity loss

In 2023 a review of 30 years of research into the effects of ocean warming on marine ecosystems was published, with the aim of comprehensively understanding the impacts of this process. The authors classified the organisms studied as either 'winners', 'losers', or 'neutral' based on their projected (and measured) abilities to adapt to warming. A stark 78.8% of the publications included in the review identified 'losers' in warming scenarios, with just 20% expected to adapt and emerge 'winners'.[7] These 'winners' may adapt through migration to preferable habitats, thus causing imbalances in existing ecosystems and perpetuating the issues caused by warming, leaving vulnerable organisms with compound threats to overcome. The authors caution against 'winners' being denoted as such long-term, emphasising that adaptation may not be possible across all life stages of any particular organism.

There may be unpredictable losses should important ecosystem services be disrupted. For example, should coral bleaching occur across a wider area than at present, the possible habitats available to certain types of fish will be greatly constricted regardless of whether they can tolerate higher water temperatures themselves. Projections estimate that 99% of coral reefs will be untenable at 2°C or more of warming, which would represent an irreversible change with effects on myriad species.[8]

Other factors are also threatening marine biodiversity. Unsustainable fishing practices can imbalance the marine food chain, especially when certain species are considered more valuable and consequently make up a disproportionate share of catches. A 2023 report by Oceana noted that stocks of the ten fish most popular with UK consumers are under threat, with half overfished or facing critically low population levels.[9] The report calls for urgent action, reiterating the International Council for the Exploration of the Sea (ICES) recommendation on total fishing bans on three species: Celtic sea cod, West of Scotland cod and Irish Sea whiting.[10] Should fishing continue before these populations are able to recover, their long-term survival will be threatened.

Conservation and restoration efforts must take into account the full picture of the ocean's health to ensure they are robust enough to withstand a changing ocean, and to avoid inadvertently contributing to the compounding challenges.

Restoring and conserving blue carbon ecosystems

Blue carbon environments – such as saltmarshes, seagrass meadows and mangroves – have been particularly vulnerable to the triple crises of climate change, pollution and biodiversity loss. These vital ecosystems provide habitats for a range of species while also storing carbon and increasing resilience to coastal erosion. It is essential that existing blue carbon ecosystems are conserved and those that have been degraded are restored.

There have been success stories regarding blue carbon ecosystem restoration in the UK. At a saltmarsh restoration site in Teesside, annual monitoring has revealed a wide range of aquatic species are beginning to thrive, including crabs, shrimps and a variety of fish. This demonstrates a stable ecosystem where biodiversity has levelled off after steadily increasing up until 2023. The saltmarsh restoration was commissioned as part of a project to realign sea defences and enable migratory fish to access rivers that they had previously been blocked from.[11]

Similar work across England will be made easier by Natural England's Marine Restoration Potential project. One of the project's outputs is maps highlighting degraded marine and coastal habitats that may be suitable for restoration, along with areas in which this may not be possible. As a result, decision-makers and investors will be able to make informed decisions as to where the most impact could be achieved when considering restoration projects. The open-access nature of these maps also provides communities and lobbying groups with evidence to support grassroots efforts and put pressure on local and central government to act.[12]

Alongside restoration, there is ample evidence to support the case for conservation of existing blue carbon ecosystems. The World Bank Group reported flood protection services to the value of $855 billion are provided globally by mangroves alone.[13] Though the ecological toll would be stark should mangrove stocks decline, the financially quantifiable impacts of the flooding that would occur in tandem with increased extreme weather events – bringing damage to property, forcing communities to relocate and disrupting coastal industry – are undeniably significant, and their conversion to dollars lays bare the services mangroves provide. Conserving these ecosystems is therefore clearly in the interest of both the marine and coastal environment and terrestrial life.

Research and innovation

The urgency of the threat to the marine and coastal environment necessitates the quick delivery of solutions. As mentioned in our third Turning the Tide publication, Blue carbon, there is limited data on the full extent and carbon storage capacity of blue carbon ecosystems, and the same is true for many aspects of the marine environment. However, this cannot be used as a reason to delay action: it is better to trial and iteratively improve imperfect solutions than wait too long for the perfect fix – by which time restoration efforts may no longer be feasible.

Surveying of academic researchers, technologists and other conservation practitioners found that the most challenging barriers to developing solutions is cost. Respondents identified the need for collaborative, interdisciplinary bottom-up innovation practices that allow for iterative improvements and continued support throughout development processes. They also highlighted automation as a key enabler to save time and money when reviewing large datasets.[14] Machine learning and autonomous vehicles are likely to present significant opportunities in this space and could make monitoring of conservation and restoration projects cheaper and more accessible, meaning research teams could spend more of their time developing solutions.

Additionally, any reporting frameworks used to track the success of conservation and restoration efforts ideally need to be both standardised and freely available globally. Open-access, interoperable data would mean that anyone reporting on even a small part of the ocean would be able to understand the broader systems and circumstances their data was a part of. Designing standardised reporting frameworks should be a co-productive process in which the knowledge of Indigenous communities is captured to ensure that metrics reflect the priorities of all who steward the ocean.

Collaboration and engagement

Discussed in our first Turning the Tide publication, Bridging the gap between land and sea, was the importance of ocean literacy. Though this is particularly relevant to coastal communities who can support on-the-ground conservation and restoration projects, it must extend inland and into other sectors. Central to achieving this is researchers' ability to communicate with a range of stakeholders and ensure they are aware of the global importance of protecting the ocean.

In terms of engaging with coastal communities, there are two key messages that may need to be conveyed. If a conservation or restoration project is taking place locally, a community may be able to support and provide long-term stewardship. Alternatively, the community may be at risk itself due to factors like increased extreme weather events, rising sea levels, or erosion. In both instances it is important to involve local stakeholders from the outset, creating opportunities to understand their perspectives and benefit from their knowledge. Where possible, projects should be co-designed with local communities to increase buy-in and allow for valuable knowledge exchange. It is also worth emphasising that interventions on a local scale will have impacts further afield due to the interconnected nature of the marine system.

Co-designed marine and coastal management plans are becoming more mainstream, with the UK's National Environment Research Council (NERC) allocating £2.4 million to three four-year projects aiming to work with communities to address the risks posed by projected increases in flood events, pollution and erosion.[15] One of these will be taking place in the communities of Barra and Vatersay, islands in the Outer Hebrides. Scientists will work with local people from the project's outset to develop nature-based solutions to help mitigate the impacts of increasing coastal erosion and flooding. Alongside the development of solutions, the project will also act as an example for other similar communities to learn from.

Previous sections have touched on the financial and biodiversity benefits of conserving and/or restoring blue carbon ecosystems. Marine conservation and restoration can provide myriad benefits for people and nature. A study by Viana et al found that the presence of Marine Protected Areas positively impact human health and wellbeing due to a variety of reasons including improved nutrition from high quality seafood to increased income associated with tourism. Due to their designation as MPAs, this improvement in human wellbeing occurred alongside improved nature conservation in over 60% of the 234 sites monitored over the last 50 years.[16] Though these sites do not solely represent blue carbon habitats, with other forms of marine and coastal habitats included, the benefits to blue carbon ecosystems of falling under an MPA designation is clear.

Governance and regulation

Effective governance and regulation are needed on an international, national and regional level in order to conserve and restore coastal and marine environments. These approaches should also be complementary and involve collaborations across key stakeholders for effective implementation and enforcement.

International ocean governance

At the international level there are a number of initiatives in place to support marine conservation and restoration, such as the landmark High Seas Treaty signed by 105 countries in 2023. However, it is not yet legally binding, and so the High Seas Alliance is lobbying to have it ratified by 60 countries by the UN Ocean Conference 2025. At the time of writing there are seven months to go and only fifteen ratifications.[17] The majority of the fifteen countries who have ratified it are low-lying islands with significant proportions of their land being coastal, and none are landlocked. This implies a hesitancy globally to adopt its principles as law and a concerning disconnection for nations who do not have coastlines or have the advantage of major settlements being further above sea level. It is crucial that legal protections for the marine environment are advocated for by all nations, so that the burden of responsibility doesn't disproportionately fall on those who are most at risk from the effects of a polluted and warming ocean.

The Convention on Biological Diversity (CBD) is pushing for increased focus on the marine environment, with their workplan including "the Secretariat of the Convention on Biological Diversity work[ing] to facilitate efforts by Parties and relevant organizations to implement the Convention and conserve and sustainably use marine and coastal biodiversity".[18] The CBD are also providing support to countries who may be at greater risk of extreme weather events or marine biodiversity loss, with events such as regional capacity-building workshops for States of the Atlantic and Mediterranean coasts of Africa scheduled for 2025.

The United Nations Framework Convention on Climate Change (UNFCCC) focused on the topics of marine biodiversity conservation; coastal resilience; technology and finance for the marine and coastal environment during 2024's Subsidiary Body for Scientific and Technological Advice (SBSTA) Ocean Dialogue,[19] a process aiming to build global knowledge in these areas. Commencing in 2021, the UN Ocean Decade is promoting the concept that 'The ocean holds the keys to an equitable and sustainable planet', intertwining ocean science solutions with social justice. Through ten challenges spanning the breadth of marine and coastal science, the project hopes to unite global efforts to restore the ocean and connect people to it.[20]

UK marine and coastal governance

In England, Marine Protected Areas (MPAs) are a key legislative support for conservation and restoration efforts. 37% of England's offshore waters are designated as MPAs, with a small amount classed as Highly Protected Marine Areas (HMPAs). The latter means that all species, habitats and associated ecosystem processes within the site boundary, including the seabed, shore and water column are protected; MPAs have a slightly looser set of protections, with the focus being on the recovery of habitats, species and ecosystems in a specified area.[21]

Though it is positive to see protection afforded, there are criticisms of the legislation. For example, the Marine Conservation Society reports that only 6% of MPAs have banned bottom trawling and dredging, which are damaging to marine ecosystems.[22] There is currently no protection from either practice that extends more than 12 nautical miles from the English coast.

There are differences in MPAs across the devolved administrations. In Scotland, for example, there are more than 240 MPAs, which are designated under different legislation for the purpose of either nature conservation; research and demonstration; or to protect heritage areas and historic sites. The process involves input from Scottish Ministers, Statutory Nature Conservation Bodies, and the Marine Directorate Licensing Operations team.[23]

Wales has 139 MPAs, which cover 69% of the waters within 12 nautical miles of their coasts. These are designated Marine Conservation Zones (MCZ), Special Area Conservation (SAC), or Special Protection Areas (SPA). The Welsh Government works with Natural Resources Wales and the Joint Nature Conservation Committee to designate and manage these areas.[24]

Furthermore, the ocean is a complex system that cannot be broken down into discrete areas: anything happening in one part will have impacts on the wider system. As such, MPA designation can be ineffective at safeguarding an area against various forms of pollution, which can easily transgress nautical borders, and other global issues such as ocean acidification and warming, neither of which can be confined to one part of the marine environment.

A framework designed to improve MPAs and ensure they are cognizant of the wider ocean system has been shared by the Joint Nature Conservation Committee (JNCC) who currently advise the UK Government on various types of nature conservation. Their Management Effectiveness of Protected and Conserved Areas (MEPCA) Indicator “aims to support tracking the achievement of conservation outcomes across marine, freshwater, and terrestrial environments”.[25] It is designed to be used globally to standardise the reporting of conservation practices achieved in MPA equivalents around the world, and can be utilised through a spreadsheet. It also encompasses terrestrial water systems, meaning a crucial in-flow to MPAs can be mapped against the ocean system rather than treated separately. Though the issues with the permeable boundaries of MPAs exist wherever they are, steps towards all global MPAs being part of the same system will at least allow for joined-up management and observation.

Ultimately, until the whole ocean is protected and treated as a single complex system, the damage done to unprotected areas will continue to have knock-on effects – however stringently MPAs are regulated.

In addition to protecting the marine and coastal environment, it is key that damaged areas can recover. As Net Gain practices have gained traction terrestrially, the concept of Marine Net Gain (MNG) has been posited as a way to achieve this recovery. As a relatively novel approach, there are still developments to be made in practice. In a paper focusing on MNG in the context of offshore windfarms, researchers identified several areas for further consideration including the need for improved understanding of MNG among stakeholders acting in the marine environment; development of a standardised marine-specific MNG metric; and exploration into how MNG could be integrated into existing MPA legislation.[26]

The role of a sustainable blue economy

To speed up the work of governance systems and researchers, investment must be generated to support conservation and restoration efforts. Business-as-usual is not compatible with the sustainable blue economy. A potential concern for investors may be the blurring of boundaries in marine environments which does not happen on land, meaning that the effects of a financed intervention in a particular zone will not be contained in the same way they would be terrestrially, and return on investment cannot always be explicitly quantified as a result. Framing the benefits of investing in conservation and restoration outside of purely financial terms can be helpful here – as can reminders that much larger costs will be incurred down the line should the marine environment not be protected and restored. Collaboration and problem-solving across borders can foster positive relationships that allow for joint investments to be made across larger zones, creating opportunities for shared risk and reward.

A sustainable blue economy can be legislated for. For example, the Welsh Government's new Strategic Approach to Welsh Fisheries and Aquaculture emphasises the need for fish stocks to be conserved and protected to ensure their long-term sustainability as well as the economic viability of fishing off Welsh coastlines. This Strategic Approach relies upon innovative technology such as Remote Electronic Monitoring to ensure compliance, and the development of science-based limits defining the Maximum Sustainable Yield of fish stocks. It is noted that fishing and aquaculture cannot thrive in current conditions, with £40million earmarked for improvements to water quality by the end of the Senedd's current term in 2025.[27] Ultimately, it provides clear recognition that unsustainable practices have no place in a viable blue economy.

To learn more about the blue economy, we recommend accessing the third Turning the Tide publication, which explores the subject in depth.

Systems thinking

In a complex system, extractive activities or in-flows of damaging substances will cause imbalances – both in their immediate vicinity and throughout the system. Especially in the context of conservation and restoration, it is vitally important that doing good in one location does not cause harm in another, as an intervention that may be beneficial to one component of the system may cause unforeseen problems elsewhere. However, this caution must be balanced with urgency – inaction will allow existing issues to worsen and cause damage on a wider scale if left unchecked. Understanding the interlinked nature of the marine and coastal environment inherently necessitates recognising humanity's own connection to the ocean and responsibility for its wellbeing. Our use of stocks present in the marine and coastal system can only be sustainable if we also conserve and restore its vital functions. This must be for the good of the system rather than solely to fulfil our own needs.

The Turning the Tide project as a whole has made clear the interconnected nature of many of the issues associated with the marine and coastal environment and the crucial need for systems thinking as a lens through which to frame solutions. Though they each represent significant areas of research and knowledge, the project's four themes: Bridging the gap between land and sea; Blue carbon; Blue economy; and Marine conservation and restoration, are all ultimately elements of the same system – and must be considered together if a sustainable ocean is to be achieved.

Wrapping up Turning the Tide

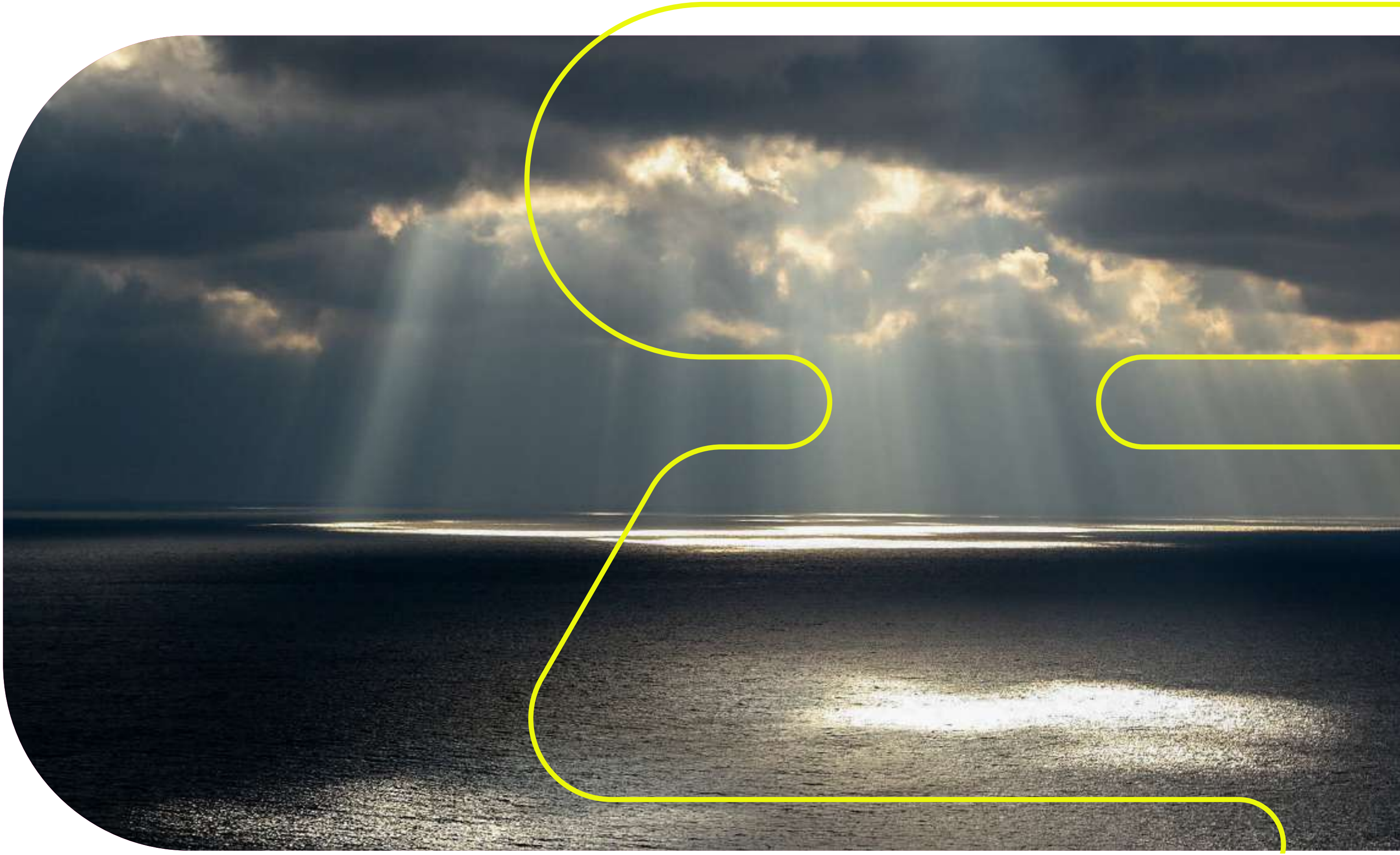
The conclusion of our final theme, Marine conservation and restoration, represents the culmination of Turning the Tide: Systems thinking for a sustainable ocean. Launched in early 2023 in collaboration with the UN Ocean Decade,[20] the project brought together a range of stakeholders from across the Marine and Coastal Science sector who shared their insights on Turning the Tide's four themes: Bridging the gap between land and sea; Blue carbon; Blue economy; and Marine conservation and restoration. Through a mixture of webinars, panel discussions, blog posts and articles, they reflected on the importance of systems thinking in transitioning to a sustainable ocean.

The first theme, Bridging the gap between land and sea, highlighted how human activities affect the marine and coastal environment. This emphasised the importance of the land-sea interface as a key transitional space in which terrestrial issues begin to affect the ocean and vice versa. Case studies highlighted how practices such as Integrated Coastal Zone Management can take this into account and support the wellbeing of both spaces simultaneously by acknowledging their intrinsic interlinkage. Ocean literacy was also flagged as a key concept in this area, and its development heralded as significant in involving coastal (and inland) communities in feeling connected to - and responsible for - the marine environment.

Next, Blue carbon explored the importance of the marine and coastal ecosystems that store carbon, with particular focus on mangroves, saltmarshes and seagrass meadows. Blue carbon restoration projects in China and Australia were highlighted to demonstrate the opportunities and challenges associated with safeguarding these ecosystems on a global scale, covering factors such as valuation of blue carbon ecosystems; the need for pioneering technology and data practices; and the role of ocean literacy.

Our penultimate theme, Blue economy investigated the variance in what a blue economy is perceived to be, from sustainable and circular to extractive and financially-driven. It was emphasised that interdisciplinary collaboration will be key to moving toward the former, especially in the context of halting harmful investment practices and redirecting financiers towards long-term investment in marine natural capital.

Finally, Marine conservation and restoration reiterated the need for joined-up, collaborative efforts to ensure vital marine and coastal ecosystems can not only survive but thrive into the future.



Systems thinking was flagged as a key mechanism for tackling so-called 'wicked problems' such as the causes of damage and degradation to the marine environment.

These four themes aimed to identify and dissect some of the most pressing issues facing our coasts and ocean, with input from sector-leading experts illuminating the action that can – and must - be taken to address them. As part of the UN Ocean Decade effort, Turning the Tide sought to share with IES members and beyond the importance of systems thinking for a sustainable ocean.

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