Ocean Sustainability: Risks, Challenges and Opportunities

Nitin Agarwala

Senior Naval Constructor Officer

Commodore Commanding Submarines (West), Mumbai

nitindu@yahoo.com

ORCID iD: https://orcid.org/0000-0003-0916-3044

Abstract

Oceans have been a source of food and numerous resources for humanity since the advent of civilisation. With an increasing population on land to feed, this dependence on ocean for food and resources has increased many folds. While the oceans have been resilient so far allowing numerous misadventures of humanity, they have reached a tipping point in their resilience due to the use of unsustainable methods. Realising the need to rejuvenate the oceans and avoid a possible destruction of humanity if business-as-usual continues, the United Nations adopted the Sustainable Development Goals 2030 in 2015. So as to appreciate and discuss the risks, challenges and opportunities to achieve the desired ocean sustainability, the article will discuss each of these aspects independently while showing their close interdependence and impact on ocean health and stability. In doing so, the discussion would be limited to the Asia-Pacific region.

Keywords: Asia-Pacific; sustainability cycle; carbon cycle; carbon emissions

1. Introduction

The marine environment is a strongly interconnected environment. However, the stability and resilience of this environment has been drastically disturbed due to anthropogenic activities/events either directly or indirectly. Since the oceans are a major source of food, medicines, clean energy, job creation, and generation of most of the oxygen we breathe while supporting the global economy through tourism, fisheries, shipping and trade, they need to be exploited sustainably to ensure that they can continue to absorb the anthropogenic impact and provide the required goods and services in the future too.

This need forced humanity towards sustainability focused studies to help policy makers in developing a road map for the future; resulting in the United Nations to adopt Sustainable Development Goals (SDG) in September 2015 with Goal 14 dedicated to conservation and sustainable use of marine resources and ocean health (UN, 2015). However, to ensure ocean sustainability, there exist numerous risks that need to be understood to appreciate the associated challenges that inhibit achieving the desired objective. Since ocean sustainability cannot be compromised and is considered essential to ensure a healthy and safe future of the planet and the future generations, it is imperative to look at existing opportunities to achieve the desired ocean sustainability while working towards future opportunities for greater sustainability.

It is with this understanding that this article aims to discuss the risks, challenges and opportunities to achieve ocean sustainability in the same breath. In doing so, each of these will be discussed independently while showing their close interdependence on each other and on the ocean health and stability. To make the discussion relevant and comprehensible, the discussion will be limited to the Asia-Pacific region that includes East Asia, South Asia, Southeast Asia, and the Oceania.

2. Background

Oceans offer numerous resources to humanity as seen in **Figure 1.** The oceans of the Asia-Pacific in particular have a diverse biological and productive marine ecosystem that is home to 17 of the 36 global biodiversity hotspots and 7 of the world's 17 mega-diverse countries. The region has the longest and most diverse coral reef systems, more than half of the world's remaining mangrove areas, and the highest seagrass diversity (UNESCAP, 2018). This vast biodiversity provides food to the local population and is a source of income due to seafood exports that account for nearly 90 per cent of the world seafood requirement (SEAFDEC, 2019). This has encouraged overfishing, unabated pollution, and destruction of marine habitat duly supported by inadequate governance. As a consequence, the region has experienced serious loss of marine biodiversity and ecosystem. Studies indicate that if no action is taken, the Asia-Pacific will lose 90 per cent of the coral reefs by 2052 and all commercially exploitable wild fish stocks by 2048 (ADB, 2018).

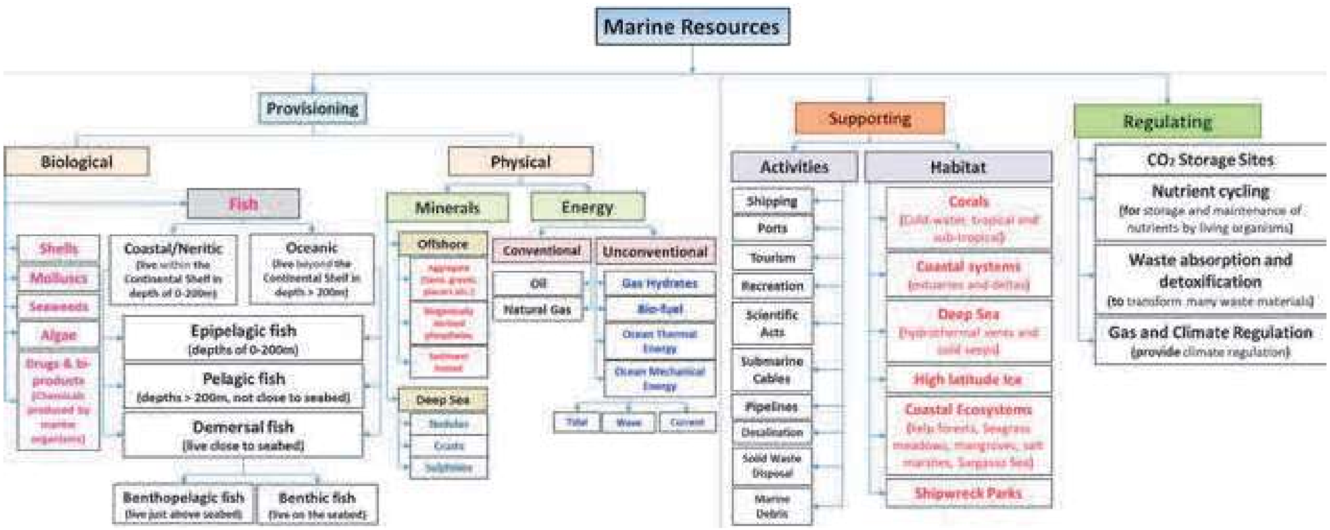

Figure 1: Taxonomy of marine resources (Source: Agarwala, 2020a)

While the concept of sustainable oceans took centre stage only in 1992 as part of the outcome document of the United Nations Conference on Environment and Development as Agenda 21 (UNDESA, 1992), that for terrestrial resources was known as early as 1987 as part of the Brundtland Report (WCED, 1987). Once introduced in 1992, sustainable ocean development became the universal principle of development that hinged on three pillars – environmental protection, economic growth, and social fairness.

Accordingly, ocean-related human activities and their impact on the oceans was studied as a multidisciplinary study area and evaluated to prioritise the sustainable use and conservation of the ocean resources. Such studies were aimed to help policy-makers, industries, businesses, and individuals to appreciate their role towards a sustainable ocean and to avoid confusion, contradictory actions, and failure to meet the said goals.

Since it is believed that the loss of the ocean biodiversity and ecosystem is eminent in the long run (Millennium Ecosystem Assessment, 2005) the United Nations declared 2021 to 2036 as a 'Decade of Ocean Science for Sustainable Development' (OceanDecade, 2019) to help nations achieve the 2030 Agenda for Sustainable Development.

3. Risks for Ocean Sustainability

As discussed, the ocean is responsible for numerous critical activities to ensure the well-being of humans. In order for the ocean to ensure this, like any other event in nature, it maintains a natural cycle that is sustainable as seen in **Figure 2.** However, this natural cycle has been impacted negatively by the anthropogenic activities. Since this sustainable cycle helps achieve productivity and a healthy and blue ocean, it is essential to understand the risks that are threatening this sustainability cycle and causing ocean degradation leading to an impact on ocean productivity and health.

3.1 Climate change

Climate change as a result of increased greenhouse gas (GHG) emissions is one of the most critical issues affecting ocean health and sustainability. While it has been amply proved that the climate changes being observed are due to anthropogenic reasons (Agarwala and Polinov, 2021), the resulting impact on different communities around the world is found to be different. Though the Asia-Pacific contributes little to the GHG emissions, the region is at maximum risk of unpredictable weather patterns such as an increase of summer temperature by 6ºC by 2100 (ADB, 2017) that can result in failing crops, spiking food prices, and spreading diseases. This would make countries like Indonesia, Thailand, and Vietnam drier and the increasing sea-level as a result of melting of the polar ice would submerge much of Maldives and 18 per cent of Bangladesh will get inundated (World Bank, 2010). Such disasters will disallow socio-economic development of the region and hinder sustainable development in the Asia-Pacific.

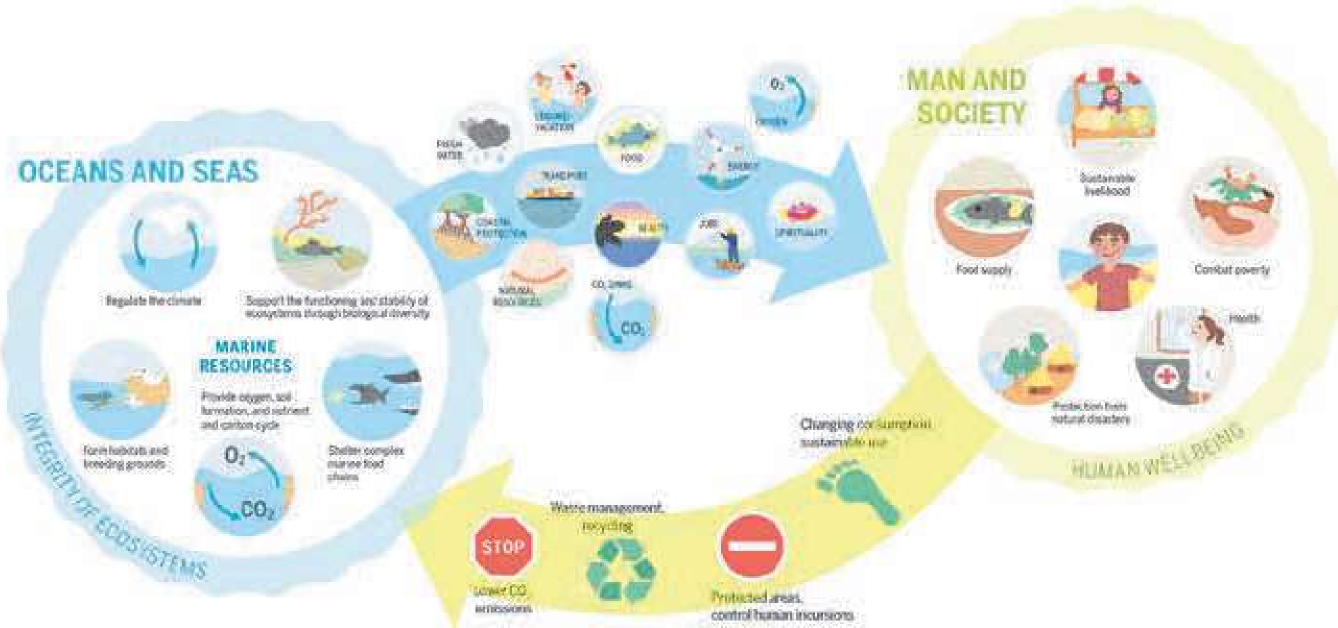

Figure 2: Circle of Sustainability (Source: Modified from Ocean Atlas, Visbeck et al., 2017)

3.2 Unsustainable resource extraction

Studies show that resource extraction has increased by more than three times since 1970. This has resulted in a biodiversity loss, water stress and an increase in the GHG emissions with the extraction and processing industry contributing to half of the total GHG emissions (UNEP, 2019). Similarly, events such as overfishing have depleted fish stocks to an extent that nearly 64 per cent of fish resource in the Asia Pacific, especially in Cambodia and the Philippines, is at a medium to high risk from overfishing. This eventually may lead to the collapse of the fisheries industry in this region due to harvest reduction by nearly 50 per cent (DeRidder and Nindang, 2018).

3.3 Land-based pollution

With an increase of the world population, waste generated on land is increasing. However, since what happens on the land has a direct or an indirect impact on the oceans, the waste generated on land eventually finds its way to the ocean through landfills, water bodies, wind dispersal or direct disposal. In countries with a weak legal and institutional framework to check waste disposal and recycling, this problem is more prevalent and of concern. It is no wonder that the Asia-Pacific accounts for nearly 80 per cent of all marine pollution with the major portion coming from municipal, industrial, agricultural wastes and run-off. Studies indicate that each year nearly 8 million tons of plastic waste is dumped into the oceans with China, Indonesia, Philippines, Sri Lanka, Egypt, South Africa, Nigeria, Morocco, Thailand, Malaysia, Vietnam, Algeria, Turkey, India, Brazil, Pakistan, North Korea, United States, Myanmar, and Bangladesh, being responsible for 83 per cent of global plastic waste mismanagement (Jambeck et al., 2015). Since the rate of degradation of such solid waste especially plastics in the ocean is low, it has resulted in a gradual increase in marine litter both in and under the sea, which in return is impacting the human health and the marine ecosystem and hence the proper function of the sustainability cycle of the oceans.

3.4 Marine habitat degradation

Estuaries, swamps, marshes, and wetlands are ocean spaces that provide habitat for numerous marine species. These ecosystems are highly effective in carbon dioxide sequestering with mangroves absorbing around 30 million tonnes of carbon a year (National Academies of Science, 2019), salt marshes as much as 80 million tonnes and seagrass around 100 million tonnes (Pearce, 2019). In addition, they protect the coastline from storms and erosion and help buffer the impacts of sea-level rise.

However, with increasing anthropogenic activities such as dredging, filling, pollution, construction, oil spills and tourism activities to name a few, and natural events such as hurricanes, typhoons, storm surges and tsunamis in these oceanic spaces, the existing habitats of inshore coral reefs and coastal mangrove forests, seagrass, birds, and fishes (National Geographic, 2010) that are otherwise considered essential for maintaining the health of the marine ecosystem are being destroyed. In addition, rising sea-level as a result of climate change and coastal erosion is causing an irreparable marine habitat loss. Studies indicate that nearly 340,000 to 980,000 hectares of coastal wetland ecosystems are being lost annually (The Blue Carbon Initiative, n.d), majorly due to localised human activities, sea-level rise, warming, and extreme climate events (IPCC, 2019).

In the Asia-Pacific this habitat degradation has a great significance for the Small Island Developing States that include twenty states in the Pacific and nine in the Africa, Indian Ocean, Mediterranean and South China Sea (AIMS) as they are the only source of food and revenue for these nations.

3.5 Ocean Acidification

Carbon is the main ingredient of all life on Earth. It is an essential element to form proteins and DNA. It is a key ingredient in food, essential for the plants to generate their food, a major source of energy, an essential element to regulate the temperature of the planet and many more. This carbon is recycled in nature between the atmosphere and the Earth through a natural cycle called 'carbon cycle'. On Earth, this carbon is stored in rocks, the ocean, plants, soil, and organisms with the excess carbon removed and stored as fossil fuels that act as reservoirs. However, this carbon is not static but flows naturally between these reservoirs. Similarly, since the atmosphere and the Earth form one system, there is an exchange of carbon between them too. The plants exchange it through photosynthesis and the water bodies through molecular diffusion and life-forms such as planktons and algae.

After the Industrial Revolution, anthropogenic activities to remove this carbon from the reservoirs and adding it to the atmosphere increased many folds with the use of coal and fossil fuel. This increased the carbon in the Earth's atmosphere and hence the demand on water bodies to absorb the extra carbon dioxide. This increased absorption of carbon dioxide by the oceans is resulting in a decreased pH of the water making it acidic. This in return reduces the carbonate in seawater which is considered essential for marine organisms to form their shells and skeletons forcing the existing corals and shells in the oceans to dissolve eventually resulting in the reduction of the sea food available to humanity. Hence, ocean acidification is a serious risk to ocean health and needs to be addressed.

4. Challenges to achieve Ocean Sustainability

Though achieving ocean sustainability is an accepted commitment by nations as an outcome of the UN SDG-2030, achieving it has numerous challenges. These vary from lack of funding to at times lack of intent. These notwithstanding, sustainable oceans are a must for the existence of future generations on Earth. It is hence essential that these challenges are understood so as to better address them. Some challenges that plague ocean sustainability include:

4.1 Economics

Sustainable ocean economy came into prominence because of the Small Island Developing States (SIDS), who were concerned about the well-being of ocean health as their own existence and survival depended entirely on the oceans. These nations are economically weak and unable to implement new technologies and policies. While the need is urgent, lack of available funds is an impediment to implement sustainable use of ocean resources by these nations. For the larger nations while ocean sustainability is important, it is not critical as they have terrestrial resources for their growth and hence the intent of investing towards ways and means of achieving ocean sustainability is limited.

4.2 Policy making

Ocean based economic activities and the resulting deterioration of the marine environment and ecosystem has increased pressure on governance and hence policy making. Accordingly, various world organisations run programmes to address issues that will help better policy making. While the UN Environment addresses management and pollution related issues,[1] FAO addresses those of fisheries[2] through Port State Measures Agreement to eradicate IUU fishing and the IOC handles development of scientific solutions.[3]

Since a business-as-usual model in the ocean is no more acceptable, it needs to be avoided. This puts enormous pressure on coastal states who need to

1 See, https://www.unenvironment.org/ accessed on 10 November 2021

2 See, http://www.fao.org/fisheries/en/ accessed on 10 November 2021

3 See, https://en.unesco.org/ocean-decade accessed on 10 November 2021

introduce and implement policies to encourage sustainability, thereby increasing the cost of operations and governance, a difficult path especially for the SIDS which are otherwise poor nations and have only the ocean resources for their food and economy to depend upon. Additionally, since the adoption of disruptive technology in the maritime industries is a slow process (Agarwala, 2021a), putting the requisite policies in place and ensuring compliance is even slower, difficult and sometimes ineffective.

4.3 Technology

With a basic understanding that technology can address and resolve human problems, a number of fixed, submerged, remote, autonomous and drifting systems have been developed. These systems acquire, process and transfer large volumes of ocean data to provide a better understanding of the ocean and to support a safe, effective and sustainable use of ocean resources and to monitor the risks towards ocean sustainability.

While many technologies have been developed we still know little about the numerous marine species and topography in waters greater than 3,000 metres. Furthermore, humanity lacks a detailed scientific understanding of the role of oceans in climate change and their influence on weather that are considered essential to manage ocean ecosystems and sustainable operations of ocean-based industries.

4.4 Voluntary commitments of developing and poor nations

It is important to understand that even though globally the general principle of growth and development has been to 'develop first and clean-up later' (Agarwala, 2021b), this principle cannot be employed by the developing and poor nations. This is primarily because Mother Nature has run out of resilience and cannot absorb anthropogenic abuse any further. Hence, if growth and development is to be achieved by these nations, they need to follow the path of sustainability, thereby making their growth process expensive and sometimes difficult to achieve. This is forcing developing and poor nations to either not commit to emission targets or commit to lower values. A point in case is the INDCs of most nations that provide the commitments of reduced carbon emissions while ensuring growth and prosperity of their citizens. Though these INDCs have been made voluntarily by the nations, they are either not being achieved or are grossly inadequate to meet the commitments of the Paris Agreement (Agarwala and Polinov, 2021).

Though the situation may look grim, it is not that nothing has been achieved to date. Studies have shown that though the world was on a 3.6°C track in 2015, concerted efforts by nations have put it on a 2.9°C path by 2020 (CAT, 2020). However, this is far from the desired path of 2°C to 1.5°C path as committed by nations during the Paris Agreement. Even today, 37 per cent of the 127 countries do not have a net-zero target and only 48 countries have submitted new INDC targets.

4.5 Understanding the requirement to achieve sustainability

The available literature on Blue Economy and Sustainability has increased many folds in recent years that make it even more complicated for one to appreciate as to what needs to be done. This said, it is, however, not clear as to how this sustainable ocean economy, generally addressed as the Blue Economy, should look like (Patil et al., 2016). The need for a definition, policy and the path required for its development, therefore, has become critical as there looms a large risk if the ocean-based activities are undertaken without this clarity. The problem becomes even more acute as, according to the Organisation for Economic Co-operation and Development (OECD), many ocean-based industries have the potential to outperform the growth of the global economy as a whole, thereby boosting employment and doubling the economic contribution to GDP equivalent from the ocean economy in the next fifteen years through 2030 (OECD, 2016). It is because of this that, in recent years, there is a consistent focus of humanity to develop this economy.

It thus becomes important that one understands as a basic minimum as to what is required to ensure a sustainable ocean development. In the understanding of the author, the following are essential and need to be focused on to achieve sustainable ocean development:

(a) Protecting and restoring coral reefs.

(b) Develop restorative aquaculture.

(c) Invest in nature based solutions to climate change.

(d) Invest in sustainable methods for exploiting ocean resources.

(e) Develop technology to support marine protected areas.

(f) Develop technology to monitor and fight marine pollution.

5. Opportunities to achieve Ocean Sustainability

Having discussed the risks and challenges in achieving ocean sustainability we need to look at the opportunities that can encourage steps towards a sustainable ocean economy. While we look at the existing opportunities we need to encourage innovation networks of research institutes, enterprises, and universities to work together on a range of scientific and technological innovations to achieve a sustainable ocean economy. This would however be possible only if adequate capacity is created to develop and provide affordable, ethical and socially acceptable innovation and technologies that are environmentally sustainable and are capable of delivering solutions to even the most marginalised communities and income groups. Some available opportunities that exist and under development are:

5.1 Use of digitalisation for pollution control

Anthropogenic efforts post the First Industrial Revolution has been greatly responsible for initiating the human woes with respect to environmental pollution. However, the Fourth Industrial Revolution or the Digital Revolution through the use of Artificial Intelligence (AI) is creating a societal shift to address this environmental deterioration that is threatening future life on Earth even though numerous challenges, such as high cost and the need for regulatory approvals, act as barriers to their effective use. By using AI along with Machine learning (ML) and Deep Learning (DL) the complex process of the environment can be understood and sustainable trends of resource utilised. This, in turn, would help nations to achieve the SDG-14 goal of conserving and using ocean resources sustainably (UN, 2015). In order to ensure sustainability and a healthy ocean, issues of pollution, habitat, species, climate change impact, and biodiversity, as seen in **Figure. 3**, need to be addressed, which can be and are being done extensively through the use of AI (Agarwala, 2021c).

Similarly, digital platform technologies (blockchain, IoT, cloud data, and big data analytics) are helping towards better administration, logistics, shipping, terminal, and port working. This in return is helping in decarbonising of the shipping industry (Agarwala et al., 2021) and encouraging saving energy, fuel in transport, and limiting pollution (Agarwala and Guduru, 2021).

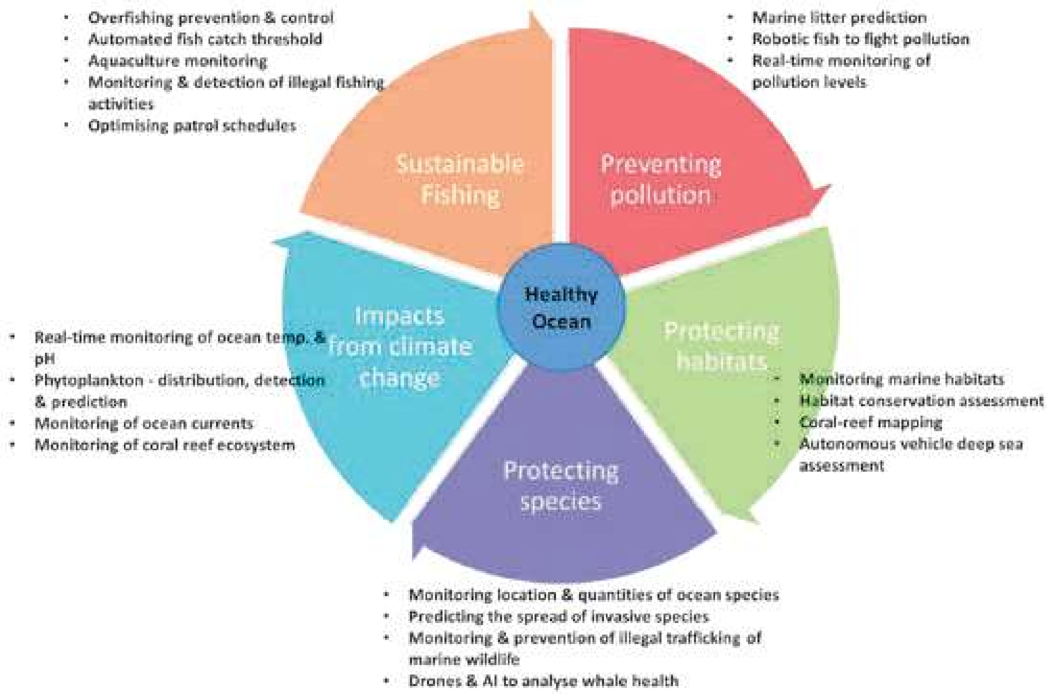

Figure 3: Utilising AI for ensuring a healthy ocean (Source: Agarwala, 2021c)

5.2 Use of technology for understanding the Ocean

Technological advancements are impacting every aspect of ocean economy so much so that the next Industrial Revolution is likely to be driven by Digital Revolution which is referred to as Industry 4.0. These innovations are happening in numerous fields such as advanced materials, subsea engineering and technology, sensors and imaging, satellite technologies, computerisation and Big Data analytics, autonomous systems, biotechnology, and nanotechnology. Since these technologies are cross-cutting and not area specific, they are likely to impact every facet of ocean economy.

To understand the ocean better, dedicated ocean observation procedures and technologies have been employed over the years (Agarwala, 2020b). The data collected in some cases is free and open that allows multi-stakeholder contributions thereby creating better opportunities for the scientific community at large. Such efforts can help forecast sea conditions, improve marine safety and support ocean-based business activities such as shipping, aquaculture, fisheries, algae blooms, port navigation, disaster management and protection of species by altering shipping lanes, to name a few. Yet another form of dynamic observatories for marine scientific research being proposed is through the use of "green cables" (Agarwala, 2018; Agarwala, 2019).

5.3 Use of ocean energy to power a sustainable ocean economy

Energy in general is considered essential to support the growth of shipping, fisheries and ports and the high-growth industries of marine aquaculture, ocean observing, marine robotics, biofuels and mineral extraction. Since the coastal real-estate is at a premium, the energy sector has moved inshore to avoid conflict with other users. This in return has made energy for ocean economy activities costly, forcing energy generation on site in the marine environment using ocean energy. Accordingly, a number of ocean energy technologies have been developed over the years. These include processes of kinetic energy (winds and currents), potential energy (tidal amplitude), mechanical energy (waves), thermal potential (vertical temperature gradients) or even osmotic pressure (horizontal gradients of salinity) (Agarwala, 2021d).

However most of these technologies are still under development with many economic, technical, governance and environmental problems to be solved (Melikoglu, 2018). While technologies, like wind, are maturing and have already achieved commercial success, technologies such as Ocean thermal energy conversion (OTEC) promise both freshwater and electricity and hence can be used for dual purposes. For ecologically fragile regions and small islands, a Low-Temperature Thermal Desalination (LTTD) combined with the OTEC can be used by the SIDS of the Indo-Pacific region (Maitreyee and Agarwala, 2019).

As humanity tries to harness the ocean-energy, a variety of methods have been experimented with for each of these sources, but so far cost, performance and/or reliability benefits have not been demonstrated. Furthermore, since waves and currents are influenced by the shape of the ocean floor, each site needs to be studied independently and exploited accordingly. As the industry matures, a convergence of a number of technologies is expected, similar to what was seen by the terrestrial wind-energy industry.

5.4 Committing funds from recovery

It is an accepted fact that the nations of the world have a disparity in their economic status. This disparity has disallowed developing and poor nations to commit funds towards recovery from the impact of climate changes. Even though some sectors believe that developed nations should step forward to financially support this recovery process since the carbon emissions of today is because of these nations. However, there is little acceptance of this thought and lack of funds is the usually cited reason. This explanation notwithstanding, the recent events of COVID-19 which brought the global scientific community and funding together is proof enough that if the global community decides to address an issue, they will be able to do so provided it is supported by a political will.

In the initial months of COVID (01 January to 24 May 2020), various funding agencies of the global community pledged nearly US$ 14.0 trillion alone to fight COVID-19 and to revive their economies (Cornis, 2020). Of these, the EU alone has gone ahead to proceed the 'green' way when moving towards an economic recovery (Rowlatt, 2020). If only the world was to consider a mere one per cent of such committed funding for development of technology to address climate change and towards sustainability, it would deliver amazing results.

5.5 Invest in sustainable methods to address IUU fishing

Technological solutions exist for curbing *IUU fishing*. These solutions vary from vessel tracking to law enforcement using mobile technology (USAID, n.d) or dedicated transmitters (USAID, 2018). It is worth mentioning that nations tend to comply, make changes and deliver under international pressure. A case in point is the successful efforts of Thailand to curb IUU fishing after they were warned by the EU in 2015. To address this issue Thailand used modern day technology to develop a robust and reliable system.

Accordingly, all fishing vessels above 30 GT were installed with Vessel Monitoring System (VMS) and the fishing gear verified with a fishing licence. After 01 April 2018, vessels caught without a valid licence were prosecuted. This resulted in locking up of 1,098 commercial fishing vessels (Starn, 2018). Additionally, illegal vessels were purchased by the government and all new registrations were suspended for two years starting July 2018. Destructive fishing methods were prohibited and the validity of their licence was redefined to encourage sustainable fishing. To support law enforcement, monitoring, control and surveillance (MCS) was improved and aircraft and unmanned aerial vehicles were used to support sea patrols (MFA, 2018). All fish catches were recorded electronically (EJF, 2019) and prosecution was adequately supported by strengthening local laws.

This effectively means that mechanisms to stop IUU fishing and shift to sustainable methods exist and can be applied if the nation involved is forced to do so. Since IUU fishing is one risk for the sustainability cycle, it needs to be stopped immediately to ensure a sustainable ocean economy.

5.6 Eco engineering

Eco-engineering schemes refer to the modification of planned or existing structures to become multifunctional. By installing artificial floating islands (AFIs) a habitat for biodiversity can be created. The AFIs are typically two square metres that broadly consist of a buoyant mat of non-woven plastic matrix, integrated connection grid and polyurethane foam, planting media and emergent vegetation. They are a novel technique that has been employed in the UK (Ware and Callaway, 2019).

5.7 Geo engineering

Geo-engineering is an engineering process wherein CO2 from the air is removed to tackle climate change. Limiting sunlight reaching the planet is yet another process that geo-engineering employs to tackle the impact of climate change. Although large-scale geo-engineering systems are still a concept, they are presently treated as a distraction for reducing emissions. It may become a reality if climate change continues (--, 2011). They are considered as the last resort since even after Paris Agreement the world nations have not been able to limit the rise of temperature to below 2°C and it is felt that as a last resort such geo-engineering efforts would necessarily be required. However, some researchers feel that utilising such methods would give a free hand to economies to pollute without any control. The five carbon capture technologies that are being explored include Direct Air Capture (DAC), Bioenergy with carbon capture and storage (BECCS), Biochar, Enhanced Weathering and Trees and Soil (Collin, 2020). While the IPCC estimates that BECCS could potentially remove around 10 billion tonnes of CO2 from the atmosphere each year (Jacobson, 2019), 'the Orca' carbon-capture plant, outside Reykjavik in Iceland, using the DAC technology has been switched on in September 2021 to remove 4,000 tonnes (approximately 4,409 tons) of carbon dioxide every year that is equivalent to emission from 870-cars (France-Presse, 2021).

5.7 Marine biotechnology

Advances in science and technology in molecular biology have supported the development of *marine biotechnology*. These studies have helped to improve our understanding about the marine life. It has also provided access to marine organisms, ecosystems, and bio-resources and allowed their study which so far has been lacking (OECD, 2013). This technology has application in sectors of energy, pharmaceuticals, food, and chemical industries. The technology aims to significantly increase production efficiency and product quality in sectors by introducing new species for intensive cultivation thereby encouraging sustainability through better understanding.

6. Way Ahead

As discussed in the preceding sections, the ocean resources are under serious stress from human activities and hence there is a serious and urgent need to ensure sustainable ocean development. Accordingly, the known risks, challenges and opportunities have been discussed. It is felt that there is an urgent need to build capacity; provide access to affordable innovation and technologies; and ensure research and innovation that are ethically and socially acceptable, environmentally sustainable, and that can be utilised by the poorest and most marginalised communities and income groups. It is only once such solutions are available that ocean assets will be protected, restored, and enhanced. While some broad based opportunities have been discussed, to achieve ocean sustainability, the following are considered essential.

(a) *Regional cooperation*, to address the complex and trans-boundary nature of ocean and coastal issues and challenges.

(b) *Best practices* of ecosystem-based management to be utilised proactively to protect and sustain marine and coastal ecosystems and their functions.

(c) *Integrating fisheries and marine resources* as part of food security would provide a better understanding of the link between fisheries, food security and food safety thereby promoting healthier practices in fisheries management; combating IUU fishing; and sustainable mariculture practices.

(d) *Knowledge dissemination* about the role of coastal and marine ecosystems needs to be encouraged for greater public awareness of the benefits these ecosystems provide during natural disasters.

7. Conclusion

Sustainability of oceans for a prosperous future of humanity is an essentiality. Even though oceans have sustained the requirements of mankind to date, unsustainable means have brought the oceans to a point where they can no more support the excesses of humans. It is in response to this understanding the United Nations adopted the Sustainable Development Goals 2030, Goal 14, while various international organisations have begun focusing on encouraging sustainable ocean economy.

To better appreciate the risks, challenges and opportunities available towards a sustainable ocean economy and encourage greater public participation, the article has discussed these aspects. It is important to appreciate that ocean sustainability cannot be achieved by technology and innovation alone, as they are only facilitators. The need of the hour is political will and human participation that can help strengthen the policy and regulatory frameworks; sharing knowledge on lessons learned and support regional cooperation on trans-boundary issues.

Disclaimer

The views expressed in the paper are those of the author and do not reflect the views or policies of the Government of India or the Indian Navy. The author can be reached at nitindu@yahoo.com.

References

ADB. 2017. "A Region at Risk: The Human Dimensions of Climate Change in Asia and the Pacific", *Asian Development Bank*, https://www.adb.org/sites/default/files/publication/325251/region-risk-climate-change.pdf

ADB. 2018. "The Action Plan for Healthy Oceans and Sustainable Blue Economies", Flyer, *Asian Development Bank*, https://www.adb.org/sites/default/files/am-content/484066/action-plan-flyer-20190430.pdf

Agarwala, N. 2018. "'Green cables' – Development, opportunities and legal challenges: Part I", *Maritime Affairs: Journal of the National Maritime Foundation of India*, 14:2, 49-62, DOI: 10.1080/09733159.2018.1562456

Agarwala, N. 2019. "Green cables – Development, opportunities and legal challenges; Part-II", *Maritime Affairs: Journal of the National Maritime Foundation of India*, 15:1, 93-107, DOI:10.1080/09733159.2019.1631538

Agarwala, N. 2020a. "Science, technology and innovation for a healthy, blue ocean and sustainable ocean economy in the Asia-Pacific", *UNESCAP Asia-Pacific Tech Monitor*, 37(1), Jan-Mar 2020, https://repository.unescap.org/bitstream/handle/20.500.12870/2619/20Jan-Mar_tm_final.pdf?sequence=1

Agarwala, N. 2020b. "Monitoring the Ocean Environment Using Robotic Systems: Advancements, Trends, and Challenges", *Marine Technology Society Journal*, Volume 54, Number 5, September/October 2020, pp. 42-60(19), DOI: 10.4031/MTSJ.54.5.7

Agarwala, N and Guduru, SKS. 2021. "The potential of 5G in Commercial Shipping", *Maritime Technology and Research, Thai Journals Online*, 2021; 3(3), 254-267, DOI: 10.33175/mtr.2021.248995

Agarwala, N and Polinov, S. 2021. "Curtailing Anthropogenic Carbon dioxide to meet the targets of the Paris Agreement using technology support mechanisms", *Journal of Human-centric Research in Humanities and Social Sciences*, 2021, Volume 2, No. 1, 2021, 24 pages, DOI: https://dx.doi.org/10.21742/jhrhss.2021.2.1.01

Agarwala, N. 2021a. "Role of Policy Framework for Disruptive Technologies in the Maritime Domain", *Australian Journal of Maritime & Ocean Affairs,* 23 March 2021, 3(3): DOI: 10.1080/18366503.2021.1904602

Agarwala, N. 2021b. "China: Combating Environmental Degradation", International Journal of Environmental Studies, Sep 2021, DOI: 10.1080/00207233.2021.1974756

Agarwala, N. 2021c. "Managing Marine Environmental Pollution using Artificial Intelligence", Maritime Technology and Research, Thai Journals Online, 3(2): 120-136, DOI: 10.33175/mtr.2021.248053

Agarwala, N. 2021d. "Powering India's Blue Economy through Ocean Energy", *Australian Journal of Maritime & Ocean Affairs,* Jul 2021, 3(4), DOI: 10.1080/18366503.2021.1954494

Agarwala, P., Chhabra, S., and Agarwala, N, 2021. "Using Digitalisation to achieve Decarbonisation in the Shipping Industry", *International Journal of Maritime Safety, Environmental Affairs and Shipping* 5:4, 161-174, DOI: 10.1080/25725084.2021.2009420

CAT. 2020. "Paris Agreement Turning Point", Climate Action Tracker, December, https://climateactiontracker.org/documents/829/CAT_2020-12-01_Briefing_GlobalUpdate_Paris5Years_Dec2020.pdf

Collins, Leight. 2020. “Climate saviours? The five leading carbon-negative solutions needed to reach net-zero emissions”, *Recharge*, November 13, 2020, https://www.*recharge*news.com/transition/climate-saviours-the-five-leading-carbon-negative-solutions-needed-to-reach-net-zero-emissions/2-1-912037

Cornis, L. 2020. “Interactive: Who's funding the COVID-19 response and what are the priorities?”, *Devex*, May 28, 2020, https://www.devex.com/news/interactive-who-s-funding-the-covid-19-response-and-what-are-the-priorities-96833

DeRidder, Kim J. and Nindang, Shanti. 2018. “Southeast Asia’s Fisheries Near Collapse from Overfishing”, *Asia Foundation*, March 28, 2018, https://asiafoundation.org/2018/03/28/southeast-asias-fisheries-near-collapse-overfishing/

EJF. 2019. “Thailand’s progress in combating IUU, forced labour & human trafficking, Observations and Recommendations”, *Environmental Justice Foundation (EJF)*, Vol. 7, https://ejfoundation.org/resources/downloads/EJF-PIPO-Technical-Report-update-spring-2019.pdf

France-Presse, Agence. 2021. “World’s biggest machine capturing carbon from air turned on in Iceland”, *The Guardian*, September 09, 2021, https://www.theguardian.com/environment/2021/sep/09/worlds-biggest-plant-to-turn-carbon-dioxide-into-rock-opens-in-iceland-orca

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R., and Law, K. L. 2015. “Plastic waste inputs from land into the ocean”, Science, 347(6223), 768–771. DOI:10.1126/science.1260352

Jacobson, Mark Z. 2019. “The health and climate impacts of carbon capture and direct air capture”, *Energy and Environmental Science*, 12, 3567-3574, https://doi.org/10.1039/C9EE02709B

IPCC. 2019. “The Ocean and Cryosphere in a Changing Climate”, *A Special Report of the Intergovernmental Panel on Climate Change* (IPCC), p. 13, https://www.ipcc.ch/site/assets/uploads/sites/3/2019/12/SROCC_FullReport_FINAL.pdf

MFA, Thailand. 2018. “Illegal fishing clampdown”, *Reuters*, October 15, 2018, https://www.*reuters*.com/sponsored/article/turning-the-tide/illegal-fishing-clampdown

Millennium Ecosystem Assessment. 2005. “Ecosystems and Human Well-being: Synthesis”, Island Press, Washington DC. https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Melikoglu, M. 2018. “Current status and future of ocean energy sources: A global review”. Ocean Engineering, 148, 563–573. DOI:10.1016/j.oceaneng.2017.11.045

Maitreyee SK & Agarwala, N. 2019. “Sustainable desalination technologies: Avenues for cooperation in the Indo-Pacific”, *Maritime Affairs: Journal of the National Maritime Foundation of India*, 15:1, 78-92, DOI: 10.1080/09733159.2019.1628335

National Academies of Sciences, Engineering, and Medicine. 2019. “Negative Emissions Technologies and Reliable Sequestration: A Research Agenda”. Washington, DC: The National Academies Press. https://doi.org/10.17226/25259

National Geographic. 2010. “*Marine Habitat Destruction*”, April 27, 2010, https://www.nationalgeographic.com/environment/oceans/critical-issues-marine-habitat-destruction/

OECD. 2013. “Marine Biotechnology: Enabling Solutions for Ocean Productivity and Sustainability”, *OECD Publishing*, https://doi.org/10.1787/9789264194243-en

OECD. 2016. “The Ocean Economy in 2030, Organisation for Economic Co-operation and Development”, DOI:10.1787/9789264251724-en

Oceandecade. 2019. “The Science We Need for the Ocean We Want, The United Nations Decade of Ocean Science for Sustainable Development (2021-2030)”, https://www.oceandecade.org/assets/The_Science_We_Need_For_The_Ocean_We_Want.pdf

Patil, P. G., J. Virdin, S. M. Diez, J. Roberts, and A. Singh. 2016. “Toward a Blue Economy: A Promise for Sustainable Growth in the Caribbean; an Overview”. Washington D.C.: The World Bank, https://openknowledge.worldbank.org/bitstream/handle/10986/25061/Demystifying0t0the0Caribbean0Region.pdf?sequence=4

Pearce, Fred. 2019. “The natural solutions to climate change held in the ocean”, China *Dialogue Ocean*, November 26, 2019, https://chinadialogueocean.net/11915-coastal-ecosystem-natural-solutions-climate-change/

Rowlatt, J. 2020. “Climate Change: How a green new deal could go global”, 31 May, BBC, https://www.bbc.com/news/science-environment-52848184

SEAFDEC. 2019. “USAID the Ocean and Fisheries Partnership”, *USAID Oceans*, https://www.seafdec-oceanspartnership.org/about/

Starn, Claire. 2018. “Thailand confident to ban illegal fishing, forced labour by end of year, says ambassador”, *Euractiv.com*, July 17, 2018, https://www.*euractiv.com*/section/agriculture-food/news/thailand-confident-to-ban-illegal-fishing-forced-labor-by-end-of-year-says-ambassador/

The Blue Carbon Initiative. n.d. “About Blue Carbon”, *TheBlueCarbonInitiative.org*, https://www.*thebluecarboninitiative.org*/about-blue-carbon

UN. 2015. “Transforming our world: The 2030 agenda for sustainable development”, A/RES/70/1, https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981

UNDESA. 1992. “Agenda 21”, https://www.un.org/esa/dsd/agenda21/res_agenda21_00.shtml

UNESCAP. 2018. “Key environment issues, trends and challenges in the Asia-Pacific region”, UNESCAP, ESCAP/CED/2018/1, pp. 7-8, September 12, 2018, https://www.unescap.org/sites/default/files/CED5_1E_0.pdf

UNEP. 2019. “Global Resources Outlook 2019 Natural Resources for the Future We Want”, UN Environment, https://wedocs.unep.org/bitstream/handle/20.500.11822/27517/GRO_2019.pdf?sequence=3&isAllowed=y

USAID. n.d. “Building Cross-Sector Partnerships for Seafood Traceability (2015-2020)”, *USAID/RDMA Oceans and Fisheries Partnership* (*USAID Oceans*), https://www.resonanceglobal.com/project-profiles/usaid-oceans

USAID. 2018. “USAID brings Philippines Small-Scale Fisheries Online in New Traceability Pilot”, *USAID/RDMA Oceans and Fisheries Partnership* (*USAID Oceans*), June 27, 2018, https://www.usaid.gov/asia-regional/press-releases/jun-27-2018-usaid-brings-philippines-small-scale-fisheries-online

Visbeck, M. et al. 2017. “Facts and Figures on the Threats to Our Marine Ecosystems”. *Ocean-Atlas*, pp. 42-43, https://meeresatlas.org/wp-content/uploads/2017/06/*Ocean-Atlas*-Web-EN.pdf

WCED. 1987. “Our Common Future”, Report of the World Commission on Environment and Development (WCED), https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html

Ware, J. and Callaway, R. 2019. “Public perception of coastal habitat loss and habitat creation using artificial floating islands in the UK”, PLoS ONE, 14(10): e0224424, https://doi.org/10.1371/journal.pone.0224424

World Bank. 2010. "*Changing the Climate for Development*", World Development Report 2010, p.6, https://openknowledge.worldbank.org/bitstream/handle/10986/4387/9780821379875_overview.pdf

World Bank. 2011. "What is geoengineering?", *The Guardian*, February 18, 2011, https://www.theguardian.com/environment/2011/feb/18/geo-engineering