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Transformation

Ocean Tech: Savers

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Key takeaways

- Dwindling oceanic health due to anthropogenic activities poses challenges, including rising sea levels, ocean acidification, loss of biodiversity and pollution. But what technologies can help us address these threats in order to continue exploring all the ocean has to offer and harnessing the resources it possesses?
- Bank of America Institute's three-part 'Ocean Tech' series explores ocean technologies through three lenses: Transformers, Explorers, and Savers - all focused on entry points that interrelate with the ocean.
- In this final installment, we discuss 'Savers,' the ideas and technologies that can help restore ocean health, including aquaculture, carbon removal, and ocean waste clean-up.

Ocean Tech

The ocean is the backbone of global technology with 99% of data traffic flowing through subsea cables, carries more than 80% of world trade, and provides 15% of our protein intake. The resource potential of the ocean is massive; however, we can't fully harness the opportunities it offers if we simultaneously harm it.

In part one of our Ocean Tech series, we explored technologies that could act as 'Transformers' and help us both adapt to the ocean and unlock its resources to help address scarcity in food, energy, water and land (see: Ocean Tech: Transformers). However, before we get too deep, we need more data to help grasp what's possible. That's where part two of the series came in. 'Explorers' discussed innovations that would first allow us to understand the ocean (see: Ocean Tech: Explorers).

In this final installment, we dive in to the 'Savers' – the technologies that can help restore ocean health, including aquaculture, carbon removal, and ocean waste clean-up – to help mitigate threats to the ocean before we're able to harness all it has to offer.

Choppy waters

The ocean faces dwindling health due to several factors. As water temperatures rise, oxygen content decreases, which can reduce biodiversity. In fact, one-third of reef-building corals face elevated extinction risk from changes in climate.[1] And since a quarter of all marine species including fish, invertebrates, plants, sea turtles, birds and marine mammals can be found in, on and around coral reefs,[2] this can have a significant impact on marine life.

Additionally, more than 80% of marine pollution comes from land-based activities.[3] As a result, nitrogen concentrations in the ocean have increased three times that of pre-industrial times, causing overgrowth of plants and algae. By 2050, there could be more plastic than fish in the sea by weight,[4] but the potential threats do not stop at plastic.

According to the Intergovernmental Panel on Climate Change (IPCC), sea levels could also rise by over three and a half feet by 2100 if current emissions are not restricted to less than 2°C above preindustrial levels.[5] And more than half of the world's population lives within 120 miles of the coast, making them particularly vulnerable.[6]

That said, rising temperatures and acidity also mean sound could travel further through the ocean making the ocean five times noisier by the end of the century.[7] Not only would this reduce the ability for marine life communication, but noisier oceans would

[1] Carpenter et al
[2] National Oceanic and Atmospheric Administration (NOAA)
[3] Vanderzwaag and Powers
[4] Ellen MacArthur Foundation
[5] Intergovernmental Panel on Climate Change (IPCC)
[6] United Nations (UN)
[7] Possenti

also have an impact on underwater data centers, as they are sensitive to 'acoustic attacks' (see: Ocean Tech: Transformers for more).

Lastly, three-quarters of marine fisheries are exploited up to, or beyond, their maximum capacity.[8] With the ever-growing global demand for seafood, our fishing practices have reached unsustainable levels, with severe consequences for global fish stocks. In fact, the proportion of the world's fish that is overexploited has increased significantly over the past 40 years from 10% in 1974 to 35% in 2019.

We know that declining marine health, rising sea levels and more could negatively affect all the ocean can offer. But what are the potential solutions? Here, we highlight traditional entry points as well as moonshot – or 'OceanShot' – technologies across food, carbon renewal and waste clean up to help restore the ocean's health and unlock its potential resources.

Future Fish

Conventional salmon farming requires constant mild water temperatures and an optimal water flow rate, meaning there are relatively few suitable locations. However, there are two features under development that could potentially revolutionize the industry: (1) automated feeding (to reduce feed waste) and (2) predictive analysis (e.g., suggesting to a farmer when it would be best to treat fish for sea lice, based on analysis of historical data). In the future, systems could automatically monitor biomass, lice and growth levels of the fish.[9]

Land-based farming

Land-based supply growth, in contrast to conventional salmon farming, is only restricted by the efficiency of the technology, water availability and capital requirements. Critically, RAS (recirculating aquaculture system) technology means land-based farms can control the contents of the water in which the salmon are farmed and thereby (theoretically) provide greater protection against the biological issues that have severely impacted net pen farming. Until recently, progress had nonetheless been restricted by both technology (not proven at scale) and capital requirements. The latter constraint has eased due to consistently high salmon prices since 2015, while BofA Global Research believes that technology is becoming sufficiently proven by indoor shrimp farming.

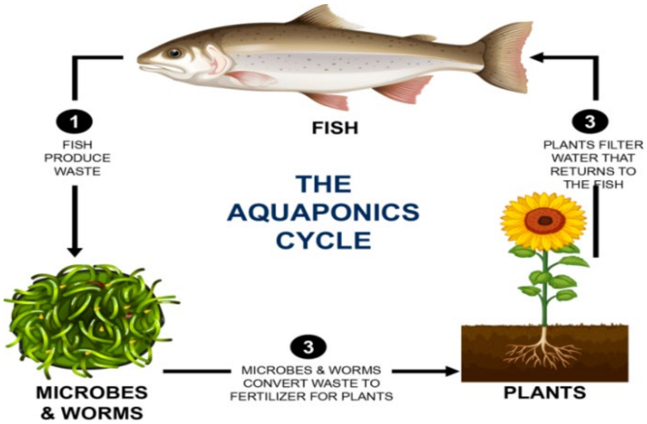
The largest advantage of land-based salmon farming is the opportunity to better control biological risks given that this means growth is less constrained and the costs involved in dealing with sea lice and disease can be avoided. However, there are several other key advantages: (1) it can have a significantly lower impact on the surrounding environment as waste and excess feed can be prevented from entering the natural water system; (2) production can be located near end-market demand, which saves the cost and CO_2 emissions involved in air-freighting salmon and also means the salmon is fresher for the consumer; and (3) optimal growing conditions year-round could reduce the length of the production cycle and therefore costs.

Aquaponics: A fast-emerging food solution

Aquaponics is the integration of soil-free agriculture (hydroponics) and fish farming (aquaculture) and is quickly emerging as a food solution. This freshwater method uses water at almost half the rate of conventional farming while raising a significant number of fish. The fish then produce waste, which is used as fertilizer for the plants. In turn, the plants filter the water for the fish (Exhibit 1). This system reduces the need to correct pH levels and nutrient composition of water for the growth of crops.[10]

[8] United National Environment Programme (UNEP)
[9] Aquabyte, Mowi
[10] Value Market Research 2018

Exhibit 1: In the cycle, the fish produce waste, which is used as fertilizer for the plants. The plants then filter the water for the fish.
The aquaponics cycle



Source: The Aquaponic Source
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Ocean carbon ecosystems

Our oceans, vast and teeming with biodiversity, are not just the lifeblood of Earth's biological system, but also a critical component in our planet's climate regulation. The ocean generates over half of the world's oxygen, essentially serving as the planet's primary lungs.[11] It also acts as a "carbon sink" and absorbs about 27% of the CO2 emissions released into the atmosphere. However, shifts in climate, including ocean acidification, are taking a heavy toll on the marine environment.

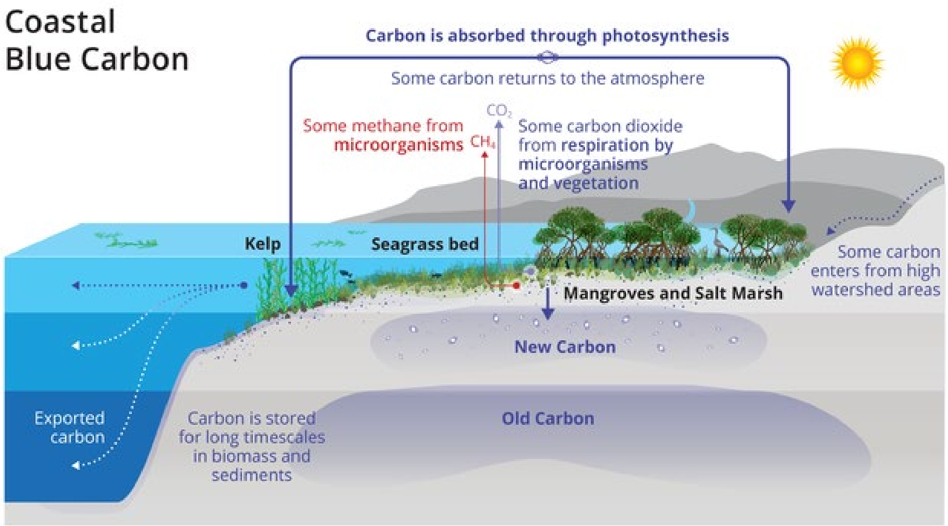
Ocean carbon dioxide removal falls into two general categories: biotic and abiotic approaches. Where biotic approaches leverage photosynthesizing organisms in seawater to take up carbon dioxide and store that carbon as biomass, abiotic approaches harness the physical or chemical properties of the ocean to remove CO2 from the air. What does this mean? The ocean's potential for carbon removal and storage involves harvesting carbon from the atmosphere through direct air capture or waste combustion, then pumping the liquified carbon below the seabed where it can be stored permanently, which could save up to one gigatons in emissions.[12]

The ocean's carbon ecosystems

Blue carbon ecosystems (e.g., mangroves, seagrass meadows and salt marshes) can preserve biodiversity as they are habitats for marine and coastal species. They also protect coastlines from storms, floods and erosion, and thus water quality and food security at a local level. Additionally, blue carbon ecosystems prevent saltwater from mixing with freshwater resources, and naturally remove carbon from the atmosphere. They can store up to five times more carbon per area than tropical forests[13] and absorb it from the atmosphere three times as fast.[14] And while they cover only 0.5% of the seafloor, they may account for more than 50% of all carbon in marine sediments.[15]

[11] National Oceanic and Atmospheric Administration (NOAA)
[12] World resources Institute (WRI)
[13] National Ocean Service
[14] Alongi
[15] Macreadie et al

Exhibit 2: Using coastlines to naturally absorb carbon dioxide
Infographic illustrating Coastal blue carbon



Source: National Oceanic and Atmospheric Administration (NOAA)
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Mangroves

Mangroves are a natural form of infrastructure that protect populated coastal areas by reducing erosion and absorbing storm surges. They also reduce ocean acidification and provide coastal habitats for sea life and wildlife as well as provide a living for artisanal fishermen while being a tourist attraction on a global scale.

As such, governments are starting to see the importance of mangroves, marshes, sea grasses, and other coastal ecosystems in providing natural protection, food security, and sanctuary for living things. A 2023 report, "The Mangrove Breakthrough Financial Roadmap," estimates that $4 billion is needed by 2030 to halt the loss and degradation of mangrove forests and restore just half of recent losses.

Mangroves may only be one small aspect of natural capital, but they punch well above their weight in carbon capture. They are less than 1% of the world's tropical forests, but they sequester carbon at 3-5x (and potentially up to 5-10x or higher) the rate of other types of forests. Globally, mangroves store the carbon equivalent of over 22 gigatons of CO2.[16]

Coral reefs

Coral reefs are the 'rainforests of the sea' and among the most ecologically and economically valuable ecosystems on our planet. Covering less than 0.1% of the world's ocean, they support over 25% of marine biodiversity and serve up to a billion people with coastal protection, fisheries, sources of medicine, recreational benefits, and tourism revenues.

Recent advancements focus on coral reef replacements including 3D prints customized to suit a particular shoreline and local environment. By understanding water flows and marine topography, manmade structures can provide microenvironments for marine life to survive. In fact, a single cubic meter of a reef can provide a new home to more than 20,000 animals, 20 corals, 60 fish and more.[17]

Waste solutions

Did you know that the world produces a million plastic bottles a minute? That's 500 billion bottles in one year. So, it's no surprise global plastics usage has far outpaced population growth, rising by about 4.5% year-over-year (YoY) on average since 1990, or nearly triple the 1.3% increase in population. And global plastics consumption rose 250% from 1990-2019.

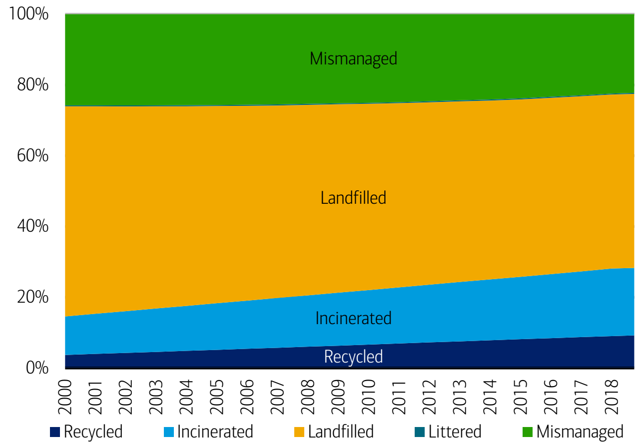
As plastics demand has grown, so has the need for plastics recycling. In the US, less than 10% of plastic waste is recycled (Exhibit 3). In fact, US landfills are overflowing with two million tons of discarded water bottles alone.[18] To come anywhere close to tackling plastics pollution, recycling rates will need to increase dramatically, especially for short lifecycle plastic packaging materials.

[16] Mangrove Breakthrough Financial Roadmap
[17] Springwise
[18] idswater.org

But what does this mean for the ocean? Well, every year, approximately eight million tons of plastic waste escapes into the ocean,[19] equivalent to the contents of one garbage truck every minute.[20] The total economic damage to the world's marine ecosystem caused by plastic is estimated to be at least $13 billion annually.[21]

Exhibit 3: Plastic waste recycling rates remain exceptionally low at about 10% today according to OECD data

Global plastic waste by end-of-life fate (%)



Source: Organization for Economic Co-operation and Development (OECD)
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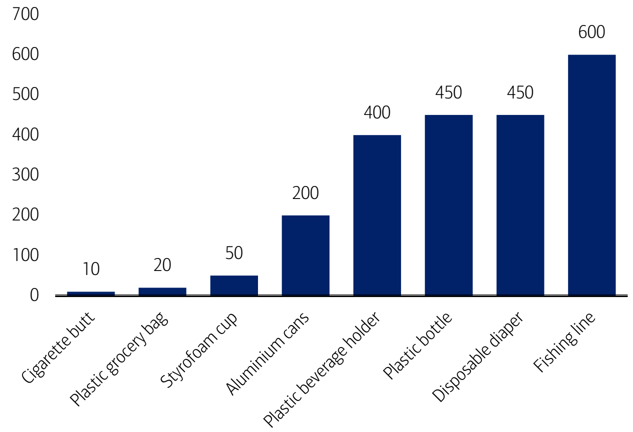
Exhibit 4: Plastics can take upwards of 400 years to biodegrade in the ocean

Estimated number of years for selected items that contain plastic to biodegrade in a marine environment



Source: NOAA, Woods Hole Sea Grant
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Biodegradable alternatives

Bioplastics have been presented as an alternative to plastic packaging, but currently they rarely measure up to the low-cost and versatile properties of typical plastics. Further, many biodegradable plastics only break down completely if exposed to prolonged high temperatures above 122°F. While these conditions can be met in an incinerator, they often cannot be met in the natural environment and therefore, even bioplastics derived from plant-based sources, such as corn starch, sugarcane and cassava roots, do not quickly degrade.[22] Certain bioplastics, like polylactic acid (PLA), can also contaminate the material and create recycling challenges. Additionally, cost continues to be a problem, as many bio-alternatives for plastic packaging are relatively expensive.

What about paper? As seen in Exhibit 4, while plastic can take 400-1,000 years to decompose in the environment, paper is more widely recycled than plastic and decomposes at a much faster rate. However, it tends to have a larger carbon footprint given the amount of material and energy it consumes to produce. According to a lifecycle study conducted by the UK Environmental Agency, a paper bag would need to be used at least three times before becoming more carbon-friendly than standard HDPE (high-density polyethylene) bags.

Significantly more plastic recycling capacity is needed…

The lion's share of plastics recycling occurs through mechanical processes, and a large portion of mechanically recycled plastic comes from PET (polyethylene terephthalate) and HDPE resins. Mechanical recycling works well for PET bottles but is not ideal for many other types of plastic. The recycling industry has been working on other technologies that utilize chemical recycling in a depolymerization process that transforms other types of plastic waste into monomer material, which can then be used as fuel or virgin feedstock for plastic polymer production once more.

Mechanical recycling

As noted in What goes around comes around: Circular plastics, mechanical recycling is the process of recycling post-consumer waste (PCR) into "new" raw materials without changing the basic chemical structure of the material. For example, taking recycled PET resin to recreate a new PET bottle or processing plastic bags into pellets to be reused in other applications, such as toys, shoes or new plastic bags. However, the high amounts of plastics mechanically processed for recycling doesn't produce equally high recycled plastics. Due to losses in plastic waste processing, the plastic recyclates produced by mechanical recycling plants are only about 65% of the plastic waste entering such facilities.

[19] National Geographic
[20] Ellen MacArthur Foundation
[21] UN Sustainability
[22] UN Sustainability

Chemical recycling

Chemical recycling complements mechanical recycling, as it further depolymerizes the material that can be used as feedstock for new plastics, preventing mixed plastic waste being sent to landfill. Chemical recycling is the process of breaking down plastic to its core building blocks, i.e., the molecular level. Whereas mechanical recycling keeps the polymer intact, this process takes recycling one step further by depolymerizing the material that can be used as feedstock for new plastics, fuels, or other petrochemicals. Chemical recycling can help reach higher recycling rates, and prevent mixed plastics waste being sent to incineration or landfill.

Enzymatic recycling

This approach uses enzymes to break down plastics into their constituent monomers, which can then be repurposed to make new plastics. Unlike mechanical recycling, which often results in the degradation of plastic quality, enzymatic recycling maintains the integrity of the monomers. Scientists have found enzymes from different sources (e.g., bacteria and fungi), which can break down PET, and polyurethane (PU).

Some data suggests that enzymatic recycling could have a smaller carbon footprint than making plastics anew. Using enzymes to break down PET to isolate one of its monomers, terephthalic acid (TPA), can reduce the total supply-chain energy use by up to 83% and lower greenhouse gas emission by as much as 43% compared to making TPA from scratch.[23]

Advantages include: (1) the ability to recycle plastics that are difficult to recycle (e.g., films, multilayer plastics); (2) operates under relatively mild conditions – normal temperatures and pressures – making it less energy-intensive and more ecofriendly than chemical recycling; and (3) the quality of the recycled material. Enzymatic recycling can produce monomers that are indistinguishable from those derived from virgin materials. This can create plastics with no compromise on material properties, which is not the case with mechanical recycling.

However, this approach is not without challenges; the economic viability, i.e., creating cost-effective processes for enzyme production and recycling operations, is key in order to compete with traditional recycling methods and production of virgin plastics.

[23] Singh et al

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Disclosures