# BLUE ACCELERATION: AN OCEAN OF RISKS AND OPPORTUNITIES

REPORT
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# Key messages

**A new ocean reality –** While humanity has depended on the ocean for millennia, the extent and diversity of today's ocean use is unprecedented. Many ocean-based industries are growing faster than the global economy, and in many cases exponentially. Driven in part by technological innovation, the ocean is widely seen as the next economic frontier and the solution for sustainable future human development. Yet this is unfolding in a complex and uncertain governance landscape and concerns have been raised over what this new ocean reality entails and who it is supposed to benefit.

**Ocean for food, energy, material and space –** Since 2000: aquaculture has been the world's fastest growing food production sector; offshore wind energy capacity has increased five hundred-fold and 70% of the major discoveries of hydrocarbon deposits have happened offshore; more than 13,000 marine genetic sequences have been registered in patents, and a surge in desalination plants has led to 65 million cubic metres of seawater being desalinated every day; nearly one million kilometres of fibre-optic cables have been laid on the seabed to carry 99% of international telecommunications, the annual volume of cargo transported by container shipping has quadrupled, and an area of ocean floor equivalent to the size of Peru has been leased for exploratory deep-sea mining. This is the "Blue Acceleration".

**Blue Acceleration: for whom? –** The Blue Acceleration represents a new phase in humanity's relationship with the ocean that exhibits a phenomenal rate of change over the last 30 years, with a sharp acceleration characterising the onset of the 21$^{st}$ century. But this scramble for the seas also poses issues of equity and benefit sharing: if there is a rush for the ocean, then who is winning? And who is being left behind? With a tendency to prioritize economic growth and an unequal distribution of technical and financial capacity to engage in ocean sectors, benefits from ocean use disproportionately flow to economically powerful states and corporations, while harms are largely felt by developing nations and local communities. A small number of corporations, headquartered in an even smaller number of countries, generate most of the revenues from ocean-based industries. Virtually none of the 100 largest corporate beneficiaries of ocean use are headquartered in small island developing states (SIDS) or coastal least developed countries (LDCs), except for a handful of companies based in Singapore, and more than half of all their revenues end up in just seven countries: the USA, Saudi Arabia, China, Norway, France, the UK and South Korea.

**Equity and benefit sharing –** Serious concerns exist about unsustainable growth trajectories and systemic inequity in the current ocean economy. A geographical focus on SIDS and LDCs shows a striking pattern with little if any acceleration. Consider for instance the promising biotech industry and the 13,000+ marine genetic sequences that have been associated with a patent since 1988: only 4 of these are from institutions located in SIDS. Likewise, while 18 countries in the world have installed offshore wind capacity (the three largest ones – UK, China and Germany – accounting for more than 79% of global capacity), none of the SIDS and LDCs are among those. Aquaculture is the world's fastest food production sector but only 0.09% of global production is taking place in SIDS and LDCs. On the other hand, they collectively account for 13% of the global marine protected areas and are "state sponsors" for almost a third of the seabed area under deep-sea mining exploration contracts.

**A new risk landscape –** As commercial uses of the ocean accelerate and climate change impacts worsen, marine ecosystems and the communities who depend on them face unprecedented cumulative pressures and the emergence of new interconnected risks. Interactions and conflicts among users also intensify as the ocean space becomes more crowded. Addressing ocean risks – defined as the degree of deviation from the path to a sustainable and equitable ocean – must recognise the multidimensionality of risks (i.e., beyond biophysical hazards to also include social, geopolitical and financial dimensions). How financial institutions define "risks", for instance, rarely aligns with the complex nature of ocean risks and may fail to account for the materiality of non-financial information. Risk assessment in the Anthropocene is made ever more complicated as the baseline of stressors and hazards is rapidly shifting.

**Stranded ocean assets –** Investments in the ocean economy may become stranded assets and lose economic value ahead of their anticipated useful life due to changes in legislation, market forces, disruptive innovation, societal norms, or environmental shocks. Similarly, marine resources may become stranded resources if they are considered unprofitable or cannot be developed as a result of technological, spatial, regulatory, political, social, or environmental changes. SIDS and LDCs are particularly exposed in this context as they often qualify as latecomers (as opposed to first-comers), and are at risk of e.g., losing the opportunity to exploit their resources or being the recipients of stranded technologies (no longer wanted by first-comers).

**Ocean finance –** There is growing momentum on the role that public and private finance can play in assisting transformation towards sustainability. In the context of the ocean economy, sustainable finance is arguably two dimensional: financiers can act either as "enablers" by unlocking capital and increasing finance where it is lacking (e.g., SDG 14 remains the least financed goal and, in the last 10 years, less than 1% of the total value of the ocean economy has been invested in sustainable projects through philanthropy and official development assistance), or as "gatekeepers" by redirecting investments towards more sustainable and equitable practices (by deciding what to finance and under which conditions). This requires the mainstreaming of non-financial sustainability factors within the financial risk system and the continued analysis of how multidimensional ocean risks translate into financial risks.

# Content

# Definitions

**Anthropocene –** a proposed new geological event where humans have become the dominant force of planetary change with profound impacts on the Earth's biosphere and climate system. The Anthropocene is characterized by unprecedented speed, scale and connectivity of people, places, cultures, economies and technologies across geographical locations, sectors and socioeconomic contexts [1-3].

**Anthropocene risks –** risks that (1) originate from, or are related to, anthropogenic changes in key functions of the Earth system (such as climate change, biodiversity loss and land-use change); (2) emerge due to the evolution of globally intertwined social-ecological systems, often characterized by inequality and injustice; and (3) exhibit complex cross-scale interactions, ranging from local to global, and short-term to deep-time (millennia or longer) [4].

**Blue Acceleration –** a new phase in humanity's relationship with the ocean that exhibits a phenomenal rate of change over the last 30 years, with a sharp acceleration of ocean uses characterizing the onset of the 21st century [5].

**Blue Economy –** sustainable development framework for developing countries addressing equity in access to, development of and the sharing of benefits from marine resources; offering scope for re-investment in human development and the alleviation of crippling national debt burdens [6].

**Leverage points –** places in a system where a relatively small change can lead to fundamental changes in the system as a whole and its behaviour [7].

**Ocean 100 –** the 100 corporations with the highest annual revenues from ocean use. Collectively, these companies generated USD1.1 trillion in revenues in 2018, representing 60% of total revenues from eight core ocean economy industries: offshore oil and gas, marine equipment and construction, seafood, container shipping, shipbuilding and repair, cruise tourism, port activities, and offshore wind [8].

**Ocean Economy –** defined by the Organization for Economic Co-operation and Development (OECD) as the sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems [9].

**Regime shifts –** large, persistent, and usually unexpected changes in the structure and function of ecosystems [10].

**Resilience –** the capacity of a system to cope, adapt or transform in the face of changing social or environmental conditions [11].

**SDG14 –** Sustainable Development Goal 14 ("Life Below Water") aims to conserve and sustainably use the oceans, seas and marine resources for sustainable development. It is the fourteenth of the 17 Sustainable Development Goals adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. SDG 14 is associated with 10 targets that include reducing marine pollution; protecting and restoring marine ecosystems; reducing ocean acidification; sustainable fishing; conserving coastal and marine areas; ending subsidies contributing to overfishing; increasing the economic benefits from sustainable use of marine resources; increasing scientific knowledge, research and technology for ocean health; supporting small scale fishers; and implementing and enforcing international sea law.

**Social-ecological systems –** complex adaptive systems, in which human societies are embedded in nature. The social component refers to all human activities, including economy, technology, politics and culture. The ecological component refers to the biosphere, that is, to the part of the planet on which life develops. Both components are interrelated [11].

**Threshold –** the critical point in a situation, process, or system beyond which a significant and often unstoppable effect or change takes place. For instance, a situation in which an ecosystem experiences a shift to a new state, with significant changes to biodiversity and the services to people it underpins, at a regional or global scale.

**UNCLOS –** the United Nations Convention on the Law of the Sea, adopted in 1982 and entered into force in 1994, is an international agreement that establishes a legal framework for all marine and maritime activities. Considered the 'Constitution' of the ocean, it comprises 320 articles and nine annexes, governing all aspects of ocean space and codifying the rights and obligations of states while providing the foundation for international collaboration on conservation and sustainable use of the ocean and marine resources.

# Introduction

The ocean has shaped humanity from its earliest stages. There is evidence that the transition from mobile hunter-gatherer cultures to stationary communities came as humans reached the shore, with the tides providing a stable and replenishing food supply [12]. Settlements formed, human societies developed, and cultures took shape. For much of human history, however, the ocean was a divider, restricting access and connections. Nautical developments reversed that role, making the ocean a connecting fabric, wrapped around the entire globe. In the emerging context of the Anthropocene [13] – a new era in which humans are the main drivers of change in the planet's ecosystems and climate – another equation is also shifting, with the ocean no longer just shaping humanity, but humanity fundamentally changing and reshaping the ocean [14].

> **"There are three sorts of people: the living, the dead , and those who are at sea"**
>
> **– Aristotle (attributed),** *Greek philosopher*

Perhaps the most vivid expression of how rapidly humanity's interactions with the ocean are changing is a phenomenon dubbed the "Blue Acceleration" [5]. Simply put, the Blue Acceleration describes a simultaneous and rapid expansion over the past 30 years of claims for ocean food, energy, material and space (Figure 1). The intensity and diversity of these claims is unprecedented in the ocean, with long-established industries such as fishing and shipping being joined in the past decades by entirely new ones such as offshore wind and marine bioprospecting, which have experienced explosive growth [15,16].

While the Blue Acceleration is occurring at sea, its origins are found on land. Firstly, a growing global population and increasing consumption levels have placed heavy demands on, and sometimes depleted, land-based resources [2,17]. For instance, projected future needs for certain metals and minerals used in electronics have fuelled growing interest in mining of the international seabed [18], and with the development of novel technologies that have rendered even the most remote parts of the ocean accessible, the world seems poised to soon add another sector to its list of ocean industries [19]. Attention is also increasingly turning to aquatic foods, including those captured or farmed in marine environments, to help address malnutrition, lower the environmental footprint of the global food system, and offer livelihood opportunities [20-22].

Secondly, 151 of the world's 195 countries have a coastline, and therefore direct access to the ocean economy. Many of these countries are heavily dependent on the ocean as a source of revenue, nutrition and livelihoods. Some countries such as small island developing states (SIDS) and coastal least developed countries (LDCs) have limited immediate prospects for economic growth and development. Many countries, both rich and poor, see the ocean as an engine of economic development – an engine that, if properly calibrated, will result in economic development that is also sustainable and equitable, in line with visions of a "blue economy" [23-25].

What is becoming increasingly apparent is that – contrary to notions that the ocean is too big for humans to change – the Blue Acceleration is resulting in an increasingly crowded ocean space where cumulative pressures from human activities and climate change are fundamentally altering the ocean and its ecosystems [26-28]. Ocean acidification, marine heatwaves, plastic pollution, and ecological connectivity that span across political boundaries further make the sustainable management of ocean use a uniquely complex governance challenge [29-31].

In the following sections, we rely on a synthesis of peer-reviewed and grey literature, empirical data and case-studies to:

1. Describe the new reality of the global ocean;
2. Investigate how the Blue Acceleration unfolds in the context of SIDS and LDCs;
3. Discuss what this implies for the emergence of interconnected ocean risks;
4. Explore the role that finance can play in assisting transformation towards a more equitable and sustainable ocean economy.

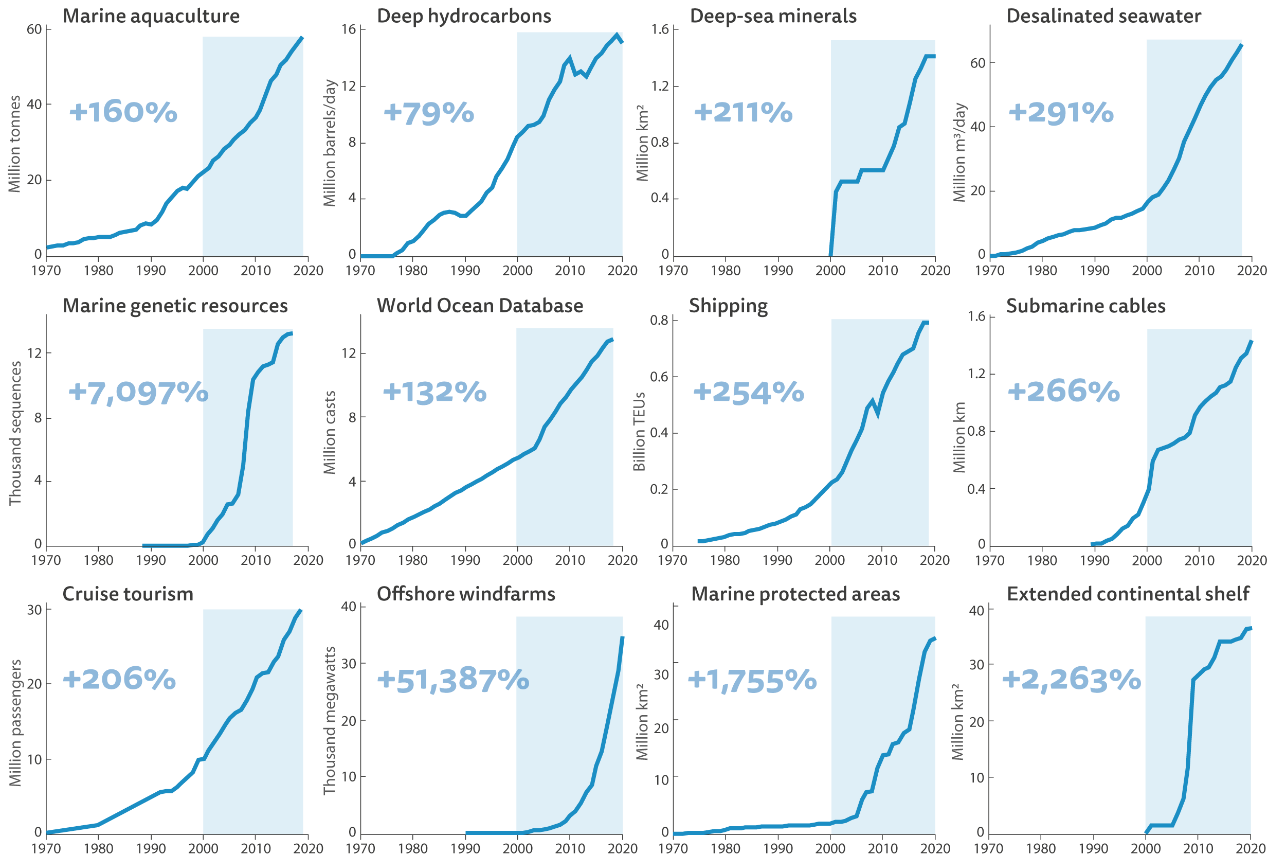



**Figure 1.** The Blue Acceleration. Global trends and percent increase since 2000. See Jouffray et al. (2020) [5] for details and data sources.

# The new ocean reality

The hopes and expectations for the ocean to sustain future human needs have become ubiquitous (Table 1). While claiming marine resources and space is not new to humanity, the extent and diversity of today's aspirations are unprecedented [5]. The recognition of the ocean as a new economic frontier, which covers more than two-thirds of the Earth's surface (Box 1), is driving growth in existing industries and the emergence of new ones, spanning an increasingly diverse range of activities. These "ocean claims" (i.e., what we are claiming the ocean for) include a wide array of uses and societal values attached to the marine environment with relevance for ecosystem sustainability, human well-being or economic growth (Figure 2). We summarize them below, along with their main impacts, under four fundamental needs for humanity: food, energy, material and space.

> **"The ocean is neither too big to fail nor too big to fix, but it is too big and too central to our future to ignore"**
>
> **– Jane Lubchenco,**
> *Oregon State University*
> *Distinguished Professor and former head of NOAA*

## Claiming the ocean for food

### Seafood

The seas have long been an important source of food for coastal communities through the provision of fish, shellfish, mammals, marine reptiles, seabirds, and seaweed. Over the past half-century, however, increasing demand and technological progress have enabled rapid industrialization of the fishing and aquaculture sectors. Today, more than 2,500 species of fish, invertebrates, and aquatic plants and seaweed are wild caught or cultivated for food (www.bluefood.earth). Since the 1960s, rates of fish consumption have been increasing twice as rapidly as population growth and fish has become one of the most widely-traded food commodities [32,33]. In 2018, global fish production reached an all-time high of 179 million tonnes – of which 87% were used for direct consumption [34]. Today, it is the world's fastest growing food sector and by far the largest employer among ocean-based industries, providing millions of jobs and a vital source of protein and nutrients (e.g., vitamin A, vitamin B-12, calcium, iodine, iron, zinc and omega-3 fatty acids) to billions of people [35-37]. Global demand for blue foods, defined as aquatic foods captured or cultivated in marine and freshwater systems, is expected to double in live weight by 2050 [38].

Wild capture fishery landing increased rapidly during the post-war period, peaking around the late 1990s, and declining since then despite an escalation in global fishing effort [39,40], and improved technology [41]. Instead, the farming of aquatic organisms dramatically increased over the last few decades and is now widely seen as a major component for future food security, with about 425 farmed species [42]. While freshwater species account for most of the production and a large share of it still takes place inland [34], aquaculture of high-value species such as salmon and shrimp has become a multi-billion industry. The amount of space suitable for marine aquaculture in coastal and offshore areas presents potential for expanding ocean aquaculture, once current limitations of aqua-feed supply and regional socio-economic and technological capacity can be overcome [43-46].

*Impacts*

The environmental footprints of both capture fisheries and aquaculture can vary significantly, depending on the species targeted and what production practices are used. Marine capture fisheries remove large quantities of biomass and apex predators from marine food webs. This can result in trophic cascades, regime shifts and the erosion of genetic diversity, raising the risk of localised extinctions and decreasing the capacity of populations to adapt to changing climatic and ecological conditions [47,48]. Some of the gears employed in capture fisheries have considerable impacts on ecosystems and non-target species. For instance, bottom trawls severely disturb benthic communities; purse seines cause bycatch and catch

| Table 1. Examples of headlines capturing the diversity of hopes and expectations for the ocean | |
|---|---|
| **Headline** | **Source** |
| "Farming the ocean to save the world" | Quartz (2018) |
| "Can the ocean feed a growing world?" | National Geographic (2018) |
| "There's tremendous room for growth in offshore oil & gas" | Oil Price (2019) |
| "Deep-sea mining to turn oceans into new industrial frontier" | The Guardian (2019) |
| "The future of technology is hiding on the ocean floor" | Gizmodo (2016) |
| "A new frontier for diamond mining: the ocean" | The Washington Post (2017) |
| "Can ocean desalination solve the world's water shortage?" | ThoughtCo (2018) |
| "Oceans: Medicine chests of the future?" | The Scientist (1999) |
| "Why the ocean holds the key to sustainable development" | World Economic Forum (2019) |
| "China to develop Arctic shipping routes opened by global warming" | BBC (2018) |
| "Google plans to expand huge undersea cables to boost cloud business" | The Wall Street Journal (2018) |
| "Tourists are turning to the ocean's depths for adventure" | Business Destinations (2018) |
| "How artificial islands could help us adapt to climate change" | BBC (2018) |
| "Floating cities could ease the world's housing crunch, the UN says" | National Geographic (2019) |
| "Can deepwater wind farms power the world?" | USA Today (2017) |
| "A new wave in renewables harnesses the power of the ocean" | Quartz (2017) |
| "Limitless wave power could cure our addiction to fossil fuels" | Wired (2017) |
| "Look to the ocean for climate change solutions" | CNN (2019) |
| "Marine protected areas for a sustainable future" | HuffPost (2018) |
| "The race to conquer the Arctic – the world's final frontier" | NewStatesman (2018) |

of juvenile fish; and longline and driftnet fishing can likewise result in substantial seabird and marine mammal bycatch. Abandoned, lost and discarded fishing gear contributes to ocean plastic pollution, generating 'ghost gear' that entangle and kill a wide range of marine life [49,50]. The carbon footprint of capture fisheries is also substantial due to fuel consumption and sediment carbon emissions from bottom trawling [51,52].

Mariculture activities can result in large scale coastal habitat modification, while the escape of non-native and genetically-modified organisms can subsequently mix and outcompete native populations. Parasites and pathogens have also crossed over to native populations, most notably perhaps in areas characterised by both wild salmon fisheries and farmed production [53]. The overuse and inappropriate application of antibiotics contribute to the global spread of antimicrobial resistance, while excess pesticides, nitrogen and other by-

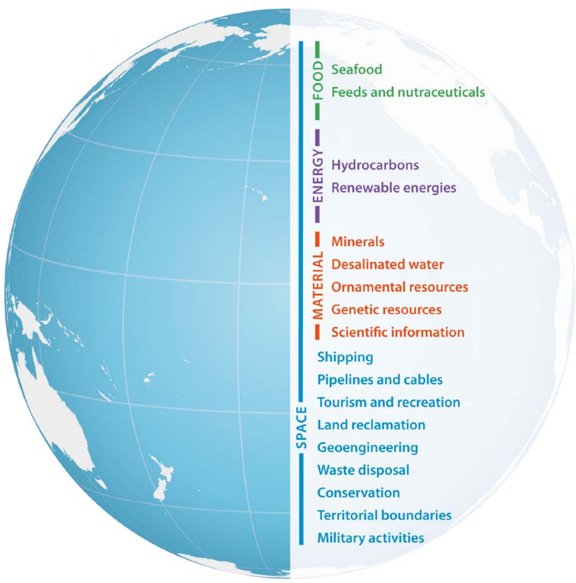



**Figure 2.** Claiming the ocean for food, energy, material and space. Modified from Jouffray et al. (2020) [5].

## Box 1 One ocean or several oceans?

From the UNESCO tagline 'One Planet, One Ocean' to the #droptheS campaign on social media, growing efforts are calling for a new ocean narrative that reflects there is only one global ocean [349]. In that regard, the geophysicist and oceanographer Athelstan F. Spilhaus (1911-1998) was a man ahead of his time. Best known for having developed the bathythermograph, a device that measures temperatures across ocean depths, Spilhaus also published a paper entitled 'Maps of the Whole World Ocean' in which he argued that because the world ocean is a continuous body of water "it is desirable to have the map interrupted within the land masses and the world ocean shown as a unit" [350].

The result is the Spilhaus Projection, a world map with a unique perspective that presents the ocean as a unified body of water bounded on all sides by the continental masses. First published in the Smithsonian article 'To see the oceans, slice up the land' in 1979 [351], the strength of the Spilhaus projection 40 years later is twofold: first, it helps visualize the *interconnectedness* of the ocean and how the different ocean basins are everything but isolated from each other. What happens somewhere in the ocean rarely stays there. Second, it offers a powerful reminder of the *finiteness* of the ocean and how every single activity increasingly fills up the finite ocean space. Likewise, growing pollution and other anthropogenic impacts, whether ocean- or land-based, do not disappear over an infinite ocean horizon but instead accumulate in a finite marine ecosystem.

While embraced by many to highlight that there is no 'ocean B' and that it is thus urgent to protect our global ocean [349], the narrative of 'one ocean' should not conceal the diversity of circumstances, worldviews, cultures, knowledges and values that underpin the complexity of human-ocean relationships [352] – not least the dramatic inequity in current impacts and benefits [24'353].


Illustration of the global ocean based on the Spilhaus Projection. Reproduced from Jouffray (2020) [371].

products pollute ecosystems locally [42,54]. However, some systems, such as aquaculture of mussels and clams, can improve the environment in which they are raised by filtering excess nutrients out of the water [21]. Feed production remains the primary driver behind most environmental impacts related to fed aquaculture systems [55].

## Feeds and nutraceuticals

While the vast majority of fisheries products are used for direct human consumption, a substantial share indirectly contributes to human nutrition when utilized as feeds for the aquaculture and livestock industries [56-58]. Fishmeal and fish oil are key ingredients in feeds, and are mainly produced through the capture of species that occupy low levels in marine food chains. For instance, most Peruvian anchoveta (Engraulis ringens) – one the world's largest fishery – are reduced to provide fishmeal and fish oil for export [59]. The pet food industry also represents a growing market for the fishmeal and fish oil sector [60]. Overall, a recent analysis estimated that 27% of reconstructed marine fisheries landings from 1950 to 2010 were destined for uses other than direct human consumption [61]. In addition, there is a rapid expansion in the range of ocean products used as nutraceuticals [62,63]. Combining the terms 'nutrition' and 'pharmaceuticals', nutraceuticals are foods containing bioactive molecules with health benefits that extend beyond nutritional value. The market for marine-derived compounds is expected to rise to USD22 billion by 2025 [64], with products such as omega-3 fatty acids driving significant investments in krill fisheries [65] as well as interests in largely untapped fish populations like lanternfish [66].

*Impacts*

The large-scale removal of small pelagic fish species (e.g., sprats, sardines, herrings) has impacts on their prey and predators, as well as bycatch species (i.e. caught unintentionally). Localised overfishing of feed-fish species can change population structure resulting in genetic drift and reduced adaptive capacity [67]. Forage fish are primarily caught using seine nets, with generally minimal impact on the seafloor, low levels of discards, but high levels of bycatch. Small pelagics are also nutritionally rich and of crucial importance in the diets of some coastal populations, leading to criticisms of their capture for use in aquaculture production bound for export markets [68,69]. The environmental impacts from marine nutraceuticals are poorly understood but can involve removal of biomass from the ocean and corresponding disruption of marine and coastal food webs.

# Claiming the ocean for energy

## Hydrocarbons

Fossil fuels account for more than three-quarters of the world's primary energy use. Driven by growing demand but dwindling land-based resources, offshore extraction is rapidly increasing and represents about 30% of current global oil and gas production [70]. Nearly 70% of the major discoveries of conventional hydrocarbon deposits between 2000-2020 happened offshore 70 and further reserves are suspected to exist in the deep-sea [71]. With more than 9,000 offshore platforms in service worldwide and one-third of the total value of the ocean economy, the oil and gas sector is the largest ocean-based industry by value [9]. As shallow water fields become depleted and novel technologies emerge, production is moving towards greater depths (Figure 3) and new territories, including the Arctic where vast undiscovered oil and gas reserves are expected [72]. The ocean floor also contains vast quantities of natural gas hydrates [73]. These ice-like solid compounds exist worldwide and may represent twice more organic carbon than the world's coal, oil and other forms of natural gas combined [19,74]. Owing to their immense energy content and the promise of energy independence they hold for some countries, natural hydrates have become attractive and experimental drilling is moving forward [75].

*Impacts*

Fossil fuels are the largest source of anthropogenic emissions of carbon dioxide [76]. Noise caused by seismic surveys can disturb, injure or kill marine animals. Drilling operations result in toxic drilling mud and drill cuttings that contaminate benthic communities over many years. Drilling also brings to the surface what is known as 'produced water', a mixture of water containing high concentrations of heavy metals, radium isotopes and hydrocarbons [77]. Oil spills and gas leaks occur at various stages of offshore production with negative impacts on the marine and terrestrial environments. While gas leaks can create anoxic zones, large oil spills represent a major threat to biodiversity with long-term effects on both deep-sea ecosystems and coastal habitats – even in areas far from the spill source due to winds and currents [77]. Mobile infrastructures also constitute a vector for the introduction of non-native species (e.g., following the relocation of rigs between drilling locations). The prospect of extracting gas hydrates from the seabed comes with its own set of challenges, including uncontrolled leakage of methane, seafloor subsidence, submarine landslides, regional ocean deoxygenation, and the dramatic increase in greenhouse gas emissions [71,74].

## Renewable energies

Faced with the urgency to reduce greenhouse gas emissions under increasing global energy demand [78], marine renewable energies are amongst the solutions with the greatest potential [79-81]. They include energy derived from wind, waves, currents, tides, salinity gradients, thermal gradients and marine biomass [82]. Although the combined exploitation of several of these (e.g., offshore wind and wave energy) holds great promise [80], marine wind power is the only one so far to have been commercially deployed at a large scale, driven by greater productivity potential, space constraints on land, technological innovations and increasing demand for electricity in coastal regions [83,84]. Since 1991, when the first commercial wind farm was set up in Denmark, the offshore wind industry has achieved a cumulative global installed capacity of 34,367 megawatts (MW), of which 73% and 26% is located in European and Chinese waters, respectively. The offshore wind industry has matured rapidly over the past decade and costs have fallen by nearly 70% since 2012 [85]. While most turbines have been installed close to shore, recent studies indicate the potential of even greater wind power generation over open ocean areas, spurring the development of technologies to also harvest wind energy in deep water environments [85-87].

*Impacts*

Ocean renewable energies provide a source of low-carbon electricity with no emissions of toxic air or water pollutants. The environmental footprint depends on the size of the installation and specific technology [88]. Potential impacts include pollution and disturbance from increased maintenance vessel traffic, high levels of underwater noise and vibration, modification of local environmental conditions, risks of collision with moving turbine blades, benthic habitat degradation, species displacement and impaired visual amenity [82,89,90]. Offshore infrastructures can also offer a base for the spread of invasive species. Submerged power cables carrying electricity to onshore stations emit heat and an electromagnetic field to which some species may be sensitive.

# Claiming the ocean for material

## Minerals

Marine mineral resources are accumulations of minerals that form at or below the seabed and from which metals, minerals, elements, or aggregates might be extracted [91]. Natural aggregates, such as sand and gravel, are today the most mined minerals in the marine environment. While sand was until recently mostly extracted from land quarries and riverbeds to satisfy the growing demand for

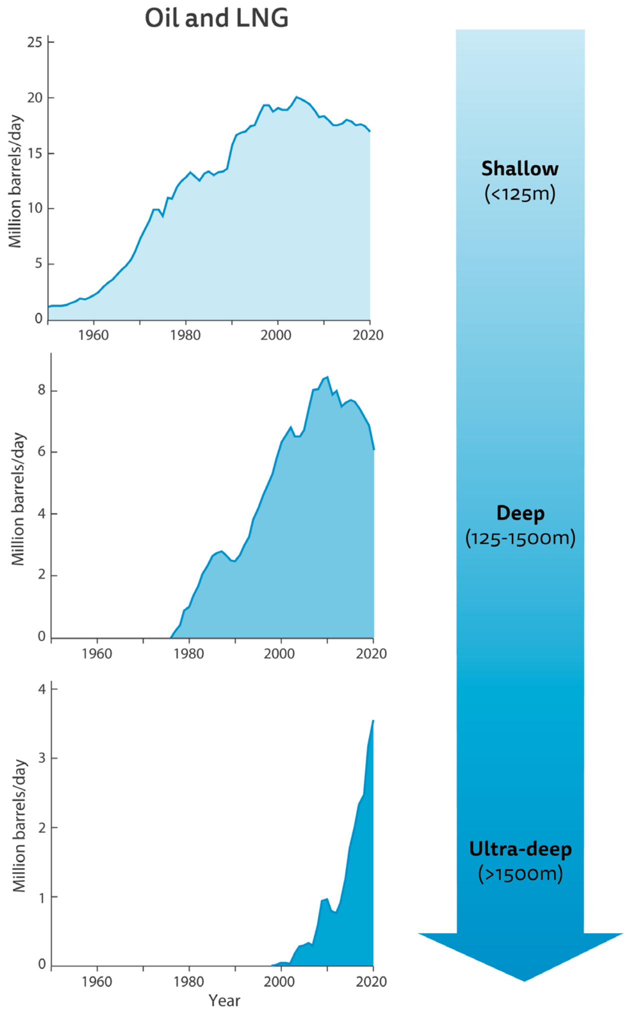



**Figure 3.** Temporal trends in global offshore production volumes of crude oil and liquefied natural gas (LNG) from 1950 to 2020, across water depth categories: shallow (<125m), deepwater (125-1500m) and ultra-deepwater (>1500m). Data from Rystad Energy.

construction materials [92-94], aggregates are now increasingly dredged from marine ecosystems too, including for land reclamation, coastal defence and beach replenishment projects [95,96]. Other resources currently mined from shallow water include placer deposits of diamonds, tin, titanium and gold [91]. However, rising demand for metals to sustain the development of high-technologies has led to a recent surge of interest in minerals from the deep sea [19,97-99]. The three major minerals considered of commercial interest are polymetallic manganese nodules, polymetallic massive sulphides and cobalt-rich ferromanganese crusts [18]. Compared to land deposits, little effort is needed to expose the mineral in deep-seabed deposits and less ore is needed to provide the same amount of metal due to the higher grade of marine resources [91]. Although deep-sea mining commercial activity is yet to take place and the regulatory framework is still under development, more than 900,000 km² have been estimated to be under exploration contracts in areas of national jurisdiction [99]. Beyond national jurisdiction, mineral-related activities fall under the International Seabed Authority (ISA) which, so far, has granted 31 exploration contracts to 22 contractors, encompassing more than 1.4 million km². Regulations concerning exploitations are expected to be approved within the coming years (Box 2).

*Impacts*

Ocean mining implies both physical and biological impacts [19,96]. Modification of the seabed topography through suction or drilling can alter local current patterns, change the composition of sediments, and damage archaeological sites. Near-shore dredging of marine aggregates also accelerates beach erosion by reducing the sediment supply to the coast [96]. Turbidity plumes generated by operations on the seafloor as well as the discharge of processed materials and waste-water at the surface impact ecosystems far beyond the mining area. The direct removal of substrata and associated seabed fauna and flora causes a net decline in species abundance and diversity. Noise, light and chemical pollution from mining vehicles further affect marine organisms [100]. Concerns about how these impacts would unfold in the deep sea have escalated given the slow rate of growth and uncertain recovery of such ecosystems [101]. Unlike terrestrial mining, deep-seabed mining is characterised by extreme knowledge gaps [18]. Potential impacts on fragile hydrothermal vents, for instance, include habitat destruction, rare species extinction and modification of fluid flux regimes.

## Desalinated water

Desalination – the process of removing salt from water – has gained a lot of attention in the context of escalating water scarcity due to population growth, urban development (primarily in coastal areas) and climate change (increasing the frequency and severity of droughts) [102,103]. Used for drinking, sanitation and irrigation purposes, desalinated water is becoming an essential source of freshwater for nations and cities. For example, desalination provides Qatar with 99% of its drinking water [104] and the city of Cape Town opened its first seawater desalination plants in early 2018 in the aftermath of three years of droughts [105,106]. The surge in installation of desalination facilities worldwide now includes about 16,000 operational plants with a global capacity of more than 95 million cubic metres per day (m³/d) [107]. Desalination of seawater accounts for the largest volume (59%), followed by brackish water (21%) and other less saline feedwater. New ocean-water desalination projects are on the rise, including floating desalination plants constructed on ships and offshore structures, which present the advantage of being mobile [108].

*Impacts*

Environmental concerns associated with desalination include the emission of greenhouse gases and air pollutants to generate the required energy, impingement and entrainment of marine biota during the intake of feedwater, and the discharge of hypersaline concentrate (termed "brine") and chemical residues to the marine environment [102]. High salinity and elevated temperature in reject streams can be fatal to marine organisms and impair the functioning of coastal ecosystems. Desalination infrastructures may also alter sediment transport along the shoreline [109].

## Ornamental resources

Marine organisms have long been traded as ornamentals and currently supply three main markets: the home decor, the jewellery industry and the live aquarium trade [110,111]. While little is known about the first two, the trade of live marine organisms for aquaria is said to have started in Sri Lanka in the 1930s, before expanding during the 1950s when more places (e.g. Hawaii, the Philippines) began to issue permits for the collection of fish species [112,113]. Since then, it has grown into a major global industry thanks to the modernisation of air transportation, changes in economic livelihoods and the advent of new technology to maintain species in captivity [114]. Today, millions of marine organisms are removed from the ocean every year to supply private and public aquaria worldwide. The marine aquarium trade is worth several hundred million dollars and involves the collection of over 1,800 species of fish – and hundreds of species of corals and invertebrates – from more than 40 countries [115]. Unlike freshwater species that are mostly farmed, nearly all marine specimens are wild-caught, primarily from coral reefs [113]. In recent years, aquarium hobbyists have shifted their preferences from fish-only tanks to miniature reef ecosystems, further increasing demand for a variety of species [116]. However, the complexity of the industry and the lack of traceability protocols prevent reliable estimates of the volumes traded globally [110].

*Impacts*

The marine aquarium trade has been criticised for destructive collection practices, overharvesting of fish and invertebrates, localised depletion of rare target species, and the release of non-native species to foreign habitats [112,113]. The removal of live rock, which increases erosion and habitat loss, and the use of cyanide to collect fish are particularly damaging to fragile coral reef ecosystems from which most marine aquarium species are harvested [116].

## Box 2 Nauru pulls the trigger on deep-sea mining

The international seabed covers some 260 million km², an area roughly equivalent to half the Earth's surface – a vast area, whose resources have been defined as the "common heritage of mankind" by the UN Convention on the Law of the Sea (UNCLOS). Yet in 2021, one nation was making headlines as the single most important factor in the future of the vast mineral resources of the international seabed: the nation of Nauru [354]. Population: 10,000, on an island a third the size of Manhattan. Was this a step forward for ocean equity? A new era for the ocean economy?

A look back at Nauru's recent history gives some indication. Nauru gained international prominence in the 1890s when rich phosphate deposits were discovered on its land [355]. It immediately joined an exclusive club of guano islands: isolated ocean outcrops visited by nesting birds across millennia, leading to buildup of nitrate-rich guano that in some instances reached depths of 200 meters. Farmers swore by its fertilizing properties, and entire islands were mined away to rejuvenate the exhausted soils of farms halfway around the world [356].

Nauru was mined as well. Within decades, millennia of guano were extracted and shipped away, leaving Nauru's land eroding and contaminated [355]. Per capita GDP briefly skyrocketed to USD50,000 in the 1970s – among the highest in the world. But with the exhaustion of the phosphate deposits, it fell to USD5,000 in the 1990s, and has slowly rebounded to around USD10,000 today. What does a post-phosphate economy look like in Nauru? For several years in the 2000s, it was a notorious tax haven, enabling unsavory financial activities by foreign actors [357]. More recently, it has hosted prison facilities for Australia [358], and attracted attention for receiving large sums of foreign aid seemingly associated with UN voting behaviour [359].

Fast forward to 2021, and Nauru, one of the smallest actors in the blue economy, seems locked in a repeating pattern of exploitation.

The Metals Company, a prominent deep-sea mining company headquartered in Vancouver, Canada, is in the midst of efforts to finalize a merger and launch an IPO in late 2021 [354]. Its viability is presaged on the ability to mine the international seabed, something that requires the International Seabed Authority to first finalize exploitation regulations. With this process stumbling during the COVID-19 pandemic, a clause in UNCLOS offers a fast-track solution by setting a hard two-year limit for finalizing the regulations. In July 2021, Nauru stepped on to the international stage, and, facing blistering criticism from civil society and other members of the international community, triggered the clause [354]. Nominally, the request was made on behalf of Nauru Ocean Resources, Inc. (NORI), but observers have underscored that the drivers and economics of the actions are coming from halfway around the world: NORI is a wholly-owned subsidiary of The Metals Company.

Aerial view of the 21 km² island of Nauru. Image courtesy of the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) user facility.

## Genetic resources

Since the first compounds were extracted from the Caribbean marine sponge Cryptotethya crypta in the early 1950s, the biodiversity of the ocean has held great promise for medical and industrial applications [117-120]. Enabled by advances in sampling technologies and remotely operated vehicles, over 37,000 natural products have been described from species found in the ocean (http://pubs.rsc.org/marinlit/). Marine organisms are of particular interest for bioprospecting since many have evolved to thrive under extreme conditions of pressure, temperature, salinity or darkness, making their genetic code the subject of great commercial interest for a wide range of industries (e.g., pharmaceuticals, nutraceuticals, cosmeceuticals, chemicals) [16,121,122]. One illustration of this trend is the growth in the number of patent claims associated with genes of marine organisms [123-125]. As of 2018,[13,171] genetic sequences from 865 marine species had been associated with patents with international protection filed under the Patent Cooperation Treaty [126].

*Impacts*

Due to recent advances in genomics and DNA sampling techniques, exploitation of marine genetic resources has had a limited effect on ocean ecosystems, even though the removal of biological material for bioprospecting purposes, including through the use of trawls or collection nets, can have minor destructive impacts [101,127]. While the mass of biological material required for this work is usually small, harvesting of marine species for cosmeceutical applications has been linked in some cases to declining local populations [128].

## Intangible material: scientific information

Commercial uses of genetic resources are closely linked to, and in many cases reliant upon, non-commercial research. The ocean offers an immense source of knowledge for future discoveries and understanding of the world [129]. Life in the ocean has existed for some 3.7 billion years, three times as long as life on land, and up to 90% of marine species remain undescribed [130]. Only 16% of all named species are marine, although the rate of their discovery has been higher than terrestrial ones since the 1950s [131,132], and much of the deep-sea environment, in particular, remains unexplored [133]. The advent of technologies such as satellite imagery, DNA sampling, and remotely operated underwater vehicles are opening up new frontiers for marine research and leading scientists to urge for exploration before exploitation. Indeed, only 5% of the seafloor has been mapped in the level of detail equivalent to the high-resolution maps of the Moon and Mars [134,135]. At the same time, novel technologies have contributed to sequencing costs dropping by four orders of magnitude over just the past 10 years [136], spurring tremendous progress in our understanding of marine taxonomic diversity. Across a broad range of disciplines and as the UN Decade of Ocean Science for Sustainable Development begins [137], the marine scientific community represents an important stakeholder in the ocean [129,138].

*Impacts*

The operation of marine research vessels and remotely operated vehicles (ROVs) is a comparatively minor contributor to anthropogenic emissions and pollution. Trawls, dredges, grabs and other repeated sampling apparatus can have a direct physical impact on deep-sea habitats [133]. For instance, scientific research remains the primary source of human disturbance at hydrothermal vents, including light pollution from submersibles and ROVs [101]. However, best practice sampling protocols and new autonomous vehicles have helped to eliminate uncontrolled specimen collection and minimise environmental impacts [139].

# Claiming ocean for space

## Shipping

From the spread of ideas and human settlements to early trade routes and globalisation, ocean shipping has been of paramount importance for the development of civilisation. The introduction of container shipping in the late 1960s revolutionised maritime transport and has triggered an unprecedented surge in the industry over the last 50 years [140]. In early 2020, the world's commercial shipping fleet consisted of 98,140 vessels [141], accounting for over 80% of global trade by volume and more than 70% of its value [142]. Today, although its impacts may severely disrupt maritime transport [143], climate change is also leading to the emergence of new trade routes that reduce shipping distances and travel times [144-146]. Decline in sea ice concentration has been associated to increased traffic across the Canadian Arctic Archipelago [147], and the possibility of connecting Northwestern Europe to East Asia through the Arctic Ocean is gathering strong economic interest [146]. Maritime traffic is therefore predicted to keep increasing in the coming years (estimated to expand by 4.8% in 2021 despite the pandemic) and ocean shipping to remain the most important mode of transport for international merchandise trade [141].

*Impacts*

Shipping represents a significant contributor to the emissions of pollutants and greenhouse gases such as sulfur and nitrogen oxides, carbon dioxide and particulate [148,149]. Nearly 70% of ship emissions occur within 400 km of the shoreline, generating air quality problems in coastal areas and harbours with heavy traffic [148]. The growth of global shipping also leads to an increasing number of ship-strikes causing injury or death to marine mammals [150,151]. Underwater noise produced by vessels can disrupt the orientation, communication and feeding patterns of marine species [152]. Additional impacts associated with marine transportation include the release of ballast water that can introduce potentially invasive species, oil and chemical spills, litter and sewage discharges, grounding and sinking damages, cargo losses as well as pollution from shipbreaking activities and use of antifoulants [151].

## Pipelines and cables

Submarine pipelines are used to carry substances such as gas, oil, water or sewage. Since the first deployment in the early 1950s, oil and gas pipelines have rapidly expanded worldwide and it is estimated that over 136,000 km have now been deployed, primarily in the United States and the North Sea [153]. In the Gulf of Mexico alone, more than 72,000 km of pipelines have been installed since 1952 [154]. The world's longest offshore pipeline is found in the Baltic Sea, carrying natural gas from Russia to Germany over 1,224 km [155]. The first submarine communication cable was laid between France and England in 1850. It was telegraphic and had a capacity of 10 words per minute [156]. More than a century later, in 1988, the first fiber optic cable was deployed across the Atlantic, marking the beginning of what would become the backbone of the global internet [157]. Today, 99% of international telecommunications is carried over 1.4 million km of undersea cables, offering more reliability, speed, capacity and cost advantages than satellite communications [158]. Submarine cables are also considered an essential infrastructure for sustainable development due to the social-economic benefits they bring to the world while having a minimal ecological footprint [159]. Faced with the ever-increasing amount of data and number of people online, new submarine cables are continuously planned to meet the demand for higher bandwidth and ensure a stable global broadband network.

*Impacts*

Offshore pipelines are either resting on top of the seabed or laid in a trench that can be filled or left open. Beyond relatively minor habitat disturbance, their biggest impact is through leakage of oil and gas due to damage from ships' anchors and fishing gear, corrosion, storms, or material failure [71]. Pipelines also present pathways for invasive species through linear infrastructure and impede bottom trawling and cable-laying activities [160]. Underwater communication cables are usually buried (in shallow waters) or simply laid on the seabed (at greater depths). Neither the physical disturbance nor the associated noise of the laying process is likely to have a significant impact in the long term [160]. Power cables carrying electricity emit heat and an electromagnetic field to which some species may be sensitive.

## Tourism and recreation

Marine and coastal tourism encompasses all ocean-related tourism and leisure activities that take place in coastal areas and the offshore waters such as recreational boating and fishing, swimming, snorkelling, diving or cruise shipping [161]. It is one of the fastest growing sectors of the world's tourism industry, providing livelihoods and income for millions of people in coastal communities [9,161] (see ORRAA report on gender*). According to the OECD's Ocean Economy Database, maritime and coastal tourism accounts for about 26% of total value added of the ocean-based industries and is the second largest employer in the ocean economy [9]. Driven by ageing populations, higher incomes and upward consumption trends, ocean tourism is expected to develop even more in the coming years. Cruise shipping, for instance, is the fastest growing segment of the leisure travel industry [162] and has seen a staggering 60-fold increase in the annual number of passengers since 1970. Growing demand from emerging economies as well as the opening of Arctic seas during summer months are likely to reinforce this trend [163].

*Impacts*

The growth of tourism in coastal areas is driving the loss of natural habitats and the development of artificial shorelines with negative consequences for biodiversity [161,164]. Hard coastal structures such as seawalls and groynes can also alter sand transport and sedimentation patterns. In the United States, for example, more than 50% of natural shorelines have been replaced by seawalls, breakwaters and other hard structures [153]. The spread of hotels, resorts and golf courses causes habitat destruction and pollution, while the influx of tourists inevitably results in problems in the treatment of sewage and solid wastes. Litter left on beaches by tourists, for instance, represents a significant source of marine debris [163]. Cruise ships are another major source of garbage and wastewater, in addition to other shipping-related impacts. Both cruise ships and small recreational boats can cause damage to coastal ecosystems by anchoring in vulnerable habitats (e.g., coral reefs, seagrass beds) and by facilitating the transfer of invasive aquatic species [163]. Recreational fishing also has some direct impact on marine biota, as does the overcrowding of tourists and divers through physical damage (including on cultural heritage) and disturbance of fish and other species [161,163].

* Wabnitz et al (2021) ORRAA Report. https://oceanrisk.earth

## Land reclamation

Land reclamation is the process of creating new land by raising the elevation of the seabed or pumping water out of wetland areas. As population, economies and cities keep expanding in coastal areas, it has become a critical feature of littoral development to resolve land shortage and accommodate the increasing need of space for urban and industrial purposes [165,166]. Land reclamation is commonly used for port expansion, industrial areas, airport runways, agriculture, residential areas and strategic military zones [167]. Iconic examples include the Palm Islands in Dubai, Dutch polders, Kansai Airport in Osaka Bay, as well as artificial islands recently built in the South China Sea in a context of intense geopolitical tensions [168]. Global data on annual area reclaimed over time is not available but a recent analysis of satellite imagery estimated that 33,700 km² of land have been added in coastal areas over the last 30 years [169], while a separate analysis projected that the physical footprint of marine built structures would reach 39,400 km² by 2028 [153]. China, in particular, has experienced severe coastal reclamation in the past decades [170].

*Impacts*

Land reclamation causes widespread ecological damage, including the loss of entire ecosystems such as vegetated coastal wetlands and coral reefs, ultimately leading to a substantial decrease in ecosystem functions and services. For instance, it is estimated that China lost more than 50% of coastal wetland areas due to land reclamation [165]. Likewise, in Japan, Tokyo Bay lost 95% of tidal flat areas that serve as critical habitat for marine and coastal organisms over the last century [171]. Building artificial islands can result in direct destruction of coral reefs, while the dredging and physical removal of seabed further affect marine life through turbidity plumes that reduce light penetration and decrease the photosynthetic activity of many organisms [172]. Large-scale coastal reclamation also increases exposure to climate-induced disaster risks such as sea-level rise and storm surge.

## Geoengineering

Defined as "the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change" [173], geoengineering is said to become implicitly embedded in international climate change policy [174]. Yet it has been, and still is, much debated among ocean and climate scientists [175,176]. In contrast to terrestrial proposals that are often limited by unrealistic land requirements, ocean geoengineering was proposed already in the late 1980s as a way to sequester carbon from the atmosphere and enhance the Earth's albedo [174,177]. In particular, ocean fertilization (i.e. increasing the supply of nutrients to enhance biological productivity) and the sequestration of carbon dioxide in sub-seabed areas have been experimentally studied or even deployed on a small scale [178,181]. Whether such approaches will ever provide realistic and sustainable solutions at larger scales remains to be seen.

*Impacts*

Due to insufficient or incomplete research, little is known about the potential benefits and risks associated with marine geoengineering [176]. However, a range of undesirable effects has been considered in the literature. For instance, large-scale fertilization of the ocean could release climate-relevant gases (e.g., methane), cause eutrophication due to deep water nutrients coming to the surface, create low-oxygen zones, change ocean acidification patterns, increase toxic phytoplankton populations, and modify benthic and pelagic ecosystem structure [178,179]. By altering biological communities, these changes would in turn likely affect fisheries [176,181].

## Waste disposal

Ocean dumping of industrial wastes, chemicals, munitions or radioactive materials was common practice until the 1972 London Convention and 1996 London Protocol drastically regulated the disposal of waste at sea [182]. For instance, hundreds of thousands of containers of radioactive materials were dumped from 1946 through 1993 by a dozen countries [183,184]. Today, the majority of reported dumping consists of dredged material in addition to fish waste and human-made structures (sometimes intended to create artificial reefs). Yet, uncertainties remain as to the real extent and nature of ocean waste disposal given the lack of information and that some of the world's largest economies are still not party to any of these international agreements [185].

*Impacts*

The dumping of munitions, radioactive materials, chemicals, and industrial wastes containing toxins such as mercury and PCBs used to be a major source of marine pollution [186]. Dumped sewage sludge and animal slurry also contributed to eutrophication problems. Although most of it is now prohibited, some wastes (e.g., munitions) still present a risk for ocean activities like trawl fishing, cable laying and construction of offshore infrastructures.
Today, the vast majority of reported dumping consists of dredged material that can smother the seabed and remobilise hazardous substances [185]. Decommissioned and abandoned man-made structures (including platforms and vessels) are sometimes converted to artificial reefs.

## Conservation

The creation of marine protected areas (MPAs) has been described as "one of the most practical and cost-effective strategies in ocean conservation" [187], whose benefits are expected to offer a wider array of ecological, social and economic contributions than just nature conservation [188]. In line with the United Nations Sustainable Development Goals (SDGs) and Aichi Biodiversity Target 11 of the Convention on Biological Diversity, coastal states had committed to protect at least 10% of the marine environment by 2020 – an unmet target – while scientists and non-governmental organizations have called for a more ambitious coverage of at least 30% [189,190]. As of October 2021, 86 countries have signaled support for placing 30% of the ocean under protection by 2030 (i.e., "30x30") and momentum towards this goal is growing [191]. Progress toward these targets has accelerated over the last few years, with more than 17,861 designated MPAs covering 7.7% of the ocean. However, just 5.9% has been implemented and only 2.7% is considered "highly or fully protected" [192]. This stresses the importance of MPA 'quality' and enforcement to achieve conservation goals as opposed to just designating a certain percent of the ocean as 'protected' [193,194]. While this trend was marked by the recent designation of very large MPAs (>100,000 km²), virtually all growth has remained focused on national waters and only 1.2% of the areas beyond national jurisdiction is currently under some protection [192].

*Impacts*

Marine protected areas are a key strategy for protecting biological resources and promoting adaptation to climate change, but they vary considerably in their effectiveness depending on monitoring and enforcement capacities [194,195]. In some cases, "paper parks" have been developed, which exist on paper, but do not result in exclusion of destructive activities or conservation benefits [196]. They can also have negative socio-cultural impacts on local communities such as conflict, displacement, change in livelihood, unequal distribution of benefits and restricted access to culturally important sites [197,198].

## Territorial boundaries

The United Nations Convention on the Law of the Sea (UNCLOS) was adopted in 1982 and came into force in 1994, providing the foundations for maritime jurisdiction and legal zoning (Figure 4). Coastal states are entitled to full sovereignty over their territorial waters that extend 12 nautical miles (22 km) from the coastline. Beyond and adjacent to the territorial sea, lies the exclusive economic zone (EEZ), up to 200 nautical miles (370 km) from shore. Within the EEZ, a state has rights to explore and exploit natural resources in both the water column and the seabed and subsoil (i.e., the continental shelf). When the distance between two state coastlines is less than 400 nautical miles, it falls upon the respective countries to define the actual maritime boundary. Prominent disputes, for instance, include the Spratly Islands in the South China Sea [199] or the question of international waters in polar regions [200,201].Depending on the recognition, or not, of some of the disputed jurisdictional claims, the global area falling within EEZ represents between 36-42% of the ocean. The rest is subject to international law and commonly designated as the High Seas (i.e., the water column) and the Area (i.e., the seabed and subsoil).

However, if a coastal state is able to provide scientific evidence that the continental shelf naturally extends beyond the country's EEZ, it is allowed under Article 76 of UNCLOS to claim an extended continental shelf – up to 350 nautical miles (648 km) from shore or 100 nautical miles seaward (185 km) from the 2,500 m isobath – giving the country exclusive rights to further explore and exploit the seafloor [202,203]. Submissions are received by the UN Commission on the Limits of the Continental Shelf, made up of 21 geologists, geophysicists and hydrologists who are responsible for reviewing the data and providing recommendations on the outer limits [204]. As of October 2021, 88 submissions by 74 countries had been received, representing a combined area of more than 37.4 million km² of seafloor claimed. This is more than twice the size of Russia, the world's largest country. Countries that include islands and overseas territories particularly stand to benefit from Article 76. Australia, for instance, was able to secure more than 2.5 million km² of additional seabed thanks to Heard Island and the McDonald Islands, two uninhabited territories of 368 and 2.5 km², respectively [205].

*Impacts*

Arbitrary territorial boundaries such as the 200 nautical miles of the exclusive economic zone have no ecological meaning and are often at odds with ecological connectivity [206]. Environmental impacts resulting from sovereign claims over marine areas will depend on the specific activities conducted and the regulatory frameworks in place under this sovereignty [207]. The recent surge in Extended Continental Shelf submissions has given rise to several overlapping claims, adding an extra dimension to maritime disputes and foreshadowing the need for future negotiations on boundary delimitation agreements [208].

## Military activities

The use of the seas for military purposes involves the development of airborne, surface, and submarine military power for war-fighting and peace-keeping operations. Activities include naval exercises, law

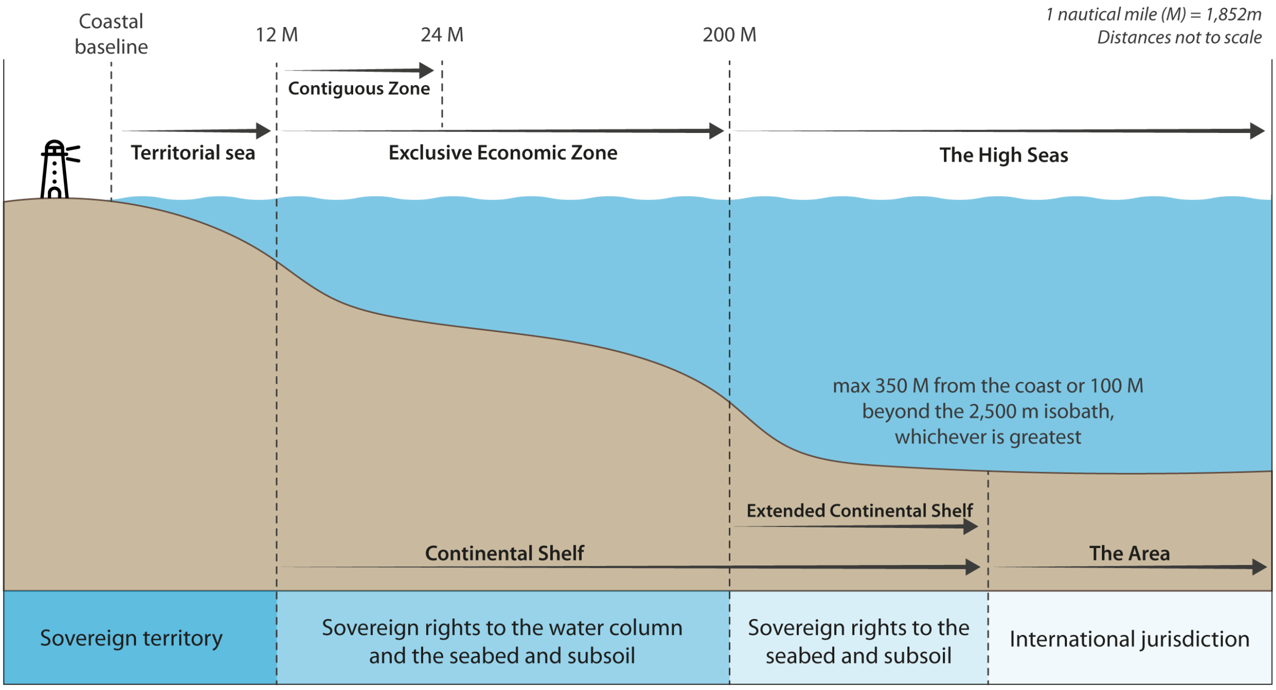



**Figure 4.** Maritime zones according to the United Nations Convention on the Law of the Sea (UNCLOS). Sovereignty in the territorial sea extends to the air space, water column, seabed and subsoil. The contiguous zone is a limited enforcement zone where a state can exert control for preventing or punishing infringement of its customs, fiscal, immigration or sanitary laws and regulations within its territory or territorial sea. The exclusive economic zone grants sovereign rights for exploring, exploiting, conserving and managing living and non-living resources of the water column, seabed and subsoil. Over the continental shelf, a state has sovereign rights for exploring and exploiting non-living resources of the seabed and subsoil, plus sedentary species. Areas beyond national jurisdiction are designated as The High Seas (water column) and the Area (seabed and subsoil).

enforcement, task force maneuvering, weapon testing, intelligence collection and surveillance, as well hydrographic surveys [209]. The number of navies has tripled since the end of the Second World War, with currently more than 160 navies across the world. This proliferation is unprecedented and a marked feature of the second half of the twentieth century [210]. Nations competitively use every aspect of sea power to promote their own security and geopolitical influence [211]. While there have been few naval conflicts since 1945, and only the United States Navy has been able to truly operate globally, both China and Russia show strong maritime ambitions. The building of artificial islands to set up military bases in the South China Sea is one illustration of these aspirations. Technological innovations have also led to the emergence of more capable vessels and the growing reliance on advanced unmanned military devices [212]. For instance, the Pentagon announced a few years ago their intention to deploy a network of mini-depots at the bottom of the ocean, which could be commanded to deliver a wide range of unmanned systems to the sub-surface, surface, and air [213].

*Impacts*

The military uses of ocean space result in a wide range of environmental impacts, including ecosystem loss, chemical contamination, noise pollution and invasive species transportation [214,215]. The building of artificial islands for military bases, for instance, causes severe damage to the local environment, and so did the testing of nuclear weapons for many years [216]. Wreckages from naval ships and dumped barrels of munitions and chemical warfare litter the ocean floor, preventing activities on the seabed and posing long-term risks once those begin to degrade and leak [215]. Excessive noise from explosive detonations and sonar technologies used during naval exercises represents a major threat to marine species behaviour and communication patterns [152]. The use of military sonar, in particular, has been associated with mass stranding mortality events in cetaceans [217]. Both aircraft and ships have also been implicated in the introduction of invasive species to remote oceanic island ecosystems.

# Blue Acceleration: for whom?

The Blue Acceleration represents a new phase in humanity's relationship with the ocean that exhibits a phenomenal rate of change over the last 30 years, with a sharp acceleration characterising the onset of the 21st century [5]. But if there is a rush for the ocean, then who is "winning"? And who is being left behind?

Unlike the broader ocean economy – defined as the sum of the economic activities of ocean-based industries, together with the assets, goods and services provided by marine ecosystems [9] – the rhetoric of the "blue" economy emerged out of the 2012 UN Conference on Sustainable Development with a strong emphasis on the sustainable and equitable use of the ocean; in particular the capacity for developing countries to address "equity in access to, development of and the sharing of benefits from marine resources" [6]. While it increasingly finds its way into national and international policy documents, concerns have been raised over competing interpretations of what the blue economy entails and who it is supposed to benefit [218-220].

> **"We are not a small island state, we are a large ocean nation"**
>
> **– Ronald Jumeau,**
> *Seychelles' ambassador to the United Nations*

Österblom et al. [24] outline the multiple ways in which inequalities are manifested in the ocean domain, from differential power and access to resources and markets embedded in existing political and economic systems, to historical and colonial legacies that perpetuate inequities in ocean use. With a tendency to prioritize economic growth and an unequal distribution of technical and financial capacity to engage in ocean sectors, benefits from the ocean economy disproportionately flow to economically powerful states and corporations, while harms are largely affecting developing nations and local communities. For instance, between 2004-2014, 25 countries were responsible for roughly 82% of global fish catch [34], while vessels flagged to high-income nations account for 97% of trackable industrial fishing in areas beyond national jurisdiction (ABNJ) [221]. Likewise, more than 74% of all patents associated with marine genetic resources are registered by entities located or headquartered in three countries only: Germany (49%), United States (13%), and Japan (12%). This figure rises to more than 98% when one considers the top 10 countries [125]. Meanwhile, 7 of the 10 most vulnerable countries to climate change impacts on fisheries are SIDS [222]. Biased access to ocean space based on historical presence, size, or current economic influence, may lead to unequal ability among nations and ocean sectors to develop and exert their rights or demands [223].

Consolidation among a small number of corporations has become a dominant feature of many economic sectors [224], and the ocean economy is no exception. A recent analysis by Virdin et al. [8] shows that a small number of large corporations, headquartered in just a few countries, generate most of the revenues from

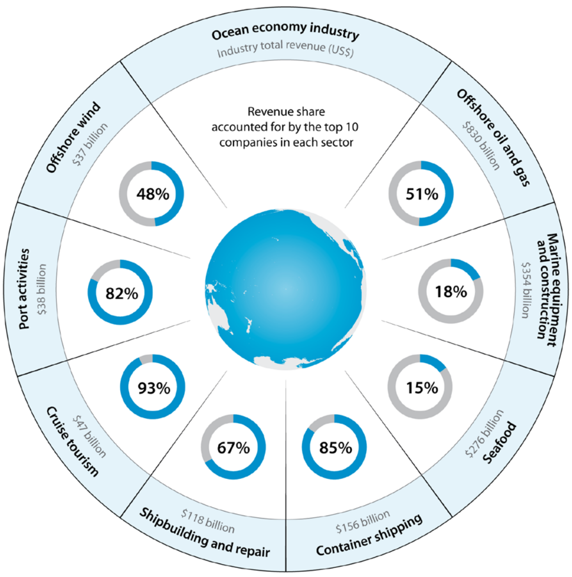



**Figure 5.** Revenue share accounted for by the 10 largest companies in each of the eight core industries of the ocean economy. Adapted from Virdin et al. (2021) [8].

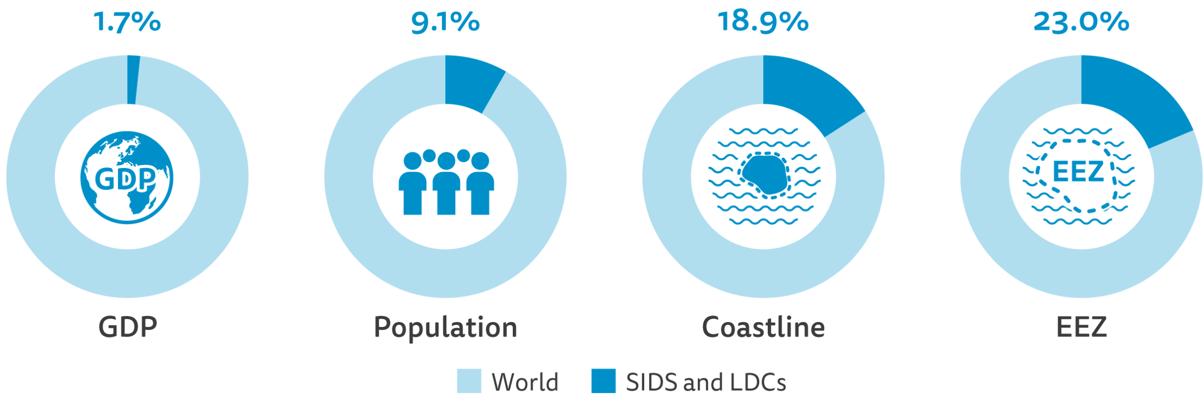



**Figure 6.** Small islands developing states (SIDS) and coastal least developed countries (LDCs) as a proportion of global gross domestic product (GDP), population, coastlines, and exclusive economic zones (EEZ). See table in supplementary material at www.oceanrisk.earth for the list of countries.

ocean-based industries. Cruise tourism, container shipping, and port activities display the highest levels of concentration, while seafood is the least concentrated sector (Figure 5). Aggregating across all industries, the 100 largest corporations (dubbed the "Ocean 100") account for 60% of total revenues, or USD1.1 trillion. This is equivalent to the 16th largest economy in the world. Nearly half of the Ocean 100 (and nine of the top 10) are oil and gas companies, illustrating a stark contrast between the aspirations of a truly "blue" economy and today's dominant paradigm of extraction from the ocean. Despite an exponential growth in renewable energy over the past two decades, only one offshore wind company appears in the Ocean 100 list. The concentration is also in specific parts of the world. Half of all revenues from the Ocean 100 end up in just seven countries: the USA, Saudi Arabia, China, Norway, France, the UK and South Korea [8].

While this pattern of concentration mirrors the structure of the global economy, the levels of technical expertise and capital needed to operate in the ocean can make it even harder to enter the ocean economy and challenge powerful interests that benefit from existing arrangements. Consider, for instance, the tremendous investments associated with emerging high-tech industries such as marine biotechnology [130], offshore renewables [15], or deep-sea mining [18]. Large, consolidated corporations can also use their power to lobby governments against social or environmental rules [225], stifle innovation, and threaten access for traditional users, such as small-scale fishers, who often end up being marginalised in political and decision-making processes [226]. Such "ocean grabbing" [227] threatens human rights, exacerbates inequity, and appears at odds with the vision of the ocean as a global commons [24].

## A focus on SIDS and LDCs

These tensions take a particular dimension in the context of SIDS and LDCs that are often heavily reliant on the ocean for their economy and livelihoods, while bearing the brunt of climate change (see ORRAA report on ocean risks in SIDS and LDCs*). Collectively, these 62 states** account for 1.7% of the world's GDP, 9.1% of the global population, 18.9% of its coastlines and 23% of its exclusive economic zones (Figure 6). In effect, this makes many of them self-identify as large ocean nations with significant untapped economic potential rather than small island states: Tuvalu's EEZ, for instance, is approximately 29,000 times its land mass. The same applies when considering claims on the extended continental shelf (ECS). In many cases, the territorial basis of a state is made of more seabed than land. The Cook Islands, for instance, have claimed an area of ECS equivalent to 1,700 times their land surface. Overall, 35 SIDS and LDCs have filed official submissions to the UN Commission on the Limits of the Continental Shelf, accounting for 6 million km² of additional seabed, or 17% of the total area claimed since 2001 (Figure 7).

Some SIDS and LDCs are also prominent sponsor states of deep-sea mining exploration contracts in the hope to diversify their economy, otherwise largely dependent on the international community for foreign development aid and tourism (see ORRAA report on ocean risks in SIDS and LDCs* and ORRAA report on gender***). Of the 31 licences that have been issued by the ISA, 7 are sponsored by SIDS and LDCs, including Nauru, Tonga, Kiribati, Singapore, Cook Islands, Jamaica and Cuba (the later through

* Tokunaga et al (2021) ORRAA Report. https://oceanrisk.earth

** See table in supplementary material at https://oceanrisk.earth

*** Wabnitz et al (2021) ORRAA Report. https://oceanrisk.earth the Interoceanmetal Joint Organization together with Bulgaria, Czech Republic, Poland, Russia and Slovakia). Collectively, these amount to 430,200 km² under contracts, equivalent to roughly one third of the total area of seabed under exploration contracts in ABNJ (Figure 7). But even though they are sponsor states, it is unclear whether they will ultimately reap the benefits of these activities (Box 2). While systems of payment and benefit-sharing are still under negotiation in the ISA, the proposed economic model suggests that around 70% of the total project proceeds would go to the mining company, 6% to the ISA, and the remainder to "the sponsoring state or whichever state is receiving profit taxed from the mining company" [18].

In contrast, several island countries such as Fiji, Vanuatu and Papua New Guinea have called for a more precautionary approach and a 10-year moratorium on seabed mining activities. SIDS and LDCs are generally strong proponents of safeguarding marine ecosystems, including through the designation of marine protected areas. As of today, 27 SIDS and LDCs have committed to protect 30% of the ocean by 2030 [191] and more than 4.3 million km² of marine protected areas have been established under SIDS and LDCs' jurisdiction – equivalent to 13% of global marine protected areas (Figure 7).

The contribution of SIDS and LDCs to many ocean industries, on the other hand, appears substantially lower. Consider for instance the promising biotech industry and the >13,000 marine genetic sequences that have been associated with a patent since 1988 [125]: only 4 of these are from institutions located in SIDS (i.e., Cuba and Singapore). The capacity to undertake genomic research and to access and use sequence data is highly inequitable and at the heart of ongoing negotiations on biodiversity in areas beyond national jurisdiction (BBNJ) to tackle questions of benefit-sharing mechanisms [16,228].

The need to build capacity and increase access to affordable technologies is a recurrent theme in the context of SIDS and LDCs' contribution to the ocean economy. While 18 countries in the world have installed offshore wind turbine capacity (the three largest ones – UK, China and Germany – accounting for more than 79% of global capacity), none of the SIDS and LDCs are among those. Yet, a recent analysis from the World Bank and the Energy Sector Management Assistance Program (ESMAP) highlighted the great potential of extractable offshore wind for many small island countries [229]. Vanuatu, for instance, has technical potential for 93 GW offshore wind generation, equivalent to roughly three-times the global installed offshore wind capacity today.

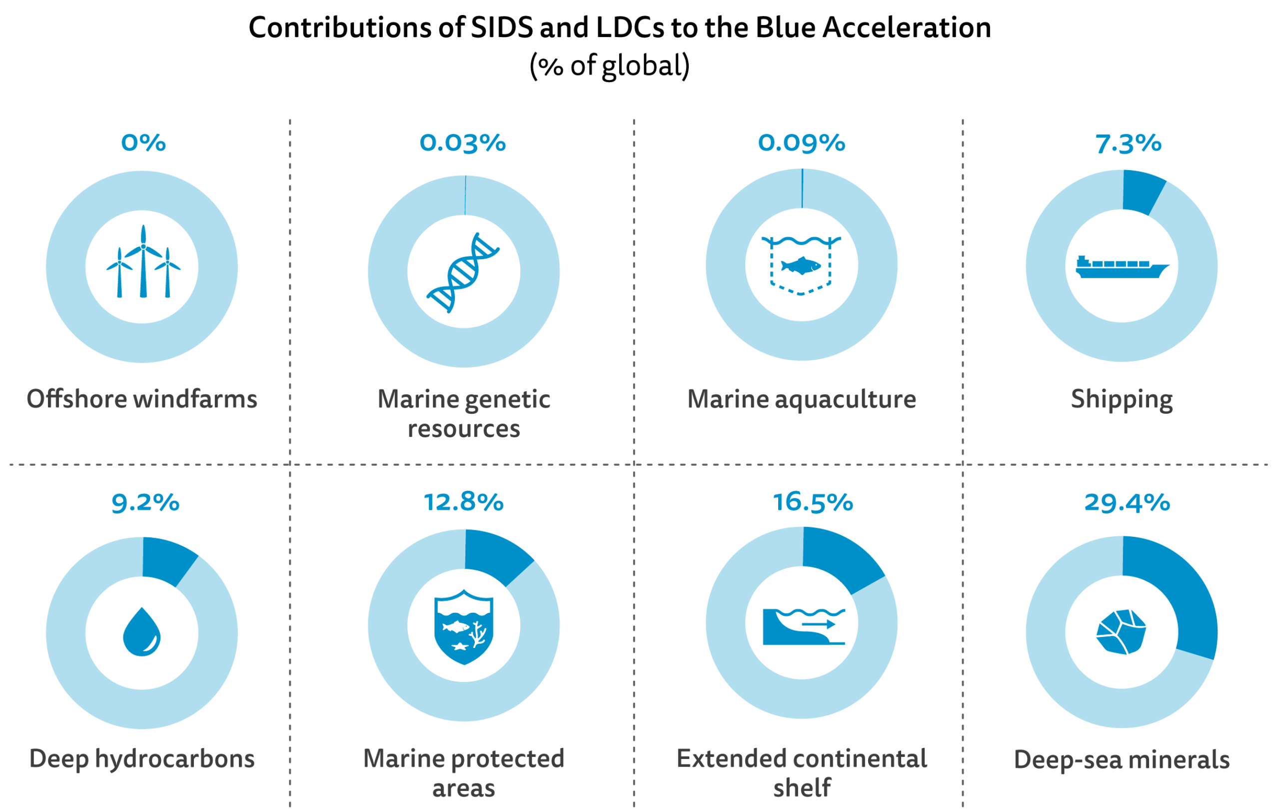



**Figure 7.** The relative contributions of SIDS and LDCs to the Blue Acceleration. Note that some of these trends can be strongly driven by just a few countries. For instance, Angola is responsible for 78% of offshore deep hydrocarbon production from SIDS and LDCs, while Singapore accounts for more than 65% of container port traffic in SIDS and LDCs.

This high-level estimate, based on wind speed and water depth only, does not consider other technical, environmental, social, or economic constraints. The realistic practical potential is therefore a fraction of that, but would still represent a substantial source of energy to reduce dependence on petroleum imports and transition away from fossil fuels – in line with the ambitious renewable energy targets set by many SIDS [230,231]. Most of that potential lies in nascent offshore floating wind turbines, as opposed to fixed ones in shallow waters, further stressing the need for more inclusive research and innovation [15,85].

The same is true for seawater desalination. SIDS and LDCs are increasingly exposed to water scarcity due to limited natural resources and climate change impacts [232]. However, due to high economic costs and how energy-intensive the process is, most desalination facilities are located in high-income countries. The examples of Cabo Verde depending upon seawater desalination for most of its supply of drinking water, or resorts in the Maldives having their own desalination plants, stress the importance of such infrastructure for SIDS and LDCs, but desalinated water remains very expensive and low-income countries end up contributing a negligible proportion (<0.1%) of today's global desalination capacity [107].

For some sectors, looking at the contribution of SIDS and LDCs together gives a misleading picture as they represent a range of geographical and socioeconomic contexts. For instance, trends in the shipping industry are heavily skewed by Singapore: while SIDS and LDCs, collectively, account for 7.3% of the global container port traffic (Figure 7), Singapore alone is responsible for more than 65% of it. Due to their size and geographical features, the majority of SIDS and LDCs face unique transport and logistical challenges, including "lower transport connectivity, a narrow export base and low cargo volumes, limited economies of scale, higher transport costs and exposure to external shocks" [141]. As a result, some SIDS are among those with the longest port ship turnaround times and lowest service frequencies [141], even though they are most dependent on shipping, notably for food delivery.

The offshore oil and gas sector is another example of the value of disaggregating data. According to data from Rystad Energy, SIDS and LDCs accounted in 2020 for some 2.3 million barrels/day, or 5.1% of global offshore hydrocarbon production. However, Angola alone was responsible for more than half of that production. The pattern is even more striking when looking at production in deep waters (below 125m), where Angola accounts for 78% of the 1.3 million barrels/day from SIDS and LDCs, which themselves represent 9.2% of global offshore deep hydrocarbon production (Figure 7). Yet the number of sub-Saharan countries that are opening new offshore exploration licences is unprecedented (e.g., Ghana, Mozambique and Senegal) and set to grow further as new fields are discovered on the Atlantic coast [233]. Examples from across the ocean, however, brings caution as to who benefits the most from those. After ExxonMobil struck a significant oil find in Guyana and started extraction off its coast, the contract became widely criticised as inequitable, with Guyana's government reporting USD309 million since the project began in 2019, while ExxonMobil and its partners took in roughly USD1.8 billion [234].

Perhaps no sector illustrates the tensions between large-scale corporate interests and local communities better than seafood. As fisheries and ocean use have become more industrialized, small-scale fishers – the ocean's largest employer – have been under increasing pressure for geographic, political and economic space [226]. These fisheries are estimated to land nearly half of the world's ocean fish catch and play a critical role in food security, nutrition and livelihoods, not least in SIDS and LDCs [235]. Yet their importance and diversity are often overlooked in policies and suffer from the frequent prioritization of profit and yield rather than equitable distribution of benefits [22,236,237]. A large share of the catch enters the global market, often as a source of fishmeal and fish oil for the aquaculture sector, rather than alleviating local nutrient deficiencies. For instance, a recent analysis found that only 1% of fish caught in the EEZ of Kiribati, a country with severe dietary risk of calcium deficiency, would suffice to provide calcium requirement for all children under 5 years of age [236]. In the context of SIDS and LDCs, small-scale fisheries are also increasingly competing with other uses of the ocean, such as tourism or extractive industries [226]. While aquaculture is among the world's fastest growing food production sectors, available FAO data indicate that only 0.09% of current global marine production is taking place in SIDS and LDCs (Figure 7).

# Ocean risks

With great promises come great perils. Serious concerns exist about unsustainable growth trajectories and systemic inequity in the current ocean economy [24,238]. Building ocean resilience is a long term, multidimensional, continuously evolving process. Likewise, addressing ocean risk – defined here as the degree of deviation from the path to a sustainable and equitable ocean – must recognise the multidimensionality of risks and how interconnected they have become in the Anthropocene. Keys et al. [4] define Anthropocene risks as those that "(1) originate from, or are related to, anthropogenic changes in key functions of the Earth system (such as climate change, biodiversity loss and land-use change); (2) emerge due to the evolution of globally intertwined social-ecological systems, often characterized by inequality and injustice; and (3) exhibit complex cross-scale interactions, ranging from local to global, and short-term to deep-time (millennia or longer)".

As the ocean space becomes more crowded [28], interactions and conflicts among users intensify [198,223,239], paving the way for new risks to emerge and regime shifts to occur [10]. Regime shifts are large and abrupt transitions with persistent and often cascading consequences that have been likened to domino effects [240]. Projecting the future of complex phenomena, such as regime shifts, by extrapolating current trends is notoriously uncertain [241]. Consequently, these types of risks are rarely accounted for in the optimisation of ocean use [242]. This creates conditions for unknown thresholds to be crossed and suggests that, in an increasingly connected world, limits to the Blue Acceleration may be set by emerging systemic risks rather than predictable finite limits of ocean resources [2] (Box 3).

**"The sea sings out its suffering,**

**Knowing too much of waste, screeching sounds**

**And pernicious poison, its depths bruised by**

**Atrocities in the Atlantic,**

**Misery in the Mediterranean,**

**Its tides the preservers of time past."**

**– Amanda Gorman,**
*American Poet*

Risk assessment in the Anthropocene ocean is made ever more complex as the baseline of stressors and hazards is rapidly shifting [243,244]. Changes in the climate, geopolitical and governance landscapes have the potential to dramatically reshape the Blue Acceleration and magnify risks. Unpredictable events are likely to occur while ideas, practices and technologies which are non-existent or marginal today may become dominant features of the future [245]. Consider for instance the impacts of COVID-19 on many ocean sectors [246] and nascent ideas such as floating cities [247], autonomous maritime transport [248] and underwater dataservers [249]. Below, we explore several dimensions of ocean risks and how they manifest.

## Interactions between sectors

The rapid and simultaneous growth of individual ocean industries means that coastlines and coastal areas around the world have grown increasingly saturated with economic activity [250,251]. No industry exists without an impact on the surrounding ecosystem, and each carries certain risks that can have wide-ranging impacts on local activities and ecosystems, leading to a complex risk profile in areas where multiple industries share the same ocean space [5,242].

Marine fisheries are dependent on healthy ecosystems for their stability and predictability, and are exposed to substantial risk in ocean spaces used by multiple industries. The 1989 Exxon-Valdez oil spill, for instance, released 257,000 barrels of oil into Alaska's Prince William Sound and triggered, among other things, the collapse of the Pacific herring fishery [252].

## Box 3 COVID-19 and cruise tourism

The vulnerabilities of the global economy have been on display during the COVID-19 pandemic, and no sector is as emblematic of this vulnerability as the cruise industry. Not only is the industry built on the premise that thousands of individuals from disparate communities could safely come together to spend days or weeks in close proximity on a vessel, its international routes are also vitally dependent on passengers as well as hundreds of support staff and crew members being able to freely and predictably cross international borders with minimal inconvenience [360]. While subsequent research into the impact of cruise tourism on the spread of COVID-19 has delivered inconclusive results [361], high-profile outbreaks early in the pandemic immediately generated severe aversion to cruise tourism [362] – for instance, the Diamond Princess, which arrived in Yokohama, Japan in February 2020 saw over 700 of its 2,670 passengers become infected [362,363].

Before the pandemic, in 2018, the cruise industry was valued at USD47 billion [8] and was the fastest growing sector of the tourism industry [364], yet by the middle of 2020 it had been stopped in its tracks with cruises cancelled well into 2021 and the entire industry facing uncertain long-term prospects.

The world's roughly 400 cruise ships have been at anchor, with older vessels being scrapped to save on costs, and at least 200,000 jobs lost in the industry since March 2020 [365]. Carnival, the world's largest cruise operator, lost over USD10.2 billion in 2020 [366]. Nearly 40% of cruise ship itineraries are in the Caribbean, a region with many SIDS that are vitally reliant on tourism for their economic well-being [361].

What is the future of the cruise industry? While the majority of the population in many of the world's most highly industrialized countries were vaccinated in 2021, some 65% of the world remains unvaccinated as of October 2021 [367]. Customers from North America and Europe have historically made up the majority of cruise passengers (74% as of 2018) [364] and high vaccination rates may seem a promising sign, but breakthrough infections remain a concern among the vaccinated, and attempts to create "travel bubbles" have seen mixed success. For instance, in November 2020, the SeaDream became the first cruise ship to resume sailing in the Caribbean after the initial travel bans. It tested all its passengers twice, and tested a third time after setting sail, yet within five days, seven passengers and two crew members had become infected [360].

Decommissioned cruise ships are being pulled apart near Izmir on Turkey's west coast, June 2020. Photo by REUTERS/Umit Bektas.

Twenty years later, the wellhead blowout that caused the Deepwater Horizon oil rig to leak 4.9 million barrels of oil into the Gulf of Mexico – the largest marine oil spill in history – led to the immediate closure of local fisheries, and the site remains severely degraded even a decade later [253].

Growing tensions have also emerged between the rapidly expanding salmon aquaculture industry and wild salmon fisheries where such activities are proximate or overlapping. The accidental release of farmed salmon when aquaculture pens have been damaged by events such as powerful storms has led to their mixing with wild salmon populations, diminishing their genetic diversity and undermining the resilience of wild populations [16,254,255]. Transfer of parasites like sea lice and disease are additional concerns [256]. In Norway, salmon fisheries and aquaculture uneasily share the country's coastline [257], and with the Norwegian government proposing in 2014 to achieve a five-fold increase in salmon production by 2050, these tensions are unlikely to dissipate [258].

Interactions among ocean sectors are not limited to shallow, coastal seas, but also exist in the deepest parts of the ocean. With growing demand for minerals such as cobalt and manganese, commercial mining of the international seabed is poised to begin, with implications for multiple ocean industries [18,19]. Seabed cables, which form the backbone of international telecommunications, for instance, now criss-cross several parts of the international seabed where exploratory mining licenses have been granted by the ISA [159]. The liability and legal implications that would be triggered by mining activities that inadvertently damage such cables are unclear and, to date, untested [259].

The deep sea is also a rich source of marine natural products – secondary metabolites generated by deep-sea organisms that allow them to thrive in extreme environments [130]. Success rates of drug discovery are up to four times higher for marine natural products than their terrestrial counterparts, and the deep sea is considered a promising source of potential novel antibiotics [122,130,260]. Seabed mining threatens to undermine the functioning of entire swathes of the seabed and countless species of interest for bioprospecting [19]. Finally, the ecological impacts of plumes of sediment that would permeate the water column as a result of industrial mining operations are poorly understood [19,261,262]. The existence of billion-dollar Pacific tuna fisheries that are distributed in the waters above the Clarion-Clipperton Zone, where the most mining licenses have been granted, is a of particular concern as tuna are top predators and bioaccumulating species [263,264] and such impacts could take years to detect and be exacerbated by other stressors such as climate change [265].

## Climate risks

The trajectories of the Blue Acceleration will increasingly be shaped by climate risks, particularly as the impacts associated with a rapidly changing climate become evident (see ORRAA report on ocean risks in SIDS and LDCs*). Hurricanes, cyclones and tropical storms are among the most devastating events for island and coastal communities in many parts of the world. For instance, when Hurricane Maria hit the Caribbean Island of Dominica in 2017, it destroyed over 90% of the island's buildings [266]. Dominica saw visitor numbers plunge by 88% in the first half of 2018, and economic damages from the hurricane were estimated at twice the level of the country's entire GDP [267]. Such extreme weather events can undermine many ocean-based industries, including aquaculture [268], capture fisheries [269], tourism [270], shipping [271], windfarms [272], and offshore oil drilling [273].

Sea level rise is expected to be among the most costly risks associated with climate change, with estimates of annual costs of USD14 trillion under a high emissions scenario (RCP 8.5) [274]. Many SIDS and low-lying megacities are projected to experience once-in-a-century high water levels on an annual basis by 2050 [275]. The magnitude of storm surges associated with typhoons is likewise expected to increase [275], with severe impacts for the coastal infrastructure associated with ocean-based industries. The potential of mass migration due to rising seas and more extreme weather events could provoke geopolitical crises and threaten peace [276].

Another example at the interface of climate and geopolitics is the management of capture fisheries. Fish are unconstrained by political boundaries, and altered oceanic conditions associated with climate change are already causing changes in their distribution and abundance [277], with warming waters expected to result in a poleward shift of fish populations [278]. Such movements will create new transboundary management contexts that have proven challenging to effectively navigate, despite legal obligations for states to engage in collaboration on management of shared fisheries, and even in data-rich contexts where long-established regional management bodies exist [279,280]. Increasingly acidic ocean waters also threaten to undermine marine food webs by hindering shell formation among coccolithophores (considered to be the most productive calcifying organisms on earth) and other species [281].

Marine heatwaves are likewise resulting in mass mortality events for marine life and widespread bleaching of corals [282,283]. The IPCC projected that the world's coral reefs will decline by 70 to 90% with a 1.5°C increase in the global mean temperature from

* Tokunaga et al (2021) ORRAA Report. https://oceanrisk.earth

pre-industrial levels, and by more than 99% with a 2°C increase [275]. This can have severe knock-on effects for capture fisheries in some areas where corals serve as nurseries for juvenile fish [284]. An estimated 6 million coral reef fishers live around the world, yet catches peaked in 2002, and the overall capacity of coral reefs to provide ecosystem services has dropped by 50% since the 1950s [285]. Under an RCP 8.5 scenario, marine heatwaves are expected to grow 50 times more frequent and with a ten-fold increase in intensity by the end of the century compared with a historical baseline [275], significantly adding to the estimated losses in resource biomass and potential catches from mean climate change impacts [286].

## Geopolitical risks

While the blue economy is tied to the ocean, it is equally tied to the fates of nations, markets and industries, with geopolitical risk considered a leading source of uncertainty [287,288]. Multiple nations aspire to make the ocean and the industries it supports a key aspect of economic development policies. For example, China has dubbed the ocean the "21st century hope" [289]. Territorial disputes over maritime boundaries have often been tension points for management of resources such as fisheries [290], and the multiple disputed boundaries in the South China Sea have long been identified as a severe geopolitical risk [291]. The region is thought to contain vast untapped oil (11 billion barrels) and natural gas (190 trillion cubic feet) resources, is a key channel for international maritime transport and telecommunications through seabed cables, and is home to valuable fishery resources [292,293].

With over 80% of goods transported by sea, maritime shipping lanes are the arteries and veins that keep global commerce alive. The temporary blockage of the Suez Canal for six days in March 2021 when the Ever Given container ship became stuck delayed the passage of 422 ships and some USD9.6 billion of goods [294] (Box 4). Previous work has estimated that the possibility of a product being traded generally drops by 1% and the product loses 0.8% of its value for each day it is delayed [295-297]. While accidental, the temporary blockage of the Suez Canal underscored the global vulnerability of maritime shipping routes and the geopolitical risk of armed conflict or restricted traffic at key points in the system (Box 4). Likewise, the rapidly changing restrictions on entry and free movement of people associated with the COVID-19 pandemic have resulted in severe strain on the workers who operate these ships, generating psychological stress and extraordinary conditions that remain largely unresolved as of late 2021 [298,299] and which have pushed shipping costs to record highs [300].

The interrelated nature of risk is also evident in the nexus of climate risk and geopolitical risk. Climate change impacts on the ocean have become increasingly evident in the polar regions. As Arctic Sea ice retreats, new commercial shipping routes become accessible. For instance, the Northern Sea Route, which extends across the length of Russia and rests entirely within its national jurisdiction, was traversed in 2017 for the first time without icebreakers [301], and again in 2018 by Maersk with an "ice-class" container ship [302]. Likewise, as Greenland's ice melts, rich oil, gas and mineral deposits are growing increasingly accessible and attractive for commercial development, spurring massive interest from external stakeholders, domestic policy changes, and a growing support for Greenland to secede from Denmark [303,304]. The rush for resources is mirrored in recent growth and investment in Antarctic krill fisheries (one of less than 6% of global fisheries that are classified by the FAO as "underfished") [34], and which have grown increasingly accessible due to decreasing sea ice extent [305,306].

Severe geopolitical risks associated with a changing climate are also found in SIDS and LDCs. While most LDCs have some of the lightest carbon footprints in the world, they are disproportionately vulnerable to the impacts of climate change [222] (see ORRAA report on ocean risks in SIDS and LDCs*). Countries such as Bangladesh are already seeing the rapid inundation and loss of coastal areas to sea level rise, and such trends alongside extreme weather events and storm surges have the potential to trigger mass displacement of people and regional instability [307]. Atoll nations like Kiribati, the Maldives and Tuvalu face an existential threat from rising sea levels [308]. Strategically important military bases located on small island states are also at risk from climate impacts [276,309].

## Financial risks

As much as the ocean is seen as a promising frontier for investment, it remains poorly understood and often perceived as risky. However, how financial institutions define "risk" rarely aligns with the complex nature of ocean risks. Current financial risk frameworks focus primarily on financial materiality (e.g. growth, profitability, capital efficiency), failing to account how investment externalities can aggravate the climate and the environment, and ultimately create risks back to financiers [310]. Calls for ecologists to care about the financial sector [311], and for finance to care about ecology [312] have highlighted the need for greater mutual understanding in the face of social-ecological risks and how they may translate into financial risks.

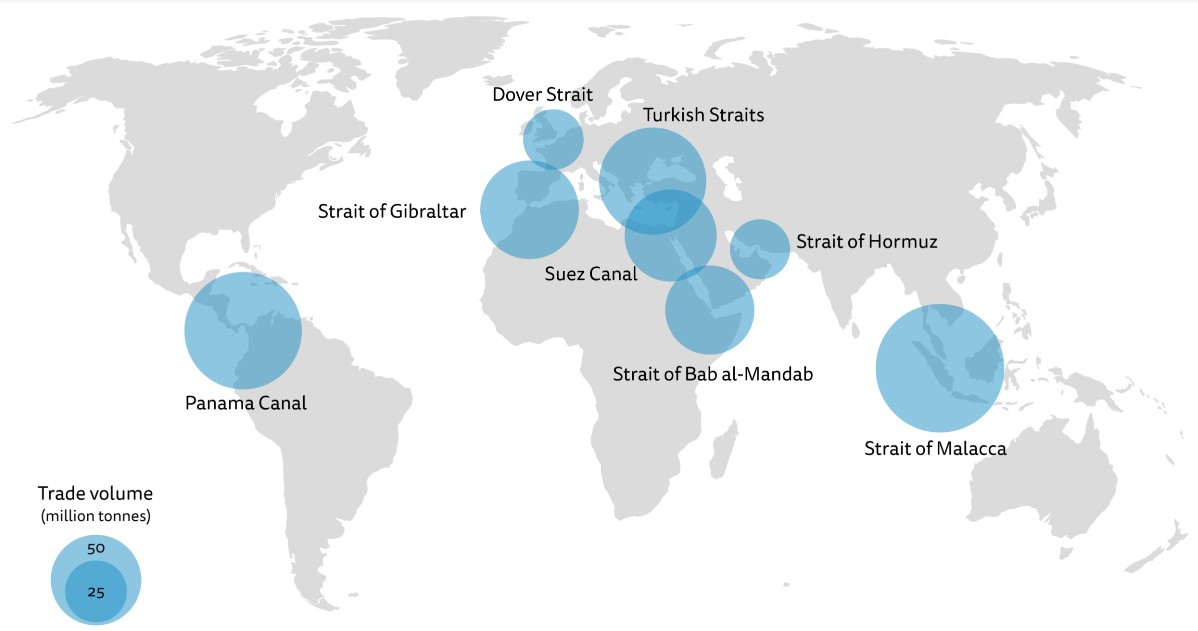
Infamous examples include the initial public offering (IPO) of China Tuna to the Hong Kong Stock Exchange, for which the company used outdated fish stock data and reported fishing operations exceeding catch

* Tokunaga et al (2021) ORRAA Report. https://oceanrisk.earth

## Box 4 Maritime chokepoints

International trade has undergone huge expansion in the past few decades [368] with ocean shipping accounting for the bulk of all transportation [141]. On 23 March 2021, the Ever Given, one of the largest container ships in the world, was passing through the Suez Canal on its way to Rotterdam when strong winds forced the 400 meters long and 220,000 tons heavy vessel off-course and aground diagonally. Blocking the entire Suez Canal in both directions, the grounded Ever Given forced hundreds of ships at standstill for six days causing a loss of billions of USD worth of trade.

This unfortunate event points at an important aspect of ocean risk, namely the vulnerability of maritime infrastructure. The Suez Canal is, together with Panama Canal, Strait of Malacca, Turkish Straits, Strait of Hormuz, Strait of Bab al-Mandab and the Strait of Gibraltar, one of the critical maritime chokepoints through which huge amounts of commodities pass each year [369]. For example, it has been estimated that one fifth of all global exports of wheat and one sixth of all maize pass through the Turkish Straits; around one quarter of global soybean and rice exports transit the Straits of Malacca toward markets in China and Southeast Asia; and more than half of all internationally traded grain and fertilizers pass through at least one maritime chokepoint before reaching their destination [369]. Disruptions at these bottlenecks can have major consequences due to knock-on effects on supply chains, including food insecurity, shortages, price volatility and civil unrest [370].




Annual maritime chokepoint throughput of maize, wheat, rice and soybean in 2015. Adapted from Bailey and Wellesley (2021) [369].

limits as part of its risk analysis [313]. After a complaint from Greenpeace and an official condemnation from China's Bureau of Fisheries, describing the company's actions as "gravely misleading investors and the international community", the Hong Kong Stock Exchange suspended the draft IPO before China Tuna eventually withdrew its application. The company, at that time a major supplier of tuna to Japan, was never to be heard of again, while Deutsche Bank, the sole sponsor of the IPO, was put under pressure and declined to comment [314]. The failure of what had once been touted as the "world's first deep-sea mine" off the coast of Papa New Guinea is another example. The company Nautilus Minerals Ltd. was granted its first mining license in 2011, with the support of several banks [315] and the government purchasing a 30% stake in the Solwara-1 project. Fast forward to 2019 and several years of controversy, community resistance, legal challenges, and funding difficulties, the creditors voted to liquidate the company [316], leaving the country in debt worth USD120 million and the prime minister to describe the project as "a total failure" [317].

Although anecdotical, these two cases might be symptomatic of the broader inability of contemporary financial markets to recognize social and environmental impacts as material, and price sustainability accordingly [318]. Limited information on the ocean economy and a lack of common principles and industry standards might also hinder the ability of financiers (and their regulators) to consider the ecological impact of their operations. A recent survey of assets managers and owners found that three in four investor respondents had not assessed their portfolios for ocean impacts or risk exposure [319], while the latest KPMG's Survey of Sustainability Reporting identified Sustainable Development Goal 14 ('Life Below Water'), as one of the least prioritized SDGs [320]. One consequence of this is the risk of stranded ocean assets.

The coupled effect of climate change and the Blue Acceleration, unfolding in a highly dynamic ocean landscape characterized by regulatory gaps and competing political interests, poses considerable risks to investors. Investments in the ocean economy may become stranded ocean assets and lose economic value well ahead of their anticipated useful life due to changes in legislation, market forces, disruptive innovation, societal norms, or climate and environmental shocks [321]. Similarly, natural resources may become stranded ocean resources if they are considered unprofitable or cannot be developed because of technological, spatial, regulatory, political, social or environmental changes [321]. Importantly, if resources get stranded this will inevitably also impact on the assets. For instance, the International Energy Agency (IEA) indicated in its latest report that ending new oil and gas exploration was the only viable climate path to reach net-zero by 2050 [322] – in theory turning any untapped oil and gas reserve into "unburnable carbon" [323]. Likewise, the migration of fish populations due to climate change may impact catch allocations and fishing fleets [324,325]. Stranded ocean assets can also materialize because of complex Earth system dynamics and globalized value chains that connect asset classes across geographies. For example, previously uncorrelated, aquaculture in Norway or China is now highly dependent on oilseed for feed and therefore directly affected by climate-change driven droughts or crop pest outbreaks in places such as South or North America [2].

A focus on the interplay between "first-comers "and "latecomers" with regard to stranded assets and resources is particularly relevant for SIDS and LDCs since many of them qualify as latecomers to development [321]. Research is ongoing to try to characterize these relationships in the context of the ocean economy, building on the work from Bos and Gupta [321] who identified 7 dimensions to the implications of stranded assets and resources for latecomers: spatial, technological, economic, ecological, political, legal/policy and social (Table 2). Overall, the potential for stranded assets and resources in the ocean domain remain unexplored and new data and analytical tools are urgently needed to help ocean investors and policymakers differentiate between assets and companies that are more or less exposed to ocean risks.

Table 2. Seven first comer-latecomer dimensions of stranded resources and assets. Adapted from Bos and Gupta (2019) [321].

| Dimension | Explanation |
|---|---|
| Spatial | Where first comers use their own resources and resources of other countries for their own development leaving little environmental utilization space for latecomers to develop |
| Technological | When first comers 'dump' older technologies (stranded assets) on latecomers |
| Economic | When first comers avoid paying compensation for damage caused to latecomers or for the stranding of resources in latecomer countries; and first comers may potentially also indirectly transfer their soon to be worthless shares on latecomers |
| Ecological | When knowledge from first comers may prevent latecomers from using their resources or may accelerate the rate at which their resources and assets become stranded |
| Political | When first comers refuse to take environmental action claiming that latecomers are not doing so; while latecomers may claim that first comers should take action first |
| Legal/Policy | When investments in resources and assets in a globalizing world involve long-term contracts protected under private law may cause policy freezing and liabilities in latecomers |
| Social | When latecomers adopt different notions on development than first comers |

# Ocean finance

Scaling up and accelerating the shift towards ocean stewardship [326] requires a collective and collaborative effort across entire value chains, from policymakers and regulatory bodies to business, civil society, the scientific community and the financial sector. Financial investments – public or private – are increasingly recognized as important leverage points for achieving sustainability [313, 327-329]. In the context of the ocean economy, sustainable finance is arguably two dimensional: financiers can act either as "enablers" or "gatekeepers".

## Financiers as "enablers"

The notion of financiers as enablers emphasises the need to unlock capital and increase finance where it is lacking – that is, towards a sustainable and equitable ocean economy. In the last 10 years, less than 1% of the total value of the ocean has been invested in sustainable projects through philanthropy and official development assistance [329] and SDG 14 ('Life Below Water') remains the least financed goal, both globally and for SIDS and LDCs (Figure 8). While an estimated USD175 billion per year is needed to fund SDG 14 [330], it received just below USD10 billion in total over the period 2015-2019 [331]. It is therefore critical to bridge the current finance gap [332] by creating the right enabling environment and enhancing investor confidence.

A recent survey of assets managers and owners across more than 34 countries found that interest in sustainable ocean economy investments is high among investors but industry expertise is low [319]. Close to a third of asset owners reported they did not address the sustainable ocean economy at all in their current investments, citing barriers such as lack of investment-grade project, no internal expertise and limited support from their hierarchy [319]. This suggests an under-appreciation of the tangible benefits of more sustainable operations and an opportunity for multilateral banks to partner with commercial banks to help unlock private capital, fund innovations, and overcome the short-term costs of implementing sustainability measures [333]. Blue bonds, whereby funds raised are earmarked for marine and coastal protection projects, are also emerging as a new innovative solution to provide sustainable financing [334]. Previous issuances have focused on investments within marine conservation and restoration. For instance, the Republic of Seychelles launched the world's first sovereign blue bond in 2018 to advance sustainable marine and fisheries projects [335]. By building the market, expanding eligibility criteria and including corporate issuances, blue bonds can also fund business opportunities that positively impact the ocean and support sustainable development [333]. Global issuance of green bonds recently surpassed USD250 billion, representing 3.5% of total global bond issuance [310] and momentum is rising in many ocean sectors, with past issuances of social and sustainable bonds within the blue sphere having been widely over-subscribed [336].

> **"If we are to be true stewards of our islands, all investment and financing into SIDS should be required to ensure that it is environmentally sustainable, socially inclusive and equitable"**
>
> – **Peter Thomson**, *UN Special Envoy for the Ocean*

However, as much as the "ocean finance gap" is a reality when it comes to sustainable investments, the Blue Acceleration also illustrates that billions of dollars are currently entering the ocean economy and fuelling the development trajectory of ocean sectors [5], many of which are dominated by a small number of large corporations [8]. A focus on who and what is financing the Blue Acceleration could therefore unlock powerful leverage points to redirect corporate finance.

## Financiers as "gatekeepers"

In this role, public and private financiers can ensure investments are directed towards more

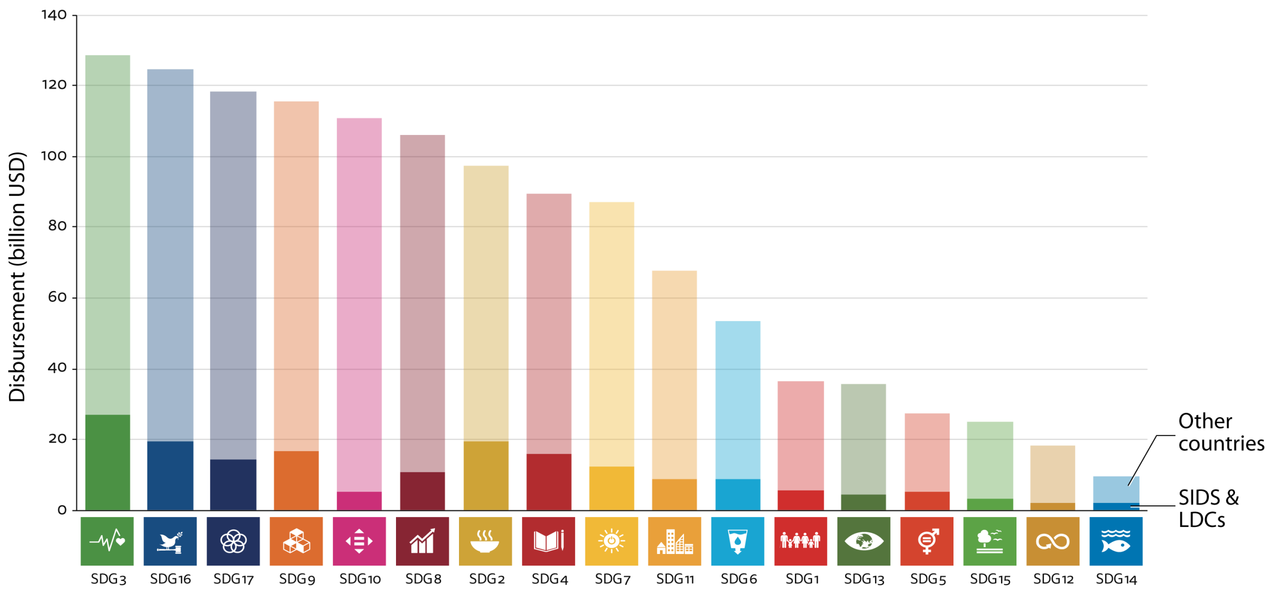



**Figure 8.** Estimates of financing in support of the Sustainable Development Goal based on the OECD Creditor Reporting System. The figure shows actual payments (disbursement) effectuated by all providers during the period 2015-2019.
Explore more at https://sdg-financing-lab.oecd.org/

sustainable practices and decent working conditions. For instance, after more than two decades of negotiations, the World Trade Organization will convene in November 2021 to possibly put an end to harmful fisheries subsidies that fuel overcapacity and lead to overfishing [337,338]. Similarly, financial institutions, such as banks, stock exchanges and insurers, can leverage their power and influence sustainability by deciding what to finance and under which conditions.

Banks are particularly influential given their ability to monitor companies in detail and to tailor loan terms. Regardless of a firm's ownership structure, bank loans account on average for more than half of a company's external financing [339]. By embedding sustainability requirements into contracts and loan documentation and binding companies explicitly to non-financial performance, banks can be key to incentivise sustainable transformation, and reward not only transparency but also performance [313]. Unlike blue bonds, these sustainability-linked loans do not have to be earmarked for specific projects and can be used for general corporate purposes [340]. As a result, they have become increasingly popular.

For instance, in February 2021, the seafood company Thai Union secured a USD400 million loan for which the interest rate is coupled to the company's sustainability performance, as determined by key performance indicators such as a reduction in greenhouse gas emissions or improved supply-chain traceability via an increase in the use of electronic monitoring and human observers onboard vessels [341]. Most recently, Ørsted, the world's largest offshore wind farm company, signed a USD2.3 billion 5-year sustainability-linked syndicated revolving credit [342] for which the interest margin will be adjusted based on the company's ability to reduce its carbon emissions and to align its investments with the EU taxonomy – a classification system introduced to have a common reference point to identify and assess sustainable economic activities.

The recently established Poseidon Principles (www.poseidonprinciples.org) provide a sector-specific framework for integrating climate considerations into lending decisions and promoting shipping decarbonization. The signatories – 27 leading banks jointly representing USD185 billion, or about half of global shipping finance – incentivise shipowners to decarbonize their fleets by lowering their interest rate as they decrease their emissions [343]. Overall, there is a growing ecosystem of emerging initiatives [328] and principles that could inform and support a more sustainable ocean economy, including the Sustainable Blue Economy Finance Principles, the Task Forces on Climate- and Nature-related Financial Disclosures, the Principle for Responsible Banking, the Science-Based Target Initiative, and the Sustainable Stock Exchange Initiative.

Stock exchanges are particularly interesting in the context of sustainability disclosure and performance as they can act as regulatory bodies via their listing rules, both at the time of the listing and on an annual basis [344]. In the seafood sector, for instance, more stringent sustainability criteria in the listing rules of just a few stock exchanges could have big effects on the industry. The Tokyo Stock Exchange alone concentrates 53% of the combined revenue of the world's largest 45 publicly-listed seafood companies, while the exchanges of Tokyo, Oslo, Korea and Thailand together account for 86% of revenues [313]. Although this level of concentration is not a consistent feature across ocean sectors, 60% of the Ocean 100 companies are publicly-listed on stock markets, and therefore subject to listing requirements as well as shareholder pressure [8].

Insurance companies, too, can act as powerful gatekeepers for sustainability. Sumaila et al. [329] outline three key roles in particular: institutional investors – by choosing to support clients and projects that contribute to sustainability and divesting from those that do not; risks managers – by communicating recommendations for more sustainable practices to their clients; and risks carriers – by prohibiting or restricting access to insurance to clients that engage in unsustainable or illegal practice [345]. This notably also has several benefits for the insurance sector, including improved reputation and reduced risk of accidents, criminal activities, fraud and legal complications [333]. Innovative finance products, such as parametric insurances that offer pre-specified payouts based upon a trigger event, are also increasingly used to support countries' effort to mitigate ocean risk and build resilience, in particular to climate change (see ORRAA report on ocean risks in SIDS and LDCs* and ORRAA report on gender**).

While creativity and innovation with respect to sustainable finance should be encouraged, it is also meaningful to try scaling up more systematically existing financial products, such as sustainability-linked loans which today remain the exception rather the norm. Policy-makers and regulators have an important role to play in providing impetus for financial institutions by implementing mandatory non-financial sustainability factors into the banking risk system; for instance, by lowering the risk capital allocation for loans to more sustainable companies (or conversely increasing it for unsustainable activities). This requires the mainstreaming of non-financial sustainability factors within the financial risk system and the continued analysis of how social-ecological risks translate into financial risks [310,313]. In the context of SIDS and LDCs, development and impact finance can also help support this transition by investing in expanded training for banking institutions and loan officers to assess risks and promote sustainable lending.

"The Science We Need For The Ocean We Want" is the tagline of the UN Decade of Ocean Science for Sustainable Development (2021-2030). From the shoreline to the deep sea, the Blue Acceleration is rapidly transforming the ocean and having major economic, social and ecological consequences. While the past few years have seen ambitious pledges made by nations to safeguard the ocean [346] and an increasing number of voluntary commitments [347], the time has come for governments, financial institutions and corporations to listen to the science and turn words into action [348]. Should governance mechanisms succeed in connecting the momentum and aspirations of the Blue Acceleration to norms of equity, conservation, and sustainable use, this new phase of humanity's relationship with the biosphere can present a unique opportunity.

* Tokunaga et al (2021) ORRAA Report. https://oceanrisk.earth

** Wabnitz et al (2021) ORRAA Report. https://oceanrisk.earth

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