Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Environmental Sustainability

Pathways to a blue economy

Susan Gourvenec[1,2], Wassim Dbouk[1,3], Fraser Sturt[1,4] and Damon A.H. Teagle[1,5]

Charting a path to a blue economy is imperative to avoid major climate change and irreversible damage to marine ecosystems, the wider environment and society. The blue-ness of the future ocean economy and the associated health of the oceans and our planet will be determined by the pathways chosen, the strategies developed and decisions made now. Here, through bibliometric analysis, multidisciplinary literature review and data synthesis, we present prospective pathways that define different future ocean economies. The intention is to provoke interdisciplinary debate, exchange of ideas, further research and action towards shifting the ocean economy from grey to blue. We show that a business-as-usual pathway that sustains the current grey ocean economy will lead to accelerated violation of planetary boundaries and ultimately destruction of the natural capital on which the ocean economy and humanity depend; that a probable pathway, based on optimistic trends, which attempt to meet the conflicting increasing demand of populations globally and need to curb carbon emissions, is insufficient to meet decarbonisation and broader sustainability targets; and that a pathway to transition to a blue economy requires ambitious proactive strategies and immediate decisions, based on principles that aspire to the collaborative, fair and sustainable use of the ocean.

Addresses
[1] Southampton Marine & Maritime Institute (SMMI), University of Southampton, Boldrewood Innovation Campus, Burgess Road, Southampton, Hampshire, SO16 7QF, United Kingdom
[2] School of Engineering, University of Southampton, Boldrewood Innovation Campus, Burgess Road, Southampton, Hampshire, SO16 7QF, United Kingdom
[3] Public Policy Southampton, University of Southampton, University Road, Southampton, Hampshire, SO17 1BJ, United Kingdom
[4] School of Arts & Humanities, University of Southampton, Avenue Campus, Highfield Road, Southampton SO17 1BF, United Kingdom
[5] School of Ocean & Earth Science, University of Southampton, National Oceanography Centre, European Way, SO14 3ZH, United Kingdom

Corresponding author: Gourvenec, Susan (susan.gourvenec@southampton.ac.uk).

Current Opinion in Environmental Sustainability 2025, **77**:101570

This review comes from a themed issue on **Decade of Sustainability Action**

Edited by **Opha Pauline Dube, Victor Galaz** and **William Solecki**

For complete overview of the section, please refer to the article collection, "Decade of Sustainability Action"

Available online 1 October 2025

Received: 20 November 2024; Revised: 9 July 2025; Accepted: 10 September 2025

https://doi.org/10.1016/j.cosust.2025.101570

Introduction

The 'blue economy' and 'ocean economy' are often used interchangeably to describe economic activities in the oceans, along coastlines and on land supporting ocean-based activities. Although there is no internationally agreed definition of the 'blue economy' [1], its origin can be traced to the United Nations Rio+20 outcome document 'The Future We Want' [2], in which member states pledged to '*protect and restore the health, productivity and resilience of oceans and marine ecosystems, to maintain their biodiversity, enabling their conservation and sustainable use for present and future generations*'. The United Nations' 2030 Agenda for Sustainable Development and the Sustainable Development Goals have further embedded concepts of a just transition into the framework of sustainability underpinning the blue economy. Here, we define the ocean economy as all economic activities connected to the ocean, whereas the blue economy is a social construct and nascent subset of the ocean economy embracing aspirations for sustainable use of the ocean in line with the Rio+20 vision.

The ocean, and economic activities supported by the ocean, provide populations worldwide (coastal and inland) with food, energy, water and other resources. It enables global trade and transport, creates markets for marine and maritime manufacturing, technology and service industries, supports tourism, protects coastlines, hosts recreation and leisure activities, and enables the projection of power by both friendly and hostile nations and other actors. Throughout human history, the ocean has enabled waves of pioneering settlement and forced human migration, such that the ocean and coasts are culturally significant for communities worldwide.

Coastal populations are increasing at accelerating rates, with more than one billion people living along the coast and nearly three billion living within 100 km of the coast [3]; 8 of the world's 10 largest cities are coastal, and half a billion people live on fragile deltas [4]. The ocean economy contributes 2.5% of global GDP and provides formal direct employment to an estimated 1.5% of the global workforce [5]. If the global ocean economy were a national economy, it would be the seventh largest in the world, and the ocean as an economic entity would be a member of the G7 [6].

Aside from its economic, social and cultural importance, oceans have essential moderating influences on Earth's climate and biogeochemical systems that sustain life. The ocean produces ~50% of atmospheric oxygen and has absorbed ~30% of anthropogenic carbon dioxide (CO_2) emissions and heat, partially mitigating the impacts of global warming. It must play a central role in climate action as a provider of zero-carbon energy, fuels, food, resources, and as a critical means for carbon sequestration and waste management, including CO_2 disposal. Over 20% of the necessary greenhouse gas reductions by 2050 are predicted to come from ocean-based solutions, including renewable energy, transport, ecosystems, fisheries and carbon storage [7]. Concurrently, the natural capital[1] of the ocean must be protected and current protections strengthened [8]. The "Outcome of the first global stocktake" decision adopted during COP28 [9] explicitly recognised the important role of the ocean and coastal ecosystems for mitigation action, adaptation and resilience, whilst noting the intersection between climate and biodiversity action and the importance of climate justice when addressing climate change. By focusing on the need for a fair and equitable shift toward sustainable economic activities that protect both people and the environment, the Just Transitions Work Programme [9] operationalised during the same COP offers a vehicle to drive ocean-based industries to evolve in a way that is inclusive, sustainable, and socially responsible.

In this review paper, we explore prospective pathways that will define future ocean economies and what is needed to transition from a grey to blue ocean economy. Firstly, we present a bibliometric analysis and literature review on the ocean and blue economy to underpin the proposal of different ocean futures and the different pathways that will lead there: the business-as-usual pathway, probable pathway and blue pathway. The pathways are intended as counterfactuals, supported by the current literature, and actionable frameworks that are or can be taken, which will lead us to perpetuate a grey economy or to transition to a blue economy.

[1] Natural capital is considered as the stock of renewable and non-renewable resources (e.g. plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people

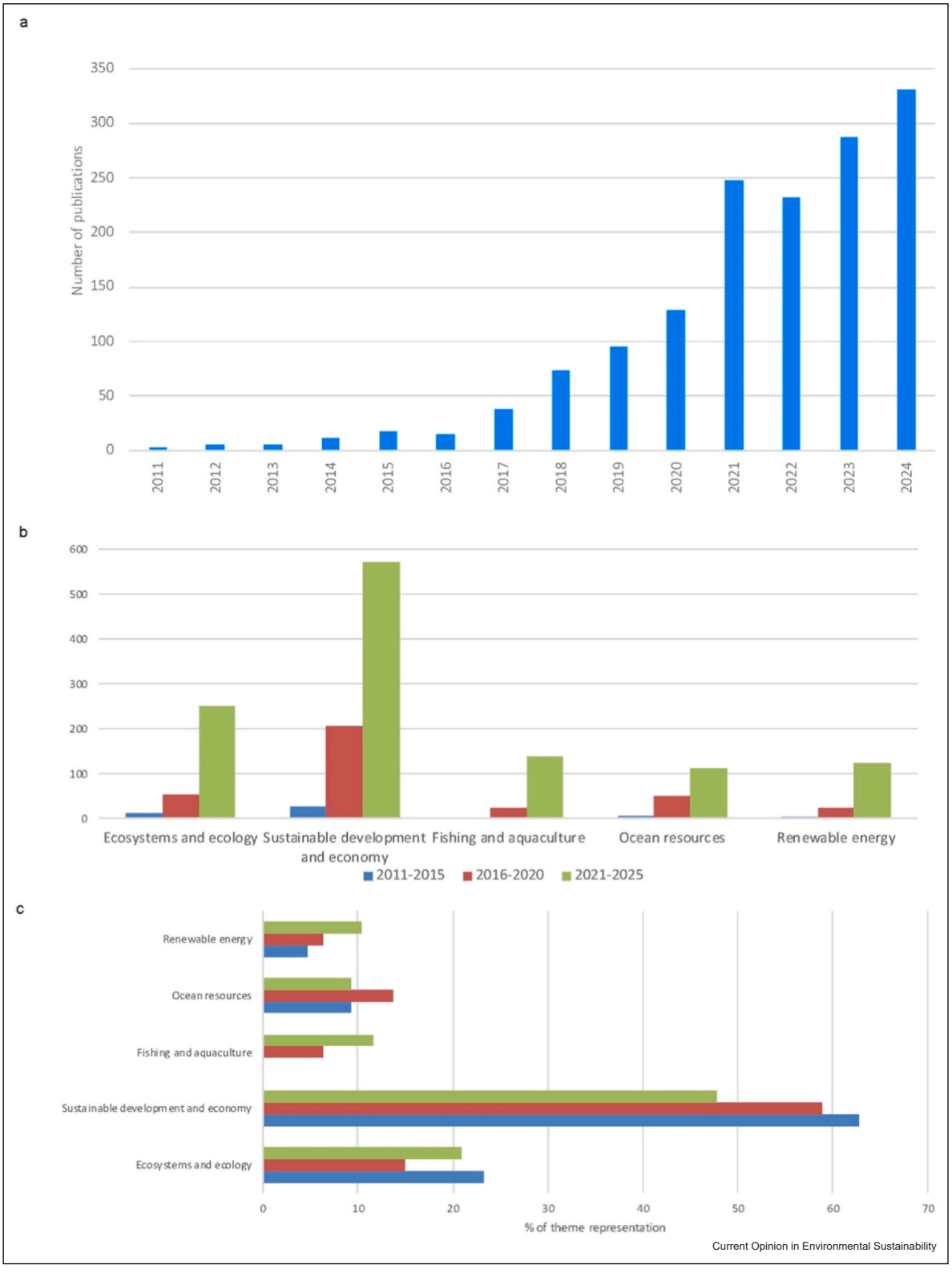
Materials and methods

To better understand the development of the concept of the 'blue' and 'ocean' economy, bibliometric analysis and literature review were carried out. Following best practice [10], this utilised Web of Science (WOS) as a primary database with Python and NVIVO used for Latent Dirichlet Allocation (LDA) analysis and additional visualisation. Within WOS, searches were carried out via 'topic', ensuring the selected terms were searched for across title, keywords and abstract fields. The search for 'blue economy' revealed 1587 publications between 2011 and 2025, with a rapid increase in activity from 2020 onwards (Figure 1a). A search for 'ocean economy' gave 247 results, with the first use of the term arising in 2004. The overall shape of the curve mirrors that given in Figure 1a, reflecting the increasing rate, but at a lower order of magnitude. Most publications come from environmental sciences (763) and incorporate a mix of foci. Analysis of author-selected keywords reflects this mix of foci, giving a view of a heterogeneous corpus of works. In order to enable comparisons, this varied body of literature LDA analysis was undertaken to determine principal thematic areas of research by five-year windows from 2011 onwards. LDA is an unsupervised machine learning topic modelling algorithm. It was used to look across both author-selected keywords and within abstracts to identify predominant topics. These topics are shown in Figure 1b (by frequency) and in Figure 1c, normalised against the total of publications within each five-year window. What emerges from this is the centrality of sustainability, sustainable development and blue growth in discourse on the blue economy, and the increasing importance of fisheries and aquaculture, as well as renewable energy.

Although WOS is an invaluable resource, incorporating over 50 000 000 articles across 250 categories, it should be noted that it favours English language publications and in some subject areas can be seen to be Eurocentric in focus [11]. Consequently, our view of the 'blue economy' may be similarly skewed, with 1564 of the 1587 of the source articles being in English.

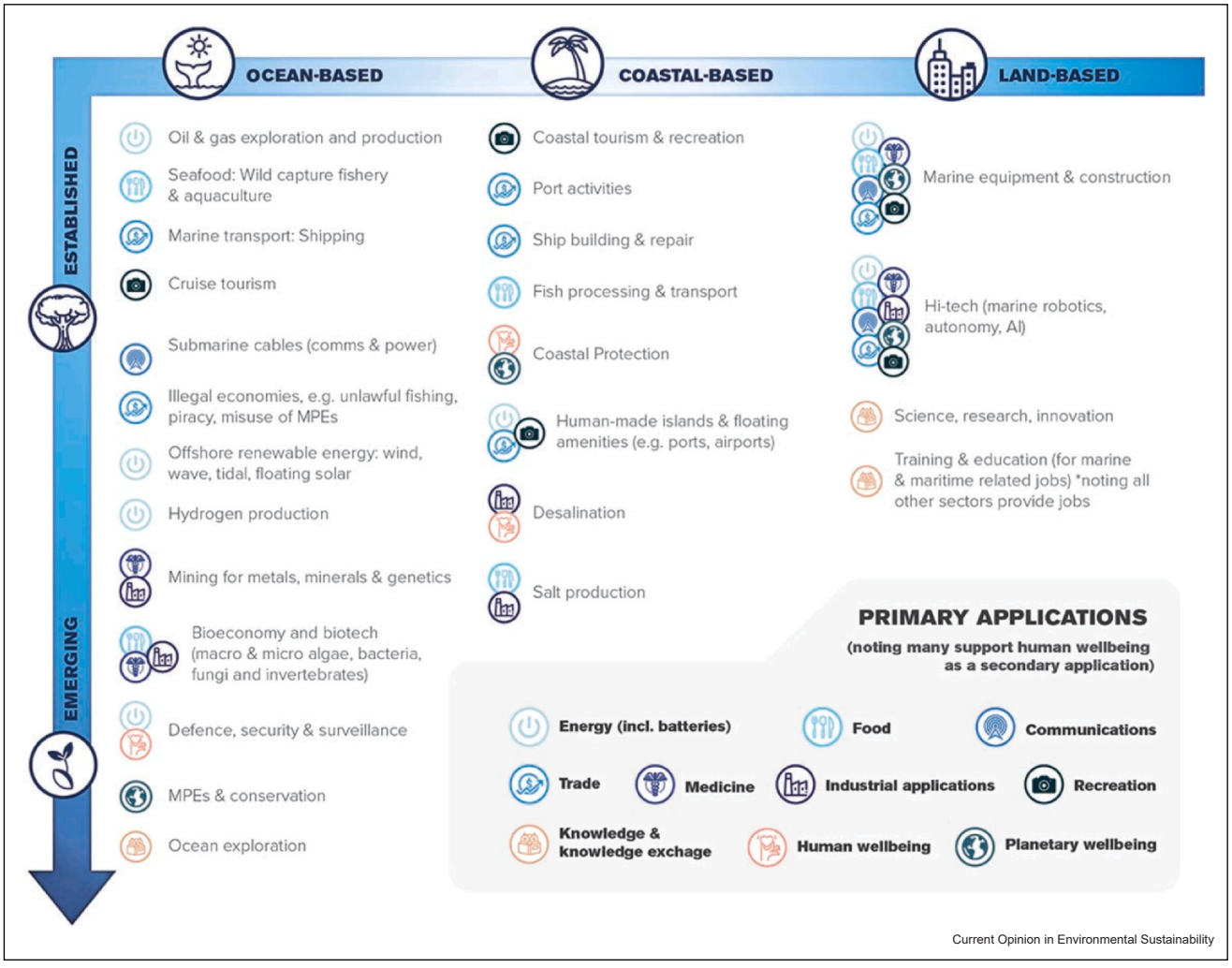
While the bibliometric analysis provided a view of broad trends within the literature, it also pointed to a shifting focus on particular sectors and a trend towards generalising accounts. To move beyond this, and to incorporate a broader spectrum of ocean economic activity, we have identified and subdivided the activity into 25 sectors (Figure 2), each placed on a spectrum from established to emerging and by whether the activities take place in the ocean, along the coastal zone or on land. The established-emerging categorisation is not binary but a continuum, recognising that sectors emerging in one region may be established in others, or can be considered emerging by offering significant potential for economic growth, sustainability transition, as well as job creation [12].

Figure 1



Bibliometric analysis: **(a)** number of publications for 'blue economy' 2011–2025, **(b)** LDA thematic analysis over five-year periods, and **(c)** LDA themes normalised by number of publications within a five-year window.

Figure 2



Established and emerging components of the ocean economy and their applications.

Much greater use of the ocean is inevitable by the mid-century if we are to meet the demands of a 9+ billion global population with increasing per capita consumption of energy and resources. Future ocean use must be underpinned by recognition of the limits of ocean resources and the vulnerability of its ecosystems to human activities, to avoid replication in the ocean of practices evolved from industrialised energy extraction, agriculture, mining, manufacturing and urbanisation, and further violation of planetary boundaries [13,14].

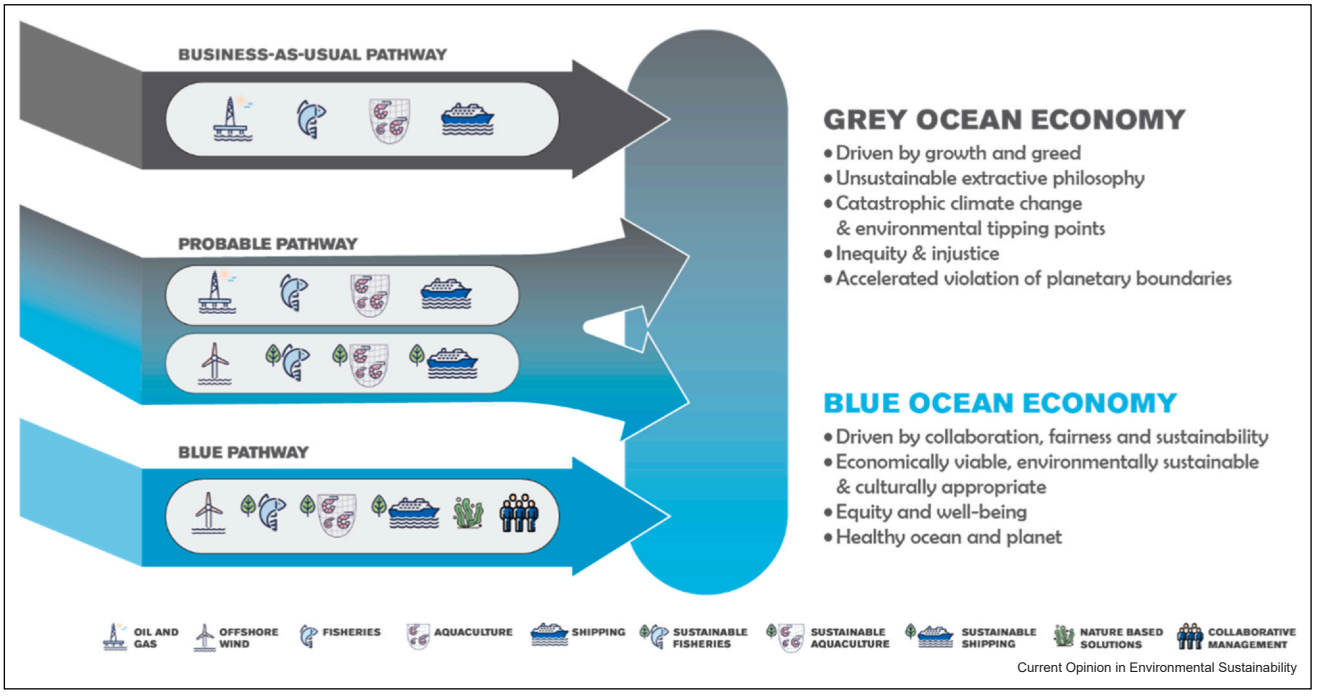
Ocean futures

Strategies for the future ocean economy must weigh the tensions of protecting the ocean against the needs and demands of an increasing global population, as well as the drive for growth from corporations and governments. The resolution of these tensions underpins the concept of the blue economy: that through the responsible use and stewardship of the ocean, society can enjoy economic prosperity whilst reducing inequalities and poverty, and supporting a sustainable ocean environment. Here we postulate alternative ocean economy outlooks arrived at through different pathways: business-as-usual, probable and blue (Figure 3). There are of course infinite outcomes for the ocean economy across the spectrum from grey to blue, and numerous routes through each pathway, depending on decisions made now and actions taken. The decisions that will take us down each of these pathways are developed in the following sections.

Business-as-usual pathway

The greatest uses of the ocean are for food, energy and seaborne transport [12,15], and, as such, these sectors currently contribute the greatest damage to the ocean and the ocean's natural capital, providing the basis for the business-as-usual future elaborated on here. We also

Figure 3



Prospective pathways to alternative ocean futures.

touch on a range of emerging ocean sectors that have the potential to cause significant environmental harm, as well as land-based activities that impact ocean health.

Food

Illegal, unreported and unregulated fishing is one of the most damaging anthropogenic impacts on ocean ecosystems [16]; even licenced activity such as bottom-trawling alters seabed habitats, damaging or killing a range of seabed fauna [17] and releasing significant carbon stores from the seabed [18]. Abandoned, lost and discarded fishing gear (ALDFG) threatens marine species [19], and entanglement or ingestion of macro-plastics (including but not limited to ALDFG) by marine life is widespread [20]. Escapes from aquaculture introduce invasive species and disease, while other threats include pharmaceuticals, organic waste, chemical discharges and marine littering [19]. A third of the loss of mangroves in Southeast Asia between 2000 and 2012 has been traced to aquaculture [21], removing important marine habitats and ecosystem services, natural carbon capture and critical coastal protection, which, in turn, causes detrimental effects to land-based environments and communities, including destruction of crops, dwellings and climate-induced migration.

Energy

The greatest environmental threat from the ocean-based oil and gas sector is global warming from burning hydrocarbons. Oil spills during exploration, production and transport also pose threats to marine environments [19]. Offshore renewable energy can benefit the natural environment by reducing greenhouse gas emissions from burning fossil fuels and minimising pollution to the air, water or seabed. However, the construction, installation and decommissioning of marine renewables structures pose potential threats to the natural environment given their lower areal energy yield compared to oil and gas installations [22] and the ensuing greater number of such structures required. These impacts may be direct, such as noise pollution or indirect, including embedded carbon in the offshore renewable infrastructure, and disposing of the infrastructure at the end of the design life [23]. Nonetheless, life-cycle analysis indicates that the environmental effects of renewable energy developments are considerably lower and more manageable than those of global warming from burning fossil fuels (e.g. [24]).

Transport

Shipping enables the global economy but produces almost 3% of global carbon emissions [25], comparable to the emissions of Japan or Germany with additional impacts from methane, nitrogen and sulfur oxides, particulate matter and black carbon. Environmental threats from shipping also include noise, biofouling, ballast and operational water discharges contaminated with chemicals and invasive species, and impacts of shipping routes on marine mammals [19]. Significant risk to the ocean-,

coast- and land-based environment is also posed by the widespread ship recycling practice of beaching [26].

Emerging ocean sectors

Some emerging ocean industries have potential to cause significant damage to the ocean environment, with mining and dredging for seabed resources attracting controversy [27]. There is currently uncertainty regarding both the potential damage to the ocean from seabed mining activities [28] and the effectiveness of international regulations and restrictions governing these practices. These include access to mineral resources by state and non-state actors, the distribution of benefits, and raising technological capacities in developed states [28].

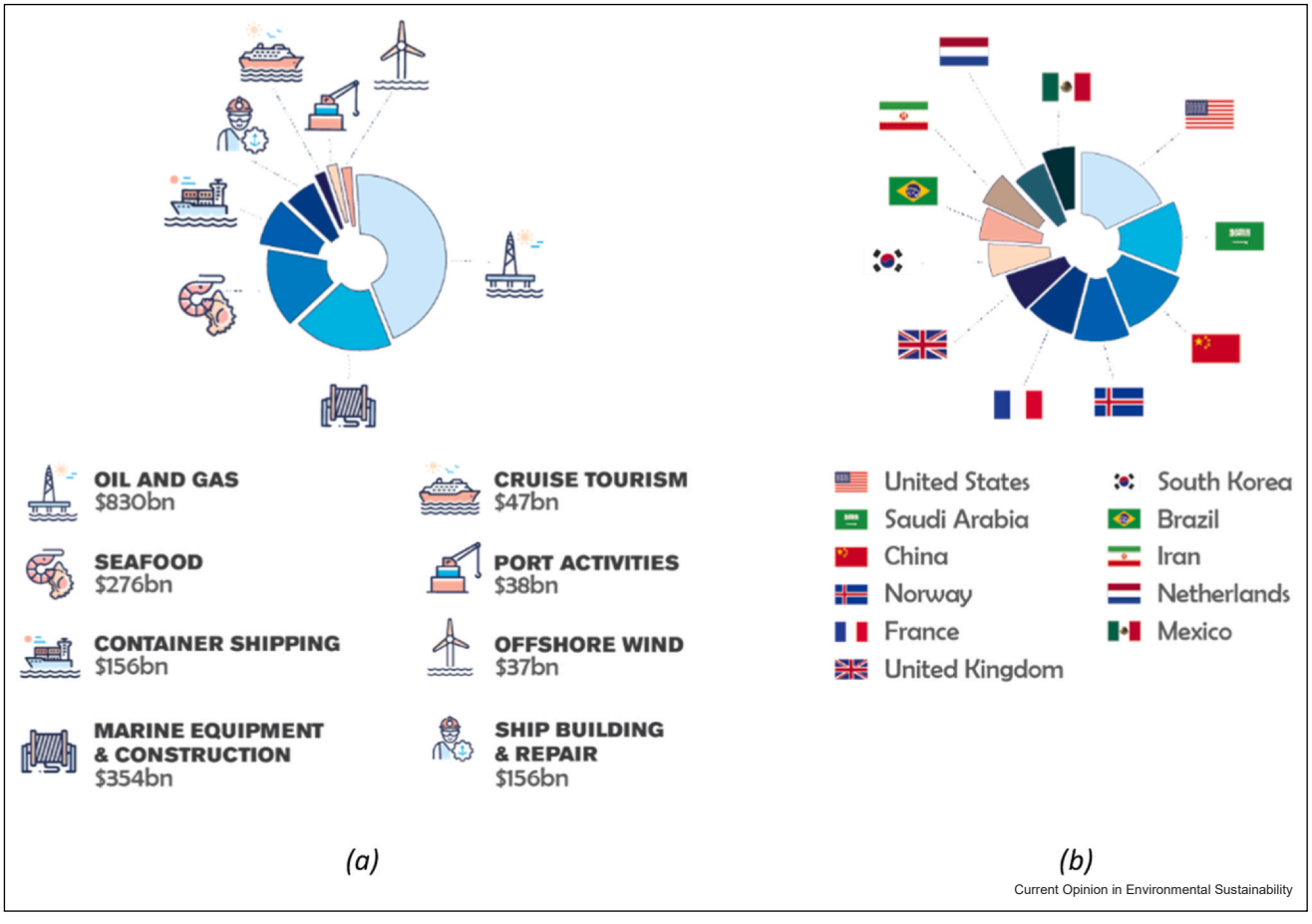
Land-based activities

The ocean, and the ecosystem that the ocean economy depends on, is further threatened by a range of land-based activities separate from the ocean economy. Onshore anthropogenic CO_2 emissions, causing global warming, also lead to ocean acidification. Excess fertiliser and other run-offs from land agriculture eventually drain into the ocean, causing eutrophication and increased turbidity that damage important ecosystems, particularly coral reefs [29]. Nine to 23 million tonnes of plastic enter the ocean every year, mostly derived from the land [30].

Damage to the ocean, irrespective of source, will negatively impact marine biodiversity and the health of the ocean ecosystems. A healthy ocean is essential to support the transition to a resilient and sustainable blue ocean economy and maintain the ocean's moderation of global warming and damaging climate change.

While the health of the ocean is inextricably linked to human activities both in and beyond the ocean, here we focus on those with the power to influence the ocean economy, with a view to addressing the pathways to achieving a blue economy. The largest industry by revenue in the ocean economy is offshore oil and gas, with 9 of the top 10 largest companies in the ocean, followed by marine equipment and construction (principally supporting the oil and gas sector amongst others), and then seafood (Figure 4a). The 100 largest corporations

Figure 4



Distribution of revenue **(a)** across eight core ocean economy sectors, and (b) by country of Ocean 100 Headquarters (HQ). Created from data compiled for the year 2018 from Ref. [15].

operating in the ocean economy, coined the 'Ocean 100' [15], are transnational corporations that operate worldwide, although the concentration of headquarters (HQ) indicates geographical power hotspots and domestic economies that benefit most from the ocean economy (Figure 4b). The governments of these countries play influential roles, either by facilitating the ocean economy through state ownership of corporations (60 of the Ocean 100 are publicly listed, though several are majority state-owned and 21 are wholly state-owned), via subsidies, or as recipients of tax revenue. Large transnational corporations operate across extended supply chains and exercise considerable capacity to capitalise on and monopolise markets [31], affording both threats and opportunities for achieving a sustainable and just future blue economy.

Governments, government agencies, intergovernmental organisations, environmental actors, think tanks and charities have demonstrated ability to raise awareness and mobilise support or collaboration, even between actors with conflicting priorities. This includes transparency initiatives to increase corporate accountability in global supply chains [32].

Notably lacking global influence on the ocean economy, and often politically marginalised, are the traditional users of the ocean. For example, loss of access for small-scale fisheries, by far the ocean's largest employers, threatens human rights and exacerbates inequalities [33].

The extrapolated business-as-usual pathway will lead to an ocean economy that continues to be dominated by hydrocarbon exploitation, over-fishing, unsustainable aquaculture practices, terrestrial waste and polluting shipping. This future will be catastrophic for the environment and will continue to impose inequality and injustice. A business-as-usual future ocean economy continues to be based on unsustainable and extractive philosophies and practices adopted from industrialised land agriculture, mining, manufacturing and urbanisation, driven by a preoccupation with growth and ever-increasing consumption. Environmental and social injustices in the ocean and global economy will persist, while current practices risk catastrophic climate change, depleting the natural capital essential to both the ocean economy and humanity. The business-as-usual approach accelerates the violation of planetary boundaries, leading to a tragic future.

Probable pathway

Probable pathways are shaped by optimistic trends, with growth in established industries, the emergence of new sectors and fledgling industries striving to meet global demand while curbing emissions [34].

Future trajectories of different ocean economy industries vary markedly, with strong growth forecast in offshore wind, marine aquaculture, fish processing, cruise and coastal tourism [12], whereas capture fisheries [35] and ship building show limited potential for growth. Other sectors, such as oil and gas production [36] and related commodity shipments [19] must, and are forecast to, decline to 2050 and beyond. However, given the dominance of oil and gas in the ocean economy, this declining sector will retain an influential role. By contrast, strong growth, even multiple-fold increases, in emerging ocean economy sectors results in only minor proportional changes in the makeup of the ocean economy.

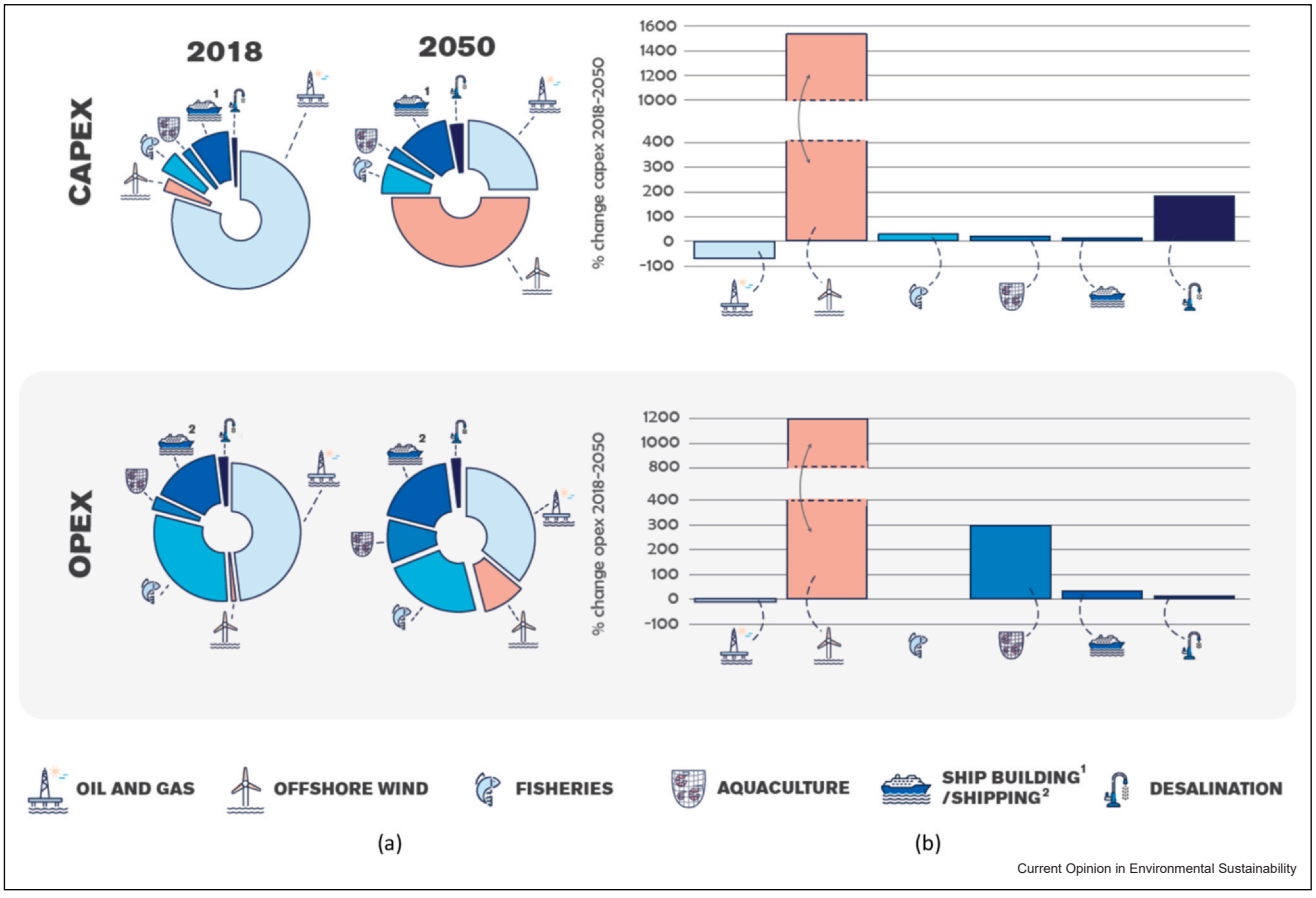
Significant shifts in investment are forecast by the mid-century, particularly in renewable ocean energy and food [19], visualised in Figure 5. The proportion of ocean capital expenditure (capex) in the oil and gas industry falls from 80% to 25% by 2050, compared to an increase in offshore wind from < 3% to 50%, with similar shifts in forecast operating expenditure (opex). Despite this, these trends are insufficient to reach the Paris Agreement targets or net zero by 2050, leading to unsafe levels of global warming [37].

Marine seafood production is forecast to grow by 25% by 2050, principally driven by aquaculture, as capture fisheries are expected to experience downturns driven by effects of climate change and the impact on fish stocks of successive generations of overfishing. However, forecast catch sizes still exceed the maximum sustainable yield for capture fisheries [38], reinforcing the need for stronger fisheries management to avoid whole food chain collapse.

Significant increase in desalination is notable, driven by growing prosperous coastal populations and by rising water stress, much of which is linked to climate change [19]; capacity and capex is forecast to almost triple by 2050, although still making up a relatively small part of the ocean economy. Seabed mining for minerals and marine genetic resources are much smaller and less mature markets than even the smallest of the sectors illustrated in Figure 4. Nonetheless, these industries have the potential to escalate rapidly should technology and regulation permit, and market needs grow.

Following a probable pathway, based on current optimistic forecasts, offshore energy will continue to dominate the ocean economy. Despite investment shifting from hydrocarbons to offshore wind, oil and gas are expected to still provide over 70% of offshore energy by 2050 in the absence of more ambitious proactive intervention [19]. Despite growth in offshore wind, the Global Wind Energy Council has warned that current rates and forecasts are insufficient to reach the Paris Agreement targets or net-zero by 2050 [37]. Marine seafood production will grow, driven by aquaculture, as wild capture reduces due to the effects of climate change and overfishing. However, forecast catch sizes will still exceed the maximum sustainable yield for capture fisheries [38]. Emission reduction targets set by the IMO aim to reduce

Figure 5



Distribution of **(a)** global capex and opex in the ocean economy by industry 2018 and 2050, and **(b)** % change in capex and opex over the period. Created from data in Ref. [19].

the contribution of global shipping to climate change [39] but remain challenging due to slow technological progress and adoption, insufficient green fuel supply chains and concerns of climate (in)justice [40,41]. Evidence indicates that probable pathways will see some shifts in the dominant ocean sectors; however, the pace of change will be insufficient to meet decarbonisation and broader sustainability targets by mid-century. In a world where oil and gas remain the dominant energy source, we breach all reasonable climate targets [13].

Blue pathway

Here, we define the blue pathway as one which leads to an ocean economy that ensures both a healthy ocean and a fair, inclusive global society, transitioning from the current 'grey' ocean economy to a truly sustainable and equitable blue economy. This requires decisions based on what *should* happen, not just what *could* happen. Although short-term priorities may differ among actors, the long-term vision is clear: a blue economy grounded in principles of the fair, collaborative and sustainable use of the ocean. Achieving this vision requires balancing ocean interventions for energy, food, shipping and more, with environmental protection, restoring marine ecosystems, and empowering communities to take on their role as stewards of the future ocean through enforceable and inclusive ocean policies.

Effective transitions towards this vision require both targeted, context-specific interventions and structural reform across ocean governance regimes. Evidence from diverse pilot projects, including those presented at the 2023 and 2024 UNFCCC Ocean and Climate Change Dialogues [42,43][2] shows that successful case studies are often grounded in participatory design, locally tailored implementation, ecosystem regeneration and co-benefits

[2] Unlike previous years, the 2025 Ocean Dialogue did not include formal case-study presentations but rather informal 'good practice' discussions in breakout groups, and those contributions have not been analysed in this paper.

for climate, biodiversity and equity. At the same time, long-term structural changes need to embed principles of justice, decolonisation and sustainability at the heart of global ocean governance and economic policy [44,45]. These dynamics are captured in Table 1, which outlines selected examples of short- and long-term interventions, policies, technologies and financing instruments across key ocean sectors. Table 2 synthesises the cross-cutting patterns, enablers and justice dimensions that emerge from these case studies, offering a concise lens on the common success factors and persistent gaps in blue economy transitions.

A substantial expansion of ocean-based economic activities is required, which must be achieved responsibly and sustainably to avoid irreversible and irreparable damage to the ecosystem that ultimately sustains us [8,91]. As such, investors and governments need to urgently direct capital away from damaging activities such as overfishing and hydrocarbon extraction — $869 Bn on fossil fuel financing alone in 2024 [92], and into low-carbon food and energy solutions, nature-based solutions and marine conservation [93]. Notably, many of the case studies in Table 1 have been financed by the Green Climate Fund (GCF) and the Global Environment Facility (GEF), underscoring its catalytic role in advancing blue economy initiatives [84]. Evidence indicates that investing across offshore wind, sustainable ocean-based food production, decarbonising international shipping and conserving and restoring mangroves would generate benefits more than five times the costs by 2050 [94]. Emerging technologies and governance have key roles to play in enabling progression along the blue pathway.

Technology has been central to human intervention in the ocean, which has enabled an 'ocean economy' to exist. Innovations in advanced materials, subsea engineering and technology, sensors and imaging, satellite technologies, optimisation, big data analytics, autonomous systems, biotechnology and nanotechnology will potentially affect every sector of the ocean economy. History shows that past interventions have positive and negative consequences on the ocean by providing food, clean energy, efficient transport and more, whilst supporting livelihoods worldwide, but simultaneously causing damage to the ocean environment through overfishing, oil spills, pollution and greenhouse gas emissions (as evidenced in the business-as-usual and probable pathways). The UN Global Compact identified five essential activities to ensure healthy and productive oceans [95], each of which is grounded in technology developments: fully traceable sustainable seafood, zero emission shipping, harnessing ocean electricity, mapping the ocean and ending waste entering the ocean.

Scientific and technological advances are crucial for the development of ocean-based economic activities and addressing ocean-related environmental challenges [12]. Such advances will necessitate substantial research, development and investment, and require responsive regulatory frameworks to be developed to enable the rapid advancements they will drive.

Thirty-five years on from the World Commission on Environment and Development's early recognition of the 'fundamental unity' of our ocean and the interconnectedness of its resources and their uses [96], recent literature continues to stress the urgent need for governance reform to address ongoing and emerging challenges. The dichotomy remains between the current Law of the Sea framework, which distinguishes between areas that fall under state jurisdiction and areas beyond national jurisdiction (ABNJ) and proposals that treat the ocean as a global commons [97]. Strengthening scientific understanding and recognising the complex interplay of actors in ocean governance is crucial to ensure widespread commitment to ocean protection and stewardship [66]. There is a pressing need for greater accountability, transparency and participation that enable fair, equitable and efficacious responses to the global challenges facing our ocean [89].

As activities in the ocean diversify and scale up, so too does the potential for unrecognised cumulative impacts on ocean health, and thus human health and wellbeing. The interconnected nature of ocean ecosystems creates challenges for the accurate prediction of large upscaling of human activity. Overfishing of Western Baltic cod remains one of the best examples of this [98]. While the gradual impact was realised, the impact of crossing the tipping point was not well understood until the threshold had been crossed. Following this resource breakdown, routes to recovery were also not well understood. It is essential that we develop our abilities to identify ecological and environmental thresholds, such as the collapse of critical fish stocks or the terminal bleaching of coral reefs, and act with sufficient speed and coordination to mitigate them [99].

The pathway to a blue economy is challenging, but it will prevent the destruction of the natural capital vital for the ocean economy and for humanity. Scientific evidence is plentiful to develop strategies and decisions needed to realise a blue economy — one that is economically viable, environmentally sustainable, culturally appropriate and focused on social equity and well-being. It is equally clear that strategies and decisions made now will determine the pathway of the actual realised future in the mid-century and beyond.

Table 1

Case studies and pathways to a just and sustainable blue economy.

Sector	Geographic & institutional context	Key actions/ projects	Enabling conditions	Justice-oriented measures
Fisheries & aquatic foods	Palau, Peru, Madagascar, Costa Rica, New Zealand, Pacific Islands	Community-led marine protection (e.g. Locally Managed Marine Areas) [43] Habitat restoration (e.g. mangroves) [42] Artisanal fishery zones [45] Indigenous quota rights [44]	Traditional knowledge integration [46] National fisheries plans integrating spatial management, stakeholder inclusion and climate resilience [47] Targeted subsidies for sustainability measures and removal of inefficient subsidies [48]	Rights-based laws [49] Indigenous participation [50] Co-management governance [51] Redistribution of catch shares [44]
Offshore renewable energy	Colombia, Vanuatu, Japan, USA, EU, UK	Offshore wind zoning [52] Wave/tidal pilots [53] Regional power grids [42]	National research and development plans [54] Government support for the renewable energy industry [55] Marine Spatial Planning [56] Public-private partnerships [57]	Tech transfer and capacity building requirements under Article 4 of the UNFCCC and Article 10 of the Paris Agreement [58] Avoiding ecosystem displacement and ensuring environmental impact safeguards are in place [59]
Shipping and maritime transport	Panama–Fiji–Namibia corridor, Singapore, Nauru, EU, US	Green shipping corridors [60] Port electrification [61] Clean fuel [62]	IMO decarbonisation targets [63] Port infrastructure funding [64] Carbon pricing and trading schemes [65]	Ending fossil fuel subsidies [66] Target finance access for clean shipping in developing countries [67] Support the development and deployment of low-emission vessel technologies [68]
Tourism and coastal livelihoods	Indonesia, Fiji, Cabo Verde, Maldives, Mauritius	Ecotourism and mangrove/forest restoration [42] MPAs for reef protection [69] Seaweed-based products [70] Social enterprise financing [71]	Nature-friendly tourism policy [72] Climate resilience funds [73] Accelerating sustainable blue finance for SMEs [74]	Funding for women/youth-led businesses [45] Ecosystem revenue-sharing [42] Targeted support for women, informal workers, and other marginalised groups [75]
Finance and planning tools	Singapore, Fiji, United Nations Environment Programme, Global Environment Facility, Global Green Growth Institute	Blue carbon credits, blue bonds and loans [76] Nationally determined contribution/ National Adaptation Plan integration [42] Earth observation systems for coastal and marine planning [77]	Legal frameworks for carbon rights [78] Blue finance guidelines [79] Blended finance instruments [80] Institutional coordination [81]	Ensuring equitable access to finance [82] Direct funding to marginalised groups [82,83] Governance safeguards in climate finance [84]
Cross-cutting governance	National, regional and global, including Bangladesh, UNFCCC dialogues, EU bodies, and academic proposals	Legal recognition of ocean rights [44] Integrated management and sustainable development of ocean economy sectors [85] Integrate justice frameworks into all stages of marine planning to address the intersectional, inequities [45]	International coordination/multi-level governance (e.g. UNFCCC, IMO, FAO; CBD) [86,87] Knowledge-sharing and capacity-building hubs [87,88] Public participation and consent protocols [88]	Democratise ocean governance [44,45] Addressing structural power asymmetries and colonial legacies in ocean governance [45,89] Limits on corporate ocean capture [44] Align ocean law with climate justice[90]

Table 2

Cross-cutting patterns, gaps and enablers in blue economy transitions.

Dimension	Shared characteristics
Approach	Ecosystem-based, community-led, tech-enabled
Scale	Short-term pilots embedded in long-term plans
Finance	Mix of grants, loans, blended finance, and carbon markets
Institutions	Move toward integrated, cross-sectoral ocean governance
Equity lens	Local rights, gender/youth/indigenous inclusion, Global South access
Justice gaps identified	Power asymmetries, neocolonial governance structures, exclusion or marginalisation of primary end users of ocean economy sectors

Concluding remarks

A healthy ocean is essential for the transition to a sustainable, just blue economy and for moderating global warming and climate change. Evidence indicates that investing in a blue economy will generate benefits far outweighing the costs, yet investors and governments continue to direct investment towards damaging activities, including overfishing and hydrocarbon extraction.

Shifting our current and forecast grey ocean economy to a sustainable and just blue economy requires ambitious proactive strategies and decisions now, which will ultimately protect the health of the oceans on which the ocean economy and humanity depend. Sustainable levels of wild capture fishing, careful planning of aquaculture expansion, rapid increase in renewable energy, coupled with rapid decline in hydrocarbon production, decreased consumption in the developed world and decreased waste from land-based agriculture and coastal cities are all vital.

Realisation of such strategies will depend on a coalition of actors, including the major nations and companies in the ocean economy, to articulate a common vision and enforce required best practice through collective action, innovative legal measures, and financial tools to monitor and protect the global ocean and prosecute rogue actors. Global trends and cooperation can change rapidly due to geopolitical circumstances, requiring monitoring and transparency to chart these shifts, evaluate their impact and keep course to shift the ocean economy from grey to blue.

CRediT authorship contribution statement

SG: Conceptualization, Funding acquisition, Investigation, Project administration, Supervision, Validation, Visualization, Writing – original draft. **WD:** Investigation, Validation, Writing – original draft. **FS:** Investigation, Validation, Writing – review & editing. **DT:** Conceptualization, Funding acquisition, Writing – review & editing.

Data Availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships that may be considered as potential competing interests. Susan Gourvenec reports financial support from His Majesty's Government of the United Kingdom of Great Britain and Northern Ireland and from the Royal Academy of Engineering. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Elements of the research presented in this paper were funded by the UK Government Development, Concepts and Doctrine Centre for the Global Strategic Trends Programme. Susan Gourvenec is supported by the Royal Academy of Engineering under the Chairs in Emerging Technologies scheme (www.southampton.ac.uk/iroc). All authors are members of the leadership team of the Southampton Marine & Maritime Institute at the University of Southampton (www.southampton.ac.uk/smmi).

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Eikeset A, Mazzarella A, Davíðsdóttir B, Klinger D, Levin S, Rovenskaya E, Stenseth N: **What is blue growth? The semantics of "Sustainable Development" of marine environments**. *Mar Policy* 2018, **87**:177-179, https://doi.org/10.1016/j.marpol.2017.10.019

2. UN: **The future we want**. *Rio de Janeiro, Brazil*; 20 – 22 June 2012 ⟨https://sustainabledevelopment.un.org/content/documents/733FutureWeWant.pdf⟩.

3. •• Glavovic BC, Dawson R, Chow W, Garschagen M, Haasnoot M, Singh C, Thomas A: **Cross-Chapter Paper 2: Cities and settlements by the sea**. In *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by Pörtner H-O, *et al*.. Cambridge University Press; 2022:2163-2194, https://doi.org/10.1017/9781009325844.019.
Forming part of the 6th IPCC report, this paper sets out the scale, economic and social significance of, and threats to, coastal cities and settlements (C&S) across the world in the face of climate change, and proposes a mix of interventions necessary. The paper highlights that 11% of the global population, or 896 million people, live in coastal areas, and regardless of climate and socioeconomic scenario, many coastal C &S face severe disruption to coastal ecosystems and livelihoods by 2050—extending to all C&S by 2100 and beyond—caused by compound and cascading risks, including submergence of some low-lying island states.

4. Neumann B, Vafeidis AT, Zimmermann J, Nicholls RJ: **Future coastal population growth and exposure to sea-level rise and**

coastal flooding — a global assessment. *PLoS One* 2015, **10**:e011857, https://doi.org/10.1371/journal.pone.0118571

5. Directorate-General for Maritime Affairs and Fisheries (European Commission), Addamo AM, Calvo Santos A, Carvalho N, *et al*.: **The EU Blue Economy Report 2021**. Publications Office of the European Union; 2021, ⟨https://op.europa.eu/en/publication-detail/-/publication/0b0c5bfd-c737-11eb-a925-01aa75ed71a1⟩.

6. EU: **Transforming the EU's Blue Economy for a Sustainable Future**; 2021. Available from ⟨https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0240&from=EN⟩.

7. Hoegh-Gulderg O, Northrop E, Roy J, Konar M, Lubchenco J: **The Ocean as a Solution for Climate Change: Five Opportunities for Action**. World Resources Institute; 2019⟨https://oceanpanel.org/publication/the-ocean-as-a-solution-to-climate-change-five-opportunities-for-action/⟩ see also blog by same authors https://www.wri.org/insights/turning-tide-ocean-based-solutions-could-close-emission-gap-21.

8. Dasgupta P: **The Economics of Biodiversity: The Dasgupta Review**. HM Treasury; 2021⟨https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf⟩.

9. UNFCC: **Outcome of the first global stocktake**. *Conference of the Parties (COP) 28, United Arab Emirates*; 2024. ⟨https://unfccc.int/sites/default/files/resource/cma2023_16a01E.pdf⟩.

10. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM: **How to conduct a bibliometric analysis: an overview and guidelines**. *J Bus Res* 2021, **133**:285-296.

11. Vlase I, Lähdesmäki T: **A bibliometric analysis of cultural heritage research in the humanities: the Web of Science as a tool of knowledge management**. *Humanit Soc Sci Commun* 2023, **10**:1-14.

12. OECD: **The Ocean Economy in 2030**. OECD Publishing; 2016, https://doi.org/10.1787/9789264251724-en

13. Caesar L, Sakschewski B, Andersen LS, *et al*.: **Planetary Health Check: A Scientific Assessment of the State of the Planet**. Potsdam Institute for Climate Impact Research; 2024⟨https://www.planetaryhealthcheck.org⟩.

14. Ripple WJ, Wolf C, Gregg JW, *et al*.: **The 2024 state of the climate report: perilous times on planet earth**. *BioScience* 2024, **2024**:1-13, https://doi.org/10.1093/biosci/biae087

15. Virdin J, Vegh T, Jouffray J-B, Blasiak R, Mason S, Österblom H, Vermeer D, Wachtmeister H, Werner N: **The Ocean 100: Transnational corporations in the ocean economy**. *Sci Adv* 2021, **7**:eabc8041, https://doi.org/10.1126/sciadv.abc8041 ⟨https://www.science.org/doi/⟩.

16. IPBES: In *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Edited by Brondizio ES, Settele J, Díaz S, Ngo HT. IPBES secretariat; 2019:1148, https://doi.org/10.5281/zenodo.3831673

17. M. Sciberras M, Hiddink JG, Jennings S, *et al*.: **Response of benthic fauna to experimental bottom fishing: a global meta-analysis**. *Fish Fish* 2018, **19**:698-715, https://doi.org/10.1111/faf.12283

18. Zhang W, Porz L, Yilmaz R, *et al*.: **Long-term carbon storage in shelf sea sediments reduced by intensive bottom trawling**. *Nat Geosci* 2024, **17**:1268-1276, https://doi.org/10.1038/s41561-024-01581-4

19. DNV: **Ocean's Future to 2050: A Sectoral and Regional Forecast of the Blue Economy**; 2021. ⟨https://www.dnv.com/Publications/ocean-s-future-to-2050-report-213872⟩.

20. Macleod M, Arp HPH, Tekhumans MB, Jahnke A: **The global threat from plastic pollution**. *Science* 2021, **373**:61-65, https://doi.org/10.1126/science.abg5433

21. Richards DR, Friess DA: **Rates and drivers of mangrove deforestation in Southeast Asia, 2000–2012**. *Proc Natl Acad Sci USA* 2016, **113**:344-349, https://doi.org/10.1073/pnas.1510272113

22. Gourvenec S: **Shaping the offshore decommissioning agenda and design of next generation offshore infrastructure**. *Smart Infrastruct Constr* 2018, **171**:54-66, https://doi.org/10.1680/jsmic.18.00002

23. Jenson JP, Skelton K: **Wind turbine blade recycling: experiences, challenges and possibilities in a circular economy**. *Renew Sustain Energy Rev* 2019, **97**:165-176, https://doi.org/10.1016/j.rser.2018.08.041

24. Gayen D, Chatterjee R, Roy S: **A review on environmental impacts of renewable energy for sustainable development**. *Int J Environ Sci Technol* 2024, **21**:5285-5310, https://doi.org/10.1007/s13762-023-05380-z

25. IEA: **Global Energy Review: CO2 Emissions in 2023**. *International Energy Agency*; 2024. ⟨https://www.iea.org/reports/co2-emissions-in-2023⟩.

26. Gourvenec: **Obsolete ships and offshore structures — an urgent safety challenge**. *The Engineer*; 2022. ⟨https://www.theengineer.co.uk/ships-structures-offshore-decommissioning-safety/⟩.

27. • Gilbert N: **First approval for controversial sea-bed mining worries scientists**. *Nature* 2024, **625**:435-436, https://doi.org/10.1038/d41586-024-00088-7.
Following Norway becoming the first country to allow exploratory deep-sea mining, concern is renewed about risk of irreversibly damaging biodiversity and ecosystems and reviving the greed vs need argument. Many researchers and governments are calling for a moratorium on seabed mining until more is known about the effects on deep-sea ecosystems. The article outlines the threat from this potential, if not even yet emerging ocean sector, and references other scientific works on the topic.

28. Miller KA, Thompson KF, Johnston P, Santillo D: **An overview of seabed mining Including the current state of development, environmental impacts, and knowledge gaps**. *Front Mar Sci* 2018, **4**:418, https://doi.org/10.3389/fmars.2017.00418

29. D'Angelo C, Wiedenmann J: **Impacts of nutrient enrichment on coral reefs: new perspectives and implications for coastal management and reef survival**. *Curr Opin Environ Sustain* 2014, **7**:82-93, https://doi.org/10.1016/j.cosust.2013.11.029

30. Borrelle SB, Ringma J, Law KL, *et al*.: **Predicted growth in plastic waste exceeds efforts to mitigate plastic pollution**. *Science* 2020, **369**:1515-1518, https://doi.org/10.1126/science.aba3656

31. Blasiak R, Spijkers J, Tokunaga K, Pittman J, Yagi N, Österblom H: **Climate change and marine fisheries: least developed countries top global index of vulnerability**. *PLoS One* 2017, **12**:e0179632, https://doi.org/10.1371/journal.pone.0179632

32. Bebbington J, Österblom H, Crona B, Jouffray J-B, Larrinaga C, Russell S, Scholtens B: **Accounting and accountability in the Anthropocene**. *Account Audit Account J* 2019, **33**:152-177, https://doi.org/10.1108/AAAJ-11-2018-3745

33. Cohen P, Allison EH, Andrew NL, Cinner J, Evans LS, Fabinyi M, Garces LR, Hall SJ, Hicks CC, Hughes TP, Jentoft S, Mills DJ, Masu R, Mbaru EK, Ratner BD: **Securing a just space for small-scale fisheries in the blue economy**. *Front Mar Sci* 2019, **6**:171, https://doi.org/10.3389/fmars.2019.00171/full ⟨https://www.frontiersin.org/articles/⟩.

34. UK Government, Ministry of Defence: **Global Strategic Trends: Out to 2055 (Seventh Edition)**; 2024. ⟨https://www.gov.uk/government/publications/global-strategic-trends-out-to-2055⟩.

35. FAO: **The State of World Fisheries and Aquaculture: Sustainability in Action**. Food and Agriculture Organization of the United Nations; 2020.

36. • Gourvenec S, Sturt F, Reid E, Trigos F: **Global assessment of historical, current and forecast ocean energy infrastructure: implications for marine space planning, sustainable design and end-of-engineered-life management**. *Renew Sustain Energy Rev* 2022, **154**:111794, https://doi.org/10.1016/j.rser.2021.111794.
Quantifies spatio-temporal distribution of offshore energy infrastructure globally 1960–2040 through creation of a comprehensive global dataset of past, current and forecast ocean energy infrastructure and offshore energy resources, both hydrocarbon and wind. The data is collected together for the first time and made available in the public domain through an interactive online map. The resulting oceanscape provides

insight into the type, quantity, density and geographic centres of the accumulating asset base, which in turn enables informed consideration of how marine space alongside design and end-of-engineered-life of ocean infrastructure can be managed responsibly and sustainably.

37. GWEC: **Global Offshore Wind Report 2022**. Global Wind Energy Council; 2022, ⟨https://gwec.net/global-offshore-wind-report-2022/⟩.

38. • Edgar GJ, Bates AE, Krueck NC, Baker SC, Stuart-Smith RD, Brown CJ: **Stock assessment models overstate sustainability of the world's fisheries**. *Science* 2024, **385**:860-865, https://doi.org/10.1126/science.adl6282.
Publicly available data on 230 of the best-known fisheries species is used to test whether stock biomass estimates made in the year of the estimate were as accurate as specifically calculated hindcast models. The study shows that, especially in overfished species, historical estimates were higher than later estimates, indicating the presence of excessively positive assessments of stock status. The authors note that with consideration of bias identified retrospectively, 85% more stocks than currently recognized have likely collapsed below 10% of maximum historical biomass.

39. IMO: **Reduction of GHG emissions from SHIPS: report of the fifteenth meeting of the intersessional working group on reduction of GHG emissions from ships (ISWG-GHG 15)**. *Maritime Environment Protection Committee, 80th session*; 2023. ⟨https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx⟩.

40. Manias P, McKinlay C, Teagle DAH, Hudson D, Turnock S: **A wind-to-wake approach for selecting future marine fuels and powertrains**. *Int J Hydrog Energy* 2024, **82**:1039-1050, https://doi.org/10.1016/j.ijhydene.2024.07.377

41. Singh S, Ballini F: **Socio-economic impacts of maritime GHG emission control measures on sustainable development in SIDS: insights from a systematic literature review**. *Mar Pollut Bull* 2025, **214**:117687, https://doi.org/10.1016/j.marpolbul.2025.117687

42. United Nations Framework Convention on Climate Change (UNFCCC): **Informal summary report by the co-facilitators of the Ocean and Climate Change Dialogue 2023–2024**. *Bonn, Germany: UNFCCC*; 2023 Sep 15. Available from: ⟨https://unfccc.int/sites/default/files/resource/Ocean%20dialogue_informal%20summary%20report_SB58_2023%20UNFCCC%20webpage%20publication%20%282%29.pdf⟩.

43. United Nations Framework Convention on Climate Change (UNFCCC): **Informal summary report by the co-facilitators of the Ocean and Climate Change Dialogue 2023–2024**. *Bonn, Germany: UNFCCC*; 2024 Oct 2. Available from: ⟨https://unfccc.int/sites/default/files/resource/Informal_Summary_Report_Ocean_Dialogue_2024.pdf⟩.

44. • Armstrong C: **A Blue New Deal: Why We Need a New Politics for the Ocean**. Yale University Press; 2022 Available from: ⟨https://imp.dayawisesa.com/wp-content/uploads/2024/02/A-Blue-New-Deal-Why-We-Need-a-New-Politics-for-the-Ocean.pdf⟩.
Reveals how existing governing institutions are failing to respond to the massive environmental destruction and spiralling inequality in the ocean economy. Armstrong examines these crises—from the fate of people whose lands will be submerged by sea level rise to the exploitation of people working in fishing to the rights of marine animals—and makes the case for a powerful World Ocean Authority capable of tackling them. The book presents a radical manifesto for putting equality, democracy, and sustainability at the heart of ocean politics.

45. •• In *Confronting Climate Coloniality: Decolonizing Pathways for Climate Justice [Internet]*. Edited by Sultana F. 1st edn, Routledge; 2024.
This edited volume examines how colonial legacies and power imbalances shape climate impacts and responses, arguing for decolonised, justice-centred approaches to climate action. It highlights the need to shift ocean governance and economic models away from exploitative, extractive practices, which are central to the "grey" economy, toward inclusive, equitable frameworks essential for a truly "blue" economy transition.

46. United Nations Educational, Scientific and Cultural Organization (UNESCO): **Indigenous Knowledge of the Ocean [Internet]**. *Paris: UNESCO*; 2025. Available from: ⟨https://www.unesco.org/en/links/ocean⟩ [cited 2025 Jun 18].

47. World Bank: **Sustainable Fisheries: Blue Economy for Resilient Africa Program – Operational Brief [Internet]**. *Washington, DC*; 2022. Available from: ⟨https://thedocs.worldbank.org/en/doc/3613d3450378640a1b86a7bca15830e2-0320012022/original/Sustainable-Fisheries.pdf⟩.

48. World Trade Organization (WTO): **Agreement on Fisheries Subsidies [Internet]**. *Geneva: WTO*; 2022. Available from: ⟨https://www.wto.org/english/tratop_e/rulesneg_e/fish_e/fish_e.htm⟩ [cited 2025 Jun 18].

49. Congress of the Republic of Peru: **General Environmental Law, Law No. 28611 [Internet]**. *Lima: Congress of the Republic of Peru*; 2005. Available from: ⟨https://www.perupetro.com.pe/wps/wcm/connect/f102bb26-8b10-497e-8d2c-1bb8e1c3025a/Law+28611+General+Law+of+Environment.docx?MOD=AJPERES⟩.

50. Bennett NJ, Bodwitch H, Snook J, Lowitt K, Paul-Burkem K, McGregorm D, *et al*.: **Indigenous self-determination in fisheries governance: implications from New Zealand and Atlantic Canada**. *Front Mar Sci* 2024, **11**:1297975, https://doi.org/10.3389/fmars.2024.1297975/full Available from: ⟨https://www.frontiersin.org/journals/marine-science/articles/⟩.

51. Gutiérrez NL, Hilborn R, Defeo O: **Leadership, social capital and incentives promote successful fisheries**. *Nature* 2011, **470**:386-389. Available from: ⟨https://pubmed.ncbi.nlm.nih.gov/21209616/⟩.

52. RWE: **Norfolk Offshore Wind Zone [Internet]**. *Essen: RWE AG*. Available from: ⟨https://norfolkzone.rwe.com/⟩ [cited 2025 Jun 18].

53. Offshore Magazine: **Global wave and tidal energy market set for 'significant growth' by 2034 [Internet]**; 2025 Mar 6. Available from: ⟨https://www.offshore-mag.com/renewable-energy/new⟩ [cited 2025 Jun 18].

54. International Renewable Energy Agency (IRENA): **Offshore renewables: an action agenda for deployment [Internet]**. Abu Dhabi; 2021. Available from: ⟨https://www.irena.org/Publications/2021/Jul/Offshore-Renewables-An-Action-Agenda-for-Deployment⟩.

55. Walker A, Hinson S, Sutherland N: **Government support for the marine renewables industry. Commons Library Debate Pack, Number CDP 2025/0011 [Internet]**. *London: House of Commons Library*; 2025 Jan 13. Available from: ⟨https://researchbriefings.files.parliament.uk/documents/CDP-2025-0011/CDP-2025-0011.pdf⟩.

56. UNESCO-IOC, European Commission: **MSPglobal International Guide on Marine/Maritime Spatial Planning [Internet]**. *Paris. (IOC Manuals and Guides no. 89)*; 2021. Available from: ⟨https://www.mspglobal2030.org/wp-content/uploads/2021/12/MSPglobal_InternationalGuideMSP_HighRes_202112.pdf⟩.

57. World Bank Group: **Key Factors for Successful Development of Offshore Wind in Emerging Markets [Internet]**. *Washington, DC: ESMAP*; 2021. Available from: ⟨https://documents1.worldbank.org/curated/en/343861632842395836/pdf/Key-Factors-for-Successful-Development-of-Offshore-Wind-in-Emerging-Markets.pdf⟩.

58. Climate Technology Centre & Network: **Climate Technology Centre & Network [Internet]**. *Copenhagen: CTCN*; 2025. Available from: ⟨https://www.ctc-n.org/⟩ [cited 2025 Jun 18].

59. Zaucha J, Gee K, Ramieri E, Ehler CN: **Implementing the EU MSP Directive: current status and lessons learned in 22 EU Member States**. *Mar Policy* 2025, **173**:106535Available from: ⟨https://www.sciencedirect.com/science/article/pii/S0308597X24004251⟩.

60. International Maritime Organization: **Green Corridors [Internet]**. *London: IMO*; 2025. Available from: ⟨https://futurefuels.imo.org/home/future-insight/innovation/green-corridors/⟩ [cited 2025 Jun 18].

61. Meng Z, Comer B: **Electrifying ports to reduce diesel pollution from ships and trucks and benefit public health: Case studies of the Port of Seattle and the Port of New York and New Jersey [Internet]**. *Washington, DC: International Council on Clean Transportation*; 2023 Feb. (Working Paper 2023-05). Available

from: ⟨https://theicct.org/wp-content/uploads/2023/02/Ports-electrification-US_final.pdf⟩.

62. Green Climate Fund: **FP052: Sustainable and Climate Resilient Connectivity for Nauru [Internet]**. *Incheon: Green Climate Fund*; 2025. Available from: ⟨https://www.greenclimate.fund/project/fp052⟩ [cited 2025 Jun 18].

63. International Maritime Organization: **Strategy on reduction of GHG emissions from ships as adopted subject to any final editorials [Internet]**. *London: IMO*; 2023. Available from: ⟨https://wwwcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/2023%20Strategy%20%20on%20Reduction%20of%20GHG%20emissions%20from%20ships%20as%20adopted%20subject%20to%20any%20final%20editorials_.pdf⟩[cited 2025 Jun 18].

64. European Climate, Infrastructure and Environment Executive Agency: **Connecting Europe Facility (CEF) [Internet]**. *Brussels: European Commission*; 2025. Available from: ⟨https://cinea.ec.europa.eu/programmes/connecting-europe-facility_en⟩ [cited 2025 Jun 18].

65. European Commission: **EU Emissions Trading System (EU ETS) [Internet]**. *Brussels: European Commission*; 2025. Available from: ⟨https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en⟩ [cited 2025 Jun 18].

66. International Energy Agency: **Fossil fuel subsidies [Internet]**. *Paris: IEA*; 2025. Available from: ⟨https://www.iea.org/topics/fossil-fuel-subsidies⟩ [cited 2025 Jun 18].

67. United Nations Conference on Trade and Development: **An equitable and just transition to low-carbon shipping**. UNCTAD Policy Brief No. 112 [Internet]. *Geneva: UNCTAD*; 2023 Nov. Available from: ⟨https://unctad.org/system/files/official-document/presspb2023d6_en.pdf⟩ [cited 2025 Jun 18].

68. International Maritime Organization: **GreenVoyage2050 [Internet]**. *London: IMO*; 2025. Available from: ⟨https://www.imo.org/en/OurWork/PartnershipsProjects/Pages/GreenVoyage2050.aspx⟩ [cited 2025 Jun 18].

69. United Nations Environment Programme: **Marine protected areas: an essential tool for the ocean's health [Internet]**. *Nairobi*; 2019. Available from: ⟨https://wedocs.unep.org/bitstream/handle/20.500.11822/27790/MPA.pdf?sequence=1&isAllowed=y⟩ [cited 2025 Jun 18].

70. Environmental Protection and Conservation Organisation. **Resilient Island Endeavour (RISE) Project: Seaweed-based multipurpose agricultural system in Mauritius [Internet]**. *Port Louis: EPCO*; 2025. Available from: ⟨https://epco.ngo/resilient-island-endeavour-rise-project/⟩ [cited 2025 Jun 18].

71. Cabo Verde Stock Exchange (Bolsa de Valores de Cabo Verde): **Blu-X: Leveraging sustainable finance for the impact economy [Internet]**. *Praia: Cabo Verde Stock Exchange*. Available from: ⟨https://www.blu-x.cv/bvcv/page6.aspx⟩ [cited 2025 Jun 18].

72. International Union for Conservation of Nature: **Achieving 30x30: the role of Nature Positive Tourism in meeting global biodiversity targets [Internet]**. *Gland: IUCN*; 2024 Sep 24. Available from: ⟨https://iucn.org/story/202409/achieving-30x30-role-nature-positive-tourism-meeting-global-biodiversity-targets⟩ [cited 2025 Jun 18].

73. United Nations Framework Convention on Climate Change: **Adaptation Fund [Internet]**. *Bonn: UNFCCC*; 2025. Available from: ⟨https://unfccc.int/Adaptation-Fund⟩ [cited 2025 Jun 18].

74. World Bank: **Accelerating blue finance: instruments, case studies, and pathways to scale [Internet]**. *Washington, D.C.: World Bank*; 2023 May 29. Available from: ⟨https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099052925003028261⟩ [cited 2025 Jun 18].

75. Northrop E, Schuhmann P, Burke L, & Godovykh M: **Opportunities for transforming coastal and marine tourism: towards sustainability, regeneration and resilience [Internet]**. *Oslo: High Level Panel for a Sustainable Ocean Economy*; 2022. Available from: ⟨https://oceanpanel.org/wp-content/uploads/2022/06/Sustainable-Tourism-Full-Report.pdf⟩ [cited 2025 Jun 18].

76. Verra: **Seascape Carbon Initiative [Internet]**. *Washington, D.C.: Verra*; 2025. Available from: ⟨https://verra.org/programs/verified-carbon-standard/seascape-carbon-initiative/⟩ [cited 2025 Jun 18].

77. European Space Agency (ESA). **Copernicus Data Space Ecosystem Browser [Internet]**. Available from: ⟨https://browser.dataspace.copernicus.eu/?zoom=5&lat=50.16282&lng=20.78613&demSource3D=%22MAPZEN%22&cloudCoverage=30&dateMode=SINGLE⟩ [cited 2025 Jun 18].

78. Parliament of the Republic of Fiji: **Climate Change Act 2021 (Act No. 43 of 2021) [Internet]**. *Suva: Parliament of the Republic of Fiji*; 2021 Sep 23. Available from: ⟨https://www.parliament.gov.fj/wp-content/uploads/2021/09/Act-No.-43-Climate-Change.pdf⟩ [cited 2025 Jun 18].

79. International Finance Corporation, World Bank Group: **Guidance for financing the blue economy: building on the Green Bond Principles and the Green Loan Principles [Internet]**. *Washington, D.C.: IFC*; 2022 Jan. Available from: ⟨https://documents1.worldbank.org/curated/en/099832306292211127/pdf/IDU0cb7d3e640d8b904d360974007f562050d2ef.pdf⟩ [cited 2025 Jun 18].

80. Convergence Blended Finance: **Blended Finance Market Overview 2023 [Internet]**. *Toronto: Convergence Blended Finance*; 2023. Available from: ⟨https://www.convergence.finance/⟩ (Access document: Blended Finance Market Overview 2023 PDF) [cited 2025 Jun 18].

81. Umaila UR, Walsh M, Hoareau K, & Zhang J: **Ocean finance: financing the transition to a sustainable ocean economy [Internet]**. *Washington, DC: World Resources Institute*; 2020. Available from: ⟨https://oceanpanel.org/wp-content/uploads/2022/05/Ocean-Finance-Full-Paper.pdf⟩ [cited 2025 Jun 18].

82. Bennett NJ, Cisneros-Montemayor AM, Blythe J, Silver JJ, Singh GG, Andrews N, *et al.*: **Mainstreaming equity and justice in the ocean**. *Front Mar Sci* 2022, **9**:873572, https://doi.org/10.3389/fmars.2022.873572/full Available from: ⟨https://www.frontiersin.org/journals/marine-science/articles/⟩.

83. Kimberley Land Council, AFPAT, and partners: **Principles & guidelines for direct access funding for Indigenous Peoples' climate action, biodiversity conservation and fighting desertification for a sustainable planet [Internet]**. *[S.l.]: AFPAT*; 2023 Feb. Available from: ⟨https://www.afpat.net/wp-content/uploads/2023/02/Indigenous-Peoples-Direct-Access-to-Funding-ENGLISH.pdf⟩ [cited 2025 Jun 18].

84. OECD: **Promoting Sustainable Ocean Economies: Ensuring adequate and effective financing [Internet]**. *Paris: Organisation for Economic Co-operation and Development*; 2024. Available from: ⟨https://www.oecd.org/en/publications/promoting-sustainable-ocean-economies_72055d7f-en/full-report/ensuring-adequate-and-effective-financing_ca28ca52.html⟩.

85. Das J, Govender M, Irfanullah HM, Selim SA, Glaser M: **Stakeholder perceptions of blue economy governance networks and their equity implications in Bangladesh**. *Mar Policy* 2024, **170**:106359, https://doi.org/10.1016/j.marpol.2024.106359

86. • Evans T, Fletcher S, Failler P, Fletcher R, Potts J: **Radical and incremental, a multi-leverage point approach to transformation in ocean governance**. *Sustain Sci* 2024, **19**:1243-1258, https://doi.org/10.1007/s11625-024-01507-4.
This article shows that both radical and incremental changes, coordinated across local, national, and international levels, are necessary to transform ocean governance from unsustainable practices to a blue economy. The authors highlight the importance of breaking down silos, improving collaboration, and reforming decision-making processes, demonstrating that effective transition depends on integrated, multi-level governance and international coordination.

87. Intergovernmental Oceanographic Commission of UNESCO: **Ocean Decade Capacity Development Facility [Internet]**. *Paris: IOC-UNESCO*; 2025. Available from: ⟨https://oceandecade.org/capacity-development-facility/⟩ [cited 2025 Jun 18].

88. Ardron J, Lily H, Jaeckel A: **Public participation in the governance of deep-seabed mining in the Area**, Chapter 16, In *Research Handbook on International Marine Environmental Law*.

Edited by Rayfuse R, Jaeckel A, Klein N. 2nd edn, Edward Elgar Publishing; 2023, https://doi.org/10.4337/9781789909081.00026

89. •• Poto M: **Thinking about Ocean Governance – By Whom, for Whom?** In *International Law and Marine Areas beyond National Jurisdiction – Reflections on Justice, Space, Knowledge and Power*. Edited by De Lucia V, Elferink A, Nguyen L. Brill; 2022, https://doi.org/10.1163/9789004506367_007.
Poto interrogates who holds power and whose interests are served in ocean governance, especially in areas beyond national jurisdiction. The chapter advocates for participatory, just, and inclusive governance, which are key for moving from traditional, top-down "grey" management to a "blue" economy that prioritises sustainability, equity, and diverse stakeholder engagement.

90. Bennett NJ, Morgera E, Boyd D: **The human right to a clean, healthy and sustainable ocean**. *Npj Ocean Sustain* 2024, **3**:19, https://doi.org/10.1038/s44183-024-00057-7

91. Kelly R, Foley P, Stephenson RL, *et al*.: **Foresighting future oceans: considerations and opportunities**. *Mar Policy* 2022, **140**:105021, https://doi.org/10.1016/j.marpol.2022.105021

92. Banking on Climate Chaos (BOCC) coalition: **The Banking on Climate Chaos: Fossil Fuel Finance Report 2025**; 2025. Available at: ⟨BankingonClimateChaos.org⟩.

93. Cisneros-Montemayor AM, Moreno-Báez M, Reygondeau G, Cheung WW, Crosman KM, González-Espinosa PC, Lam VW, Oyinlola MA, Singh GG, Swartz W, Zheng CW: **Enabling conditions for an equitable and sustainable blue economy**. *Nature* 2021, **591**:396-401, https://doi.org/10.1038/s41586-021-03327-3

94. Konar M, Ding H: **A Sustainable Ocean Economy for 2050: Approximating Its Benefits and Costs**. World Resources Institute; 2020⟨https://www.oceanpanel.org/Economicanalysis⟩.

95. UN: **5 Tipping Points for a Healthy and Productive Ocean By 2030**. United Nations Global Compact; 2019, ⟨https://www.unglobalcompact.org/library/5726⟩.

96. World Commission on Environment and Development: **Our Common Future**. Oxford University Press; 1987 Accessed 23 June 2022 ⟨https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf⟩.

97. Hammond A, Jones PJ: **Protecting the 'blue heart of the planet': strengthening the governance framework for marine protected areas beyond national jurisdiction**. *Mar Policy* 2020, **127**:104260, https://doi.org/10.1016/j.marpol.2020.104260

98. Möllmann C, Cormon X, Funk S, *et al*.: **Tipping point realized in cod fishery**. *Nat Sci Rep* 2021, **11**:14259, https://doi.org/10.1038/s41598-021-93843-z

99. Pearce-Kelly P, Altieri AH, Bruno JF, *et al*.: **Considerations for determining warm-water coral reef tipping points**. *EGU Earth Syst Dyn* 2025, **16**:275-292, https://doi.org/10.5194/esd-16-275-2025