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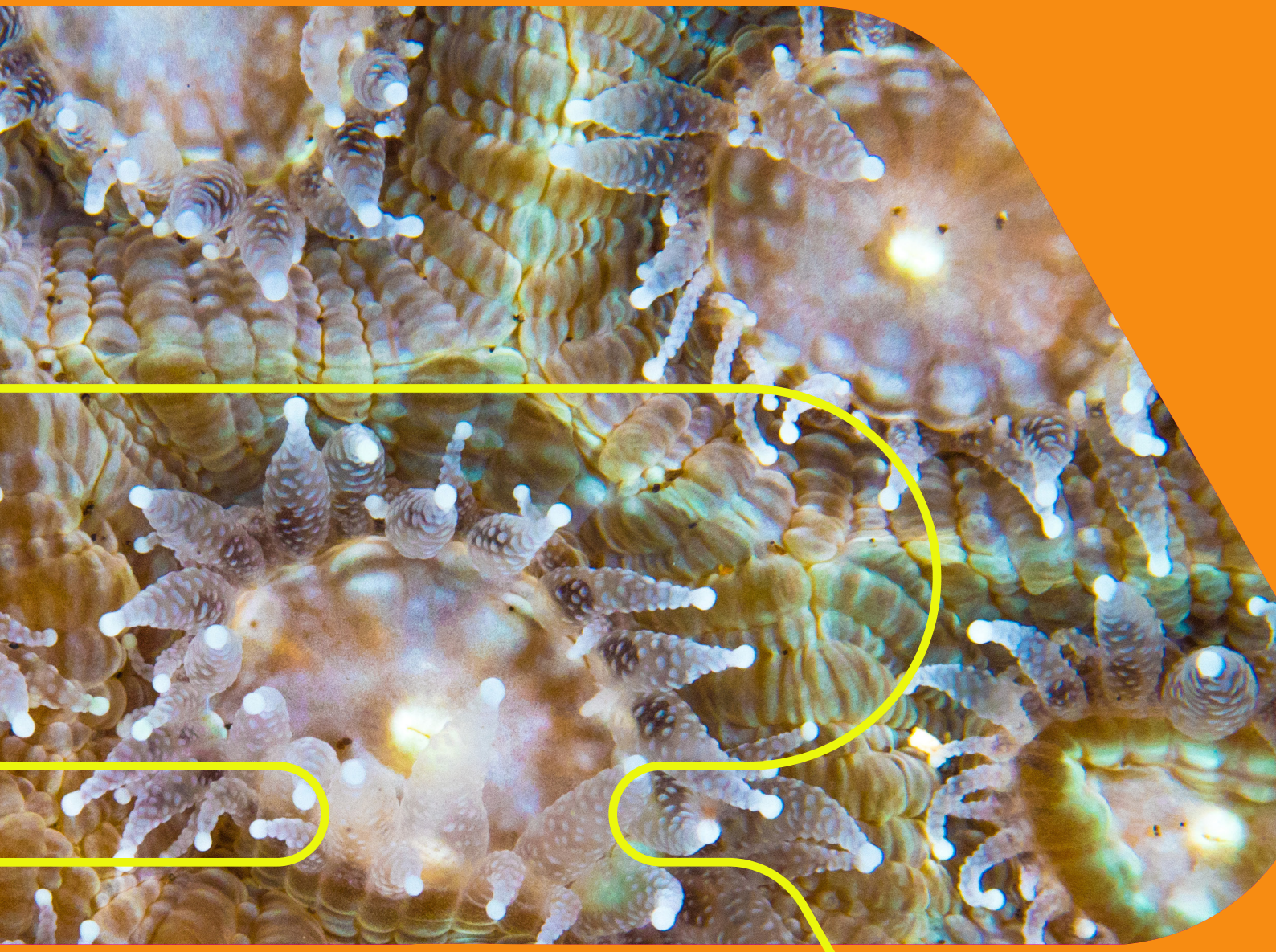
Marine conservation and restoration

Turning the Tide: Systems thinking for a sustainable ocean

March 2025



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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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