One Earth
Perspective

The Blue Acceleration: The Trajectory of Human Expansion into the Ocean

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Does humanity's future lie in the ocean? As demand for resources continues to grow and land-based sources decline, expectations for the ocean as an engine of human development are increasing. Claiming marine resources and space is not new to humanity, but the extent, intensity, and diversity of today's aspirations are unprecedented. We describe this as the blue acceleration—a race among diverse and often competing interests for ocean food, material, and space. Exploring what this new reality means for the global ocean and how to steer it in a sustainable and equitable way represents an urgent challenge.

Introduction

The ocean has been a source of food and a venue for transport and trade essential to the development of civilization.[1] Although human activity at sea was once primarily limited to shallow coastal areas, technological advances over the past decades have rendered even the most remote parts of the ocean accessible.[2] Commercial interest in the ocean has also increased as land-based sources become fully exploited or exhausted, because of continued population growth and increasing per capita consumption in many parts of the world.[3] As a result, costly endeavors such as commercial mining of the deep seabed are now considered not only feasible but imminent.[4] Likewise, the search for novel bioactive compounds to address antimicrobial resistance is increasingly focused on remote deep-sea microorganisms,[5] whereas space constraints on land have contributed to the construction of large-scale offshore wind farms and investment in deep-water installations.[6]

The subsequent recognition of the ocean as a new economic frontier, which covers more than two-thirds of the Earth's surface, has led to considerable investments that are driving growth in existing industries and the emergence of new ones, spanning an increasingly diverse range of activities.[7] In parallel, scientists and civil society organizations have called for exploration before exploitation[8] and looked to the ocean as key for achieving climate and broad societal goals.[9] Consequently, the hopes and expectations for the ocean to sustain future human needs are increasing and have become ubiquitous (Table S1).

As the capacity to industrialize the ocean grows, marine ecosystems face unprecedented cumulative pressures from human activities and climate change.[10–12] Ocean acidification, marine heatwaves, plastic pollution, and ecological connectivity all transcend political boundaries, making the sustainable governance of marine resources a uniquely international responsibility.[13–16] The rhetoric of a "blue economy" that would combine economic growth with sustainable use is increasingly finding its way into national and international policy documents.[17] Yet this is unfolding in a complex and uncertain governance landscape,[18,19] and concerns have been raised over competing interpretations of what the blue economy entails, and who it is supposed to benefit.[20,21]

Here, we synthesize and assess the trajectories of multiple ocean claims with relevance for ecosystem sustainability, human well-being, and economic growth. We review their impacts and use case descriptions to illustrate the diversity of ocean claims, their complex interactions, and the associated risks. Finally, we propose how academics, policy makers, and practitioners can help to reconcile the diversity of ocean aspirations, accommodate these within biosphere limits, and ensure they are aligned with international commitments to promoting equity.

Ocean for Food, Material, and Space

The capacity to maintain a healthy ocean for the well-being and prosperity of current and future generations hinges on understanding the new global ocean context and unpacking the diversity of existing claims (Figure 1). Traditionally, scientists and policy makers have looked at impacts or individual industries,[7,12,22] but a focus on claims makes it possible to account for a wider array of uses, expectations, and societal values attached to the marine environment. It also helps to anticipate human action before the impacts unfold. A comprehensive review of ocean claims is found in Note S1; we summarize them below under three fundamental needs for humanity: food, material, and space (Figure 1).

Ocean for Food

The seas have been an important source of food for coastal communities through the provision of fish, shellfish, mammals, marine reptiles, seabirds, and seaweed for millennia.[23] Over the past half-century, however, increasing demand and technological progress have enabled rapid industrialization of the fishing and aquaculture sectors.[12,24]

Since the 1960s, seafood has been the world's fastest-growing food industry, and fish has become one of the most-traded food commodities.[25] The seafood sector is the largest employer among ocean-based industries, providing millions of jobs and a vital source of proteins and micronutrients to billions of people.[7,25] Not only is fish increasingly regarded as a critical component of global food and nutrition security,[24] it is also one of the only sources of animal protein, depending

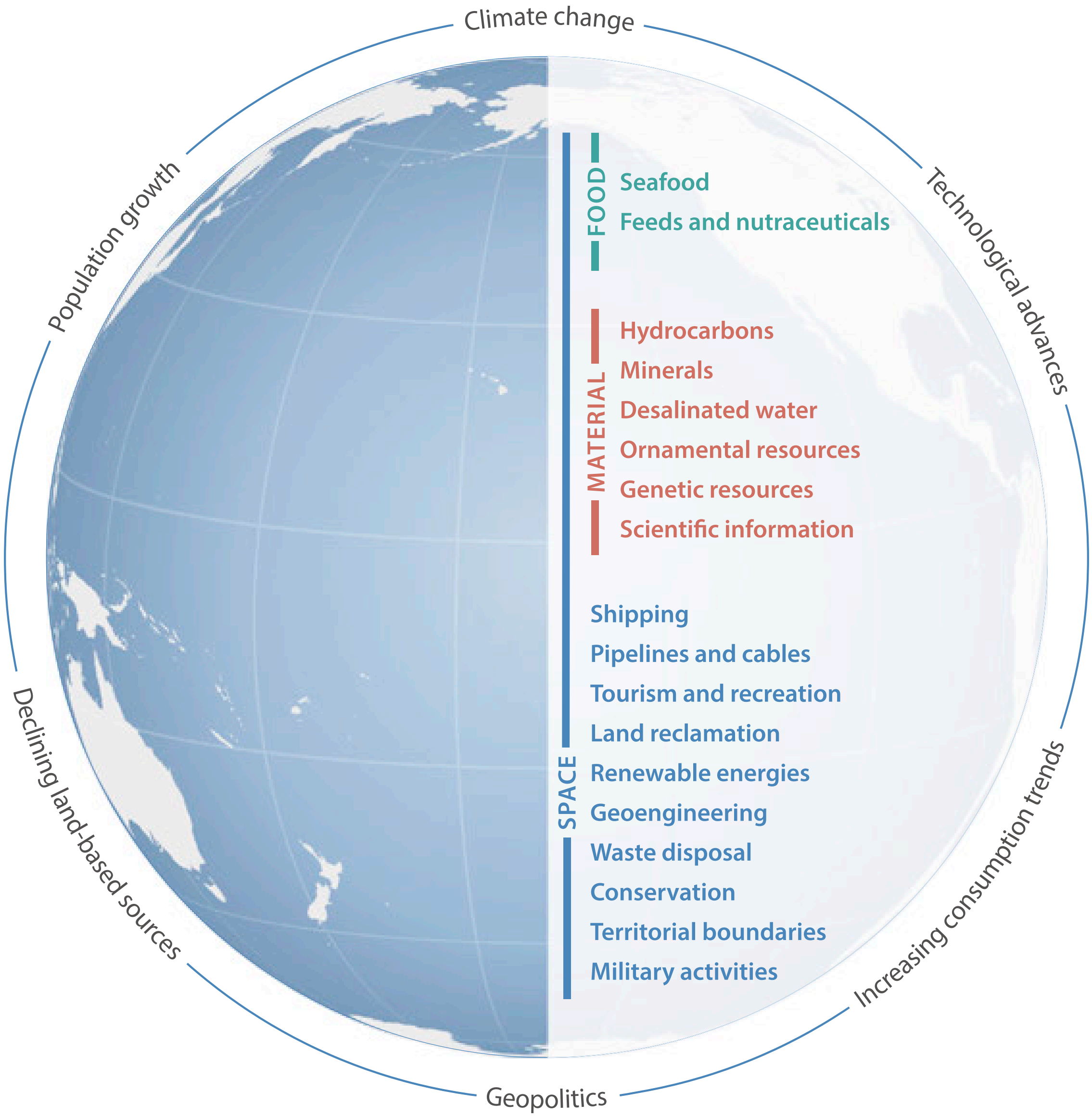


Figure 1. Ocean Claims
The ocean is increasingly regarded as an engine of present and future human needs for food, material, and space. Claims were identified and categorized through an iterative process aimed at understanding ocean uses of direct relevance for ecosystem sustainability, human well-being, and economic growth. Around the globe are some of the key distal drivers shaping this new global ocean context. See Note S1 for methodology and details on each claim.

on the species and how it is produced, for which further growth in global consumption is deemed possible within environmental limits.[26]

Wild-capture volumes peaked around the late 1990s and have remained stagnant since then (Figure S1), despite fish being caught at greater depths[27] and farther distances.[28] Future potential for increasing wild harvest lies in improved management of stocks[29] and the exploitation of untapped resources such as fish occupying lower trophic levels or mesopelagic populations.[30,31] In contrast, both the number of aquatic organisms domesticated for farming and their production volumes have dramatically increased over the past decades[32] (Figure S1). Marine aquaculture is expected to further expand in coastal and offshore areas, as limitations on aqua-feed supply are addressed, and with the development of regional socio-economic and technological capacity.[33–35]

The ocean also contributes indirectly to human nutrition when fisheries products, such as fishmeal and fish oil, are used as key ingredients in animal feeds for aquaculture and livestock.[36] A recent analysis estimated that 27% of marine fisheries landings from 1950 to 2010 were destined for uses other than direct human consumption.[37] Investments in alternative feed sources have also led to the development of new transgenic oilseed crops based on sequences from microalgae,[38] while the range of ocean products used as nutraceuticals has seen a rapid expansion.[39] Combining the terms nutrition and pharmaceuticals, nutraceuticals are foods containing bioactive molecules with health benefits that extend beyond nutritional value. Marine nutraceuticals, such as omega-3 fatty acids from krill, represent an increasingly large portion of the global nutraceutical market, expected to reach USD 385 billion by 2020.[40,41]

Ocean for Material

Materials derived from the ocean encompass a range of abiotic, biotic, and intangible resources (Figure 1, Note S1). The combination of increasing global demand, technological progress, and declining land-based sources have made extraction of a growing number of ocean materials not only feasible but economically viable. The associated industries are characterized by high levels of anticipation for future growth as well as high entry costs.[42]

Accounting for one-third of the total value of the ocean economy, the oil and gas sector is the largest ocean-based industry.[7] Nearly 70% of the major discoveries of hydrocarbon deposits between 2000 and 2010 happened offshore, and as shallow-water fields become depleted, production is moving toward greater depths (Figure S2). In addition, the seafloor holds the promise of vast quantities of natural gas hydrates, which are evenly distributed across the planet and are estimated to represent twice as much organic carbon as the world's coal, oil, and other forms of natural gas combined.[43]

Aggregates such as sand and gravel have become the most mined minerals in the marine environment because of increasing global demand from the construction industry.[44] Likewise, the surge of interest in minerals from the deep sea is linked to a growing demand for metals to sustain the development of high-tech products, including those needed for a low carbon future.[45,46] Exploratory mining licenses have been granted for more than 1.3 million km^2 of the seabed in areas beyond national jurisdiction, and exploitation regulations are expected to be approved within the next 2 years.[46] Desalination of seawater has also gained attention in the context of escalating freshwater scarcity due to climate change and coastal urbanization.[47] Desalination facilities worldwide include about 16,000 operational plants with a global capacity of more than 95 million m^3 per day.[48] 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 have the advantage of being mobile.

Interest in the ocean goes beyond resources that are declining on land to also include the exploration of new frontiers and extraction of material unique to the ocean, such as ornamental species and marine genetic resources.[49,50] Ocean biodiversity is of particular interest for bioprospecting because many organisms have evolved to thrive under extreme conditions of pressure, temperature, salinity, or darkness, making their genetic code the subject of commercial interest for a wide range of industries (e.g., pharmaceuticals, nutraceuticals, chemicals).[38,51] Enabled by advances in sampling technologies and remotely operated vehicles, over 34,000 natural products have been described from species found in the ocean (http://pubs.rsc.org/marinlit/). Commercial uses of genetic resources are closely linked to, and in many cases reliant upon, the non-commercial research that has produced vast databases of genetic sequence data[52] and continues to generate knowledge from the ocean.[53]

Ocean for Space

Claims on ocean food and material—facilitated by infrastructure such as fishing boats, aquaculture farms, offshore platforms, and deep-sea mining equipment—all require space in the ocean. However, the ocean space also provides the basis for a multitude of activities at sea that do not involve the extraction of food or material (Figure 1, Note S1).

From the spread of ideas to early trade routes, the ocean has been and still is central to globalization. The introduction of container shipping in the late 1960s revolutionized maritime transport, which now accounts for over 80% of global trade by volume and more than 70% of its value.[54] Likewise, 1.3 million km of undersea fiber optic cables carry 99% of international telecommunications, offering more reliability, speed, capacity, and cost advantages than satellite communications.[55] Submarine pipelines, too, have rapidly expanded to keep up with the development of the global offshore oil and gas industry.[56]

Ocean space is also inherently needed for marine and coastal tourism, the second largest employer in the ocean economy and one of the fastest-growing segments of the world's tourism industry.[7,57] More than 40% of the global population lives in areas within 200 km of the ocean, and 12 of 15 megacities are coastal.[58] As the population, economic activity, and urbanization keep increasing in coastal areas, land reclamation has become critical to resolve land shortages and accommodate the increasing need for urban and industrial spaces.[59,60] China, in particular, is leading the world in large-scale reclamation projects, extending its coastline by hundreds of square kilometers every year.[61]

Marine renewable energies derived from wind or waves are among the solutions with the greatest potential for meeting the increasing global energy demand while reducing carbon emissions.[62–64] The majority of turbines and large-scale wind farms have been installed close to shore but recent studies indicate the possibility of even greater wind power generation over open ocean areas, spurring the development of technologies to harvest wind energy in deep water environments.[6] In addition, and despite being much debated, marine geoengineering is increasingly suggested as a way to sequester carbon, either in the sub-seabed or via ocean fertilization.[65,66] This is a special case of ocean dumping, otherwise supposedly restricted to dredged material, fish waste, and human-made structures.

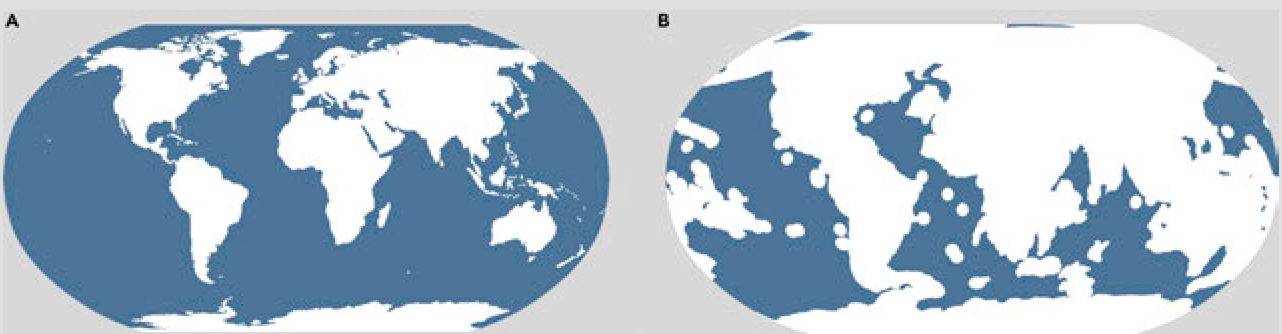
Spatial claims on the ocean also aim at limiting resource exploitation, most prominently through the designation of marine protected areas.[67] Coastal states have committed to safeguard at least 10% of the marine environment by 2020, while scientists and non-governmental organizations have begun calling for a more ambitious coverage of at least 30%.[68,69] Likewise, the notion of sense of place and the recognition of the esthetic, cultural, spiritual, indigenous, and otherwise non-monetary values associated with the sea are becoming increasingly visible in academic debates and policy processes.[70,71] Finally, the ocean space is highly geopolitical, because it is codified into different maritime jurisdictions (Figure S3) and offers an arena for nations to assert their influence and engage in military activities.[72] The prospect of commercial exploitation of the seabed, for instance, has recently led many countries to claim extended rights of national sovereignty over ocean space, with each granted claim diminishing the area designated as the common heritage of humankind (Box 1).

Box 1. Seabed Grabbing

One of the most significant geopolitical transformations in recent times is occurring in the ocean depths.[73] Article 76 of the United Nations Convention on the Law of the Sea (UNCLOS) allows countries to claim an extended continental shelf to explore and exploit the resources of the seafloor beyond the 200 nautical miles of their exclusive economic zone.[74,75]

Since the first claim was made by Russia in 2001 concerning the Arctic region, submissions or preliminary information from a total of 83 countries have been sent to the UN Commission on the Limits of the Continental Shelf, together encompassing more than 37 million km^2 of the seafloor (Note S1). This is more than twice the size of Russia—the world's largest country—and nearly 80 times the reported global area of "land grabs" since 2000 (www.landmatrix.org). In many cases, the territorial basis of a state is made of more seabed than land. Small island developing states are indeed becoming large ocean states. The Cook Islands, for instance, has claimed an area of extended continental shelf equivalent to 1,700 times its land surface. Countries that include islands and overseas territories are benefitting in particular from Article 76. Remarkably, Australia was able to secure more than 2.5 million km^2 of additional seabed thanks to Heard Island and the McDonald Islands, two uninhabited territories of 368 and 2.5 km^2, respectively.[76]

This recent surge in submissions has also given rise to several overlapping claims, adding an extra dimension to maritime disputes and foreshadowing the need for future negotiations on boundary delimitation agreements.[77,78] Overall, the expansion of national sovereignty rights over maritime space raises issues of equity and benefit sharing since only a limited number of states have access to an extended continental shelf, and every claim happens at the expense of the area of the seabed and subsoil located outside national jurisdiction. The extension of the continental shelf is therefore not only transforming the geopolitical landscape, it is also substantially shrinking the area designated as the common heritage of humankind.



The figure shows (A) landmass under national jurisdiction versus (B) landmass and seabed under national jurisdiction. The expansion of rights of national sovereignty over maritime space, including exclusive economic zones and claimed extended continental shelves, happens at the expense of the global ocean commons. Based on the extended continental shelf claims submitted as of 2019, only 48% of the seabed would remain as humanity's shared inheritance. Note the exception of Antarctica, currently governed under the international Antarctic Treaty System and for which claims are made in anticipation of 2048 when the treaty will become modifiable. See Note S1 for details and data sources.

Claiming the ocean for food, material, and space is not new to humanity, but the current rush for the ocean is unfolding with unprecedented diversity and intensity. We describe this as the blue acceleration (Figure 2), a new phase in humanity's relationship with the biosphere, where the ocean is not only crucial for sustaining global development trajectories but is being fundamentally changed in the process.

The Blue Acceleration

The multitude of claims that collectively illustrate the blue acceleration exhibit a phenomenal rate of change over the last 50 years, with a sharp acceleration characterizing the onset of the 21st century (Figure 2). With claims extending across renewable and non-renewable resources, and entailing both mobile and stationary activities, the blue acceleration is intensifying the pressure on the ocean (Table S2) and leading to a range of synergistic, antagonistic, and additive interactions between claims.[2,79–81] For example, offshore hydrocarbon operations have an impact on wild-capture fisheries through the displacement of fish stocks and altered fish biochemistry,[82] submarine pipelines and cables prevent trawl fishing, and large offshore wind farms may conflict with coastal tourism and recreational activities. In other situations, claims can benefit from each other, such as marine research enabling bioprospecting,[83] or the establishment of marine protected areas increasing fish biomass and potential catch gains in neighboring areas.[84]

As the blue acceleration unfolds, the impacts of claims will increase (Table S2) and new dynamics will emerge. Below, we use case descriptions to illustrate different aspects of how the blue acceleration manifests and what this implies for the emergence of new challenges and interconnected risks.

Case 1: Local Optimization

Many highly industrialized countries of the world are primarily focused on optimizing marine spatial planning while mitigating the inherent conflict potential related to different overlapping ocean claims. An illustrative example is the North Sea and Skagerrak management area around the southern tip of Norway. It is

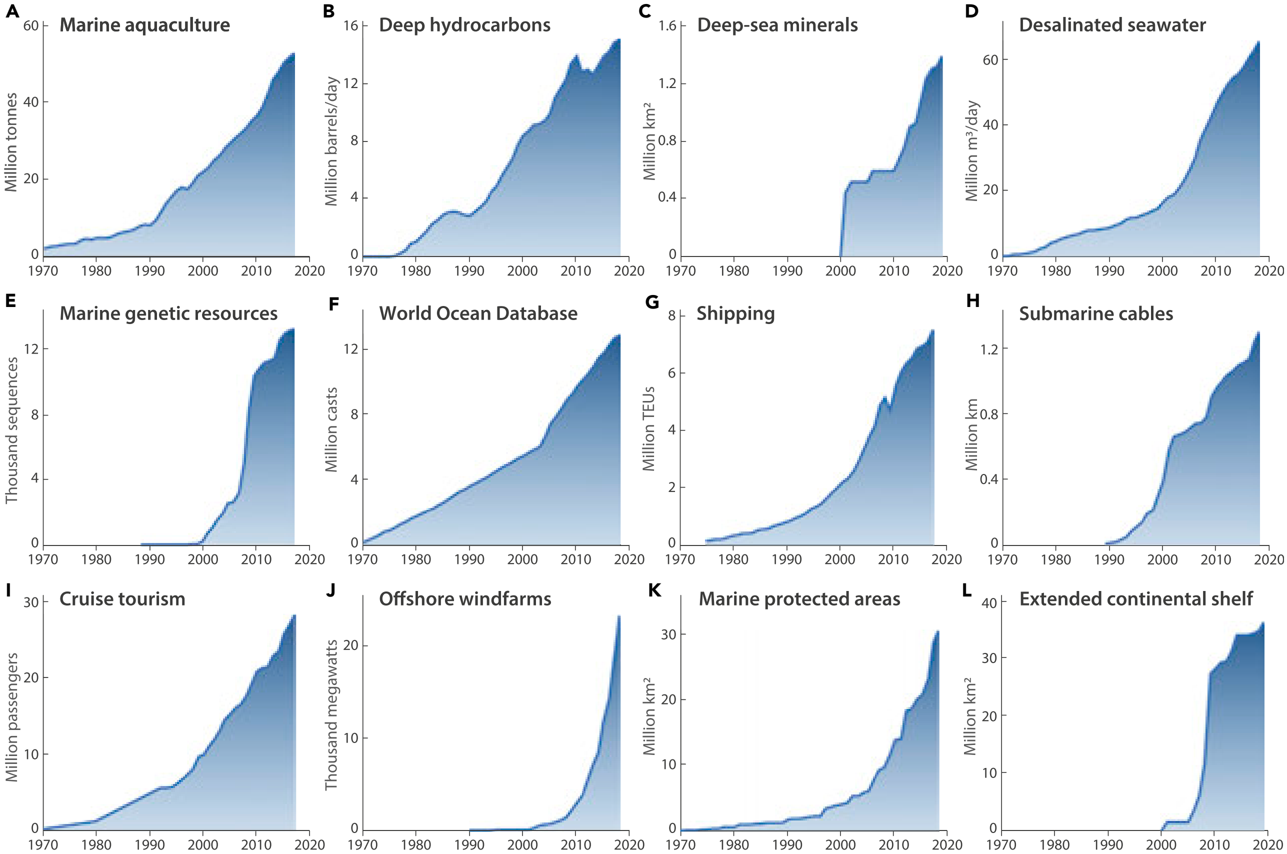


Figure 2. The Blue Acceleration

Global trends in (A) marine aquaculture production; (B) deep offshore hydrocarbon production, including gas, crude oil, and natural gas liquids below 125 m; (C) total area of seabed under mining contract in areas beyond national jurisdiction; (D) cumulative contracted seawater desalination capacity; (E) accumulated number of marine genetic sequences associated with a patent with international protection; (F) accumulated number of casts added to the World Ocean Database; (G) container port traffic measured in Twenty-Foot Equivalent Units (TEU); (H) total length of submarine fiber optic cables; (I) number of cruise passengers; (J) cumulative offshore wind energy capacity installed; (K) total marine area protected; (L) total area of claimed extended continental shelf. See Note S1 for details and data sources.

among the world's most heavily trafficked regions, its waters sustain major commercial fish populations, its coastline fosters globally important aquaculture and cruise tourism industries, and its seabed contains large oil and gas reserves.[85] Although the offshore hydrocarbon industry tops the list in economic terms, oil and gas operations are recognized to have the potential to have a negative impact on shipping, capture fisheries, tourism, and aquaculture.[86] In some cases, governance tools have been able to manage conflict risk. New traffic separation rules, for instance, have helped to minimize damage to fixed fishing gear and collisions between shipping and fishing vessels.[86]

A risk linked to local optimization efforts is the tendency for industries to embark on ambitious individual growth trajectories that threaten to collectively exceed the capacity of the ocean and result in the inequitable distribution of harms and benefits. The Norwegian government, for instance, is aiming for a 5-fold increase in salmon production by 2050,[85] although the aquaculture industry is already constrained by a lack of production spaces and the fishing sector is concerned about existing farming operations because of pollution, sea lice outbreaks, and escaped salmon mixing with wild populations.[85,87] Likewise, Norway's cruise tourism industry has grown for the last 15 years at an annual rate of 9% and is preparing for a 5-fold increase in visitors by 2030.[88] Oil and gas production is expected to continue growing for the next 5 years, while in June 2019, floating offshore wind farms were proposed off the southern tip of Norway to quadruple the country's wind power capacity,[89] and in September 2019, massive sulfide deposits rich in metals and minerals were found on Norway's continental shelf.[90] Precautionary approaches by individual industries can reduce risk, but the saturation of ocean space and tendency toward optimization render such areas particularly vulnerable to shocks.[3]

Case 2: New Frontiers

The race to claim the ocean is extending even to its most remote areas. Consider, for instance, the scaly-foot snail (*Chrysomallon squamiferum*), which was first discovered in 1999, named in 2015, and by July 2019 had already been placed on the Red List of Threatened Species by the International Union for Conservation of Nature.[91] Found more than 2,400 m beneath the ocean's surface, on just 3 deep-sea hydrothermal vent systems that collectively cover an area of 0.02 km^2, the scaly-foot snail's future was deemed threatened when two of these vent systems fell within exploratory mining leases granted by the International Seabed Authority (ISA) to Germany (2015–2030) and China (2011–2026) to mine seafloor massive sulfides, rich in gold, silver, copper, zinc, and lead.[46,92] The ISA's mandate is limited to managing the resources of the seabed beyond national jurisdiction and therefore does not extend to the third vent system located within the exclusive economic zone of Mauritius.[92] Because of its unique trilayered natural armor, the scaly-foot snail has been the focus of biomimicry research funded by the US Department of Defense,[93] and 118 sequences from its genome have been deposited in GenBank, an open-access database of nucleotide sequences that serves as a reference point for the biotechnology industry.[94]

The claims on the scaly-foot snail therefore extend from its surrounding habitat to its physical form and genetic information through to its own existence. This example illustrates several dynamics of the blue acceleration. All the metals found in seafloor massive sulfides can be mined on land, but demand for use in high-end electronics and a decline in the ore quality of land-based sources have caused the commodity values to rapidly increase since 2000 (e.g., gold, +454%; silver, +317%; copper, +360%; zinc, +259%; lead, +493%), making seabed mining a viable commercial prospect.[95,96] Contrary to the precautionary principle, exploitation is proceeding ahead of exploration,[8] with mining licenses granted prior to a consensus on how to mitigate environmental impacts of mining, and despite the three hydrothermal vent systems (Solitaire, Kairei, and Longqi fields) not yet having been studied in detail.[92] Finally, because of the placement of claims and the complexity of territorial boundaries, the survival of the scaly-foot snail moved within 5 years from a responsibility of the global community to the responsibility of three countries: China, Germany, and Mauritius.

Case 3: Global Consequences

Local or regional claims can also generate global consequences. In the South China Sea, for example, competing territorial claims have been the focus of military activity and geopolitical concern. Sovereign rights over the sea's rich natural resources and fishing grounds are disputed by Brunei, China, Malaysia, the Philippines, Taiwan, and Vietnam. More than half of the world's fishing vessels operate in the South China Sea; it is a major node in the network of undersea telecommunication cables, and an estimated one-third of global maritime traffic passes through the region, carrying some USD 3.4 trillion in goods annually.[97,98] A spike in insurance costs or the rerouting of even a portion of this trade due to the risk of armed conflict would have far-reaching consequences for the global economy and international order.[98]

Looking beyond geopolitical conflicts, the situation has also had widespread ecological impacts. In recent years, satellite imagery has revealed the scale of land reclamation in the South China Sea to increase the size of existing islands or create new ones altogether.[99] One archipelago—alternately referred to as the Paracel, Hoàng Sa, and Xisha Islands—includes 130 coral islands and atolls with a land mass of 7.75 km^2. Over the past decade, an additional 13 km^2 of land has been reclaimed across the archipelago, tripling its land area, and resulting in 20 habitable outposts with infrastructure such as wind turbines, helipads, and harbors.[100] Often militarized for strategic importance, these outposts have also facilitated a range of other claims, including industrial fishing, scientific activity, and hydrocarbon exploration.[101] Large-scale land reclamation in the South China Sea could be contributing further to the regional decline of fish stocks, down by 70%–95% since 1950,[102] because of increased access to fishing grounds and modification of the island mass effect, whereby coral islands and atolls generate areas of high biodiversity and phytoplankton density.[103,104] The conversion of coral atolls to human settlements also coincides with the almost complete disappearance of seabirds from the archipelago, although it sits in the middle of the East Asian-Australasian Flyway, which includes the most threatened or near-threatened species of any of the world's migratory routes.[105]

Unknown Consequences

As the ocean space becomes progressively saturated by different claims, interactions and conflicts among them intensify, paving the way for new risks to emerge and regime shifts to occur.[106] These large and abrupt transitions can have persistent consequences and exhibit cascading behaviors that have been likened to domino effects.[107] Because of their complex and non-linear nature, such risks are rarely accounted for in the pursuit of optimizing individual claims. This creates conditions for unknown thresholds to be crossed and suggests that, in an increasingly connected world, limits to the blue acceleration could be set by emerging systemic risks rather than predictable finite limits of ocean claims.[3]

The blue acceleration is also occurring within a highly dynamic and changing context.[108,109] Climate change is already driving fish species migrations to higher latitudes and into new jurisdictional areas,[110] forcing aquaculture to move where environmental conditions are more favorable,[35] and opening up new areas for claims to be made, such as drilling for hydrocarbons and new shipping routes as a result of the contracting Arctic ice sheet.[111,112] Likewise, changes in the geopolitical and governance landscape (e.g., China's maritime Belt and Road Initiative, renegotiations of the Antarctic Treaty) have the potential to dramatically reshape the blue acceleration. As opportunities arise and close in a rapidly evolving and unpredictable ocean context, the future will also require confronting claims that we know little about or that are yet to emerge (Box 2).

Stewardship of the Anthropocene Ocean

A once-popular view that the ocean—unlike the continents—was simply too big to be affected by human actions has been replaced by the reality of the Anthropocene Ocean,[124] in which the ocean is neither "too big to fail nor too big to fix, it is too big to ignore."[125] Although the relevance of the ocean for humanity's future is undisputed, addressing the diversity of claims, their impacts, and their interactions, will require effective governance.

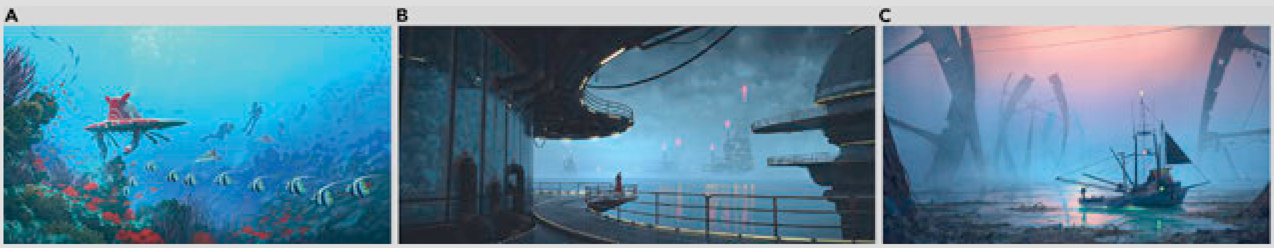
Numerous governance bodies and institutions exist with mandates and aspirations that could seem well-suited for navigating the blue acceleration (Table S3). Conservation and sustainable use of the ocean and its resources, for example, is a recurrent theme throughout the United Nations Convention on the Law of the Sea (UNCLOS), considered the Constitution of the ocean. Likewise, Sustainable Development Goal 14 is dedicated to Life Below Water and a commitment to "protect, and restore, the healthy productivity and resilience of oceans and marine

Box 2. Envisioning Ocean Futures

Anticipating how the blue acceleration will unfold presents a formidable challenge. Projecting the future of complex phenomena by extrapolating current trends is notoriously uncertain.[113] Highly unpredictable events are likely to occur,[114] while ideas, practices, and technologies that are marginal today may become dominant features of the future.[115] Consider, for instance, nascent phenomena such as floating cities,[116] autonomous maritime transport,[117] and underwater hydroponics[118] or data servers.[119]

Recent innovations in scenario planning can help deal with this uncertainty and complexity. A scenario is a plausible and simplified description of how the future could develop, based on a coherent and consistent set of assumptions about key driving forces and their relationships. Although the majority of marine scenarios have focused on climate change and the associated oceanographic and ecological consequences,[11] we argue that the challenges posed by the blue acceleration require more creative and dynamic ways of envisioning the future. Science-fiction prototyping methods, for example, have been applied to explore radical ocean futures that incorporate major surprises (e.g., tipping points) and involve co-evolutionary dynamics of integrated social-ecological systems.[120]

Participatory scenarios are another tool that has been used to identify and analyze the role of existing, but currently marginal, drivers of change in shaping the future.[121,122] However, most of this work has been conducted in the terrestrial domain. Applying participatory scenarios to the ocean, therefore, holds great potential for bringing about novel transformative pathways toward improved ocean governance and sustainability. Importantly, the inclusion of diverse stakeholders in the process of scenario creation can foster collective action to achieve common goals.[123] In the context of the blue acceleration, this means co-producing scenarios with a broad coalition of actors from industries, governments, local communities, non-governmental organizations, financial institutions, and natural resource managers. Such approaches would improve our collective capacity to not only envision but also shape a more sustainable and equitable future ocean.



The figure displays illustrations of three ocean scenarios developed in Merrie et al.[120] by applying science-fiction prototyping to incorporate and extrapolate from existing marine environmental, technological, social, and economic trends: (A) Oceans back from the brink, (B) FISH Inc., and (C) Rime of the last fisherman. Read the stories at www.radicaloceanfutures.earth. All images are copyright of Simon Stålenhag and reproduced with permission.

ecosystems to maintain their biodiversity, enabling their conservation and sustainable use for present and future generations […] to deliver on all three dimensions of sustainable development.''

Yet cumulative human impacts on marine ecosystems have continued to increase across most of the ocean.[10] UNCLOS, its implementing agreements, and associated sectoral bodies, as well as coastal states, which are granted broad autonomy over the management of marine resources within their jurisdictions, have all struggled to realize this balance of conservation and sustainable use. For instance, the proportion of commercial fish stocks that are overfished has tripled over the past 40 years,[25] and competing claims over maritime territory and fishing quotas have resulted in conflicts for which traditional governance has proven poorly adapted.[126] Despite becoming the first of the Goals to have its own exclusive international conference, recent policy surveys also indicate that Goal 14 is systematically the least prioritized,[127] regardless of the nature of the respondents (e.g., government, development partner, private sector, non-governmental organization) and although reaching its targets would carry substantial co-benefits for achieving many of the other Goals.[128]

An additional hurdle for ocean governance is that almost two-thirds of the ocean lies beyond national jurisdiction, where activities are governed by a patchwork of sectoral organizations.[129] Notable governance gaps include the lack of a mechanism to create marine protected areas and the absence of regulations on access to marine genetic resources or the definition of subsequent benefit-sharing obligations.[129] International negotiations aimed at closing these and other governance gaps for biodiversity in areas beyond national jurisdiction (BBNJ) have been underway since 2005, with the prospect of a final agreement entering into force still years away. However, the UN General Assembly decision to narrowly define the mandate of the BBNJ negotiations and to bar negotiators from ''undermining'' the mandate of existing sectoral bodies raises questions about the extent to which any eventual treaty will affect the blue acceleration. The slow pace of international policy making also suggests that few new legal tools will be available in the near future to steer the blue acceleration toward more sustainable trajectories.

With the UN Decade of Ocean Science for Sustainable Development set to begin in 2021,[130] we call attention to four future challenges for the academic, policy, and practice communities. First, although the ocean is often considered a single unit in both aspirational and cautionary narratives, it is highly heterogeneous from biophysical, social, and legal perspectives. Confronting the challenges associated with the blue acceleration therefore requires improved knowledge on where the claims are being made, the extent of resources available, and the stakeholders that will be affected. The framework we present here provides a systemic view of multiple ocean claims and trends over time, but corresponding analyses of their interactions, possible trade-offs, and social-ecological consequences remain to be done. This would allow for the mapping of areas of potential overlap and help inform the design of integrated governance structures, such as dynamic marine spatial planning.[131]

Second, greater attention should be directed to the actors placing the claims. Previous investigations have documented a high degree of consolidation among nations and companies involved in the global seafood industry[132,133] or in the patenting of marine genetic resources.[38] Identifying and engaging key corporate actors behind ocean claims would allow capitalizing on the increasing appetite of the private sector to consider biosphere stewardship.[134,135] A reflection of this is the expanding universe of sector-specific industry-led voluntary initiatives (Table S3) and initial efforts to encourage cross-sectoral engagement, as seen for instance in the UN Global Compact Sustainable Ocean Business Action Platform.[136] Although the effectiveness of such voluntary environmental programs is contingent among other things on rigorous monitoring and sanctioning mechanisms,[137] it is unclear how representative they are with regard to the actors of the blue acceleration. Their voluntary nature also underscores the need for more research to ensure that industry initiatives and voluntary programs contribute to evidence-based decision making that explicitly addresses social inclusion and equitable outcomes.[138,139]

Third, a focus on who and what is financing the blue acceleration could unlock powerful leverage points.[140,141] Incorporating more stringent sustainability criteria into ocean finance, be it from governments,[142] philanthropies,[143] insurance brokers,[144] banks or stock exchanges,[141] would redirect capital toward improved practices and accelerate action for a sustainable ocean economy. Blue bonds and other impact investment tools have emerged in recent years, but they represent only a small portion of financial flows. Although The Principles for Responsible Banking[145] or The Sustainable Blue Economy Finance Principles[146] suggest that the financial sector is starting to embrace its potential to steer businesses toward sustainability, operationalizing the principles remains a challenge. As pressures on the ocean mount, systematic social and ecological screening needs to become the norm for mainstream financial mechanisms (e.g., credit lending), in the same manner as is currently the case for financial auditing.[141]

Fourth, concerns have been raised over who is to gain from the blue acceleration. Benefits disproportionately flow to economically powerful states and corporations, whereas harms are largely affecting developing nations and local communities.[139,147,148] The vulnerability of small-island developing states and least-developed countries to the impacts of climate change faces the risk of being further augmented. Consequently, a growing number of studies are highlighting the need for social and equity issues to be considered on par with environmental concerns in discussions about ocean futures.[21,139,147,149] Navigating the blue acceleration in a just and sustainable way requires a particular emphasis on the equity implications of increased ocean use across the globe, and how these multiple claims could have an impact on the economic safety and well-being of vulnerable communities and social groups.

Conclusion

The opportunistic nature of human enterprise has continuously pushed the frontiers of exploration, responding to demand and outpacing regulatory changes, often at the expense of local communities and the environment. From the shoreline to the deep sea, the blue acceleration is already having major social and ecological consequences. Safeguarding ocean sustainability in times of rapid change will require transdisciplinary efforts to guide the activities and incentives of governments, corporations, and civil society toward ocean stewardship.[150] 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.

SUPPLEMENTAL INFORMATION

Supplemental Information can be found online at https://doi.org/10.1016/j.oneear.2019.12.016.

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AUTHORS CONTRIBUTIONS

J.-B.J. and M.N. conceived the original idea. J.-B.J. collected the data and led the writing. All authors contributed to the development and writing of the paper.

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