WHY THE OCEAN MATTERS IN CLIMATE NEGOTIATIONS

KEY MESSAGES

- **The ocean has greatly slowed the rate of climate change**. But at a cost: the ocean has also warmed, acidified and lost oxygen, whilst circulation patterns are changing, and sea levels are rising. The continuation of these changes not only threatens marine ecosystems, but also the future ability of the ocean to indirectly support all life on Earth.
- **A healthy and biodiverse ocean** provides food, wellbeing, cultural heritage, and support for the sustainable livelihoods of billions of people – as well as mitigation and adaptation options for climate change.
- **Rapid reduction in greenhouse gas emissions** to meet the Paris Agreement will decrease impacts on the ocean and benefit its ecosystems and all of society.
- **As part of the "climate system"** the ocean needs to be better integrated in UNFCCC mitigation, adaptation and financial processes, including Nationally Determined Contributions, National Adaptation Plans and the Global Stocktake.
- **Improved ocean governance and management** is needed to scale up marine protection and sustainable management of both the high seas and coastal waters.
- **Sustained, global ocean observations** and projections of ocean physics, chemistry and biology are essential to inform better short and long-term policy-making for the benefit of people, nature and the economy.
- **Innovative ocean finance** is required to achieve a sustainable ocean economy and protect the ocean's natural capital.

WHY THE OCEAN MATTERS

The ocean takes up heat and carbon, reducing the adverse effects of climate change. The ocean plays a central role in regulating our climate and weather. The ocean has taken up more than 90% of the extra heat energy stored on the planet arising from increased greenhouse gases and is taking up around 25% of the extra carbon emitted by human activities[1]. The ocean also receives all the water from melting ice. Without such ocean uptake and storage of heat and carbon from the atmosphere, there would be much greater increases in air temperature and atmospheric CO_2.

However, those benefits also have costs: the ocean is warming, the rate of sea level rise is increasing, and the ocean is acidifying and losing oxygen vital to life[1]. Furthermore, changes in ocean circulation and stratification as a consequence of climate change mean that the ocean may absorb heat and carbon at a reduced rate[2]. In particular, climate model projections with anthropogenic forcing usually reveal a weakening in the Atlantic meridional overturning circulation over the next century, affecting how the ocean redistributes heat and carbon over the globe[3].

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The ocean provides us with livelihoods, food, wellbeing, cultural heritage, trade, energy and a place to live. The ocean harbours great biodiversity and mineral resources – many species remain unknown and locations unexplored. It provides food and livelihoods for billions; around 40% of the world's population lives within 100 kilometres of the coast and it is a crucial part of traditional heritage and culture for many people, particularly indigenous peoples and coastal communities. However, the growing level of human usage has impacts on marine biodiversity, affecting nearly 60% of most species ranges[4]. The ocean is a busy place as it is the major trading route for the planet[5] with >80% of our goods transported by sea. It will only get busier as we look to the ocean to supply us with renewable energy from the movement of wind, waves and tides.

Offshore global wind power in particular has grown at 30% per year over the last decade and is likely to continue to expand given its low carbon footprint[6], with the UK leading the world in the amount of installed wind farms, which can now meet >10% of the UK's electricity needs[7]. The number of offshore wind farms is set to rapidly increase by 2030, with 40 GW being deployed in UK waters[8] and >200 GW worldwide, and plans to more than treble this amount globally by 2050 with up to 1000 GW[9]. These developments are essential to get to net-zero but will use a significant amount of marine space and the levels of large energy extraction will modify the strength of mixing[10]. The introduction of the usage of large areas of coastal seas may cause tensions between different users of the sea, such as fishing industries which will be displaced from traditional fishing grounds, affecting both large[11] and artisanal[12] fisheries.

Offshore wind farms as backdrop to enjoyment of the sea. Image credit: Kelvin Boot, Plymouth Marine Laboratory.

For centuries, societies have traditionally relied on the ocean for the catch of wild fish for a substantive proportion of our protein and for 3.3 billion people it is their major source[13]. It is estimated that 85% of fish stocks are overfished; bottom trawling has been shown to be severely disruptive of seabed habitats, species and release of CO_2[14] and the rapid growth of fish farming which until recently required fish for feed brings its own sustainability challenges[15].

The need to preserve and enhance biodiversity to keep our oceans healthy and producing food has led to the establishment of Marine Protected Areas (MPAs). However, less than 7% of the global ocean is currently protected, with only 2.7% truly no-take zones. Much higher targets have been called for, e.g. 30% by 2030[16]. However, some argue that too much optimism is placed on this one type of management action, which assumes the protection of a percentage of areas will succeed as a complete solution for biodiversity recovery.

There are benefits to more strategically embedding MPA creation within a social-ecological approach, with all aspects of the ocean used by different sectors and local communities being considered within marine spatial planning and management options[17]. Nevertheless, there are complex trade-offs in decision-making around MPAs, such as short-term aspects of current jobs to alleviate poverty versus the need for longer-term sustainable livelihoods. However, well-managed marine areas which respond to locals' needs and targeted biodiversity conservation do lead to increases in biodiversity and abundance; as such, they should not be viewed as competition to other sectors, but as a precondition for other sectors of society to flourish, enabling food security and poverty elimination[18].

IMPACTS OF CLIMATE CHANGE ON THE OCEAN

Ocean warming and marine heat waves.
The ocean is warming at all depths throughout the planet. In the open ocean this warming is greatest at the surface, reaching 0.11°C per decade in the upper 75m and reducing to 0.015°C per decade at depths of 700m in the past 50 years[19]. This warming accounts for about 93% of the increase in the heat energy arising from human-caused global warming[1]. Rates of warming in shallow coastal seas tend to be much greater, typically 0.2 to 0.4°C per decade.

Superimposed on this background warming trend, marine heat waves occur when there is unusually high sea surface temperature lasting for days to months. The number of days with marine heat waves has doubled globally in the past 50 years, from about 2.5 heatwave days per year to 5 heatwave days per year[3]. Marine heat waves are becoming longer-lasting, more intense and extensive and can have profound and lasting effects on marine ecosystems.

Sea level rise. Sea level is increasing over the globe from melting of land ice and the thermal expansion of water with rising temperatures. Between 1901 and the 1990s, global mean sea level rose between 7 and 18 cm[20]. Since 1993, satellite measurements show global sea level has risen by over 8 cm. By 2100, global mean sea level is projected to rise further due to the emission of more CO_2, ranging between an additional 61 to 110 cm in a high emission scenario, and 29 to 59 cm in a low emission scenario[20]. Sea level rise represents a major hazard, increasing the risk of coastal flooding from storm surges and high tides. Without enhanced coastal defences, these projected sea level rises will cause floods that used to happen once in a 100 years to become annual events by mid-century in many coastal regions, even in a low emissions scenario[21]. The human impacts of this flooding risk can be enhanced 3 to 4 fold by subsidence occurring in coastal cities, especially those built in estuaries[22].

Changes to ocean currents. There is emerging evidence for changes in the strength and direction of ocean currents caused by ocean warming and by episodic strong wind events[23]. Many fish stocks are dependent on ocean currents providing transport pathways between feeding and spawning grounds. Projected increases in temperature, changes in currents and the number of storms could therefore affect recruitment success of commercially important fish stocks[24]. The understanding of present-day dependences of fish populations on oceanographic characteristics is patchy, with most knowledge available in the coastal seas of developed nations. Understanding of the likely impacts of future climate change on fish stocks is much poorer.

Ocean acidification. The increase in atmospheric CO_2 leads to an increased CO_2 uptake by the ocean, decreasing seawater pH (ocean acidification). This acidifying effect reduces the future ability of the ocean to take up more carbon[25], whilst also affecting physiological processes for many marine species. Whilst there is high variability in responses, tropical corals, cold-water corals, and shelled molluscs seem most vulnerable to future ocean acidification[1]. There is also strong evidence for adverse impacts of ocean acidification on behaviour, for both fish and invertebrates.

Deoxygenation. The global ocean has lost around 2% of its dissolved oxygen in the past 50 years, caused directly by lower solubility in warmer water and indirectly by reduced mixing between surface layers and deeper water[26, 1]. Mid-water (1,000-5,000 m depth) deoxygenation has been greatest in the North Pacific, South Atlantic and Arctic, expanding the volumes of low oxygen water unsuitable for many fish. Highly active species, such as sharks and tuna, are the most affected. Productive shallow coastal seas are also experiencing deoxygenation due to a combination of increased inputs of land-derived nutrients (fuelling extra biological production, which then leads to lower oxygen concentrations as the organic material is recycled) and increasing winter temperatures . Such deoxygenation is projected to greatly worsen under high emission scenarios, although with marked regional variability[1].

Ecosystem responses. All marine ecosystems and organisms – from coast to abyssal depth and from the equator to the poles – are now already affected, to some degree, by one or more of these human-driven climate change stressors[1]. Such pressures will intensify in future, superimposed on (and potentially interacting with) a wide range of other, non-climatic stressors. Food-web interactions accentuate such effects. Thus climate change effects on the distribution and abundance of phytoplankton (microscopic marine plants) affect their productivity, thereby becoming a driver for additional impacts, either positive or negative, on nearly all other marine life: from zooplankton and microbes, to fish, seafloor organisms, marine mammals and seabirds[27].

The implications of climate change for marine fish populations can therefore occur at multiple levels, from individual-level physiological and behavioural changes; to population-level response; to environmental and ecosystem changes[24]. For example, migrations of key fish stocks between feeding and spawning grounds are often dependent on temperature as the trigger to initialise long-distance migration. The rapidly warming coastal waters could lead to potentially important changes to these triggers[28,29].

Since not all species respond to environmental change at the same rate (e.g. through poleward movements in their distributions), the overall effect is a reduction in the functional integrity of ecosystems, with associated reductions in all the benefits they provide to human society as ecosystem services[30, 1]. Both our coastal seas (See Box 1) and open ocean (See Box 2) are important to sustaining life and regulating climate[1].

BOX 1: WHY COASTAL SEAS ARE IMPORTANT

Coastal warming is generally faster than in the open ocean because of the limited depth.

The shallow coastal seas experience a large proportion and diverse range of human activities but also respond readily to the changing temperature of the atmosphere[1]. The increasing air temperature transfers directly into increased temperatures in the shallow coastal seas, so that rates of warming are much higher than observed in the open ocean leading to shifts in the populations of key plankton species.

Reductions in oxygen, sufficient to stress fish and seabed animals, are becoming more common in shallow seas. In shallow seas, a warmer winter will lead to reduced concentrations of dissolved oxygen, as warmer water can hold less oxygen. The winter concentration of oxygen sets the environmental conditions for the rest of the productive season through spring and summer. There is evidence that coastal seas in summer will experience more time in an oxygen deplete state as winter temperatures increase, which leads to stress on pelagic and demersal fish and seabed-dwelling animals.

Harmful algal blooms and pathogenic organisms may increase risk to coastal communities. Harmful algal blooms and pathogenic microbes (e.g. Vibrio) may display changes in their range and occurrence in coastal areas in response to both climatic (ocean warming, marine heatwaves, oxygen loss) and non-climatic drivers, including increased riverine nutrients run-off, coastal pollution and excessive algal growth[27, 31]. Increases in the incidence of harmful algal blooms and marine pathogens would negatively impact economic sectors such as fisheries, aquaculture, and tourism, compromise seafood safety, and heighten risks to human health. Coastal communities in areas with limited or non-existent monitoring programmes and early warning systems, and indigenous communities with traditional diets relying on high seafood consumption, are facing the largest projected risks[27].

Heat stress inducing large-scale ecosystem decline. Coastal ecosystems structured by warm-water corals, rooted vegetation (seagrasses, mangroves and saltmarsh) and seaweed are particularly sensitive to marine heat waves[27]. Coral bleaching occurs when the coral (animal) loses its symbiotic algae due to heat stress. Reef recovery may take several years, and is further jeopardised by ocean acidification, deoxygenation, increased storminess and sea level rise; as a result, the future survival of many tropical coral reefs and their associated biodiversity is at risk. Their global value, in preventing coastal erosion, also for fisheries and tourism, is estimated at >$1,000 billion.

Climate interactions with human pressures. Coastal seas are facing the most diverse range of human pressures and uses[27]. For example, the rate of pollution and land-use change is greatest near the coast – through agriculture, aquaculture, settlement, port development and tourism – affecting the ability of coastal ecosystems to accumulate carbon, and potentially releasing large amounts of CO_2 from coastal sediments[32].

Coastal waters are often busy places with multiple uses. Image credit: Kelvin Boot, Plymouth Marine Laboratory.

Governance and finance challenges in coastal seas. Comprehensive marine spatial planning and consistent implementation of ecosystem-based management mandates are key to manage this area effectively and equitably. Marine spatial planning must, however, also effectively integrate climate change[17]. Better coastal governance, including a reduction of the pressures from land to sea, can help open up space for new opportunities for local livelihoods, innovation and well-being. Developing the economic activities and value creation based on sustainable and smart use of renewable aquatic resources (the blue bio-economy) along our coasts whilst addressing adaptation requires joint thinking and financial engagement, and will be a critical component of a just and sustainable transition. A combination of tools will be necessary to achieve the Sustainable Development Goal 14[33] targets in coastal seas, including fully and partially protected areas and locally managed marine areas. Adequate disclosure of impacts of activities, including nature-based risk assessment and accounting in marine ecosystems, is required and needs to be supported through public funding of adaptation and resilience measures, as well as public-private partnership engagement.

BOX 2: WHY THE OPEN AND DEEP OCEAN IS IMPORTANT

Major role in Earth's climate. The ocean acts as a flywheel for our planet, providing the largest reservoir of heat in the climate system and holding over 90% of the extra heat stored on the planet from global warming[1]. While the surface waters are warming more rapidly than the deep waters, the deep ocean is the major potential sink of the additional anthropogenic heating; acting to decrease the extent of surface warming and so lessening some of the adverse effects of anthropogenic change. The ocean is also one of the largest carbon reservoirs on Earth, holding about 50 times more carbon than the atmosphere, with the largest reservoir occurring in the deep ocean (around 40,000 Gt C)[34, 1]. Around a quarter of current man-made carbon emissions are absorbed by the ocean, reducing the rate of global warming.

Around 50% of global primary biological production occurs in the sunlit surface ocean. This primary production accounts for about half of atmospheric oxygen production. Ocean currents transport heat, gas, nutrients and organisms around the globe and surface waters constantly interact with the atmosphere. The open and deep ocean therefore has a large impact on the climate of our planet.

Largest living space on the planet. The deep and open ocean is the largest habitable space for life on Earth. Changes in temperature, oxygen, acidity and ocean currents driven by climate change rapidly cascade through deep and open ocean ecosystems[27]. It is projected that by 2100 the mesopelagic realm – below sunlit depths – could become more productive but that the ecological communities in this complex realm may become less diverse[35].

Beyond the edge of the continental shelves, the seabed slopes down steeply, sometimes incised with dramatic submarine canyons, descending to abyssal depths of between 3 and 6 km. These are home to diverse animal communities that rely on the trickle of food from the sunlit realm above. This food input is projected to decline by up to 55% over the next century[36].

The ocean seafloor is far from a flat featureless plain. Isolated seamounts, pinnacles, offshore banks and submarine canyons provide hard rocky habitat colonised by cold-water corals, sponges and other animals that rely on catching their prey from the water column. A few species of cold-water coral are ecosystem engineers whose limestone skeletons accumulate over millennia trapping sands and muds to form large deep-sea reefs providing habitats and spawning areas for other species[37,38]. As anthropogenic CO_2 spreads through the global ocean, the progressive acidification of deeper waters means that most of these deep-sea reefs will be exposed to water corrosive to exposed skeletons within the next century, making their skeletons more porous and weakening the very foundations of the reefs that form such significant habitats[39].

Governance and finance challenges. Traditional sectoral and regional approaches to the High Seas have been inadequate in addressing the massive pressures that ocean ecosystems are facing. The ongoing discussions on an overall biodiversity agreement under the United Nations Convention on the Law of the Sea need to be brought to a successful conclusion. Increased commercial activities, such as industrial fishing and shipping, mean that effective all-ocean system management is urgently required. Whilst the UN Decade of Ocean Science for Sustainable Development can provide guidance as to the roadmap, G7 and G20 nations need to lead the effort to deliver a much more significant financial commitment from public and private sources to the international ocean as a key component of the Earth system. An integrated all-ocean data infrastructure that combines satellite and subsea coverage and remote sensing for real-time ocean observation and management would provide a significant investment opportunity to deliver not only the data required for Earth system measurement, but also operational benefits for shipping and global cooperation in ocean monitoring so that activities such as illegal, unregulated and unreported fishing could be significantly reduced.

MITIGATION STRATEGIES AND ADAPTATION ACTIONS FOR AND BY THE OCEAN

Meeting the Paris Agreement will reduce impacts on the ocean and its ecosystems and benefit society. The most important action for the ocean, under the UNFCCC, is to have greater ambition on greenhouse gas emission reduction, and to deliver the Paris Agreement target of limiting the increase in global warming to 'well below 2°C', with a goal to keep it to 1.5°C.

Preserve, restore and investigate ecosystems including "blue carbon". There is increasing scientific and policy interest in using nature-based solutions to mitigate climate change, including 'blue carbon' based on coastal vegetation. Better protection of saltmarshes, seagrass meadows and mangroves would prevent the release of the carbon stored in their sediments. The restoration of coastal blue carbon ecosystems is worthwhile for the many ecosystem services they provide; however, climatic benefits are modest and affected by many uncertainties[27, 40]. There may also be scope for climatically-significant seaweed cultivation (for use as a biofuel, linked with carbon capture and storage), although large areal coverage would be needed. The role, magnitude and state of other carbon stores (e.g. carbon rich coastal and shelf sea sediments) and the impact of human activities, such as bottom trawling and dredging, on them have been less well researched but may be significant[14].

Healthy coastal ecosystems can also deliver biodiversity and societal co-benefits, such as protecting land and infrastructure from sea level rise. For example, one of Europe's largest restored saltmarshes, Hesketh Out Marsh, where lagoons were recreated and tidal flooding was allowed into areas where climate change has increased sea levels, has greatly enhanced biodiversity and bird foraging areas and decreased local flooding risk[41].

Create climate-smart, innovative and networked Marine Protected Areas (MPA). Great expectations are placed on the effectiveness of MPAs now and in the future. There are currently 187 countries with marine protection[16] having either single, grouped or truly networked MPAs. Reviews of MPAs have shown that they do increase biodiversity, size and abundance of species if they have had high levels of protection, are ecologically-coherent, have high connectivity, are distant from human activities and have been established for some years[42]. Highly protected MPAs could also provide co-benefits of food provision and protection of carbon stores in addition to biodiversity protection[14]. The most important indicator of well-functioning MPAs is effective management.

Currently, most do not fall in that category[43], in particular as they were not co-developed within ecosystem-based fisheries management that integrate MPAs as critical components rather than as a competing interest[44]. It is also unclear how resilient existing MPAs will be to future climate change. Thoughtful design and long-term monitoring are required to protect or restore their mitigation potential as well as monitor their climate resilience under future ocean conditions[45]. Even "climate smart" MPAs that are designed specifically for climate adaptation will have their intended benefits continually eroded by climate change if stringent emissions reductions are not agreed[46]. There is also a need to ensure that the creation of new MPAs around the world respects human rights, particularly those of indigenous peoples and local communities.

Develop sustainable and regulated fisheries. Reducing pressures from non-climate sources such as illegal, unregulated and unreported (IUU) fishing will help preserve fish stocks and detrimental impacts on food security, livelihoods, the economy and the environment. Ending IUU is target 14.4 of the UN Sustainable Development Goals[33] but requires strong global cooperation and transparent ocean governance to address failures that have hampered progress in tackling IUU fishing over many years. In addition, new and more affordable electronic technologies are emerging that can improve monitoring of fishing fleet locations and activity, and full traceability of fish products from their origin to the end use[47].

There is a need to work directly with fishing industries to ensure accurate stock assessment and management for sustainable fishing. Encouraging more local use of fish products caught in fisheries determined sustainable (e.g. by the Marine Stewardship Council), and for vessels to change from fossil fuel to alternatives produced by renewable energy (e.g. green hydrogen based power[48]) to help reduce their carbon footprint, is also important.

Consider sub-seabed carbon capture and storage (CCS) for greenhouse gas removal. Even under the most optimistic scenarios, several gigatons of CO_2 will need to be removed each year from the atmosphere to meet the net zero requirements of the Paris Agreement. Sub-seabed CO_2 storage could make a significant contribution to achieving net zero, especially for coastal nations without large onshore storage capacity but with suitable marine geological formations and appropriate infrastructure (such as used for oil and gas fields). However, storing large volumes of CO_2 in rock formations beneath the seabed must avoid leakage and associated negative impacts on the marine environment. Geological surveys for storage integrity, reliable seepage detection and monitoring techniques and environmental impact modelling and assessments are all essential[49].

Consider smart marine spatial planning to enhance the multiple uses of the marine environment. Understanding the distribution of marine habitats, and the multiple uses of the marine environment, is key to effective marine spatial planning and making the best and most sustainable use of the ocean. Transitioning towards this spatially-led decision-making process requires a distinction between areas that are important for biodiversity (species-rich, functionally diverse or important for an iconic aspect of biodiversity) and areas that are important for ecosystem services (e.g. recreation services, flood protection and food and energy provision). For example, the introduction of very large wind farms will displace fishing activity, as well as cause increased mixing around the structures. This can alter local primary production[50], affecting the biological carrying-capacity of the region and the ability to absorb CO_2 from the atmosphere. The consequences of such ocean-based renewable energy structures need to be assessed and consideration given to how they could deliver co-benefits for ecosystems, biodiversity and society.

Invest in international coordination and integration of ocean observations. Information on the dynamic physical, chemical and biological status of the global ocean is crucial to understanding climate change: its impacts to date, how those might change in future, and what responses will be most effective. Ocean observing systems over a range of water depths and spatial scales also provide operational data for shipping, greatly improve weather forecasts, support effective conservation, and facilitate the sustainable use of marine resources. Whilst almost all data-collection is nationally funded, the value of ocean measurements is greatly enhanced by international coordination and integration, primarily through the Global Ocean Observing System[51]. Support in the development of a global initiative for an enhanced, global, sustained sea and ocean observing system such as proposed by the G7 Future of the Seas and Oceans Initiative[52] and the development of a Digital Twin of the Ocean[53] (a digital model of the ocean that assimilates all the available data), would enhance the assessment of the current and future state of the ocean, and ultimately improve mitigation and adaptation plans.

Reduce other anthropogenic stressors. Reduction of anthropogenic stressors on ecosystems (e.g. pollutants, eutrophication, tourism, fishery activities and introduction of alien species) helps to maintain biological biodiversity and protects trophic and reproductive functioning[54]. Sustained and wide-coverage in monitoring programmes and early warning systems with sufficient lead time can support fisheries, aquaculture and public health sectors to set-up adequate resources for prevention and timely disease-incidence-response actions, and so reduce risks to human health[10].

WHAT NATIONS CAN DO

Recognise that the ocean plays a critical role in supporting life on Earth and in mitigating climate change. However, climate change is having an impact on its physics, its chemistry, and its ecosystems, which will in turn have a substantial impact on human society.

Urgently reduce greenhouse gas emissions as this will reduce impacts on the ocean. Reducing greenhouse gas emissions will greatly reduce impacts on all areas of the ocean, its ecosystems and the wealth of goods and services they supply to society.

Promote the development of a sustainable ocean observing system. To track the ongoing effects of climate change on the ocean, and the ocean's role in climate change, requires an efficient observing system for the global open ocean and for regional seas, taking advantage of modern technologies such as satellites and autonomous observing platforms, and supported by state-of-the-art modelling systems (Digital Twins[53]). Currently most ocean observations are supported by short term research funding, making them vulnerable to interrupted data records and so leaving key gaps in critical observations. Moving these observations to a more sustained footing will require international will and cooperation.

Support better inclusion of the ocean in the UNFCCC process. The ocean is an extensive and important part of the biosphere and hydrosphere, and so falls under the remit of the UNFCCC's aim to stabilise greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. There has been some progress on inclusion of the ocean in UNFCCC processes, but more can be achieved:

- There needs to be adequate access to ocean science, sufficient engagement in the relevant ocean-climate discussions and enhanced coordination and cooperation among and with UN bodies as well as through strengthened ocean-climate finance action via the Green Climate Fund.
- The Chair of the UNFCCC Subsidiary Body for Scientific and Technological Advice convened the first official Ocean and Climate Dialogue (December 2020), on how to strengthen adaptation and mitigation action on ocean and climate change within the UNFCCC, the report[55] will be formally shared during COP26. A mandate for an annual Ocean and Climate Dialogue would better inform the UNFCCC process.

- Revise UNFCCC Parties' Nationally Determined Contributions (NDCs) and National Adaptation Plans to address the broader context of ocean-based actions for both mitigation and ecological adaptation. Blue Carbon opportunities are increasingly recognised in NDCs and include efforts to protect and preserve wetlands and nature-based solutions, as well as protecting and restoring marine and coastal ecosystems as cost-effective means of addressing climate change and biodiversity.
- Global climate indicators can inform the UNFCCC and the Global Stocktake. Of the seven World Meteorological Organization Global Climate Indicators[56] there are four that are specifically relevant to the ocean (ocean heat content, ocean acidification, sea level, and sea ice extent). Adoption of these in the Global Stocktake would help to harmonise ocean actions more fully within the UNFCCC process and can put us on track to prevent dangerous anthropogenic interference in the whole "climate system".

Prioritise ocean finance and leverage of co-benefits. Ocean finance, a term used for mechanisms to invest in different sectors of the blue economy, can play a critical role in helping achieve a sustainable ocean economy. This requires a financial regime that acknowledges climate and ocean risk, including at central bank level, and incentivises sustainable ocean finance. Current investments fall well below what is required. Innovation also means development of new capital market instruments, such as blue bonds, and finance and insurance concepts for coastal zone resilience and blue infrastructure, integrating nature-based solutions[57]. Blue carbon projects can provide an important contribution to the delivery of market-based approaches.

There is also a need to address the biodiversity, resilience and livelihoods aspects of coastal ecosystems. These are crucial to the long-term viability of projects and at the core of blue natural capital as an emerging asset class for long-term, biodiversity-positive investors. The benefits of protecting the planet's natural capital can be quantified and far exceed the cost, yet there remains a large biodiversity finance gap, in particular for the ocean.

Strengthening governance policies for the sustainable management of areas beyond national jurisdiction. Given the size and depth of the ocean beyond national jurisdiction, and the double crisis of climate change and biodiversity loss, improved ocean governance through the proposed Marine Biodiversity of Areas Beyond National Jurisdiction (BBNJ) agreement is a critical tool to scale up marine protection and sustainable High Seas management. It must enable all nation states to act individually and collectively to safeguard marine biodiversity and enhance ocean resilience. It will need to be adequately supported both institutionally and financially, for instance through the establishment of an Ocean Sustainability Bank[58].

This requires a fresh framing for enhanced multilateral collaboration, including by a prompt and comprehensive implementation of the BBNJ with comprehensive monitoring and enforcement. Development of public-private partnerships and investment cases, together with sectoral and regional bodies, as well as multilateral finance institutions along a science-based roadmap to sustainable development, should be explored. Concepts such as High Seas user fees similar to user fees in existing MPAs[59] need to be explored further to ensure that the obligations to protect marine biodiversity are fully met.

Increase ocean literacy in all nations, sectors and ages groups. Ocean literacy leads to more informed participation in the discussion on the importance of the ocean to humankind, and the future of the ocean and its resources in a changing climate, enabling more responsible and effective decision making regarding the ocean.

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PML Plymouth Marine Laboratory

NEODAAS NERC Earth Observation Data Acquisition and Analysis Service

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