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Mapping Global Transformations

Briefing
Oceans

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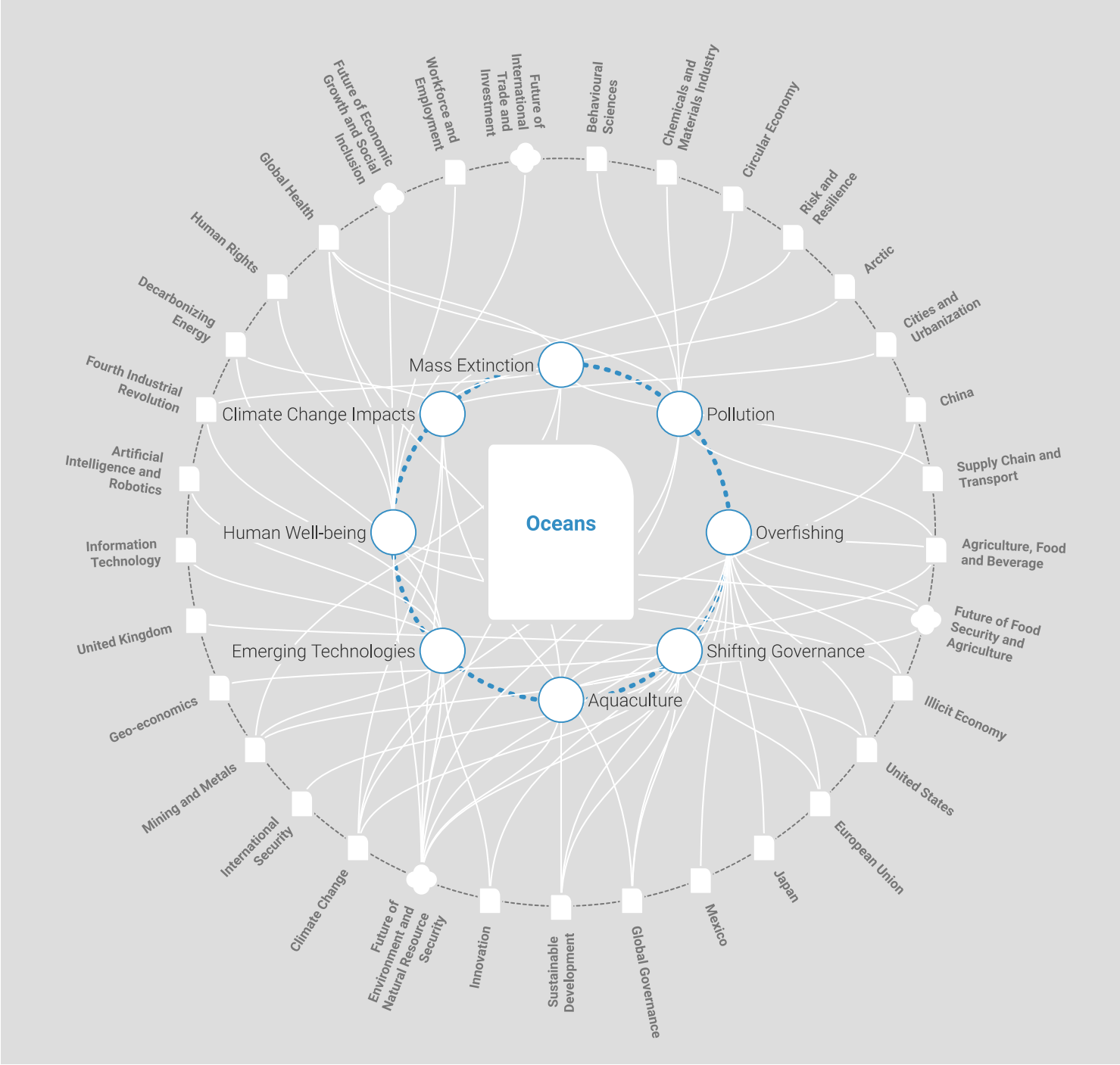
Mapping Global Transformations

At the Annual Meeting 2015, the World Economic Forum introduced Transformations Maps as part of its comprehensive knowledge platform. By drawing on the collective intelligence of the Forum network, Transformation Maps allow users to explore the connections between industry, regional and global issues, and thus better understand the forces shaping our world.

Insight briefings provide an overview of these issues, highlighting the most relevant developments, and tracking how they change over time. They are continuously updated with the latest thinking of the leaders and experts across the Forum network, and with insight areas from Forum meetings, projects communities and activities.

Key Issues

The most important developments within this field.



Emerging Technologies

New technologies are opening up opportunities for the ocean industry but also present challenges

Emerging technologies are changing the way we harvest food, energy, minerals, and data from the ocean. This includes rapid innovation in marine robotics, artificial intelligence, low-cost sensors, satellite systems, and methods for collecting and using ocean big data. Some of these disruptive marine technologies can help us navigate towards a cleaner and safer future for our oceans. Others could themselves represent new challenges for ocean health.

Protecting the vitality of the oceans and our economic stake in them will require markedly slowing climate change. The oceans themselves may be part of the solution. The oceans are an enormous storehouse of green energy that we are just beginning to plug into. This includes possibilities in wave, offshore wind, tidal and thermal energy. Ocean thermal energy conversion technology, which exploits the temperature difference between shallow tropical waters and the deep sea to generate electricity, was successfully implemented in Hawaii last year at its largest scale yet. Offshore wind capacity has grown over 2300% globally in the period 2000-2015, according to a 2015 report by the Global Wind Energy Council. The next hurdles are scaling up and making ocean energy harvest cost-efficient.

Ocean mining is another tech-driven emerging industry. Portions of the seafloor are rich in rare and precious metals like gold, platinum, cobalt, and rare earth elements. These marine mineral resources have, up until now, lain mostly out of reach. New 300-ton waterproof mining machines were recently developed that can travel to some of the deepest parts of the sea to mine these metals. Over a million square kilometres of ocean have been gazetted as mining claims in the Pacific, Atlantic and Indian oceans, and extraction may begin as early as 2017. Mining the seafloor for these resources without destroying critical deep sea ecosystems remains an important challenge that must be solved.

Just as in other sectors of life, the oceans are now teeming with new data. Multiple organizations and companies, for example, are collecting and processing billions of data points of publically accessible information coming off of large oceangoing vessels. This data is being harnessed to detect illegal fishing, empower sustainable companies to connect with consumers, to promote maritime security, and help build intelligent zoning plans that better balance the needs of fishermen, marine transport and ocean conservation.

Myriad other exciting innovations are also emerging: a robot that swims like a tuna; underwater data centres; autonomous self-driving ships; coastal sensor systems that text alerts about sharks in swimming areas; and geodesic spheres that serve as offshore fish farms. Properly embraced disruptive ocean technologies will help us successfully take more from the ocean while simultaneously damaging them less.

Related Insight Areas: Information Technology, Artificial Intelligence and Robotics, Fourth Industrial Revolution, Decarbonizing Energy, Innovation, Mining and Metals, Climate Change, Future of Environment and Natural Resource Security

Overfishing

Unsustainable fishing is removing fish from the sea faster than they can be replaced

The famous scientific philosopher and former President of the Royal Society Thomas Henry Huxley remarked in 1883 that it was impossible to deplete populations of prolific fishes like cod, mackerel and herring. Within about 100 years these predictions were proven unambiguously wrong. The Food and Agriculture Organization of the United Nations' 2016 *The State of World Fisheries and Aquaculture* report estimates that almost a third (31.4%) of global fish stocks are overfished. Stock collapses have been observed in both more and less developed nations.

Overfishing is an unfolding tragedy of the commons. Because fish are often managed as a communally owned resource, fishers often adopt the philosophy that any fish they fail to harvest will be taken by others. A research published in the May 2016 edition of the *Proceedings of the National Academy of Sciences* suggests that replacing antiquated fishery governance systems with rights-based fishery management could increase annual fisheries profit by $53 billion and global catch by 16 million tons. These tools allocate individual fishing rights to local fishermen or fishing communities. Successes adopting these strategies have been registered in Australia, Iceland and Mexico.

Many fisheries capture, kill and discard non-target marine species that are not used as food such as sharks, dolphins, sea turtles and deep sea corals. This collateral damage to these ecologically important species imperils ecosystem health. Innovation has made important progress to reduce mortality of non-target species, but acceleration and adoption of these technologies is needed.

Illegal and unreported fishing exacerbates overfishing, and is becoming a growing problem. For example, a study that appeared in the September 2014 issue of *Marine Policy* found that up to a third of all the wild seafood imported into the United States is believed to be illegally caught. In the case of long-lived, slow growing marine species, a single incidence of illegal fishing can set affected ocean ecosystems back by decades. New technologies for marine surveillance and platforms for international data sharing are critically needed to rein in illegal fishing. One positive advance in this arena was that a global treaty called the Port State Measures Agreement went into force in 2016. If properly enforced, the treaty will help curb illegal fishing vessels' access to ports, thereby helping to block the flow of illegally caught fish to markets.

There are a variety of other pathways for combating overfishing. We should more strategically review the merits of the estimated $38 billion (2009) in global fishery subsidies that, in many instances, contribute to overfishing. We would benefit from replicating the successes of the European Union's yellow/red card program for combating illegal fishing by blocking market access to non-compliant foreign supply nations. We also need to better manage destructive fishing practices that damage habitats crucial to fishery health. Successfully controlling overfishing will be a critically important part of safeguarding food security and ensuring the long-term health of coastal economies.

Related Insight Areas: Agriculture, Food and Beverage, Future of Food Security and Agriculture, Illicit Economy, United States, European Union, Japan, Mexico, Global Governance, Sustainable Development, Innovation, Future of Environment and Natural Resource Security

Pollution

The oceans have become a catch-all for the world's pollution

Rivers and runoff vector myriad man-made pollutants from land into the ocean. The most threatening form of pollution to ocean health and global health is by far carbon pollution. In the last decade the oceans have absorbed about 30% of the carbon dioxide emitted by industry. This has significantly slowed the advance of climate change but at a large cost to ocean health. When carbon dioxide is absorbed by seawater it increases the acidity of the oceans. The direct and indirect effects of ocean acidification threaten the future of ocean life from microscopic snails that feed salmon populations to coral reefs that feed economies of coastal tourism.

Plastics are a conspicuous and insidious form of ocean pollution. A 2015 study led by researchers from the University of Georgia's College of Engineering found that coastal nations generate 275 million metric tons of plastic waste each year. 4.8 to 12.7 million tons of plastic are believed to enter the ocean annually. The Ellen MacArthur Foundation and the World Economic Forum used these numbers to predict that there will be more plastic than fish (by weight) in the ocean by 2050 in the 2016 report *The New Plastics Economy: Rethinking the future of plastics*. In addition to their ubiquitous presence on coastlines, plastic pollution has been documented in the deepest parts of the ocean (for example, near the Mariana Trench) and our most remote ocean ecosystems (for example, Antarctica). Certain forms of plastic pollution can last for hundreds of years or longer.

The United Nations Environmental Programme reports that more than 660 species of ocean animals have been documented to have encountered plastic pollution. This includes species such as sea turtles, dolphins, whales, seabirds, manta rays, and numerous other fish species. Plastic pollution and other man-made debris have been detected in seafood sold for human consumption. A 2015 study by a joint team of UC Davis and University of Hasanuddin researchers reported anthropogenic debris in 25% of individual seafood market fish and in 67% of all species sampled in the United States. Ingestion of plastics has deleterious impacts on ocean animal health. Researchers are now endeavouring to understand what impacts this pollution may have on human health. Solutions to curbing the flow of plastic pollution into the oceans include adopting policies that curtail the use of single-use plastics; improving capture of plastics leaking out of waste systems, particularly in known hotspots of plastic pollution; and re-thinking the design of plastics so as to optimizes re-use.

Another major source of ocean pollution comes from runoff of excess fertilizers used in agriculture. These fertilizers are carried down rivers and into the ocean where they create population explosions of algae and then bacteria. This in turns depletes oxygen levels precipitating fish kills and creating conditions that are inhospitable to marine life. Over 400 so-called ocean dead zones have been documented worldwide. Practices that manage wasteful use of fertilizers can help prevent the spread and persistence of ocean dead zones.

Related Insight Areas: Agriculture, Food and Beverage, Future of Environment and Natural Resource Security, Behavioural Sciences, Chemicals and Materials Industry, Circular Economy, Climate Change, Global Health

Mass Extinction

Ocean life is sitting on an extinction cliff

Life on land is facing the rapid approach of what scientists call the Sixth Mass Extinction. On land, human-caused extinction rates are approaching those observed during historical mass extinctions - such as the end-Cretaceous mass extinction that brought an end to many dinosaur lineages.

The situation in the oceans is a little brighter - for the moment. The International Union for Conservation of Nature recognizes only about 15 ocean animal extinctions as having occurred in the last 500 years. In the same period over 500 land animals have been driven extinct by human activity. This good news, however, is fragile. A 2016 report in the journal *Science* evaluating risk profiles for ocean animals reported that rates of extinction in the oceans could rapidly approach proportions of loss observed during previous mass extinctions. Without a change in the business as usual scenario of ocean management we could soon initiate a Sixth Mass Extinction in the oceans as well.

An industrial revolution is beginning in the ocean that parallels the industrial revolutions that already took place on land. In the ocean this includes a rapid expansion of many marine industries: 1570% growth in ocean farming or aquaculture; near 35-fold increase in marine transport; and 4.6-fold increase in the amount of ocean area being explored for deep sea mining. This may shape extinction futures in the ocean. On land, animal extinction rates began accelerating rapidly during the first two industrial revolutions. During the early 1800s there was much less awareness that human health and environmental health were interlinked. Poorly managed industrial growth polluted and damaged many terrestrial habitats precipitating the extinction of numerous species. The oceans present an exciting opportunity to intelligently walk forward the emerging marine industrial revolution without associated spikes in animal extinction rates.

Extinction reduces the diversity of our planet's biodiversity portfolio. But equally or more importantly extinction also can compromise the life support services yielded from the ocean in the form of oxygen delivery, coastal protection, carbon fixation, and food provisioning.

Related Insight Areas: Global Health, Future of Environment and Natural Resource Security, Supply Chain and Transport, Mining and Metals, Fourth Industrial Revolution

Shifting Governance

Current regulatory frameworks do not adequately cover our rapidly changing oceans

The oceans have always been a difficult place to govern. Covering 90% of habitable space on earth, the oceans are an immense hyper-international domain that presents unique regulatory challenges. Unlike many natural assets on land, such as forests, many high priority oceans resources (for example, bluefin tuna) swim across jurisdictional boundaries. Additionally, damages levied in one nation’s jurisdiction (for example, plastic pollution) can impact nations thousands of miles away. We have for decades deferred developing policy solutions that accurately address and engage these ecopolitical complexities. Further delays cannot be sustained as we cross or approach tipping points on overfishing, pollution and climate

change in the oceans.

Sixty-four percent of the ocean lies outside of the jurisdiction of any country - our high-seas waters. This presents a major challenge for the responsible management of biodiversity and resources. In 2015, the United Nations committed to develop a first of its kind legally binding treaty to better manage high-seas biodiversity. Alongside these conversations, the International Seabed Authority is developing a new legal instrument that will ensure that ocean mining in the high seas happens in a way that equitably shares these global commons resources and does not deleteriously impact ocean ecosystems. Over a million square kilometres of high seas seabed have been gazetted in exploration claims for ocean mining. The manner by which both of these high level agreements is resolved will determine the ecological and economic futures of the largest ecosystem on our planet.

Climate change is causing fish to shifts their ranges. Often, although not always, fish stocks move poleward - escaping waters that become too warm. This is problematic on multiple levels. First, it creates new and worrisome volatilities in low-latitude, often less developed regions. This will cause certain fish resources to travel out of reach of countries that need them the most for food security and economic stability. These are the same regions where illegal fishing is most intense, ocean governance is weakest, and populations are growing the fastest. Recognition of this brewing perfect storm of instability in coastal low-latitude areas is much needed.

The second emerging challenge of climate change and ocean policy is that a mass migration of fish stocks would create a wholly new travelling tragedy of the commons scenario. Nations that can now count on drawing interest from reserves of fish, like mackerel or cod, are incentivized to responsibly manage the health of these natural assets. If, however, nations begin to realize their assets are migrating beyond their borders, this could tragically disincentivize good ocean stewardship. The Mackerel Wars (2009 to the present) between Iceland, the European Union, and other stakeholders showcases the start of such difficulties. This has been a damaging battle over how to divide harvest rights to fish that have shifted north as oceans warmed. The clearest loser has been the mackerel, now fished at unsustainable levels.

One positive recent shift in ocean governance has come through the rapid global establishment of protected areas in the ocean. Marine protected areas are known to be one important tool for protect at-risk ecosystems and sourcing spillover of fish beyond their boundaries to boost fisheries. Based upon a review of 144 studies, researchers at the University of York concluded that nations would need to protect about 30% of the ocean in order to meet marine management goals. Currently only about 3% of the ocean is well-protected. With revolutionary momentum, nations around the world have begun heading in the direction of that goal. The United Kingdom has recently protected an area of ocean that collectively is larger than their own land mass. Chile, the United States and Kiribati each established protected areas larger than Italy. The new challenge will be identifying both policies and technologies that can help effectively monitor and meaningfully protect these massive and often remote ocean parks.

Related Insight Areas: Global Governance, Climate Change, Future of Environment and Natural Resource Security, Sustainable Development, International Security, Mining and Metals, Geo-economics, European Union, United States, United Kingdom

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Climate Change Impacts

Oceans are one of the most vulnerable ecosystems in the face of climate change

Climate change will impact all facets of our planet's life support system. The oceans, however, will be hit particularly hard. Climate change's three most significant impacts on the ocean come via ocean warming, ocean acidification and oxygen depletion. A future ocean that is hotter, more acidic and harder for ocean life to breathe in presents some obvious challenges to the survival of marine biodiversity.

The oceans have absorbed more than 90% of the heat produced via greenhouse gas associated warming since the 1970s. Average sea-surface temperatures for 2015 were the highest on record, followed in second place by warming in 2014. Ocean warming will be profoundly disruptive because ocean life is largely accustomed to living with very stable temperatures. Ocean fauna from sea turtles to Antarctic krill are vulnerable. Coral reefs have been famously impacted. Increasing temperatures can cause corals to bleach. The year 2016 has thus far produced some of the most severe coral bleaching events ever recorded. Australia's National Coral Bleaching Taskforce has found that approximately 80% of the northern Great Barrier Reef showed extremely bleached conditions during this period. These shocks matter in an ocean in which coral reefs have already declined by approximately 40%, according to a 2015 study in *Science* from University of California Santa Barbara Douglas J. McCauley *et al.*. Such losses matter. A 2013 Deloitte study found that the Great Barrier Reef alone generates just over $7 billion to Australia, largely via tourism income. Reefs also are home to over a million other species, a major chunk of our ocean biodiversity portfolio.

The oceans have absorbed a large amount of the carbon dioxide generated by human industry. This has helped slow global warming. Unfortunately, this addition of carbon dioxide has caused the oceans to become more acidic. Since the First Industrial Revolution, the acidity of the oceans has increased approximately 30%. Ocean acidification makes it increasingly difficult for many organisms, from corals to oysters, to form healthy skeletons and shells. Extreme ocean acidification events that occurred naturally during earth's history have been identified as triggers of mass extinction in the ocean.

Climate change is expected to gradually deplete oxygen levels in the ocean. Deoxygenation is caused as a result of simple physics: warmer water holds less dissolved oxygen. Because marine life requires oxygen (for example, as extracted by fish using their gills), oxygen declines will bring widespread negative impacts. Scientists from the University of British Columbia's Institute for the Oceans and Fisheries have predicted that contractions in the range, size, and productivity of fisheries may cause global fisheries to suffer $10 billion in annual revenue loss by 2050 if climate change continues unchecked.

Sea level rise may be the most obvious and impactful form of ocean-related climate change on humanity. Sea level rise is caused by the expansion of warming sea water and melting of land ice. The rate of sea level rise in the last decade is almost double that of the last century. Scientists predict that half of the population in 25 megacities will eventually be affected by sea level rise if climate change is not slowed. Cities like Miami and Shanghai are already experiencing the first effects of sea level rise. A study in the August 2013 edition of *Nature Climate Change* argues that without adaptation, aggregate losses associated with sea level rise could amount to more than $1 trillion annually by 2050.

Climate change will also reorder the distribution of life in the oceans. Populations of fish and shellfish, for example that are adapted to making a living in cold waters are predicted to shift their ranges to escape warming conditions. Some of these movements will move stocks wholly or partially out of certain nations' jurisdictional boundaries. This creates obvious complications for countries that depend on these

resources for income and food.

Research has demonstrated that some marine species can adapt to climate change. Certain strains of corals, for example, have been shown to be more resistant to thermal stress and could slowly expand to replace less resistant strains. Climate change, however, must be aggressively slowed to provide opportunity for adaptation and evolution to occur. Such processes can be easily swamped and overwhelmed by rapidly advancing change.

While a number of geoengineering solutions have been proposed to mitigate the impacts of climate change in the oceans, scientists typically concur that the best pathway forward is the difficult task of directly reducing global carbon emission

Related Insight Areas: Decarbonizing Energy, Risk and Resilience, Climate Change, Future of Environment and Natural Resource Security, Global Governance, Arctic, Cities and Urbanization

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Aquaculture

The world is undergoing a revolutionary shift from being hunter-gatherers to farmers of the ocean

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In 2014, for the first time in history, the world ate more farmed fish than wild fish. This shift is as transformative for the oceans as was the shift on land from hunting and gathering of wild foods to relying on agriculture.

Aquaculture in the ocean is a booming industry. According to Food and Agriculture Organization statistics on global aquaculture production, the industry has grown 1570% in the last four decades and growth is projected to continue. Growth in aquaculture has been highly geographically heterogeneous. The vast majority of current aquaculture is centred in Asian nations. China alone represents more than 60% of global aquaculture production. This growth may help meet demand for animal source foods which may skyrocket by 80% by 2050. Population growth and increasing wealth are fuelling global demand. Human populations are expected to grow by up to 50% by the end of the century and increasing wealth in poor nations is bringing animal foods within reach of millions of new consumers.

Aquaculture could clearly play an important role in promoting global food security. There are, however, challenges that need to be overcome in getting the nutritious products often produced in lower-income nations into domestic markets where they can fight malnutrition and undernutrition. Much of the production of farmed seafood, like shrimp, is often exported from developing nations to developed nations.

Just like farming on land, farming in the ocean can be environmentally clean or dirty. Proponents of aquaculture highlight that it can take pressure off overfished wild fish stocks. New innovations in offshore aquaculture, in particular, may suggest pathways for cleaner fish farming with high growth potential. Negative impacts of aquaculture include feed inefficiencies that require at-risk wild fish be harvested to feed farmed fish; pollution; and the destruction of wild fish nursery grounds (for example, mangrove forests) to build fish farms.

In an increasingly crowded and protein hungry world, we must look to the oceans for new ways to make food. The challenge ahead will be to make the blue revolution of ocean aquaculture something that can successfully meet food shortfalls without inflicting new sources of unwanted damage on ocean ecosystem health.

Related Insight Areas: Agriculture, Food and Beverage, Future of Food Security and Agriculture, Future of Environment and Natural Resource Security, Global Health, China, Sustainable Development

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Human Well-being

The fates of our oceans and humanity are increasingly intertwined

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The oceans are an edifying place to recreate, a beautiful place to recharge, and a home to impressive wildlife. But their value and influence on human condition runs much deeper than this. The oceans provide a critically important source of nutritious food, income and stability to humanity.

The 2015 World Wildlife Fund *Reviving the Ocean Economy* report estimated the oceans to be a $24 trillion asset that yields $2.5 trillion annually in goods and services. If the ocean was a nation, it would be the 7th largest economy in the world. The sustained vitality of the ocean provides employment for about 38 million fishers worldwide and millions of additional jobs in sectors like aquaculture, tourism, energy, transportation and biotechnology. The value of ocean resources is acutely recognizable in the economic portfolios of poor countries. Fishery net exports from developing countries, for example, were valued at $42 billion, higher than other major agricultural commodities (for example, meat, tobacco, rice and sugar) combined, according to the Food and Agriculture Organization (FAO)'s 2016 edition of *The State of World Fisheries and Aquaculture*. Fisheries, however, matter to nations rich or poor. The collapse of cod stocks along the east coast of Canada, for example, sparked the single largest mass layoff in Canadian history and prompted large-scale out-migration from affected provinces. Canada spent almost $2 billion between 1994 and 1998 on aid and recovery programs trying to cope with loss of this single important fish species.

In addition to their economic value, the oceans act as a refrigerator of free-range, highly nutritious food for humanity. According to the FAO's *The State of World Fisheries and Aquaculture* report, fish provide more than 3.1 billion people with 20% of their average intake of animal protein. Equally or more importantly, seafood provides a critically important source of nutrients essential to good health, like iron, zinc and omega-3 fatty acids. Researchers estimate that if current trajectories in fishery decline are allowed to persist, this could put 845 million people at risk of diseases associated with malnutrition.

Ocean health and human health intersect in other important but sometimes less obvious ways. Fishery declines, for instance, have been linked to human trafficking. Here the escalating effort required to harvest increasingly rare fish in some regions is being met by child labour and slave labour. Some analysts suggest that the origin of piracy in Somalia and West Africa can partially be explained by disenfranchised fishermen turning to violence to protect decreasing fish stocks on offshore fishing grounds. In other situations where overfishing has depleted certain lucrative marine species, organized crime has escalated. In Mexico's Sea of Cortez, for example, it is believed that drug cartels may be

involved in trafficking in swim bladders in an illicit industry that is both depleting a critically endangered fish and threatening to trigger the world’s first extinction of a marine cetacean - the porpoise-like vaquita.

Related Insight Areas: Human Rights, Illicit Economy, Global Health, Future of Food Security and Agriculture, Future of Economic Growth and Social Inclusion, Future of Environment and Natural Resource Security, Workforce and Employment, Future of International Trade and Investment