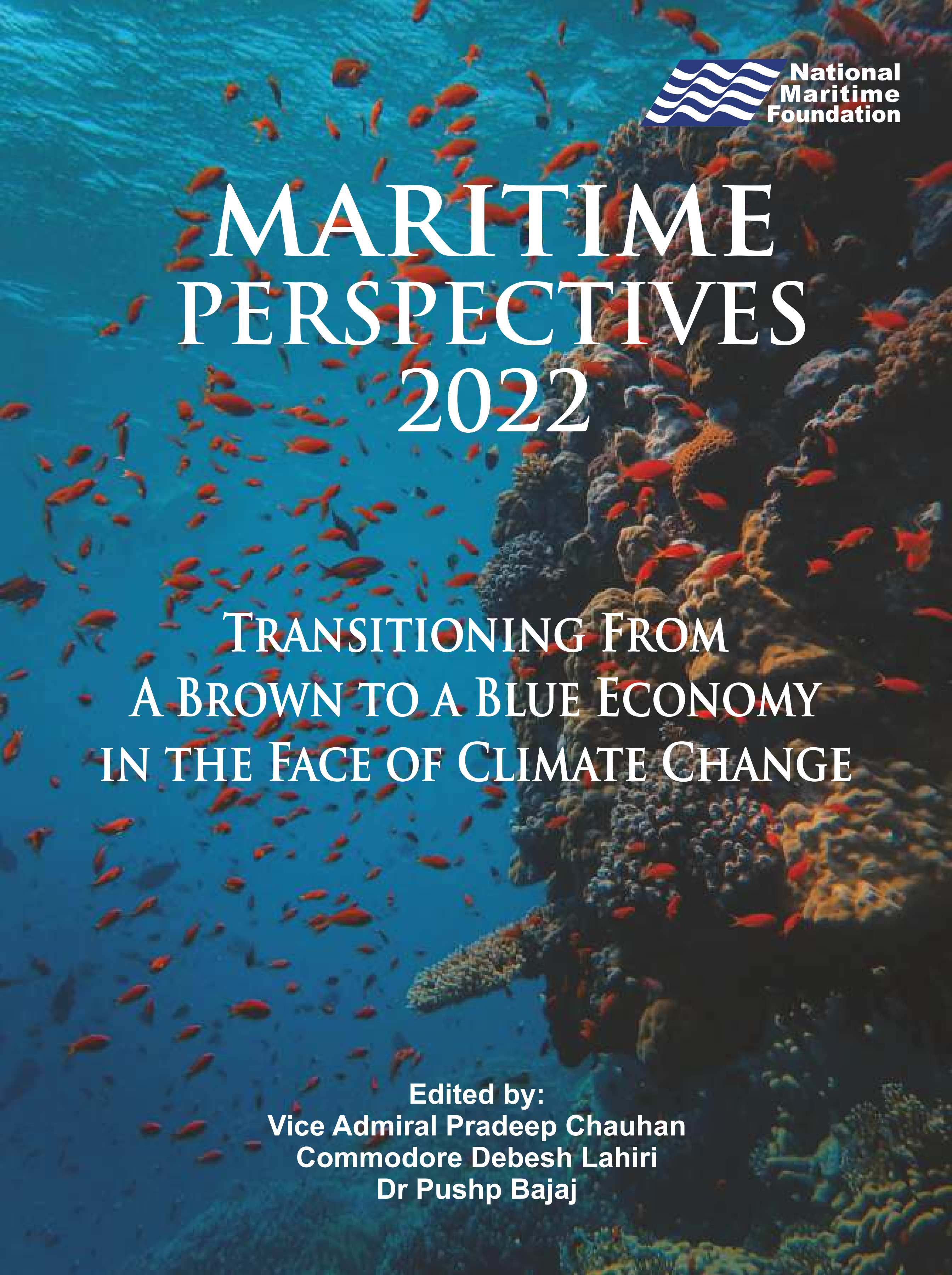

National Maritime Foundation

MARITIME PERSPECTIVES 2022

Transitioning From A Brown to a Blue Economy in the Face of Climate Change

Edited by:
Vice Admiral Pradeep Chauhan
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First Published in 2022

Cover Picture Credit: Photo by Francesco Ungaro:
https://www.pexels.com/photo/school-of-fish-in-body-of-water-4620471/

ISBN: 978-81-959079-3-9 (Paperback)
ISBN: 978-81-959079-7-7 (eBook)

Rs. 550.00

Maritime Perspectives, published since 2014, is an annual publication of the National Maritime Foundation (NMF) which compiles thematically arranged research articles that have been published on the NMF website on issues related to holistic maritime security. As a consequence of COVID-induced disruptions, *Maritime Perspectives 2022,* the sixth edition of the series, compiles articles covering the period February 2019 to October 2022 in six thematically focused volumes. Articles published by the NMF Research Faculty elsewhere are reproduced with permission of the original publisher.

The editors would like to acknowledge the contribution of former Executive Directors of the NMF, Captain GS Khurana (03 June 2014 – 03 June 2019) and Captain Sarabjeet S Parmar (04 June 2019 – 03 January 2022).

The editors would also like to acknowledge the production team comprising:

Overall Project Coordination	:	Captain Himadri Das, Dr Oliver Nelson Gonsalves, and Ms Krithi Ganesh
Volume Coordination	:	Dr Chime Youdon
Compilation	:	Ms Gargee Priyadarshini, Mr Mohammad Umar Shakil, and Ms Krithi Ganesh
Cover Design	:	Ms Krithi Ganesh
Administrative Support	:	Commander Saurav Mohanty, Mr Kamal Meena, and Bhupinder Kumar LLOG(MAT)

Published by:
NATIONAL MARITIME FOUNDATION
Varuna Complex, Airport Road,
NH-8, New Delhi-110 010

Printed by:
Alpha Graphics
6A/1, Ganga Chambers, W.E.A.,
Karol Bagh, New Delhi-110005

Foreword

In the current world order, the economy of every coastal and island nation relies heavily on its surrounding ocean and the living and non-living ocean resources. Landlocked countries, too, are inextricably linked-to the ocean through international merchandise trade, which takes place primarily via sea-routes. Indeed, over 80 per cent, by volume, of all international merchandise trade is carried upon the sea. For India, this number is around 95 per cent. According to the "2022 State of World Fisheries and Aquaculture Report" of the United Nations (UN) Food and Agriculture Organization (FAO), total fisheries and aquaculture production hit an all-time high of 214 million tonnes in 2020, accounting for US$ 151 billion worth of international trade in fisheries and aquaculture products.

All across the globe, ocean-based tourism is burgeoning and is the economic mainstay of many Small Island Developing States (SIDS), quite apart from its growing importance even in the more-diversified economies of larger coastal States. Much of the appeal of this ocean-based tourism is centred upon beaches, snorkelling, diving, and the controlled engagement of human beings with a variety of aquatic wildlife, such as whales, dolphin, and shark. Every year, hundreds of cruise-liners not only offer luxurious onboard attractions, but also bring increasing numbers of tourists to relatively unexplored and biologically sensitive areas. None of this economic activity can be sustained without an abundance of natural coastal ecosystems such as mangrove forests, seagrass meadows, and coral reefs.

The global ocean and the vast seabed constitute a huge storehouse of precious mineral resources such as copper, zinc, nickel, gold, silver, cobalt, phosphorous, lime mud, etc, many of which are critical to support land-based construction and industrial activity, including the manufacture of electronic devices, and green technologies such wind turbines, solar panels, and batteries for electric vehicles.

Additionally, of course, the ocean is universally recognised as being a source of clean renewable energy that is stored in ocean waves, currents, tides, salinity differentials, and temperature differentials as a function of depth.

All these obvious natural gifts notwithstanding, recent decades have witnessed increasingly obvious, deeply disturbing physical and chemical transformation, resulting primarily from human greed and overexploitation, marine pollution, and a series of adverse impacts of climate-change wrought by human activity. Since the advent of the first industrial revolution, the world ocean has absorbed nearly one-third of the excess carbon dioxide (CO_2) that has been emitted into the atmosphere by humans and as much as 90 per cent of the excess heat generated by greenhouse gas (GHG) emissions. The effect upon ocean ecosystems such as coral reefs, mangrove forests, and seagrass, and the marine life supported by these ecosystems, has been nothing short of catastrophic. Increasing ocean temperature is also a major cause of sea level rise since water expands when heated, which is scientifically known as *"thermal expansion"*. Studies have shown that increasing ocean temperatures have also contributed to a decline in dissolved oxygen content in the ocean, which, in turn, has led not only to the expansion of existing *"dead zones"* in the ocean but the creation of new ones, too. Overall, combined with overexploitation of resources and ever-growing marine pollution, these climate-change-induced changes are causing major disruptions to marine life and destabilising entire ecosystems with significant socio-economic consequences for nearly all maritime sectors of the economy.

This volume of *Maritime Perspectives 2022* presents a few of the more significant contemporary anthropogenic challenges facing the ocean ecosystem and its resources under the current, exploitative ***'Brown'*** economic model and outlines the steps that we must take as a nation, a region, and a global community, in our mandatory transition to a sustainable and resilient ***'Blue'*** economic model. It is extremely important for nations and their governing elites to recognise that the 'Blue Economy' is not the same as an 'Ocean Economy'. A 'Blue Economy' is not a part of some other type or colour of the national economy. It is very nearly the entire economy, predicated upon three assertions: First, that the ocean is the font of all life on earth. Second, that we can no longer afford (if we ever could) any further degradation of the environment, ecological destruction, or loss of biodiversity. Third, that any harvesting of the earth's resources can only be permitted on a strictly sustainable basis. The manner in which GDP — our most common metric of economic measurement — is calculated is increasingly open to question. What, for example, ought to be the GDP-component value of a mangrove forest? Should it be the merely the cost of the wood? What about its carbon sequestration? How ought this to be valued when computing its contribution to the national GDP? These are the sort of questions that this volume seeks to raise in the minds of its readers — whether they be planners or practitioners, and whether experts or the public at large.

It is my personal conviction that these are perhaps the most important questions, issues, and challenges, for together, the Blue Economy and Climate Change (BECC) present all mankind with an existential threat of rapidly increasing urgency.

Jai Hind! Sam no Varunah!

Vice Admiral Pradeep Chauhan
AVSM and Bar, VSM, IN (Retd)
Director-General
National Maritime Foundation

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Setting the Context

The Ocean: Life Below Water and Why it Matters

Dr Norma Patricia Muñoz Sevilla, Marisa Lopez, and Ana Hanhausen

The ocean covers around three-quarters of the Earth's surface and contains more than 90% of living species on our planet. The ocean is also the single largest ecosystem in the world, and it provides food for billions of people worldwide, as well as maritime transport, renewable energies, and other goods and services like regulating, cultural and supporting services.

Nevertheless, the ocean is not indestructible, and our footprint is very large. Overfishing, toxic pollution, invasive species, nutrient over-enrichment, habitat degradation and destruction, biodiversity loss, the dependence of a growing global population on its goods and services, and coastal development, all threaten the sustainability of coastal ocean ecosystems.[1] Ocean acidification is also a growing threat that may be more important than warming, pollution and overfishing.[2]

Why Does the Ocean Matter?

"Oceans mean different things to different people: life, passion or wonderment; vastly important; a very important source of life and energy; an incredible source of food and an amazing source of biodiversity; it's wild, exciting, terrifying and exhilarating; means a lot to me, if something happens I will not have the fun I'm used to; it's a livelihood, it's been there for generations and hopefully will be there for generations to come."[3]

According to the World Wildlife Fund, the ocean is currently valued at $24 trillion dollars. The goods and services from marine environments add up to an additional $2.5 trillion yearly. This means the ocean would have the seventh-largest GDP in the world. However, the value of the ocean relies on its current output, which in turn depends on its conditions. Climate change, ocean acidification, habitat destruction, pollution and overfishing are endangering the ocean and threatening its value and the security and livelihood of the three billion people who depend on it. Most of these people live in Small Island Developing States, they are among the ones who contribute least to these issues, but they are the ones at most risk, as they're already vulnerable.[4]

Agenda 2030: SDG 13 and SDG 14

A historical change has been taking place for the past 23 years, from Agenda 21 to Agenda 2030. At the Rio de Janeiro Earth Summit in 1992, more than 178 countries adopted Agenda 21. The Millennium declaration was adopted after the 2000 Millennium Summit in New York. 10 years after the Rio Earth Summit, in the Millennium Development Goals (MDGs) that were adopted during the Earth Summit in Johannesburg, ocean issues were included in the conversation for the first time.

In 2012, at the United Nations Conference on Sustainable Development (also popularly known as Rio+20), member states adopted the document titled *"The Future We Want"*, which set the process of developing the sustainable development goals (SDGs) building on the MDGs. Finally, during the UN Sustainable Development Summit in 2015, seventeen SDGs were adopted which are an integral part of the 2030 Agenda.

Progress of SDG 14 in 2019

The expansion of protected areas for marine biodiversity and existing policies and treaties that encourage responsible use of ocean resources are still insufficient to combat the adverse effects of overfishing, growing ocean acidification and worsening coastal eutrophication. As billions of people depend on oceans for their livelihood and food source, increased efforts and interventions are needed to conserve and sustainably use ocean resources at all levels.

- Ocean acidification is caused by the uptake of atmospheric CO_2 by the ocean, which changes the chemical composition of the seawater. Long-term observations over the past 30 years have shown an average increase of acidity of 26 per cent since pre-industrial times. At this rate, an increase of 100 to 150 per cent is predicted by the end of the century, with serious consequences for marine life.

- To achieve sustainable development of fisheries, fish stocks must be maintained at a biologically sustainable level. Analysis reveals that the fraction of world marine fish stocks that are within biologically sustainable levels declined from 90 per cent in 1974 to 66.9 per cent in 2015.
- As of December 2018, over 24 million km^2 (17.2 per cent) of waters under national jurisdiction (0–200 nautical miles from a national border) were covered by protected areas, a significant increase from 12 per cent in 2015 and more than double the extent covered in 2010. The protected areas increased from 31.2 per cent in 2000 to 44.7 per cent in 2015 and to 45.7 per cent in 2018.
- Illegal, unreported and unregulated fishing remains one of the greatest threats to sustainable fisheries, the livelihoods of those who depend upon them and marine ecosystems. Most countries have taken measures to combat such fishing and have adopted an increasing number of fisheries management instruments in the past decade.
- Small-scale fisheries are present in almost all countries, accounting for more than half of total production on average, in terms of both quantity and value. To promote small-scale fishers' access to productive resources, services and markets, most countries have developed targeted regulatory and institutional frameworks. However, more than 20 per cent of countries have a low to medium level of implementation of such frameworks, particularly in Oceania and Central and South Asia.

The Ocean Decade

To recognize that more needs to be done to mitigate the global decline in ocean health, in December 2017, the UN declared 2021 to 2030 as the decade of 'Ocean Science and Sustainable Development'. The Ocean Decade will strengthen international cooperation at all levels by strengthening dialogues, developing partnerships, developing capacity-building and leveraging investment, while supporting the entire 2030 Agenda for sustainable development. Other critical goals include improving ocean literacy and education to modify social norms and behaviours, and creating new models for ocean action.

The Ocean Decade aims to include science-informed mitigation and adaptation policies around the world and share knowledge with coastal communities that are most vulnerable to the changes of the ocean.[5]

The COVID-19 Pandemic and the Ocean

From Little Blue Letter, Glen Wright

- Marine creatures are enjoying some quiet time as underwater noise levels drop. Scientists are studying these effects on marine mammals.
- From Florida to Thailand, the number of sea turtles' nests has increased on the now-empty beaches. The rapid recovery of marine wildlife in coastal areas shows how extensive our impacts are and highlights the importance of protected areas.
- Fishers around the world are struggling with decreased demand, lack of sanitary conditions and logistical challenges. In some countries, like India, the food security of the communities may be affected by this disruption of supply chains.
- PADI and Rash'R are producing (non-profit) reusable face masks made from Ocean plastic, with designs based on sea animals!

Final Remarks

We can all take small steps towards protecting our ocean. Reduction of single-use plastic, responsible fish consumption, avoiding ocean harming products, and making your voice heard can all directly contribute towards a healthier ocean. However, more indirect approaches can be taken by reducing the amount of greenhouse gases produced by our daily activities and, therefore, reducing our carbon footprint. Reducing red meat consumption, consuming locally sourced products, and using personal vehicles less are all examples of small steps we can take towards reducing our impact. The sum of individual actions can truly make a difference in the fate of our ocean.

Collectively, we need to form a global ocean community, acknowledging that all of our actions have an impact on the ocean.[6] And, although it is incumbent on each of us to take steps to protect the ocean, collective action is also required. New models for ocean action, which are collaborative, intergenerational, cross-cultural, and multi-sectoral, are needed in the coming decade, in order to protect our beloved ocean.

"The ocean is our life support system, it connects every one of us; you can think of the ocean as the blue heart of this planet, but then we look after that heart and we know how we are damaging it and it needs intensive care. We know that scientists, politicians and stakeholders are talking to each other, but it isn't just up to them, each and every one of us can make a difference, even if the difference might be small, after all individual small drops of sea water can make up the vast ocean."[7]

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Note

This article is an analytical brief from the Climate Ambition and Sustainability Action (CASA) section of the World Sustainable Development Forum (WSDF) website, published in May 2020 and was later hosted on the Website of the National Maritime Foundation on 04 July 2020

On Oceans and Climate Change

Dr Pushp Bajaj

The ocean is and always has been essential to life on planet Earth. In fact, the ocean is where the very first life forms emerged on the planet. Even today, the world's oceans support nearly all life on Earth either directly or indirectly. In the current world order, every coastal nation's economy relies heavily on its surrounding ocean and the living and non-living ocean resources. The lesser appreciated fact, however, is that the oceans also regulate our climate, they are important components of the carbon cycle and the water cycle, and they are responsible for transporting heat across the planet through global water circulation patterns. Due to current anthropogenic climate change, the ocean is undergoing a remarkable chemical and physical transformation that will have profound implications for marine life, Earth's climate, coastal human populations, and ocean economies around the world.

This chapter seeks to provide an overview of how the global ocean is closely interlinked with climate change, how it is changing dramatically, and what the consequences of these changes will be for marine life and, in turn, for the billions of people that depend on marine life. The chapter will also discuss the importance of sustainable management and conservation of marine and coastal ecosystems, so as to restore the health of the ocean and, in the process, contribute to the mitigation of climate change.

The importance of the oceans for the sustenance of human life cannot be overstated. Microscopic plants in the oceans, called phytoplankton, form the base of the marine food-chain. They consume carbon dioxide (CO_2) through photosynthesis and generate oxygen, in the same way as do land-based plants. According to scientific estimates, phytoplankton produce as much as 80 per cent of the world's oxygen and feed everything from microscopic zooplankton to small fish, and invertebrates to multi-tonne whales.[1] The oceans also regulate the global climate by participating in the carbon cycle, the water cycle, and the heat cycle, the last-named through ocean circulation patterns that transport heat across the planet. For instance, changes in temperature and currents of the Indian Ocean regulate the Indian monsoon, which supplies over 70 per cent of India's annual rainfall.[2] At the global scale, the Atlantic Meridional Overturning Circulation (AMOC), which is a large system of ocean currents driven by differences in temperature and salinity of water, carries warm ocean water from the tropics to the North Atlantic, evenly distributing heat across the world's oceans and maintaining the climate in the Northern Hemisphere.[3]

The Ocean as the First Line of Defence Against Climate Change

In addition to the uptake of carbon dioxide by phytoplankton, the ocean also absorbs carbon by simply dissolving atmospheric CO_2 in the water. Through these two processes, the global ocean acts as a massive carbon sink, absorbing CO_2 from the atmosphere, just as is the case with forests and soils. More than a third of all human-caused (anthropogenic) carbon emissions end up in the ocean. When CO_2 is dissolved in water, it forms an acid called carbonic acid.

Therefore, as more and more CO_2 is absorbed by the oceans, they are becoming more and more acidic. This is commonly referred to as 'ocean acidification'. According to a Special Report by the United Nations' Intergovernmental Panel on Climate Change (IPCC) on *"The Ocean and Cryosphere in a Changing Climate"*, published in 2019, the pH (a measure of acidity) of open ocean surface-water has been declining at the rate of 0.017-0.027 units per decade since the late 1980s.[4] The current rate of acidification is faster than anything experienced during the last 300 million years.[5] The same report projects that if carbon emissions continue at the current rate, the pH of ocean surface-water will likely drop by 0.287-0.291 units by 2081-2100, relative to 2006-2015 levels, with the Arctic and north Atlantic ocean-basins experiencing the largest changes.

In addition to acting as a carbon sink, the ocean also acts as an enormous heat sink. It absorbs as much as 90 per cent of the excess heat generated by the increasing greenhouse gases in the atmosphere. Data records maintained by the USA's National Oceanic and Atmospheric Administration (NOAA) show that the "ocean heat content" has been rising relentlessly since 1970 (see Figure 1). Because of the sheer size and depth of the ocean and the amount of water that is available, it takes a long time to heat up all the ocean. Consequently, the heat-absorption capacity of the oceans is huge. Without the oceans, all this energy would have gone into the atmosphere and greatly increased temperatures around the planet. In other words, the ocean has significantly slowed down global warming in the atmosphere and over land. This phenomenon is well established within the scientific community and is sometimes referred to as "climate inertia". There is a lag between the time that a CO_2 molecule is emitted into the atmosphere and the time when its full warming potential is realised. The main reason for this time lag is that because the upper ocean waters initially absorb most of the added heat, which then gradually mixes with deeper waters and eventually comes to equilibrium with the atmosphere. The entire process can take many decades and even up to a century or more.

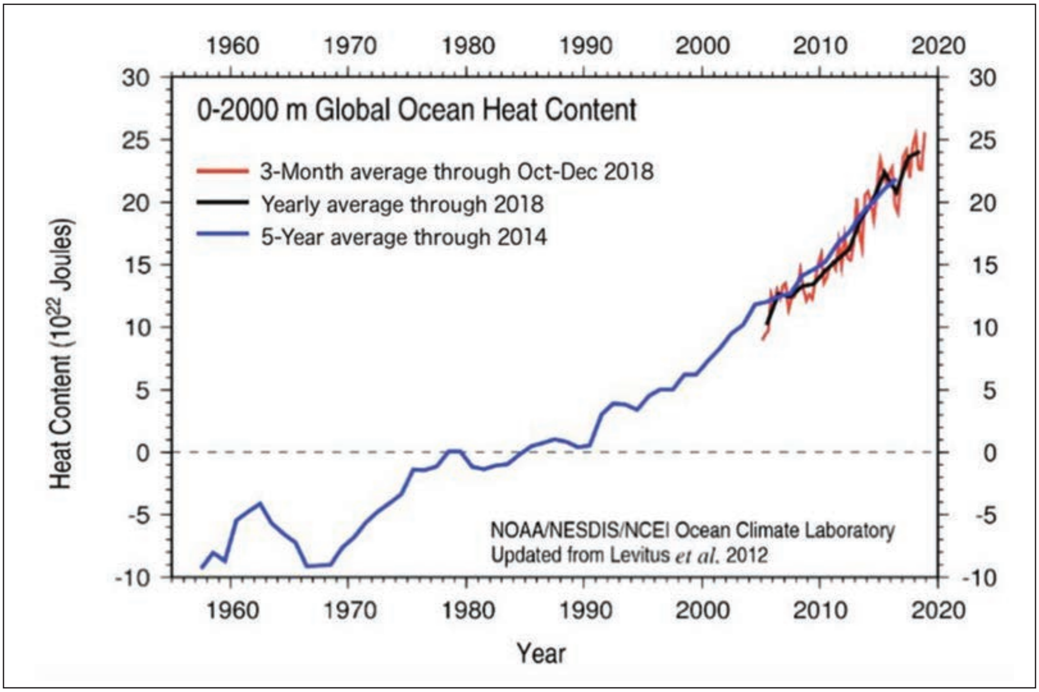

Figure 1: Time series of global ocean content up to 2000 m depth.
Source: US National Oceanic and Atmospheric Administration (NOAA).

This delayed response of the climate system can be further established by considering the trends in global average temperature and CO_2 levels in the atmosphere. Figure 2 shows the CO_2 concentration (in blue) in the atmosphere over the past 800,000 years, along with the polar temperature (in red) as an indicator of the average climatic conditions. The close relationship between CO_2 concentration and temperature is quite evident from the graph. The peaks and the valleys align very closely between the two, until one arrives towards the end of the graph, which represents the present time. Clearly, there is a sharp, unprecedented (at least in the past 800,000 years) rise in CO_2 concentration, undoubtedly driven by emissions from human activities, in the time-period following the industrial revolution. The temperature curve, however, appears to have not yet caught up with the sudden meteoric rise of CO_2. In 2014, atmospheric CO_2 concentration crossed the crucial threshold of 400 ppm (parts per million). The last time atmospheric CO_2 levels were that high was around 5 to 3 million years ago, during what is known as the Pliocene Epoch, when the global average temperature was 2-3° C higher than it is today. CO_2 levels in the atmosphere are still increasing at an accelerating pace.

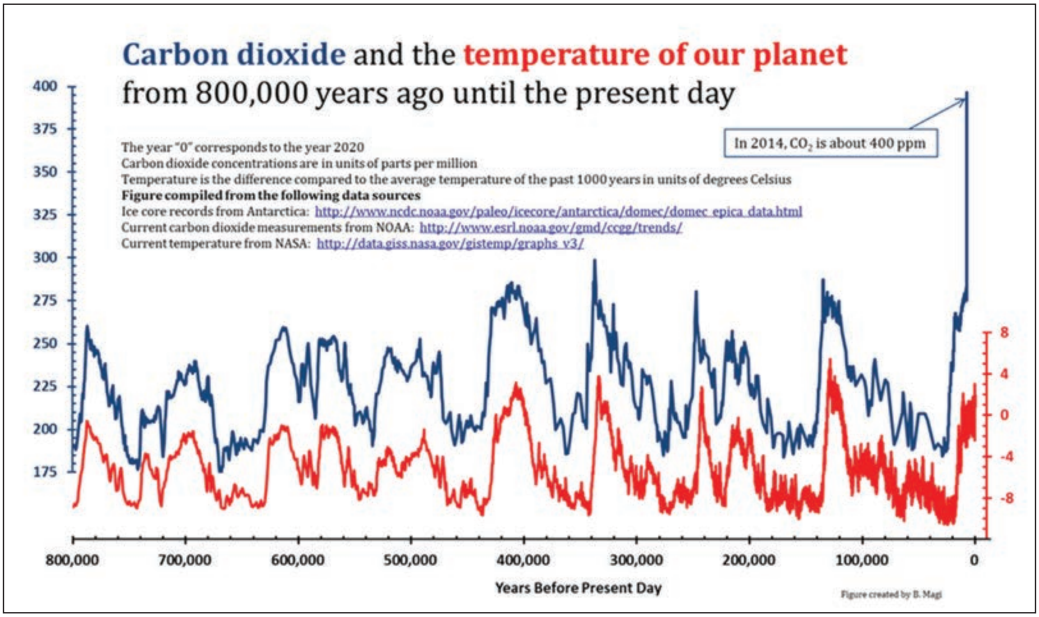

Figure 2: Time series of atmospheric CO2 concentration and average temperature from 800,000 years ago to 2014

Source: Image created by Brian Magi. Data sources listed in the image.

To the best of current scientific understanding, if the CO_2 concentration does not drop significantly, the global average temperature will eventually reach levels similar to those that prevailed in the Pliocene Epoch. This implies that there is more global warming that is still *"in the pipeline"* from the carbon that has already been added to the atmosphere. It is difficult to predict how and when the climate system will attain equilibrium and reach those temperature levels. In this context, the ocean has provided humanity with the crucial gift of time. We could, at least in principle, get the atmospheric CO_2 levels down to a safe level before the equilibrium response is reached. This is, however, a double-edged sword, because if we do not account for this delayed response, it may leave us complacent and push us beyond the point-of-no-return. In any case, while that may appear, at first glance, to be a blessing, the ocean's ability to absorb CO_2 and heat has severe implications for marine plant and animal species.

The Cost that the Ocean Pays

The above-mentioned changes in the chemistry and physics of the oceans have drastic and widespread impacts on marine ecosystems. Ocean acidification is particularly harmful to marine species that have shells or skeletons made of calcium, such as corals, and molluscs such as oysters and mussels, as rising ocean acidity causes such shells to dissolve and also hinders their formation in the first instance. The combined effects of increasing ocean temperatures, rising acidity and declining oxygen levels are causing mass coral bleaching, mass die-offs, changes in migration patterns, reproductive cycles, and the geographical distribution of marine species (both plants and animals). Phytoplankton, for instance, are being knocked out of balance by climate-change impacts, with some species outperforming others, leading to dramatic changes in regional distributions.[6] As mentioned earlier, phytoplankton form the base of the food chain, and any changes in their distribution will have ripple-effects across the entire marine food web. According to a recent study, climate-change impacts are also making phytoplankton less efficient at sequestering carbon from the atmosphere, which could significantly reduce the overall carbon sink capacity of the ocean.[7]

The 2019 UN IPCC Special Report on *"The Ocean and Cryosphere in a Changing Climate"*, concludes that marine heat-waves are becoming more frequent, extensive, and intense, in most regions of the world, due to continually rising upper ocean temperatures.[8] A marine heat-wave refers to a period of abnormally high ocean temperatures over days or months. It can extend across thousands of kilometres and can penetrate the oceans to depths of several hundred metres.

Projections based upon carefully generated climate-models suggest that at a global level, the intensity of marine-heat-waves and the number of days over which these marine-heat-waves last per year, will continue to increase throughout this century, that too, at an accelerating pace. Thus, many parts of the oceans may reach a state where a near-permanent heat-wave is experienced (compared to the 1982-2005 average conditions).[9]

Coral reefs provide essential habitat for thousands of marine species and support nearly a quarter of all marine life. These reefs are particularly vulnerable to heat waves. The Great Barrier Reef, which lies along the north-eastern coast of Australia, has already suffered three severe marine heat-waves in the last five years (2015-2016, 2016-2017, and 2019-2020), all of which led to mass coral-bleaching.[10] Indian coral reefs in the Gulfs of Mannar and Kachchh, the Palk Bay, and the Andaman and the Lakshadweep Seas, have experienced as many as 29 widespread bleaching- events since 1989. Future projections suggest that all the world's coral reefs may be lost by 2100 if we continue with business-as-usual.[11]

Marine organisms are responding to climatic changes in a variety of different ways, depending on their habitats, geographic affinities, and biological traits. The most common responses are changes in migration patterns and geographical distribution. On land, species tend to move northward to cooler regions in response to rising response rising temperatures. In the ocean, marine animals could move both horizontally to different locations and vertically to different depths, to avoid unfavourable seawater temperatures. Other responses include changes in physiological features (such as size), growth rates, and reproduction cycles. For instance, in recent decades, the oil sardine and the Indian mackerel, two of the most important types of commercial fish in India, have, due to increasing temperatures, extended their reach to higher (northerly) latitudes, where more hospitable conditions are experienced. Fish typically have a narrow range of preferred temperatures. While the movement of the oil sardine and the Indian mackerel has, thus far, been an "extension" of geographic reach and not really a "shift", if temperatures increase beyond the physiological optimum of the fish in the southern latitudes, then entire fish populations could shift northwards permanently. Therefore, depending on the species and the magnitude of environmental change, the area that it occupies could expand, shrink, or be relocated.[12]

The full extent of these impacts on marine species and their ecosystems is difficult to assess due to lack of long-term data records of populations of different species, as also regional climatic and oceanographic parameters. At longer timescales, such geographic redistributions of marine plant and animal populations could fundamentally change the structure and function of marine ecosystems. Naturally, these changes will have a significant impact on the fisheries industry and on coastal populations that rely heavily on fishes as a primary food source. Most likely, some regions will benefit at the expense of other regions, leading to economic competition and economic migration of coastal communities. Fishers will have to adapt accordingly, whenever possible, by extending their reach, acquiring new equipment and resources, or focussing on other fish that may now become more abundant in their region.

Ocean Conservation to Mitigate Climate-Change

Sustainable management and conservation of endangered species and habitats is essential to maintain the overall health of the ocean and marine life. Since climatic changes will impact different species differently, conservation efforts must be preceded by exhaustive 'vulnerability assessments' at the regional-, national-, and global-level, to identify the most vulnerable species/regions. This would require expanding monitoring capacity and maintaining data records, not only of species distributions and behaviour, but also of climatic changes in the oceans, to draw correct correlations and make informed decisions. Moreover, as climate-change impacts intensify in the future, it will become even more important to limit the stresses from human exploitation in terms of marine pollution, overfishing, and, Illegal, Unreported, and Unregulated (IUU) fishing. In this regard, Marine Protected Areas (MPAs) must be established, particularly around vulnerable areas, to allow under-stress habitats to recover and enhance resilience.

When it comes to ocean conservation, it is imperative to adopt a holistic approach and protect entire ecosystems to protect individual species. Coastal ecosystems such as coral reefs, seagrass meadows, mangrove forests, and wetlands, must all be protected as they provide critical habitats for vast numbers of marine species. Protecting and restoring these ecosystems will, in turn, help in mitigating climate change, as they absorb and sequester large quantities of carbon dioxide from the atmosphere, contextually referred to as 'blue carbon'. Moreover, they act as highly effective natural defences against sea-level rise and cyclonic storms. Therefore, the conservation of marine and coastal ecosystems must be central to any and all climate-change mitigation and adaptation strategies.[13]

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Note

This article was first published on 23 July 2020 on the Website of the National Maritime Foundation

Stemming the Rising Tide — Oceans and the United Nations Framework Convention on Climate Change

Dr Saurabh Thakur

The crisis of anthropogenic climate change has been framed in myriad ways, often oscillating between a wide array of definitions, political ideologies, economic pathways, and moral principles. Translating such a diverse and polarised debate into actionable policy has been at the core of all environmental negotiations, in particular the United Nations Framework Convention on Climate Change (UNFCCC), which acts as the main fulcrum for the transnational governance of climate change.[1] However, the UNFCCC negotiations remain shrouded in a sort of *"constructive ambiguity"*,[2] which allows for differences to perpetuate and solidify over time, so much so that an ambiguous outcome is considered preferable over non- compliance by member countries. Summing up the 2015 Paris Agreement, a much-lauded yet legally non-binding instrument, George Monbiot (2015) wrote that, *"by comparison to what it could have been, it's a miracle. By comparison to what it should have been, it's a disaster."*[3]

One of the key oversights of the three-decade long UNFCCC negotiations is the oceans. Despite their critical importance for the mitigation and adaptation outcomes, oceans have largely remained absent from the negotiating table. The word 'ocean' finds no mention in the Kyoto Protocol (1997) and a solitary nod in the preambular section of the Paris Agreement.[4] It may seem counter-intuitive, but apart from the 1992 foundational text of the UNFCCC (Article 4.1d), which promotes sustainable management, *"of sinks and reservoirs…including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems"*,[5] the largest known carbon sink in the world has had to compete for attention amidst a host of other issues such as finance, CBDR-RC, carbon markets, deforestation, etc. This indifference gets particularly stark when compared with the other major sinks like the forest systems, which have received significant attention and even led to a dedicated workstream, under the aegis of the UNFCCC, called "Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries" (REDD+).[6]

Another example of this neglect can be seen in the allocation of the side events at the annual COP meetings, which constitute the core of the negotiations. At the critical Copenhagen COP meeting of 2009, only four such events focused on oceans as against the thirty-one that were devoted to forests. A similar story unfolded at the following meetings in Cancun COP16 (3/31) and Durban COP17 (4/28), where the foundations for the Paris Agreement were laid out.[7] Although oceans did feature prominently in the "Structured Expert Dialogue (2013-2015)", in which several dialogues were focused on the exchange of views and scientific knowledge regarding long term global goals relevant to the oceans, oceans did not find equal currency at the Paris COP21 meeting in 2015.[8]

Fortunately, the post-Paris phase, which saw intense negotiations on the "Paris Rulebook" and the publication of the "IPCC Special Report on the Ocean and Cryosphere in a Changing Climate", has witnessed a surge of interest in ocean-related issues, which indicates that the priorities are being redrawn within the UNFCCC. This chapter analyses the reasons underpinning the absence of oceans within the UNFCCC and recent developments that are seemingly reversing this trend.

Dependencies and Pathways

The conspicuous absence of oceans within the UNFCCC negotiations can be explained by assessing the impact of path-dependence on the institutional structure, and stakeholder- preferences. "Path dependence" refers to a historical inertia wherein, "*early sequences of choices can set in motion a course of events that becomes self-reinforcing over time.*"[9] This is sought to be schematically depicted in Figure 1. Institutional path dependence creates a positive feedback mechanism, accumulated through years

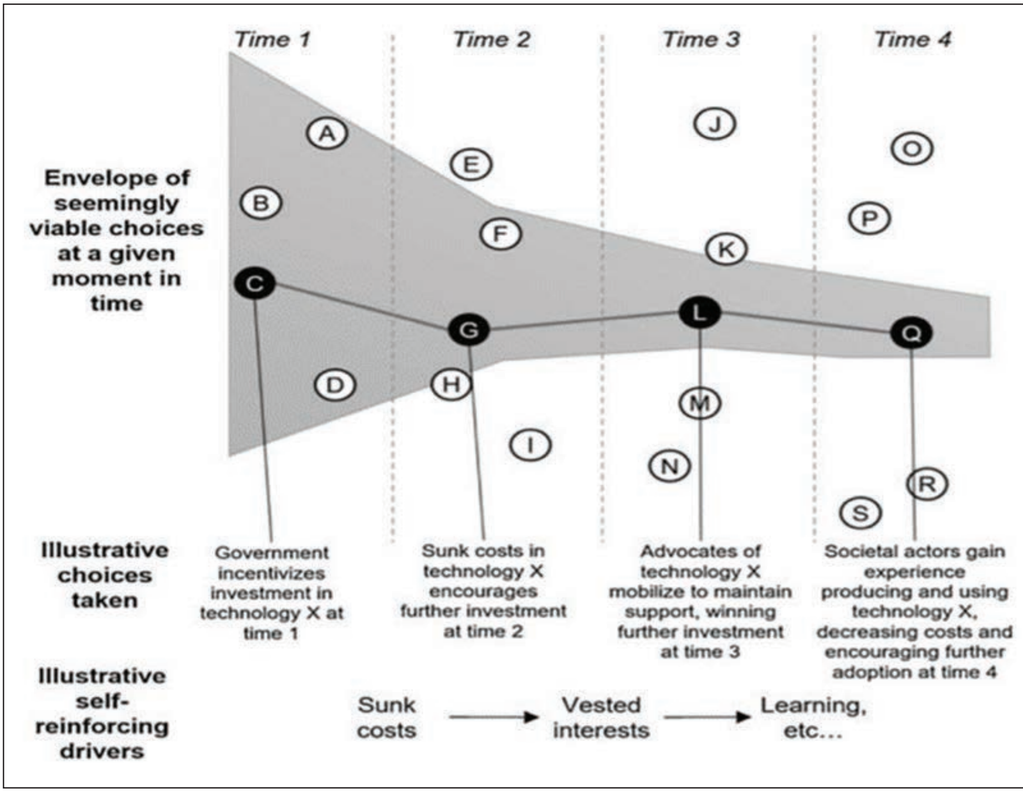

Figure 1: Schematic Representation of a Path-Dependent Process
Source: Daniel Rosenbloom, James Meadowcroft, and Benjamin Cashore, "Stability and climate policy? Harnessing insights on path dependence, policy feedback, and transition pathways", Energy Research & Social Science, No 50 (2019): 171.

of experience, and financial investments, along with a standardisation and diffusion of values and technologies, all of which, taken in aggregate, make it difficult to veer off towards new institutional paradigms, and transition pathways.

An example of path dependency in the context of the climate change is the well-known 'carbon lock-in', "*whereby initial conditions, increasing economic returns to scale, and social and individual dynamics act to inhibit innovation and competitiveness of low-carbon alternatives*."[10] The path dependency within the UNFCCC explains the absence of any institutional mechanisms addressing oceans, even though insurmountable evidence of its linkage with climate change has only grown with time. Oceans are the largest CO_2 sink, having absorbed 40 per cent of CO_2 emissions since the industrial era and nearly 90 per cent since the 1970s, the period which has been described as the period of 'Great Acceleration'.[11]

When read in the context of intergovernmental organisations, path-continuity becomes a political problem, as institutions are conceived as "*distributional instruments laden with power implications*," which are not merely driven by fortuity and chance events in the early years, but also through the conscious reinforcement by powerful actors within such organisations.[12] Although policymakers and non-State stakeholders prefer stability and durability within climate policy making process, the evidence on the ground suggests that the political process favours a balance between durability and flexibility. A good example of this balance is the Paris Agreement itself a flexible instrument of climate change governance, which struck a compromise with its adoption of a hybrid approach, wherein an enhanced transparency framework was adopted to meet the 2° C temperature-target and non-State actors were brought on board as stakeholders so as to ratchet up the collective ambition, but, at the same time, States were provided with the flexibility to determine their commitments, "*in light of their different national circumstances.*"[13]

Yet another factor that has contributed towards this resistance to change is the institutional ambiguity that stems from the complicated legal status of the maritime sphere. States, as well as international organisations, have consistently struggled with employing legal- jurisdictional approaches to tackle the complex challenge of climate change in the maritime sphere.[14] While States remain the dominant actors, many key regional platforms and conventions have, indeed, become relevant over time. Examples include the 1982 United Nations Convention on the Law of the Sea (UNCLOS), which forms the regulatory framework for the usage of oceans, and the International Maritime Organisation (IMO), a specialised agency of the UN which deals with shipping. That said, the lack of rules to tackle the overlapping 'institutional settings' of these organisations has created an opportunity for the dominant actors to shape the norms and negotiate and alter the existing rules-based order.[15] Much like path-dependency, "institutional ambiguity" also resists change as it provides an asymmetric opportunity for powerful actors to exercise influence.

The critical takeaway from all this is the immense weight that the choices that are made in the here-and-now have in shaping the future of climate policy. The overriding imperative of anthropogenic climate change and the availability of credible scientific evidence has created a space in which to grapple with the issue of path dependency in the context of climate policymaking. A key example of this change is the Representative Concentration Pathways (RCPs), which were used in the 2014 IPCC Fifth Assessment Report (AR5). RCPs are a set of transition scenarios that assess the concentration trajectory of Greenhouse Gases (GHG) in the atmosphere, over time. The IPCC reports use four different pathways — RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5. While RCP 2.6 is the most ambitious and stringent of the pathways, RCP 8.5 lies at the other end of the spectrum and represents a 'business as usual' (BAU) scenario of continuous rise in emissions through the 21st century.[16]

The IPCC Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC) notes, *"It is virtually certain that the global ocean has warmed unabated since 1970 and has taken up more than 90% of the excess heat in the climate system (high confidence) … sea level rise has accelerated (extremely likely) due to the combined increased ice loss from the Greenland and Antarctic ice sheets (very high confidence). Mass loss from the Antarctic ice sheet over the period 2007-2016 tripled relative to 1997-2006."*[17]

The report makes a number of grim observations and provides critical evidence that can nevertheless prove beneficial in limiting the global temperatures to "well below" the 2° Celsius point, in line with the Paris Agreement. Recognising that the health of the oceans is directly linked with food security, water security, marine ecosystems, tourism, transport, livelihoods, health, culture and identity, and so on, the SROCC report projects four separate scenarios or pathways, which open a window into the imminent future and how it will be impacted by choices made in the present (See Table 1).

Post-Paris Climate Architecture: Rising Profile of Oceans

The publication of the Special Report on the Ocean and Cryosphere in a Changing Climate has provided a major fillip to the campaign to bring oceans to the front and centre of UNFCCC attention in the post-Paris phase of negotiations. Article 4.1

Table 1: Projected global mean surface temperature change relative to 1850–1900 for two time periods under four RCPs

Scenario	Near-term: 2031–2050		End-of-century: 2081–2100	
	Mean (°C)	Likely range (°C)	Mean (°C)	Likely range (°C)
RCP 2.6	1.6	1.1 to 2.0	1.6	0.9 to 2.4
RCP 4.5	1.7	1.3 to 2.2	2.5	1.7 to 3.3
RCP 6.0	1.6	1.2 to 2.0	2.9	2.0 to 3.8
RCP 8.5	2.0	1.5 to 2.4	4.3	3.2 to 5.4

Source: IPCC, "Summary for Policymakers" in IPCC Special Report on the Ocean and Cryosphere in a Changing Climate, eds. HO. Portner, DC Roberts, V Masson-Delmotte, P Zhai, M Tignor, E Poloczanska, K Mintenbeck, A Alegría, M Nicolai, A Okem, J Petzold, B Rama, NM Weyer (In press, 2019)

(d) of the Paris Agreement acknowledged the critical importance of carbon sinks, as witnessed its Preamble, which noted, "*it is important to ensure the integrity of all ecosystems, including oceans.*"[18] Although there is still no dedicated working group within the UNFCCC that deals exclusively with the ocean, the transition from the 'Kyoto Protocol'-based top-down architecture to the hybrid governance model in the Paris Agreement has wrought a sea change in the approach to tackling this topic.[19]

One of the visible efforts in this direction has been the inclusion of an ocean-climate change linkage under the "Nairobi Work Programme" (NWP), which acts as the 'knowledge-to- action hub' of the Convention. Established in 2005, the NWP works towards a synthesis of information on different facets of climate impact and vulnerability, and further dissemination of such findings, so as to address present knowledge-gaps and help parties to convert their commitments into tangible action on the ground.[20] The 13th "Focal Point Forum" of the NWP was held in Madrid, on 06 December, 2019, in line with the outcomes of the 50th meeting of "Subsidiary Body for Scientific and Technological Advice" (SBSTA),[21] and focussed exclusively on the, "*oceans, coastal areas and ecosystems, including mega deltas, coral reefs and mangroves.*"[22] The forum discussed a Scoping Paper entitled, "Adaptation of the Ocean, Coastal Areas and Ecosystems", which noted that 112 countries, representing 73 per cent of the world's population, included goals related to oceans in their commitments that were submitted to the UNFCCC. The paper further noted that, "*Over 70% of current Nationally Determined Contributions (NDCs) mention ocean- related topics with the dominant issues being: coastal impacts, ocean warming impacts, fisheries impact, ocean research and marine ecosystem impacts*"[23] (See Figure 2).

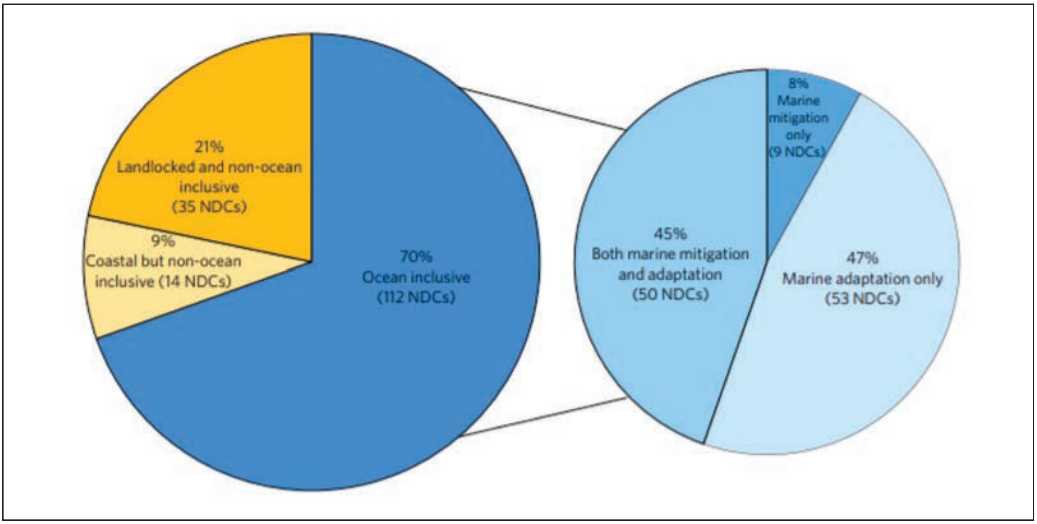

Figure 2: Inclusion of Ocean Issues in NDCs
Source: Natalya D Gallo, David G Victor, and Lisa A Levin, "Ocean commitments under the Paris Agreement", Nature Climate Change 7, no. 11 (2017): 834

Yet another promising development was the designation of the COP25 meeting in 2019 as the "Blue COP", which formed part of the effort to elevate the status of the ocean within the UNFCCC.[24] Unlike the previous and undoubtedly dismal record, the COP25 meeting saw at least 87 events related to the ocean, and witnessed a far wider participation by organisations working on the issues specific to the ocean.[25] The "Blue COP" led to the establishment of the "Platform for Science-Based Ocean Solutions" (PSBOS) with an objective, "*to encourage the incorporation of the ocean in climate strategies (NDCs, NAPs, Adaptation Communications, and National Policy Frameworks).*"[26]

The "Ocean Conference", held in 2017, was the first such dedicated effort by the United Nations to address the question of oceans and mobilise action towards the achievement of the SDG 14: Life Below Water, which is a critical part of the

Agenda 2030. The UN "Decade of Ocean Science for Sustainable Development", which extends from 2021 to 2030, provides yet another timely opportunity to create greater synergies between different stakeholders, and diverse targets such as "Nationally Determined Commitments", the "Aichi Biodiversity Targets", and, the "Sustainable Development Goals". The ascendency of ocean-related issues amidst pervasive changes brought about by anthropogenic climate change is a step in the right direction, which will, if persisted with, ensure a much-needed enhancement of attention being paid to maritime concerns and opportunities.

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Note

This article was first published on 09 June 2021 on the Website of the National Maritime Foundation.

The Challenge of Marine Pollution

Legacies & Learnings: A Case Study of Oil Spills in the Indian Ocean Region

Dr Saurabh Thakur

Oil spills cause severe distress to marine and coastal ecosystems and impair the livelihoods and health of people who are dependent on these ecosystems. These impacts have been studied and documented for decades, which has led to more effective management of oil spill disasters in recent decades (see Figure 1). However, the sharp rise in the scale of maritime trade and the evolution of ships and carriers has meant that even a single major oil spill incident can lead to severe short-term and long-term impacts. The nature of the impact on the marine ecosystems depends on a wide range of factors such as the quantity of oil spilt, type of oils, clean-up mechanisms, climate and weather conditions, location of spills, and biological composition of the environment, which includes both floral and faunal sensitivity. Apart from its environmental impacts the oil spill incidents, especially within the territorial waters of states, challenge the socio-economic and socio-ecological resilience of communities who are directly impacted by them. They also expose the lacunae in both the capacity and capability of governments, especially in the developing countries and small island states, who find themselves ineffective at containing the negative externalities of such incidents.

History of Oil Spills

The annual rate of an average number of spills above 7 tonnes in the 2010s was 6.3, which is a sharp 65 per cent drop from the average in the previous decade (see Figure 1). The key reasons behind this sharp drop are the stricter regulations and improvements made in the safety standards in the shipping industry. Another positive development has been the total volume of oil spilt at sea which has come down to 164,000 tonnes in the last decade, which is almost comparable to single year oil spillages in the previous decades. The International Tanker Owners Pollution Federation (ITOPF) notes that, *"In the 1990s there were 358 spills of 7 tonnes and over, resulting in 1,134,000 tonnes of oil lost; 73% of this amount was spilt in just 10 incidents… In the 2010s there were 63 spills of 7 tonnes and over, resulting in 164,000 tonnes of oil lost; 91% of this amount was spilt in just 10 incidents. One incident was responsible for about 70% of the quantity of oil spilt."*[1]

However, this statistic only provides half a picture because it excludes the less than 7 tonnes category of oil spills which account for more than 80 per cent of all oil spills. There is lesser clarity on the nature and damage of smaller oil spills due to a lack of reliable data. The major causes behind the larger oil spills include allisions/ collisions, groundings, hull failures, equipment failures, fires and explosions. Apart

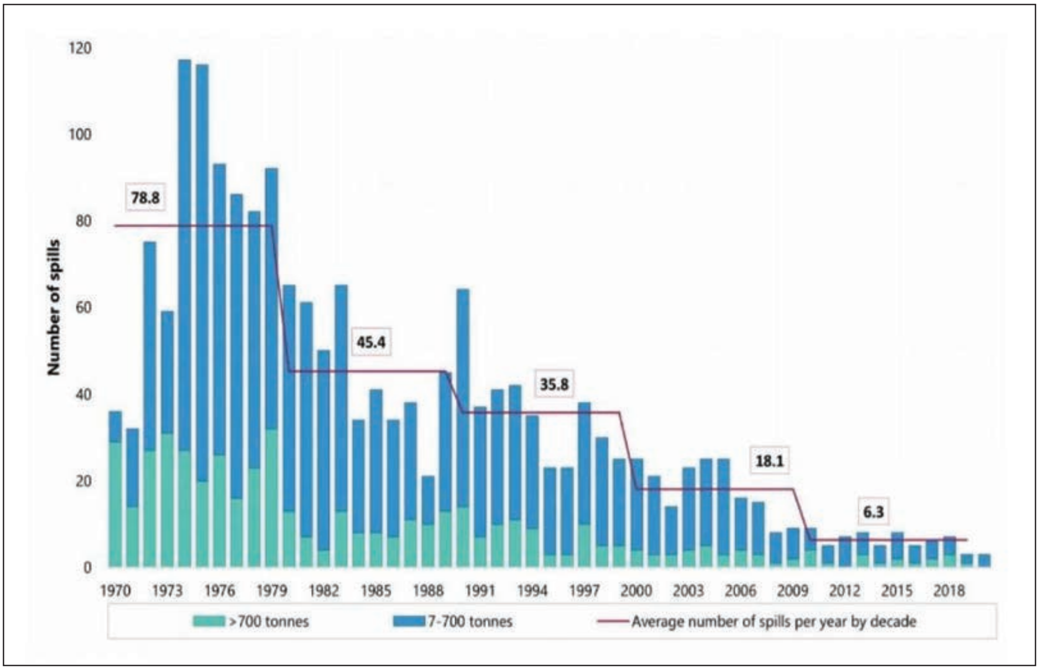

Figure 1: Number of medium and large spills (>7 tonnes) from 1970-2020
Source: Oil Tanker Spill Statistics 2020, ITOPF.

from these causes, there are "other" causes that involve human error and heavy weather damage and "unknown" causes where reliable data is not available. In the past decade alone, when the reporting improved considerably, allisions/collisions were the most common cause of oil spills, accounting for nearly 44 per cent of all medium (7-700 tonnes) as well as large spills (Above 700 tonnes). This trend could be attributed to the rise in vessel traffic and maritime trade across the world.

Case Study: MV Wakashio

On July 25, 2020, the Panama-flagged bulk carrier MV Wakashio, bound for Brazil, ran aground off the coast of Mauritius, leaking nearly 1000 metric tons of fuel into the coral reefs and wetlands inside a marine protected area. The bulk carrier, of the dimension of around 300 m length and 50 m is carrying low-sulphur fuel oil (3894 metric tonnes), diesel (207 metric tonnes) and lubricant oil (90 metric tonnes) for use onboard. This major accident raised several questions regarding national and regional state contingency planning, shipping sector and carries severe short term and long-term ecological implications. The Mauritian Ocean Territory floor has over 600 ship wreckages, retired ships, and war victims, that includes the steel-hulled Dalblair shipwreck of 1902 which struck on the reefs at Pointe D'Esny, the same site where the grounding of MV Wakashio took place in 2020.

In response to the accident, the Government of Mauritius activated its national oil spill contingency plan and two weeks later, as the ship began to break down, it declared a state of environmental emergency. A number of countries including India, France and Japan, as well as from international bodies, like the IMO and OCHA, the United Nations Development Program (UNDP) Mauritius and the ITOPF mobilised support in the form of equipment, finance and specialist teams to mitigate the tragedy. An estimated 3,000 tonnes of fuel were successfully removed from the MV Wakashio before it broke into two parts, on 15 August 2020.

The causes behind the incident have raised a number of controversial opinions, including the use of alcohol and bad weather theories. Casualty investigations, which are mandatory under MARPOL and SOLAS conventions, fall under the ambit of the flag State, which in this case was Panama. Lack of safety awareness has been listed as the main cause behind the incident in an inquiry by the owner company. The inquiry further suggested better training of staff and more effective oversight mechanisms including banning of private cell phones during work hours and setting up of speed communication systems as a way forward. A new article published by the *Forbes magazine* shed light on the incident through the use of satellite assessments. It claimed that MV Wakashio has been off its charted route much before it reached the Mauritian waters and this unusual behaviour remained unnoticed.[2]

Over the past three decades, the government of Mauritius has been a key beneficiary of capacity building assistance to prevent oil spills, which includes two Western Indian Ocean Island Oil Spill Contingency Plan and the GEF-World Bank funded Western Indian Ocean Marine Highway Development and Coastal and Marine Contamination Prevention Project (2007-2012). Yet, as the tragedy unfolded on August 7, 2020, the volunteers from local communities, ignoring the government order to leave the clean-up operation to officials and other potential risks including fines, began actively participating in the clean-up process. This local response indicates that the government plans on the matter, which seemed robust on paper, failed when it came to implementation. The public response also reflected the building of mistrust, especially after the narrowly averted tragedy in 2016, when MV Benita crashed in Mauritian waters along the coast to the south.

The Wakashio accident remains an ongoing investigation and its environmental impacts have thrown up a complex challenge to those who are running the clean-up operations. There have been serious concerns regarding the tampering allegations with the oil fingerprinting process, which is critical for conservationists to mitigate the impacts on marine life. The decision to sink a part of the ship in a primary whale nursing ground, apart from its legal validity, received a lot of criticism as it is likely to lead to heavy metal contamination. The location of the oil spill itself was in the middle of marine protected areas is a major cause of concern. The Pointe D'Esny Wetlands are a Ramsar site which are directly affected by the spill. The nearby Blue Bay Marine Park, also a Ramsar site, is home to coral reefs, mangroves and seagrass meadows. The spill location is also close to Ile aux Aigrettes Island, which is another natural reserve of importance, home to the last remaining ebony forests, Mauritian fodies and pink pigeons.

Oil can be retained within the marine ecosystems and in the sediments of the intertidal zone for decades, severely affecting the complex ecosystems such as the mangroves. The spill will leave a longer-term impact on the fishing grounds in the area, thus affecting the livelihoods of the local community. In the aftermath of the accident, 36 km of the shoreline was declared off limits for fishing or tourism activities. While the recreational activities returned to normal in the latter half of 2020, the health of the fishing grounds and mangroves remain uncertain.

Case Study: X-Press Pearl (2021)

The 2021 built container ship X-Press Pearl, sailing under the Singaporean flag, carrying 1,486 containers containing 25 tonnes of nitric acid, caught fire at the Colombo harbour on 20th May 2021, ten hours after it had docked at the Sri Lankan port. On 25 May, an explosion was reported onboard the ship, leading to debris, including plastic nurdles, crashing onto the shoreline. The owners of the newly built vessel offered apologies for the incident while defending the actions and decisions made by the crew. Both the Sri Lankan Navy and Indian coast guard were the first authorities to respond to the event with necessary equipment including oil containment booms and dispersants. The incident gained public attention as a case of mis declarations and non-compliance with safety standards on board the vessel. The issue of fire has been a major cause of oil spills in the past decade, and the sources of these fires are also changing. "*In 2019, the National Cargo Bureau conducted more than 32,000 dangerous dry and tank goods inspections in the U.S. finding that nearly eight percent were non-compliant due to poor stowage/securing, misdeclared cargo, or other issues.*"[3] The fire hazards are also a consequence of the sharply increasing size of the ships to meet the demands of trade and efficiency. The SOLAS "Safety of Life at Sea" convention was adopted in 1974 and is a key instrument that deals with safety and standards of construction and operations of ships. Both Singapore and Sri Lanka are a signatory to the Convention, but the flag state is bound by the convention to secure and comply with the requirements.

Following the accident, the Marine Environment Protection Authority (MEPA), which is the apex body responsible for the prevention and control of marine pollution in Sri Lanka, instituted a lawsuit against the X-Press owners. The government also instituted an inter-ministerial steering committee and five sub-committees under the guidance of the Ministry of Justice which will look into, *"legal action, compensation claims, environmental impacts, fisheries impacts and economic damages."*[4] Sri Lanka has seen an alarming rise in the number and frequency of distress incidents in recent years (See Table 1). *"Capsizing of vessels and vessels ran aground in 2019 marked alarming inclination of 366.6% and 500% compared to year 2018 and all such incidents were related to the Sri Lankan fishing vessels"*[5] In the past two decades, Sri Lanka has faced a number of maritime disasters which has put its ambitions to enhance shipping connectivity and developing maritime hubs into jeopardy.

Table 1: Recent maritime disasters in Sri Lanka

Vessel/year	Damages
MV Melishka (1999)	It was carrying 16,500 mt fertiliser and 200 mt of heavy fuel oil before it ran aground in Sri Lankan waters
MV Amanat (2006)	The vessel developed engine issues and sank 11 kms off coast, leading to a hazardous oil-spill of 25 metric tons.
MT Granba (2009)	The vessel faced with a leak which led to its eventual sinking and its cargo of 6,250 tonnes of sulphuric acid.
MT New Diamond (2020)	It was carrying 270,000 tonnes of oil. It caught fire east of Sri Lanka but one of the biggest potential oil spills in recent history was averted through coordinated action over ten weeks.
MV Xpress Pearl (2021)	The ship's cargo included 25 tonnes of nitric acid, 348 tonnes of oil and billions of small plastic pellets known as nurdles which washed up on the beaches.

Source: Daily Ft (2021) https://www.ft.lk/columns/Maritime-conventions-disasters-and-hubs-Sri-Lanka-s- decisive-hour-is-here/4-718947

Findings & Recommendations

The two case studies in this chapter highlighted the nature of the oil spill challenge for the littoral states of the Indian Ocean Region which is home to a rich floral and faunal biodiversity. It also highlighted the complexity of the maritime domain which is liminal, interconnected and multijurisdictional. These recent cases exposed some of these challenges ranging from operational capacity to legal interventions and liabilities, and socio-economic impacts on local populations. There are several steps taken up by regional actors which are laudable but there is scope for more coordinated and comprehensive steps that will ensure that the challenges of oil spills and marine pollution are dealt with effectively.

1. The MV Wakashio incident led to a coordinated effort by different actors who have invested heavily in the Western Indian Ocean regional maritime security architecture. IMO's efforts towards capacity building in the region have included training courses, equipment procurement and table-top exercises. However, these actors were still found wanting when it came to averting the tragedy in the real world. An important step for the states in the IOR is to develop a more robust maritime domain awareness to create networks of information sharing, joint oil spill responses, and conservation of marine resources. Given the nature of this crisis, national contingency plans must be complemented with a regional oil spill contingency plan to enhance the cleaning up mechanisms in countries that lack adequate capacity. These oil spill incidents also made clear that national plans have to be constantly updated to meet with the shifting nature of the oil and shipping sector, the changing biochemistry of oceans due to climate change and the rising scale of maritime trade.

2. The impact of oil spills on marine ecosystems is varied and complex. States must invest in evidence-based analysis of these impacts to understand the long term and short impacts on socio-economic and ecological systems. This will prove critical in the climatisation of national policies which is an important first step towards developing environmentally conscious contingency planning. States must consider declaring the fragile ecological zones in the Indian Ocean region as *Particularly Sensitive Sea Area* (PSSA) under the International Maritime Organisation (IMO) rules, which the ships can avoid on their route. It will make sailing close to the coast safer through stricter adherence to MARPOL regulations and help in the preservation of biodiversity hotspots. States in the IOR are signatories to important IMO conventions, but as the cases showed there was a requirement for them to update and ratify all necessary conventions, for legal action to become effective (See Table 3). A

good case, for example, is the issue of the typology of ships and vessels that is subject to different legal conventions. The two International Oil Pollution Compensation Funds — (International Convention on Civil Liability for Oil Pollution Damage (CLC) and the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND) and the supplementary fund, which were established in 1992 as main vehicles of compensation for oil spills only apply to oil tankers. In the case of MV Wakashio, which was a bulk carrier, the IOPC-FUND regime does not apply, which prevents Mauritius from putting any claims, despite being a signatory to the regime. None of the states in the South Asian region areis signatories to the Supplementary Fund. The IOPC Fund would have *"provided liability and compensation of up to 203 million SDR (approx. 286 million USD) for this incident (also covers reinstatement of the environment). The 2003 Supplementary Fund Protocol provides even higher liability and compensation, up to a maximum of 750 million SDR (around 1.05 billion USD) per incident, but has not been ratified by Mauritius."*[6] The convention that covers the MV Wakashio incident is the International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (Bunker Convention) but the amount of liability is much lower than the IOPC-FUND regime. All three parties, Mauritius, Japan and Panama are signatories to the convention. However, in the wider IOR region, particularly South Asia, India is the only country which has ratified the convention (See Table 2).

Table 2: Major IMO Conventions of Marine Pollution and Compensations

States	Prevention & Safety (MARPOL)					Spill Response		Compensation						
	73/78	III	IV	V	VI	OPRC	OPRC-HNS	CLC '69	CLC '76	CLC '92	Fund '92	Supp Fund	HNS*	Bunker
India														
Sri Lanka														
Maldives														
Mauritius														
Bangladesh														
Pakistan														

3. The case of X-Press Pearl also raised a key issue of 'Places of Refuge'.[7] The three-month-old vessel, before catching fire at the anchorage in Colombo, sought refuge and offloading in two ports, Hamad in Qatar and Hazira in India. The request was denied much like in the cases of Erika (1999) and Prestige (2001) tankers, which were also denied access to ports or refuge and ended up in major oil spill catastrophes. Efforts to prevent environmental disasters, particularly devastating oil spills from tankers, have incorporated multiple strategies, including vessel safety mandates, traffic control measures, artificial intelligence, and state inspection of vessels. While the preventive measures are critical, the case like X-Press Pearl shows that the dilemma of providing refuge will continue to remain a vexing one.

4. Finally, the absence of the shipping industry from the Paris Agreement is clearly a non-feasible long-term proposition. It is important that the shipping sector embraces the net-zero targets and clean energy and technological alternatives in a systematic manner.

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Note

This article was first published in the "South Asia Defence & Strategic Review" (DEFSTRAT) magazine (November-December 2021 Volume 15, Issue 5) and was later reproduced on the Website of the National Maritime Foundation on 10 January 2022 with permission of the Editor, DEFSTRAT. DEFSTRAT is a Media Partner of the National Maritime Foundation

The Fukushima Conundrum: Ocean Disposal of Nuclear Waste

Dr Saurabh Thakur

The Japanese Prime Minister, Mr Yoshihide Suga, recently made public a plan to discharge 1.25 million tonnes of treated radioactive water from the Fukushima nuclear plant into the Pacific Ocean, describing it as his country's *"most realistic option."* [1] The decision evoked consternation and rebukes from Japan's neighbours, especially China and South Korea, both of whom share a maritime border with Japan, and would be directly affected by this unilateral decision by the Japanese government. The decision is also being widely viewed as a gross abrogation of Japan's committed responsibilities under the UNCLOS. Japan certainly appears to be abandoning its commitments towards protection and preservation of the marine environment. The Japanese authorities, on the other hand, have been at pains to clarify that all traces of highly radioactive elements (strontium and caesium) have been removed from the storage tanks containing the treated wastewater. However, a lesser radioactive element named tritium, a radioactive isotope of hydrogen, which the Japanese government claims poseposes a low risk to human health and "zero impact on the environment",[2] will, indeed, be part of the disposal.[3] The International Atomic Energy Agency (IAEA) has backed the Japanese claim, saying, *"Japan's chosen water disposal method is both technically feasible and in line with international practice."*[4] The United States, in a tweet by Secretary Anthony Blinken, lauded Japan for its *"transparent efforts"* in following globally accepted standards of nuclear safety.[5] These endorsements notwithstanding, there is no gainsaying the fact that the decision has mostly drawn strong condemnation in the country's neighbourhood as well as in Japan's own coastal communities, owing to persistent and strong apprehensions of the severity of environmental as well as economic costs that the decision may incur.

Figure 1*:* Fukushima Daiichi Nuclear Power Plant Disaster in 2011
Source: BBC (2021) https://www.bbc.com/news/world-asia-56252695

Amidst these contrasting and highly emotive opinions, the whole question of ocean disposal of radioactive waste has once again risen to the fore and is likely to stir a wide- ranging debate regarding the health of the seas, radioactive waste-management, the effectiveness of international law, and the very future of nuclear energy.

Japan's Crisis of Trust

This year, Japan marks the tenth anniversary of the triple disaster that hit its shores on March 11, 2011, when a massive earthquake set off a *tsunami* that swept inland to destroy the Fukushima Daiichi nuclear power plant (see Figure 1).

More than 18,000 people died during this series of disasters, and nearly half a million lost their homes and livelihood. Alongside Chernobyl, it is the only nuclear accident classified as "Level 7", which is the highest category on the International Atomic Energy Agency's International Nuclear and Radiological Event Scale (INES).[6] Fears of radioactivity wreaked havoc in the region, severely affecting the region's coastal communities, which largely depended on agricultural businesses, fisheries and forestry. Apart from the ban on these sorts of Japanese products by its neighbouring countries, the Fukushima Prefecture also witnessed a local food avoidance, which led to economic hardship and had a severe and negative impact on indicators of psycho-social wellbeing such as community attachment, local identity, and culture.[7]

According to the "Integrated Fukushima Ocean Radionuclide Monitoring (InFORM) Network", traces of radioactive isotopes Cesium-134 and Cesium-137 from Fukushima were found in seawater and marine organisms throughout the Pacific, extending as far as the North American shoreline.[8]

Apart from its economic impacts, this catastrophic disaster had a fundamental impact on the social and political spheres as well. It was a rude wakeup call for a generation of Japanese people, which suddenly had to come to terms with the fact that even the world's most developed nations are neither immune-from nor prepared to handle the emerging risks and uncertainty. It also marked a watershed moment in the recent political history of the country, as large-scale, antinuclear protests erupted on the streets. The public outcry forced the government to immediately shut down 11 out of the 50 active nuclear reactors in the country, which then caused a significant drop in the electricity generation in the country — of the order of a whopping 40 per cent! By May 2011, all nuclear plants were ordered to shut down for testing and review.[9] The anti-nuclear protests coincided with the prime ministerial term of Shinzo Abe, whose administration's nuclear policy magnified the dilemma of the citizens, many of whom were opposed nuclear arsenals and wanted Japan to sign and ratify the 2017 UN Treaty on the Prohibition of Nuclear Weapons.[10]

One of the consequences of the anti-nuclear movement in Japan was an increase in reliance on oil and natural gas imports to meet the gaps in electricity generation. In the year 2020, Japan committed to building 22 new coal-fired plants at 17 different sites all over the country.[11] Struggling to meet the shortfall in energy supply, Japan's dependence on coal had steadily risen up to a 32 per cent share in the country's total energy generation in 2018. This dependence undermines the country's commitment to the Paris Agreement, where it has committed to cutting its emissions 26 per cent below 2013 levels by 2030, a target that has already been criticised for being 'highly insufficient'. The Global Climate Risk Index has consistently ranked Japan as the most risk-affected country globally due to its high vulnerability and exposure to extreme weather events.[12] In 2019, the United Nations rejected PM Abe's request to address the UN Climate Summit, due to his government's promotion of coal. Amidst such a convergence of crises, the nuclear waste dumping is likely to add to Japan's political and environmental woes.

Dumping of Nuclear Waste into the Ocean

Radioactive waste is typically classified in the following categories: Very Low-level Waste (VLLW), Low-level Waste (LLW), Intermediate-level Waste (ILW), and, High-level Waste (HLW). It is important to note that the currently prevailing protocol for the disposal of nuclear waste, the "London Protocol" of 2006, allows for the dumping of LLW during emergency conditions under a strict consultative process and under the guidance of competent authority.

Currently, LLW and VLLW form the bulk of the volume of radioactive waste from nuclear power production processes, and, according to IAEA estimates, nearly 80 per cent of these have been placed in disposal (see Table 1).

Table 1: Nuclear Waste Inventory (IAEA Estimates, 2018)

Category	Solid Radioactive Waste in Storage (m^3)	Solid Radioactive Waste in Disposal (m^3)	Proportion of Waste Type in Disposal
VLLW	2,356,000	7,906,000	77%
LLW	3,479,000	20,451,000	85%
ILW	460,000	107,000	19%
HLW	22,000	0	0%

Source: World Nuclear Organisation https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx

The dumping of nuclear waste, which included nuclear reactors from nuclear-powered submarines and core plates of nuclear icebreakers, into the ocean, was a common occurrence until the 1970s, when environmental movements began to raise demands for regulation of this practice. In fact, until the late 1950s, there was no recognised international institution or agreement or standards and procedures for radwaste disposal in the oceans. One of the outcomes of the United Nations Conference on the Law of the Sea (1958) was the assignment of these responsibilities to the International Atomic Energy Agency (IAEA). The IAEA set up its first "Advisory Group Meeting on Radwaste Disposal into the Oceans and Seas" in 1957, and took active steps to address this emerging crisis. In 1958, a panel of experts from nine countries was constituted to look into the issue. This panel, amidst sharp geopolitical differences and denials on the subject, eventually tabled the influential "Brynielsson Report", which noted that the range of properties of radioactive wastes was vast, while knowledge about the oceans was very limited. The report recommended that, "*at present, the release into the sea of highly-radioactive wastes from the irradiated fuel cannot be recommended as an operational practice… Wastes of low, and intermediate activity may safely be disposed of into the sea under controlled and specified conditions."* [13]

The Geneva Convention on the High Seas (1958), now well known as UNCLOS I, also took notice of the subject and its Article 25 notes, *"every State shall take measures to prevent pollution of the seas from the dumping of radioactive waste, taking into account any standards and regulations which may be formulated by the competent international organizations."* [14]

It was only in the 1970s when, inspired by Jacques Yves Cousteau's pioneering efforts to film the underwater world, popular environmental literature such as *The Silent Spring* and *The Frail Ocean*, and taking advantage of the widespread cultural and political impact of the "First United Nations Conference on the Human Environment" of 1972, the marine conservation movement, led by non-governmental organisations, began to question the unregulated disposal of radioactive waste into the oceans.[15]

The "Inter-Governmental Conference on the Convention on the Dumping of Waste at Sea", also known as the "London Convention", came into force in 1975, and this led to a voluntary moratorium on low-level radioactive waste (LLW) dumping, in 1983.[16] Almost simultaneously, the "UNCLOS Convention" of 1982 devoted a substantial part of its text— Part XII — to the Protection and Preservation of the Marine Environment. Article 197 of the UNCLOS states,

"*States shall cooperate on a global basis and, as appropriate, on a regional basis, directly or through competent international organizations, in formulating and elaborating international rules, standards and recommended practices and procedures consistent with this Convention, for the protection and preservation of the marine environment, taking into account characteristic regional features.*"

These encouraging developments notwithstanding, as many as thirteen countries continued to use the oceans as a dumping site, right up to 1993, when the Contracting Parties to the London Convention adopted a landmark resolution banning ocean dumping of LLW altogether (see Figure 2).

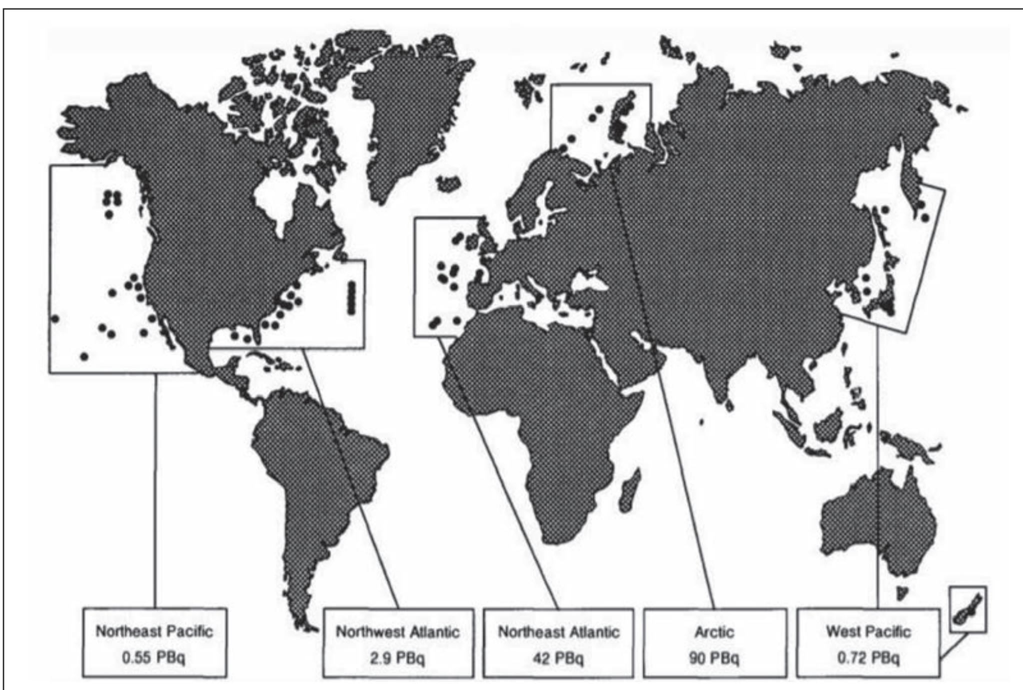

Figure 2: Ocean Disposal of Radioactive Waste
Source: Kirsti-Liisa Sjoeblom and Gordon Linsley, "Sea Disposal of Radioactive Waste: The London Convention 1972" *IAEA Bulletin 36, No 2 (1994): 12-16.*

This was a watershed moment in marine conservation history. Alexei Yablokov penned a seminal report, written after the 15th "Consultative Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter", highlighting the scale of the damage done to the oceans by Russia. This, he wrote, included, "*17,000 containers of radioactive waste, 19 ships containing radioactive waste, 14 nuclear reactors, including five that still contain spent nuclear fuel; 735 other pieces of radioactively contaminated heavy machinery, and the K-27 nuclear submarine with its two reactors loaded with nuclear fuel.*"[17] However, it would be grossly unfair to single out Russia as the sole offender, since similar practices had been prevalent elsewhere in the world, too. European nations, for instance, had dumped nuclear waste containing over 700 000 Ci of radioactivity into the Irish Sea, the English Channel, and the wider Atlantic Ocean, while the United States had dumped nearly 110,000 containers of nuclear waste containing over 94 000 Ci radioactivity off the coast of California, Massachusetts and other states.[18] In 1996, the "London Dumping Convention" of 1972 was replaced by the "London Protocol", which came into force in 2006. The new protocol upheld the precautionary approach in tackling the dumping of pollutants into the oceans and stated that, "*the polluter should, in principle, bear the cost of pollution*."[19] It banned the dumping of high-level radioactive waste (HLW), but, allowed for IAEA-regulated LLW disposal. Many non-governmental organisations, as well as State authorities such as the South Korean Ministry of Oceans and Fisheries, have repeatedly argued that the Fukushima ocean disposal is an international issue and in sharp violation of international arrangements such as the London Convention and Protocol as well as the United Nations Convention on the Law of the Sea (UNCLOS).[20] These critics have argued that Japan's government has decided to opt for the cheapest quick fix available, forgoing other viable alternatives (see Table 2). However, it must be noted that both UNCLOS and the London Convention lack any enforcement mechanisms, which means that the concerns of the neighbouring States will have to be tackled primarily through diplomatic channels.

The storage tanks at Fukushima held wastewater that had been contaminated with nucleotides such as caesium-137, carbon-14, tritium, cobalt-60, iodine-129, plutonium-239. Except for radioactive tritium and carbon-14, the Japanese government has claimed that the rest of the radioactive elements have been removed.

Table 2: Radioactive Waste-disposal Options and Proposals

Options/Proposals	Examples
Near-surface disposal at ground level, or in caverns below ground level (at depths of tens of metres)	• Suitable for LLW and short-lived ILW • Implemented for LLW in many countries, including the Czech Republic, Finland, France, Japan, Netherlands, Spain, Sweden, UK, and the USA.
Deep geological disposal (at depths between 250 m and 1000 m for mined repositories, or 2000 m to 5000 m for boreholes)	• Suitable for long-lived ILW and HLW (including used fuel) • Most countries have investigated deep geological disposal and this is, indeed, the official policy in several countries. • Implemented in the USA for defence-related transuranic waste at WIPP. • Preferred sites selected in France, Sweden, and the USA. Facility under construction and due to begin operations in 2023 in Finland. • Geological repository site selection process commenced in the UK and Canada.
Disposal at subduction zones	• Investigated by the USA. • Not implemented anywhere. • Not permitted by international agreements.
Sea disposal	• Implemented by Belgium, France, Germany, Italy, Japan, Netherlands, Russia, South Korea, Switzerland, UK, and USA. • Not permitted by international agreements.
Sub seabed disposal	• Investigated by Sweden and the UK (and organisations such as the OECD Nuclear Energy Agency). • Not implemented anywhere. • Not permitted by international agreements.
Disposal in ice sheets (proposed for wastes that are heat- generating)	• Investigated by the USA. • Rejected by countries that have signed the Antarctic Treaty or committed to providing solutions within national boundaries.
Disposal in outer space (proposed for wastes that are highly concentrated)	• Investigated by the USA. • Investigations now abandoned due to cost and potential risks of launch failure.

Source: World Nuclear Organisation https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and- disposal-of-radioactive-waste.aspx

Critics argue that the Advanced Liquid Processing System (ALPS), which is the treatment process used by Tokyo Electric Power Co. (TEPCO) at the Fukushima plant, fails to capture dangerous isotopes such as those of tritium, ruthenium, cobalt, and strontium, with absolute accuracy.[21] In the aftermath of the 2011 disaster, most of the radioactive material fell into the Pacific Ocean, which led to a mass precautionary evacuation and the destruction of the fishing economy of the region. Experts argue that the accumulation on the seafloor of radioactive isotopes, especially tritium, which can organically bind with other molecules, will affect the marine biota, thus affecting the food chain.[22]

The "United Nations Scientific Committee on the Effects of Atomic Radiation" (UNSCEAR) in its 2020 report entitled, "*Levels and Effects of Radiation Exposure due to the Accident at the Fukushima Daiichi Nuclear Power Station: Implications of Information Published since the UNSCEAR 2013 Report*", noted that the committee had not found any adverse effects on the health of Fukushima residents due to radiation impact.[23] The IAEA, which has, as has been stated earlier, extended its support for the Japanese decision, has been actively engaged in the post-disaster cleanup and recovery at the Fukushima plant, and providing technical guidelines and systematic assessment of safety for the storage tanks. The Director General of the IAEA added that, *"the Japanese Government's decision is in line with practice globally, even though the large amount of water at the Fukushima plant makes it a unique and complex case."*[24]

Implications

The Question of Trust. Given its long and painful history with industrial and nuclear disasters, Japan remains in a dilemma on the question of nuclear energy. Lessons from the Minamata Bay disaster, where industrial waste dumping led to mercury poisoning in the 1950s, are still fresh in public memory, and such accidents continue to inform public opinion, practices, and beliefs. The 2011 triple disaster exposed the heightened vulnerability of the island nation to climate change and the cascading nature of emerging risks. While studies have shown that radiation levels have fallen below harmful limits in the region, economic activities in the region, especially fishing, have failed to revive. This highlights the importance of trust in policymaking. The decontamination process, which has been approved by the IAEA, has failed to engender the trust of the coastal communities and neighbouring States, several of which apprehend that they will be directly exposed to the radwaste disposal. A peculiar example of this trust deficit was on display when the Japanese government, in order to allay public fears regarding radioactivity, decided to lower the radiation limit from 500 to 100 becquerels per kilogram of fish. While the move was intended to protect the livelihoods of local communities, it ended up escalating anxiety and food avoidance in the region. While the IAEA's nod is critical for establishing institutional transparency, the matter of nuclear waste disposal will require trust-building at all levels of governance to restore the faith of States and affected communities.

The Limits of International Law. Japan's unilateral decision to release radioactive waste exposes the glaring shortcomings of international law, which remains non-binding in nature, to tackle the issues of transboundary environmental harm. The London Convention (1972) of marine pollution defines Dumping as, *"(i) any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea; (ii) any deliberate disposal at sea of vessels, aircraft, platforms or other man-made structures at sea."* This definition does not take into account radioactive material disposed-off from land as a case of dumping. There have been political and scientific efforts in the past that actually advocated deep seabed disposal of nuclear waste by lobbying for a State recognition of the differences between the terms "dumping", "emplacement", "encasement", "insertion" and "dropping".[25] This raises the possibility that the release of Fukushima discharge might not even get covered under the international dumping convention.

Radioactive Waste. The IAEA-monitored process of radioactive disposal has proven effective, but the lack of alternatives for High-level Radioactive Waste continues to represent a defeat in the argument against nuclear power. Disposal in deep geological repositories has been suggested as a safe option for HLW, but it remains a prohibitively costly and dangerous option, especially for countries with small nuclear programmes. The IAEA has proposed a 'Multinational Repository' concept to promote multilateral cooperation for the management of radioactive waste, incorporating three different options: (1) an "add-on" concept in which where a larger facility accepts waste from smaller ones; (2) a "supranational concept", in which a facility with international management and control is established: and, "partnering scenarios", in which countries collaborate in a multinational repository.[26] The concept of a shared nuclear-waste facility at the international, regional or multinational level is expected to enhance nuclear security, promote environmental protection, and increase technical capacity and knowledge.[27]

The "Clean Energy" Dilemma. Unlike a decade ago, when climate change failed to garner public attention on a scale comparable with the question of radioactive waste, the contemporary period provides a conducive environment to debate the role of nuclear energy in the transition to clean energy and public acceptance of new technologies. However, building public trust on matters of nuclear energy is a treacherous task due to the historical iconography of death, disarmament and gross institutional failure.[28] Advocates of nuclear energy as a clean alternative to fossil fuels must take into consideration the question of trust and intention as these will be critical to their endeavours. These factors will themselves be affected by a range of subordinate ones, including, amongst others, geographical proximity to nuclear sites, international cooperation, trust in nuclear-energy governing institutions, transparency, political leanings, and, advances in technology.[29] The Fukushima radioactive disposal at sea is a case where all these factors will be at play.

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Note

This article was first published on 07 June 2021 on the Website of the National Maritime Foundation

Covid 19 and India: The Challenge of Marine Debris

Ipshita Chaturvedi

In India, the topic of waste-management is one that is almost completely ignored. It has never been on any political party's election agenda or manifesto since India's independence. An overwhelming percentage of waste that is generated in the normal course of land-based human activities eventually lands up in the oceans and is referred-to be the generic term, 'marine litter', also known as 'marine debris'. The UN defines this as *"items that have been made or used by people and deliberately discarded into the sea or rivers or on beaches; brought indirectly to the sea with rivers, sewage, storm water or winds; or accidentally lost, including material lost at sea in bad weather."*[1] Almost 80% of marine debris consists of plastics in one form or another.

As the world struggles to grapple with the ongoing COVID-19 pandemic, COVID-induced behavioural change is greatly exacerbating the problem of pollution of the oceans. For instance, as of today, we can safely surmise that there are at least a billion facemasks in India, most of which are disposable. On a global scale, this number would be exponentially higher as the law in several, if not all, affected countries mandates the compulsory usage of facemasks. While some countries are trying to make reusable masks more widely available, most people continue to depend on medical masks and latex gloves that need to be disposed of after a single usage. In a disturbing number of cases, these discarded masks, and gloves, end-up — along with much else that human beings discard — in the ocean. In fact, there have been several reports from countries worldwide that record a surge in discarded single- use latex gloves and surgical masks that have washed-up ashore, on beaches and coastlines around the world.[2]

Surgical masks are particularly problematic on two counts. One is that they are the cheapest and most easily available kind. The other is that they are made of non-woven material — mostly polypropylene — which is non-biodegradable and tends to break down into microplastics when subjected, over time, to the normal turbulence of the oceans.

Insofar as India is concerned, in March 2020, the Central Pollution Control Board of India issued guidelines on the disposal of COVID-related waste. These guidelines are required to be read together with the Bio-Medical Waste-Management Rules, 2016. The guidelines are applicable to isolation centres, camps, home-care of COVID-positive and suspected cases, healthcare facilities, etc. The normal treatment of bio-medical waste, which now includes COVID-waste, is that it is collected by designated authorities and then goes to a common bio-medical waste-treatment and disposal facility. The snag is that there is no legal requirement for surgical masks used and discarded by the normal, everyday person who has not been tested for COVID to be treated in any special way. Therefore, normal waste management rules apply to these facemasks. As a result, we will shortly be facing a reality that includes an abnormal number of discarded coronavirus masks in our landfills and eventually our seas, thereby amplifying the long looming problem of marine debris along the Indian coastline.

'Marine Debris' Law and Policy in India

Marine pollution, as a distinct subject, has neither been dealt with in policy nor economics in India. In tackling marine litter, Indian policy has been restricted to the banning of single-use plastic — a fact evidenced by an international report of the Marine Litter Legislation by the United Nations Environment Programme in 2016.[3] The report mentions Indian efforts only in the case of a ban on plastic bags. India's ban applies only to certain types of plastic — notably plastic bags of a certain thickness. While this move has been welcome, it is certainly not even close to the solution if segregation, and eventual incineration of polypropylene (coming from all sources of plastic), does not happen. For example, the UN report has several sections on developing policy to tackle marine litter. Banning any single-use plastic is under the sub-heading "Prohibiting and Disincentivizing use of Land-based Material Causing Marine Litter at the Retail Level". There are other sections on managing and restricting waste disposal into the marine environment (from landfills) — and in all these sections, Indian policy is undeveloped. This extends to policy on public and private sector engagement on tackling marine pollution, research programmes, and engagement of universities. Unless all processes — at the central, state, and regional levels — work in tandem with one another, our oceans will face continued threats in the form of plastic.

To add to this, unpacking oceans governance in India as a topic, is daunting in and of itself. One of the reasons is that there is no consolidated national institutional framework dealing with oceans in a holistic manner. The Ministry of Earth Sciences, the Ministry of Environment, Forests and Climate Change, the Ministry of External Affairs, the Ministry of New and Renewable Energy, the Ministry of Agriculture (Department of Fisheries), and the Ministry of Defence (the Indian Coast Guard and the Indian Navy) are all stakeholders in ocean governance. These ministries and departments do not necessarily mesh with one another, resulting in a significant amount of dissonance. In an attempt to resolve some of this, there has been a slew of 'Blue Economy' programmes in India over the past few years. However, the 'Blue Economy' is a large concept, within which marine debris is but a part, and not one heralding the most attention either. Given the need to bolster economic activity in the maritime sectors of fisheries, offshore oil, gas and wind, and even deep-sea mining, specific issues that are required to address marine debris in a pointed manner remain largely ignored or are paid little more than lip service. There was some talk last year of building a National Marine Litter Policy for India, which was to be funded by Norway as part of another 'Blue Economy' programme. Information on whether and how that policy developed is currently not in the public domain.

There is another unique angle to how Indian environmental policy works, or rather, doesn't work. Often, many different stakeholders end up carving the skeletal policy for a topic — such as the 'Blue Economy' and, by extension, marine pollution. To have a meaningful impact, a programme must have four elements — identifying the problem, offering pointed solutions, implementing the ideas through a pilot project, and reviewing the implementation so that successful pilot-projects can be upscaled, and plans that do not work can be altered. However, insofar as developing a well-sounded plan to address marine litter/pollution in India is concerned, we remain stuck at the "Problem Identification" stage. Several 'Blue Economy' reports highlight the need to fix the problem but none go beyond that. The importance of safeguarding our oceans and oceanic resources needs no further emphasis and no additional 'statements of noble intent'. What is needed, instead, is an end-to-end plan in which the important facets of technology, tech-finance, policy and regulation, tax, as well as revenue-positive economic models, and so forth are made to work together to find a sustainable, long-term solution that will keep our oceans healthy. At the very least, addressing marine pollution and stopping practices that add to it should be high on India's political and social agendas.

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Note

This article was first published on 29 May 2020 on the Website of the National Maritime Foundation

National and Regional Security Implications of Climate Change

A Critique of the Report on
"A Security Threat Assessment of Global Climate Change: How Likely Warming Scenarios Indicate a Catastrophic Security Future"

Kate Guy et al, Product of the National Security, Military, and Intelligence Panel on Climate Change, eds. Francesco Femia and Caitlin Werell. (Washington, DC: The Centre for Climate and Security, an Institute of the Council on Strategic Risks, 2020)

Dr Pushp Bajaj

The February 2020 report by Kate Guy *et al,* entitled "A Security Threat Assessment of Global Climate Change: How Likely Warming Scenarios Indicate a Catastrophic Security Future," was produced by the National Security, Military, and Intelligence Panel on Climate Change, comprising senior officials from the three sectors in the United States of America, under an initiative of the Centre for Climate and Security, an institute of the Council on Strategic Risks, based in Washington, DC, USA. The report provides a comprehensive overview of the impacts of climate change in different regions of the world under near-term (1-2° C above pre-industrial) and medium- to-long-term (2-4°+ C above pre-industrial) global-warming scenarios and the manner in which these scenarios would affect national, regional, and global security. While the primary focus of the report is the USA, the analyses and conclusions of the report are of great significance to all nations.

Following a relentlessly rising and accelerating trend in global warming, the global average temperature in 2020 was recorded at about 1.2° C above pre-industrial period (1850-1900 average).[1] Even though this may seem like a small number, at the planetary scale this temperature rise corresponds to an incredible amount of energy that has been absorbed by the land, ocean, and the atmosphere, owing primarily to the increase in greenhouse gases in the atmosphere. This excess energy is fuelling more intense heat-waves, both on land and in the ocean, more powerful storms, worsening droughts and extreme precipitation events, and, causing disruptions in the historically stable atmospheric and ocean circulation patterns.[2] We are fast approaching the 1.5° C global warming target that was collectively agreed upon by the international community under the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) in 2015. Considering the ever-growing trends in global greenhouse gas emissions and the continuing destruction of the global carbon sinks, it is safe to assume that we will blaze past the 1.5° C target within this decade if not the next five years. We are heading for a scorching 3-5° C of temperature rise by the end of the century. This report attempts to put these numbers into perspective by laying out the impacts of climate change and the associated security threats at increasing warming levels in the near- and medium-long-term future.

Highlights of the Report

The report is divided into six main chapters/ sections, including an introduction and a conclusion section. The first chapter after the introduction provides a detailed description of the *"climate security nexus"* corresponding to the *"negative relationships between adverse environmental effects and the triggers that lead to increased conflict and violence."* Through a brief literature review, the chapter highlights the correlations between climate change impacts such as growing resource-scarcity, extreme weather, and sea level rise, and the social tensions such as human migration, health crises, and socio-political fragility of States, all of which would be worsened by these changes. The next chapter comprises the main analysis of the report, involving a region-wise assessment of the security threats arising from climate change at different levels of global warming by the middle of the century and extending up to the end of the century. The authors divide the world into six regions which form the six subsections of the chapter: Africa, Middle East (or West Asia) and Central Asia, Europe and

Russia, Indo-Asia-Pacific, North American and the Polar Regions, and South and Central America and Caribbean. The regions were chosen so as to coincide with the US military's Geographic Combatant Command (GCC) Areas of Responsibility (AOR): AFRICOM, CENTCOM, EUCOM, INDOPACOM, NORTHCOM, and SOUTHCOM.

For each regional assessment, the security threats are categorised into three main categories, *'risks to security environment'*, *'risks to security infrastructure'*, and *'risks to security institutions'*. The level of risk determined from the three categories is divided into five levels, *'Low'* (some material risk to human social and security systems), *'Medium'* (consequential risk), *'High'* (severe risk), *'Very High'* (severe and systemic risk), and *'Catastrophic'* (calamitous risk). For Africa, the report identifies *'High'*-*'Very High'* threat levels at 1-2° C of warming, primarily due to projected loss of rural livelihoods, increase in the spread of disease, resource stress, and forced migration. Similarly, in the Middle East (aka West Asia) and Central Asia, the report highlights that 1-2° C of global warming will be accompanied by *'dangerous levels'* of temperature rise, droughts, and increasing resource-scarcity. These climate stressors would likely exacerbate the already existing socio-political instability in parts of these regions, which could create conducive conditions for violent extremist groups to expand their influence and recruit new members in these regions, as has been speculated by other independent analyses as well.[3] In Europe and Russia, climate change impacts such as intensifying extreme weather events, sea level rise, and thawing permafrost (particularly in the northern parts of Russia) pose significant threats to civil and military infrastructure. This region could also witness increasing intra-State and inter-State migration from neighbouring areas. At 1-2° C of global warming, the threat level in this region is assessed to be *'Medium'* to *'High'*.

In the Indo-Asia-Pacific region, the main challenges arise from resource scarcity, particularly water scarcity, changing rainfall patterns, and sea level rise. Recent studies have shown that climate change is altering the Asian monsoon pattern making it more erratic and unpredictable.[4] Since most of the agricultural practices within the region still rely on natural rainfall for irrigation, most of which is received during the monsoon months, this would have huge consequences. Moreover, the region is home to some of the most densely populated coastal megacities in the world and the Indian Ocean — the Bay of Bengal in particular — is experiencing a much faster sea-level rise than the global average. This puts the region in the *'High'* to *'Very High'* threat-level, even in the short-term (at 1-2° C of warming). The report points out that, *"tension between regional powers will increase against a backdrop of competitive resource and territorial claims."* In the "North America and Polar Regions", the report warns of a *'Medium'* to *'High'* level of security threat in the short term, citing more intense extreme weather events such as storms and wildfires. The recent (late-June 2021), freakish, weeks-long heat wave in the Pacific North-West, is a stark example of the kind of extreme heat events that can be expected in the short- to medium-term future.[5] Such prolonged heat waves also increase the risk of subsequent wildfires as they dry up the vegetation making it more susceptible to fire. Extreme heat simultaneously leads to an increase in lightning strikes which, too, can act as the ignition. Finally, in the "South and Central America and the Caribbean" region, there is *'High'* to *'Very High'* threat in the short-term, from changing rainfall patterns, droughts, and increasing water shortages, which would result in growing numbers of people deciding to move to more hospitable locations. The report points out that the growing destabilisation of socio-economic conditions could increase the likelihood of already persistent crime, such as narcotics- and human-trafficking.

If climate change continues unabated and the global average temperature rises to 2-4°+ C, relative to pre-industrial levels, in the second half of this century, the report projects that all the aforementioned regions will experience *'Very High'* to *'Catastrophic'* threats as a result of amplifying climate-change impacts. In this context, sea-level rise, in particular, will become an insurmountable challenge for almost all parts of the world. As it picks up momentum towards the end of the century, it would most present an existential crisis for several developing and least-developed countries, especially when combined with bouts of extreme-weather events such as cyclones and storm surges.

The following two chapters provide the *"Global Climate Security Threat Assessment"* and *"Global Climate Security Threat Profile,"* by aggregating the regional-level risk assessments from the previous chapter and incorporating cross-linkages between the sectors. As the report importantly points out, *"climate change knows no boundaries, and risks can compound across those boundaries, particularly in the context of global disaster trends."* For instance, it is inevitable that more and more parts of the world will become uninhabitable due to extreme heat or inundation by sea level rise or extreme food and water stress, in the near- and long-term future. Consequently, we can expect major redistributions of populations from the worst-affected areas. This redistribution could mean intra-State movement or inter-State migration, both of which would have significant and adverse implications across a variety of boundaries. As nations in all regions of the world experience growing threats from extreme weather shocks and resource scarcity, the critical question will be whether they will band together and counter the threats in a cooperative manner or whether internal chaos will spill-over to inter-State conflicts over competition for resources.

A Wake-Up Call

We have just entered a defining decade in the human era. According to the 2018 Special Report on Global Warming of 1.5° C by the United Nations Intergovernmental Panel on Climate Change (IPCC), we must cut the global anthropogenic carbon emissions by nearly half by the year 2030 and achieve net-zero by the year 2050 in order to have any chance of limiting global warming to below 1.5° C and avoiding the worst-case scenarios. This decade will, therefore, determine whether we will have a future with some semblance of a stable climate or whether we will start rolling down a steep hill towards the valley of climate chaos. Considering this, this report is particularly timely and does a commendable job of putting into perspective the magnitude and seriousness of the impacts of climate change that are expected to occur in the short-, medium-, and long-term future, if we do not take urgent and drastic measures to mitigate climate change. The scope of the report is quite comprehensive in that it provides detailed climate security analyses at the regional scale under different global warming scenarios and then aggregates the regional analyses to provide a holistic global picture. Of course, this broad scope prevents the report from going into some of the nuances of sub-regional- and national-level challenges and recommends appropriate interventions at those levels.

The report should serve as a wake-up call for other countries to acknowledge the urgency and the extremely high stakes of the climate crisis and conduct similar security-threat assessments for themselves at the national- and/ or regional-level and devise commensurate mitigation and adaptation strategies. In this context, India will have an important role to play in the Indian Ocean Region. The region is highly vulnerable to climate change, primarily due to the high population density and lack of economic and technological capacities to adapt to the changing climatic conditions. The responsibility will be on India, as a major power in the region, to ensure security and stability by facilitating and mediating dialogues and cooperative mechanisms to stitch together this vast region and pool its resources to meet the climate challenge. This would have to be accomplished while simultaneously managing the climate risks at the national level.

Expectedly, however, whenever the report makes comments about accountability and responsibility for action, these are addressed to all *'humans'* or *'human systems'* or *'the world'*. In the Executive Summary, the report states that *"[climate change] is caused by no single actor, but perpetuated by current human systems of energy, transportation, agriculture, and resource use."* While this is technically true, long-term records of cumulative carbon emissions and current trends of per capita emissions make it abundantly clear that certain developed countries, including the USA, have contributed and continue to contribute significantly more to creating and perpetuating the climate crisis, rather than the developing and least-developed countries. The same developed countries also possess the economic and technological capacity and capability to take much more aggressive and meaningful action not only at the national level but at the regional and global levels as well. However, as several studies have shown, their efforts continue to be significantly insufficient to mitigate their own carbon emissions, let alone facilitate mitigation measures by other countries.[6] The report completely avoids this distinction and instead calls for *"the world to achieve net-zero global emissions in a manner that is ambitious, safe, equitable, and well-governed."* This convenient phraseology, which allows the USA to duck its responsibility while continuing to pontificate to the world from a pulpit located on entirely imaginary high ground is, regrettably, a common occurrence and emblematic of much of Western literature on the subject of climate change.

Conclusion

The report stresses unequivocally that even the low-warming levels that are expected to be breached in the next three decades pose *'High'* to *'Very High'* security threats to all parts of the world. These threats are magnified to *'Very High'* and *'Catastrophic'* levels in the high-warming scenarios, that are expected to be reached towards the end of this century. According to the report, at 2-4°+ C of global warming, the climate security threats *"could lead to a breakdown of security and civilian infrastructure, economic and resource stability, and political institutions at large."* Crucially, the report also highlights that, *"more extreme or more rapid warming scenarios than those used by the IPCC-affiliated scientists whose work is summarized in this report are possible,"* while citing a 2018 study which imagined various 'Hothouse Earth' scenarios in which successive climatic tipping points could be crossed in a falling-dominoes type of effect and lead to significantly greater, faster, and irreversible global heating.[7] Considering this, we urgently need to adopt a concerted and holistic strategy — one that incorporates drastic cuts to global carbon emissions in every sector, initiates and sustains proactive climate adaptation, and promotes the expansion of natural carbon sinks and the creation of technological carbon-capture and sequestration techniques, to tackle the monumental challenge of accelerating climate change.

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Note

This article was first published on 20 August 2021 on the Website of the National Maritime Foundation

Widening the Aperture: "Climate Change and International Responses Increasing Challenges to US National Security Through 2040"

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A review of the National Intelligence Council, "Climate Change and International Responses Increasing Challenges to US National Security Through 2040" *National Intelligence Estimate, NIC-NIE-2021-10030-A* (2021)

The collective failure of States to mitigate the risks of climate change over the past three decades has led to a widespread debate on the implications of the consistent failure of intergovernmental negotiations, and on finding new ways of framing the climate crisis so as to enhance international cooperation. Recent development along these lines has been the rising interest among the security and intelligence communities, especially in developed countries, for the inclusion of climate change as a threat to national security. On the issue of climate change, the *National Intelligence Estimate (NIE)*, recently published by the National Intelligence Council (NIC), which reports to the Office of the Director of National Intelligence of the United States (US), and forms a critical link between the US intelligence communities and policymakers, is a critical document that outlines the global climate trends and provides an overview of the climate and security linkages and framings, as they may emerge in the next two decades. The NIC has had a long history of strategic-intelligence assessment, especially the NIE and the four-yearly Global Trends Report, both of which have been influential in shaping the US foreign policy and strategic analysis.[1]

The NIE outlines the risks posed by climate change to US National Security into three broad categories — Geopolitical tensions over climate responses, climate-exacerbated geopolitical flashpoints, and, climate effects impacting country-level instability. The report assesses that, *"climate change will increasingly exacerbate risks to US national security interests as the physical impacts increase and geopolitical tensions mount about how to respond to the challenge."*

This assessment is in line with a wide range of literature that has been published in recent years, including State-funded research. The *Global Trends 2040 report*,[2] published earlier in 2021 by the NIC, also lists the environment as one of the five key trends that will shape the future world. It notes, "*debate will increase over how and how fast the world should reach net zero as countries face hard choices over how to implement drastic emissions cuts and adaptive measures. Neither the burdens nor the benefits will be evenly distributed within or between countries, heightening competition, contributing to instability, straining military readiness, and encouraging political discord."*[3]

Similar to the NIC, the United Kingdom's Ministry of Defence think tank, the Development, Concepts and Doctrine Centre (DCDC) publishes the *Global Strategic Trends* which, in its sixth edition, notes that the costs of climate change to governments and societies is going to increase with passing time, and is likely to lead to inequality, social disorder, violence, and intense competition over resources. The report notes, "*defence and security planning assumptions, not least access, basing, routes, logistics and the environmental envelope in which military capabilities will have to operate, will need to be reviewed.*" Many independent organisations and think tanks have likewise pegged climate change as the foremost security risk to States. The *2021 AXA Future Risks Report*, which surveyed 3,500 risk experts from around the world, notes, *"both experts and the public agree that governments are underprepared to face climate change, with just 19% of experts expressing faith in public authorities to mitigate the climate crisis."*[4]

It is evident from this recent swell in research that climate change and national security are emerging as complex, intertwined issues. The NIE provides a stark overview of the climate security trends that are relevant for countries around the globe, especially those in South Asia, which the report lists as being the most highly vulnerable region in the world.

Highlights of the Report

There are three key judgments that the report posits will shape climate security trends over the next two decades.

Enhanced Geopolitical Tensions

Geopolitical tensions will witness an increase, given the nature of commitments required under the Paris Agreement. The report judges that the long-term objectives of the Paris Agreement are unlikely to be met as they require high-emitting countries to make rapid energy-transitions away from fossil fuels. This will require high-level investments in clean energy alternatives and a rapid decline in the use of coal and oil. Given the large sunk-costs in established fossil-based production systems and the difficulties attached to the scaling-up of clean alternatives, many sectors of the economy, particularly transportation and shipping, will find it difficult to make a rapid transition. The report cites solar photovoltaic and wind energy sectors as the most effective and economically viable alternatives, but which, too, require infrastructural and R&D investments and changes to the electricity grids and markets. Nuclear energy and hydropower are the other two non-fossil options that are unlikely to enhance their current shares in the energy basket as they are marred by several issues involving public trust, high costs, and safety. An example of this trend could be the recent commitments made by India at the COP 26, which include an increase in its non-fossil energy capacity (including hydropower and nuclear energy) to 500 GW by 2030.[5] The report outlines some of the efforts made towards legally formalising the Paris pledges, but remains sceptical, as most countries have failed to make efforts towards such formalisation through domestic laws. It assesses that most countries that rely on fossil fuel exports, such as Russia and OPEC countries, will continue to resist a rapid transition and net-zero targets. The report also flags the issue of competition over key minerals and technologies as the most pressing security concern as these sectors are witnessing high levels of investments from private firms and government agencies in China, the EU, Japan, the US and Russia. The report predicts that, in the light of the failure of States to collectively mitigate the crisis, carbon dioxide removal (CDR) technologies will emerge as a key part of climate-mitigation strategies, especially in developed countries like the United Kingdom, Norway and the US. The report also argues that India and China will play a critical role in determining the trajectory of temperature rise as their per capita and cumulative emissions numbers, unlike those of the US and Europe, are on the rise. It bases its pessimistic assessment on the nature of the Paris consensus which, it argues, is short-lived, as questions of "equity" and "common but differentiated responsibility" (CBDR) are likely to persist. These issues have been at the core of negotiations for three decades and the US has consistently maintained its objections on the question of equity since the days of the Kyoto Protocol. The listing of "equity" and climate finance commitments by developing countries as reasons behind a possible future stalemate seems to expose two core concerns within the UNFCCC negotiations — the blind disregard, especially by the US, for concerns raised by the poor and developing countries who will require these demands to meet in order to make a just transition, and, the continued relevance of the principle of "Equity" and climate justice within climate diplomacy. The report inadvertently highlights the reasons behind such as divide when it notes, *"the United States and others, however, are in a relatively better position than other countries to deal with the major costs and dislocation of forecasted change, in part because they have greater resources to adapt…The United States and key states in the developed world have greater technological capability and financial resources to adapt to climate change, and are likely to realize some benefits in terms of technological competitiveness and agriculture. Should warmer temperatures and longer growing seasons yield lower heating costs and increased agricultural production, most of the beneficiaries outside Russia are likely to be in the high latitudes, such as Canada and Scandinavian countries."* [6]

Climate Flashpoints

The second key judgement that the report makes is related to the geopolitical flashpoints that may arise as a result of the propensity of States to place their self-interest over the collective good. The report cites a number of studies and projections which, it argues, have improved considerably in terms of their accuracy, increased complexity, and ability to reduce uncertainties. In the past, these have tended to contribute towards over-simplification and misrepresentations of data. The report flags four major flashpoints across the globe:

- The strategic and military competition in the Arctic is projected to increase given the diminishing sea ice and warmer temperatures, which are opening up possibilities of increased resource exploitation, military presence and infrastructure development in the region by the Arctic states as well as the non-Arctic states. The report notes that the contested nature of such economic and military activity carries the risk of miscalculation and escalation of hostilities.

- The issue of water security, and transboundary water conflicts in major river basins such as the Indus, Mekong, and Nile, are likely to increase. The report notes that an alarming 263 river basins around the world currently lack any cooperative management agreements which could deescalate such tensions.

- The issue of migration and large-scale displacement of people due to the increased frequency of droughts and floods is a major humanitarian crisis in the making and it will require massive investments in adaptation and loss and damage mechanisms.

- Finally, the report points towards geoengineering as an important flashpoint as States can unilaterally decide to deploy such untested technologies. The use of such technology carries major ecological implications and it could trigger potential conflict between States, which might blame each other for weather disasters in the future.

All these major flashpoints have been part of discussions for a long time and their potential impacts have been flagged for years, especially in countries like Bangladesh and Pakistan. However, it is important to highlight, as the report does in Annexure A, that these potential scenarios must be viewed with caution. While a hawkish view of climate conflicts over resources remains a concern, especially in light of the emerging scientific evidence regarding tipping points, there has been considerable work done in the past by States in order to avoid such conflicts. Therefore, the development of new cooperative frameworks, and multilateral platforms must be emphasised to a far greater degree, so as to avoid the worst-case scenarios in each of these potential flashpoints.

Regional Arcs of Vulnerabilities: Climate Security in South Asia

The third major judgement that the report makes is of considerable importance for States in South Asia. The report forecasts that US interests may be indirectly impacted as its partners around the globe face hard and costly challenges. The report identifies eleven countries in South and East Asia (which includes India, Pakistan, Afghanistan, Burma, and North Korea), four countries in Central America and the Caribbean, viz., Guatemala, Honduras, Haiti and Nicaragua, and, Columbia and Iraq, as being the most vulnerable to the impacts of climate change. The report notes that these countries will face considerable challenges due to erratic patterns of weather and the unpredictability of disruptive events, which are likely to impact their infrastructure, power-generation, food-security, and exacerbate health conditions. The lack of financial resources and weak mechanisms of governance are likely to additionally contribute to the triggering of conflict, and the mass scale displacement of people. Small island States and several countries in Central Africa are flagged in the report, for a heightened risk of instability, loss of landmass and socio-economic collapse. The report also argues that militaries in these highly vulnerable regions will be faced with unforeseen operational challenges — *"under-resourced and ill-equipped militaries will face severe strains when they are called upon to respond to more natural disasters in their own and neighbouring countries…Although militaries will absorb these expenses in normal recapitalization programs spread over decades, the costs to adapt will force tradeoffs with other modernization priorities.*"

Conclusion

The linkages between violent conflict and climate change have been long standing, yet peripheral, debate within the security studies discipline that has now, in light of incontrovertible scientific evidence, emerged as a core area of research interest. The conceptualisation of climate change as a 'threat multiplier' a term coined in 2007 by the CNA's Military Advisory Board[7] has gained considerable traction within the research community.[8] However, the lack of credible ground-level analysis remains a lacuna that will make many States wary of such linkages.

The report makes a critical intervention in the field of climate security studies by highlighting the critical geopolitical flashpoints and areas of concern. However, its assessment of these impending and, in some cases, ongoing crises remain limited because it foregrounds risks rather than vulnerability. A hazard-based framing of the climate crisis tends to be reductionistic because it does not address the question of adaptation with adequate attention. The report's listing of equitable burden-sharing as a potential roadblock to climate action is the continuation of a mitigation-focused understanding of the climate crisis rather than highlighting the need for building resilience and reducing vulnerability.

As highlighted in the report, US national security interests spread well beyond the country's borders, which makes its critical for US security establishments to take cognisance of the adaptation needs in the developing parts of the world. For countries in South Asia, the report is a stark reminder of the worst-case scenarios that are likely to emerge as a result of a business-as-usual approach to climate change. The recent veto by Russia against the linking of climate and security at the UN Security Council, a position supported by India, is a good case study to understand how very different climate risks to security around the world are perceived.[9] It highlighted the need to analyse climate security with a widened aperture, which includes questions of equity, adaptation, climate finance, sovereignty and global commons. The report is a timely effort that highlights the need for countries to begin conceptualising collective security and environmental peacebuilding as critical facets of their national security. The reliance on yet-unseen future technologies, successful geoengineering solutions at scale, or unilateral conceptions of climate security, as the report assesses, are most certainly going to collapse in face of a global climate disaster.

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This article was first published on 10 January 2022 on the Website of the National Maritime Foundation

India's Food Security and the Maritime-Impacts of Climate Change — The Locust-Intermediaries

Commandant Manoranjan Srivastava

Attaining food security for India continues to remain a daunting task. Since the Green revolution of the 1960s, the country's agricultural policies have led to an increase in agricultural productivity and overall food-production. However, with a rapidly increasing population, the demand for food grains is projected to be even higher in the future. Mittal (2008) has made projections of India's food demand and supply up to 2026, using 1999-2000 as the base year and GDP growth of 8% and 9%. The rise in demand of commodities such as wheat and rice is shown to be about 55%, while that in respect of cereals is 104%.[1] With current production trends, meeting India's future demand for food grains through domestic production alone will be difficult.[2]

On a global scale, world leaders at the 2012 Conference on Sustainable Development reaffirmed the fundamental right of every individual to be free from hunger. The UN's Sustainable Development Goals (SDGs) are an important progression from the earlier Millennium Development Goals (MDGs), which were a set of 17 global goals, and also aims to improve the lives of all people around the world by 2030. Amongst these, SDG 2 seeks to 'End hunger, achieve food security, improve nutrition and promote sustainable agriculture'. Food security could, of course, be achieved through food self-sufficiency, but the latter is not a necessary precondition for the former. As Jay Maniyar of the NMF has pointed out in his opening article on Japan's Food Security (NMF Website, 09 December 2019), *"food-security might well be achieved by the country concerned simply importing the balance of food that is short. If such import-sources are entirely reliable and the transportation of* *the food from its source to its destination is assured — that is, financially and physically secure — the country may end up having an acceptable degree of food-security even while remaining deficient in terms of food self-sufficiency. This is especially true in 'caloric terms', wherein a self-sufficient country produces as much or more 'caloric-value' of food than it consumes, even if some of the actual food items consumed by its population are different from those that it produces domestically. Thus, even countries that are 'self-sufficient' may specialise their food-production to some extent and import as well as export food".*[3] It is also possible for a country to obtain self-sufficiency in food grains and yet not achieve food security for its people. India itself is a quintessential example of this — the country's 'Green Revolution' of the mid-1960s notwithstanding. Writing in Business Line (04 June, 2019), Marshall M Bouton, the highly-respected Director of the University of Pennsylvania's Centre for the Advanced Study of India (CASI), stated that *"the main goal* [of the Green Revolution] *was to ensure India's national food security, more precisely its self-reliance in food grain production… Today, India has achieved self-reliance in food grain production. It has become the world's second largest producer of both wheat and rice and the largest exporter of rice."* And yet he added, *"India's increases in total food production have, unfortunately, not translated into proportionate decreases in malnutrition."*[4] As a result, on the International Food Policy Research Institute's (IFPRI) 2018 Global Hunger Index (GHI), India ranks a dismal 103rd out of 119 countries, and is home to the largest number of malnourished people in the world, about one quarter of the global total.[5]

Studies and research on agrarian distress show that a combination of policy-induced, technological and ecological factors is responsible for India's agrarian crisis.[6] Although, India has slowly but steadily embraced technological advancements and has undertaken many reforms and schemes such as the National Food Security Act (NFSA), it is the ecological factors that now need comprehensive and urgent attention.[7]

Looking ahead, poverty and malnutrition in rural India will be exacerbated by increasingly frequent droughts, cyclones, and other weather extremes, as well as the long-term impacts of climate change. For instance, most of the country experienced successive droughts in 2014-15 and 2015-16.[8] The IFPRI's 2019 Global Food Policy Report projects that 93 million Indians will be at risk of hunger by 2030 and 45 million by 2050, if the expected effects of climate change are considered.[9]

It is a well-established fact that agricultural productivity in India is heavily dependent on rainfall — particularly the South West (SW)Monsoon. It is, therefore, only natural that any impact of climate- change on the inter-annual and inter-seasonal variability of monsoon rainfall will affect India's food production and hence its food security. The consequences of climate change in this context are already quite evident and the SW monsoon is frequently observed to be out of its normal rhythm, both in terms of duration and spatial parameters.[10]

Sadly, many Indian climate-change scholars, while quite rightly expressing great concern over the recent Australian bush fires (as of 15 February, 2020, more than 46 million acres [72,000 square miles] of land had been burnt in thousands of fires since June 2019),[11] are largely unaware of how maritime aspects of climate-change have been causing havoc amongst Indian farmers in India's hinterland, significantly and adversely impacting crops that are required to provide for India's food- security. Surprisingly this link between maritime facets of climate-change and hinterland agriculture is provided by a most unlikely, yet very significant, actor — the desert locust. This story is becoming, in the famous words of the celebrated author, Lewis Carrol, "curiouser and curiouser".[12]

Locusts belong to the grasshopper family. The desert locust (*Schistocerca gregaria*), which is found in more than 65 of the world's poorest countries, normally lives a solitary lifestyle in the deserts between West Africa and India. It breeds after periods of rainfall, because it needs moist soil to lay its eggs. But when rains are especially heavy, the population can build up rapidly, resulting in vast swarms.[13] An adult desert locust consumes roughly its own weight in fresh food, i.e., about two grams, per day. A very small part of an average swarm (or about one tonne of locusts) eats the same amount of food in one day as about 10 elephants or 25 camels or 2,500 people![14]

In February of 2020, swarms of desert locust, thick enough to blot out the sun, flew in from the West Asian deserts of Saudi Arabia, Oman, the United Arab Emirates and Yemen, and swamped farmlands in Rajasthan and Gujarat, destroying crops over nearly 1.7 lakh hectares[15] and causing a severe crop loss of more than 33 per cent.[16] Other swarms, also as also originating in the same areas made their way to Africa, triggering fears of a severe food crisis in that continent.

As already stated, these swarms of desert locusts are the link between hinterland agriculture and a significant maritime impact of climate-change, viz., the increased frequency and intensity of Tropical Revolving Storms (TRS) or 'cyclones' as they are commonly known in South Asia. The earlier 'normal' was that even in the two peaks of the 'cyclone season' (April to June and September to December) in the Arabian Sea, only one cyclone formed per year. However, the impact of climate change is altering this 'normal' very significantly and rapidly. In the year 2018, for instance, as many as three unusually strong cyclones emerged in the Arabian Sea. These were: Cyclone *Sagar* (which made landfall in north-west Somaliland and Djibouti on 19 May 2018 and is only the second tropical cyclone to have penetrated the western Gulf of Aden), Cyclone *Mekunu* (which made landfall in South West Oman on 25 May 2018), and Cyclone *Luban* (which struck the eastern portion of Yemen on 14 Oct 2018). An analysis of the impact of climate change upon weather patterns shows that the last two years have been punishing, with a sharp increase in the frequency and intensity of cyclones at sea. The sea surface temperature in 2019 was between 27° and 29°C a recipe for cyclone-formation. The years 2018 and 2019 also witnessed strong Positive Indian Ocean Dipole (PIOD) phenomena.[17] In 2019, the number of cyclones that formed in the Arabian Sea increased to five,[18] and although storm surges were experienced in Oman in one case (Cyclone *Hikka*) none of them penetrated the desert areas as deeply as the 2018 ones did. Those three 2018 cyclones (*Sagar*, *Mekunu*, and *Luban*) influenced the unpopulated desert of the southern Arabian Peninsula, also known as the Empty Quarter, as also eastern Africa. The heavy rainfall associated with these three cyclones and the prolonged bout of wet weather from May to October 2018, resulted in rainwater filling-up the troughs between the desert sand dunes, and converting them into ephemeral lakes.

This created favourable breeding conditions for desert locusts. Each desert locust lays about 150 eggs and the population rises exponentially over successive generations. The locusts have a lifespan of about three months. Hence, the three cyclones in 2018 enabled three generations of locust breeding, thereby increasing their population to a dangerous level that was incapable of being sustained by the sparse availability of food in the 'Empty Quarter'. The inherently migratory nature of these locust swarms and their ability to cover extremely large distances each day led to locust migration over the Red Sea and the Gulf of Aden. The swarms reached Ethiopia and Somalia by the summer of 2019. Cyclone *Pawan*, which struck Somalia early in December of 2019, once again provided favourable breeding conditions and the locust swarm multiplied several-fold.

These swarms then flew eastward, in search of food, towards Pakistan and India. The lack of timely and proper control measures in Pakistan, coupled with the longer duration of the monsoon in 2019 in India due to its delayed withdrawal — once again a result of climate-change — led to a further cycle of breeding of these desert locusts and their movement to India. Although locust swarms normally retreat from India by November, the delayed retreat of the monsoon created additional favourable breeding conditions for locusts in India's in the India's Thar desert, too. There are also probable linkages between the movement into India of these locust swarms with western disturbances which are a phenomenon forming over the Mediterranean over Mediterranean Sea from November onwards and moving from west to east towards areas of Pakistan and subsequently to India.

Unfortunately, news about these occurrences of locust-attacks and the enormous economic damage they caused has been swamped by the media-frenzy attending the outbreak of the COVID-19 disease. Nevertheless, the locust-attacks significantly lowers the food security of India, Pakistan and several countries of Africa. Pakistan declared an agricultural emergency and its desperate search for amelioration even forced their agriculture officials to engage with domain experts from India. The prevailing situation, wherein Pakistan's 'all-weather friend', China, is considering sending Pakistan around a hundred-thousand (one lakh) ducks to help fight the locusts,[19] would have been ludicrous were the situation not quite as serious as it is!

Interestingly, the last occasion on which desert locusts wreaked such major havoc was in 2007, a year that saw super cyclone *Gonu*— the most powerful Arabian Sea cyclone on record — strike Oman in June of that year,[20] followed by heavy rainfall brought about by a dissipating depression in November 2007.[21]

The cyclonic disturbances of 2007 and 2018 strongly indicate that the heavy rainfall that these cyclones bring in their wake, does not merely trigger the rapid growth vegetation in these normally arid segments of Africa and Arabia, but also creates fertile grounds for the rapid growth in population of desert locusts. Given this correlation the immediate future is hardly a rosy one. As we advance through April of 2020, the Inter-Tropical Convergence Zone (ITCZ) is forming close to the equator and will move northward thereafter. This is likely to result in increased rainfall over north- eastern Africa and the Arabian Peninsula. With the Indian summer monsoon to follow in June 2020, the desert-locust menace may well once again spiral out of control.

Climate-change research indicates that the enhanced number of super cyclones, the unusual paths they now follow, and erratic monsoon rainfall, are all becoming commonplace in a world that is getting steadily warmer. Climate-studies also suggest that if the planet becomes warmer by 1.5 degrees, which is a distinct possibility, the probability of the occurrence of extremely positive Indian Ocean Dipole phenomena would double.[22] Given its tropical location and the fact that it is quite so dependent for its agricultural wellbeing upon the SW monsoon, India is certainly going to be amongst one of the most adversely affected nations. With 2020, likely to usher in yet another high- intensity cyclonic season, India not only needs to undertake more aggressive control measures in bordering areas along Pakistan but also to conduct significant proto-testing of its preparedness to handle locust attacks. Indeed, the enlisting of duck-support might not be so outlandish an idea after all!

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Note

This article was first published on 27 April 2020 on the Website of the National Maritime Foundation

Climate Change Vulnerabilities of the Maldives: Implications for India

Ritika V Kapoor

This chapter addresses some of the more prominent environmental challenges faced by the Maldives, which exemplifies those faced by low-lying island-states due to rising sea-levels as a consequence of climate-change, irrespective of whether such change is attributed to anthropogenic factors or geophysical ones. It touches upon the impact that this has on India's own maritime security. The succeeding paragraphs seek to provide inputs of value to maritime-planners, policy-makers, policy-shapers and lay-readers alike.

The Republic of Maldives, with a land area of about 298 sq km, is the smallest country in Asia. It is an archipelago comprising some 1,200 tiny islands that are grouped into a total of 26 atolls.[1] Of these islands, a mere 200 are inhabited and 90 of these have been developed as tourist resorts.[2] The remaining islands are either uninhabited or are used principally for agricultural purposes. The scattered geography of these islands bestows upon the Maldives an enormous Exclusive Economic Zone (EEZ) of some 923,322 square kilometres, which is more than three thousand times its land- area. With an average elevation of 1.5 metres (4ft 11in), Maldives is the lowest-lying country on the planet. Its highest elevation is just 2.3 metres (7ft 7in) above sea level, which is the world's lowest naturally-occurring 'highest-point'!

The Maldivian economy was, until the 1970s, based on fishing, shipping, and the cultivation of coconuts. In the past half-century, the economy has switched to a very heavy dependence upon tourism and fishing, while maintaining very low levels of indigenous agricultural production. Its dazzling sun-drenched beaches and pristine waters that literally lap at one's doorstep make Maldives a tropical paradise for tourists from across the world. However, the high dependence on the import of merchandise- goods and services for domestic consumption generates significant geo-economic vulnerabilities.

With the sea dominating the quotidian affairs of this archipelagic state, the issue of climate change is a major concern. The contribution of the Maldives to greenhouse gases is amongst the lowest on the planet and accounts for a negligible 0.0003 per cent of the world's total emissions. Despite this, the low-lying scattered land mass makes the nation particularly vulnerable to the perils of climate change. Indeed, climate-driven sea-level rise poses a practically existential threat to the Maldives, given that by the year 2100 sea-levels are projected to rise to a level that will lead to the submergence of the entire island nation. Despite its vigorous advocacy of the need to adopt sustainable development policies and smart climate-resilient strategies, the Maldivian State has not, thus far, been adequately successful in bringing about the degree of global or even regional change that is required if this existential threat is to be staved off. There are several articulations of empathy and support, but not enough change in terms of regional or global geopolitics. This makes the country exceptionally susceptible to its natural vulnerabilities and to being manipulated by external powers. Obviously, this is detrimental for regional maritime stability and security. Though this is clearly a matter of great significance to the Maldives, there are also several implications of this for India, whose mainland is located just 330 nm to the Northeast (in fact, India's Minicoy Island in the Lakshadweep group is just 75 nautical miles north of the northernmost Maldivian island of *Thuraakunu*).

Climate-driven Migration

At present, Maldivians view climate-driven environmental change as just one of the reasons amongst several others that influence migration-related decisions. The 2018 edition of the United Nations International Organisation for Migration (IOM), referring to migration in the Maldives[3] states that Maldivian migrants mainly consist of students (primarily moving to India, Sri Lanka, Malaysia, Australia and the United Kingdom), followed by employment-seekers (mostly in Australia, India and the United Kingdom) and asylum seekers/refugees (mostly registered in the

United Kingdom). Since 2000, Sri Lanka has surpassed India and Australia as a major destination for Maldivian emigration (UNDP, 2015). By 2015, 48 per cent of Maldivians abroad were registered in Sri Lanka. The recent domestic political turmoil had significantly contributed to the very small number of Maldivian refugees and asylum seekers abroad. In 2016, 57 Maldivian refugees and 39 asylum seekers were registered, principally in the United Kingdom, Australia and the United States.[4]

The population of the country in 2019 was 534,256 including 70,000 foreign workers and 33,000 illegal immigrants from Nepal, Bangladesh and Sri Lanka. As sea levels rise the number of climate-change migrants from Maldives is likely to increase and, as things currently stand, its neighbouring countries, which are most likely to receive these migrants, will be underprepared for the wave of refugees.

While it is yet to be established as to whether climate change is or will indeed be the main driver for migration amongst Maldivian islanders, it is definitely one of the more significant factors and could well lead to the forced movement of islanders. The Maldivians — especially the poorer ones — would naturally be more likely to move to countries in the vicinity, such as India, Sri Lanka, Malaysia, etc. Therefore, the ramifications of such movements from Maldives to India, in particular, deserve to be studied by the strategic community.

Environmental change is triggering events that India needs to be prepared for. In 2015, climate change was the latest entry on the list of environmental security issues, and its potential to cause conflict among nations was recognised. Given India's population explosion, the burden on water resources within the country would increase tremendously, very probably leading to water-sharing disputes. This is just one of the many other concerns that India should consider while chalking out a policy for a likely flood of migrants. A sea level rise of just one metre would reportedly put close to 145 million islanders (largely from nations such as the Maldives, the Marshall Islands, Kiribati and Tuvalu) at risk and trigger forced migration.[5] Of this extrapolated figure, about 41 per cent are expected to relocate to South Asia, and 32 per cent are likely to move to East Asia. Any inflow of migrants would jeopardise the already limited resources and expose the 600 million coastal population to the risk of hunger by 2080, depending on temperature rise and population growth.[6]

China in the Maldives

Two factors that are predominant in attracting regional as well as extra-regional players to establish their presence in these Small Island Developing States (SIDS), are: the latter's strategic location, and, the abundance of marine resources within the Exclusive Economic Zones of these island-states. With China taking its global trade and infrastructure plan forward, the Maldives, which has long been a popular tourist destination, has of late, started to grow in importance as a strategic stop for powers in the region. In particular, China and India are vying to encompass the Maldives within their respective sphere of influence. Each seeks to attain its stated and unstated geoeconomic goals and objectives through intensified engagement with SIDS within the IOR. For the most part, these island nations have underdeveloped economies and are quite susceptible to being wooed by the promise of financial gain that is held out by the dominant players. This is seldom without its hidden costs. Today, the Maldives has racked up a total of USD 1.3 billion[7] as debt owed to the Chinese, which forms more than a quarter of the island-nation's Gross Domestic Product. Maldives currently owes a debt to China that would account for 70% of the external aid it receives.[8] Servicing this debt requires an annual payment of US$ 92 million[9] to China, which constitutes roughly 10 per cent of the entire Maldivian budget. Chinese loans have led the Maldives into an economic crisis, which has been likened by strategic analysts to the situation of Sri Lanka vis-à-vis the Chinese-developed port of Hambantota.

As in the case of Sri Lanka, such intensive economic involvement of China in a territory that is proximate to India — Maldives is less than 600 km from India — naturally generates security-concerns in New Delhi that loom large in its own strategic planning.

China's ostensible concern over the threat posed by climate change to these SIDS in general and the Maldives in particular, is not without worrying security-implications for India. New Delhi apprehends that China is engaging in what Americans call "the long game". For instance, using the pretext of ameliorating climate-change threats, China could initiate large-scale infrastructure developments and land-reclamation in the Maldives. These could, in the slightly more distant future, be used by China to further a major geoeconomic goal of Beijing, namely, securing its commodity-sources as well as its export-markets in Africa and West Asia, through a geostrategy of establishing and legitimising its presence in the IOR. This would almost certainly be detrimental to India's own geostrategies that New Delhi would have formulated to pursue Indian geoeconomic interests in the region. A central component of every such geostrategy requires that India reinvigorate its ties with the Maldives and other IOR island-states.

Maldivian Policies for Mitigating the Adverse Impacts of Climate Change

In 2009, the Maldivian government, under the presidency of Mr Mohamed Nasheed, dramatically held a cabinet-meeting underwater, to draw the attention of world leaders to the plight of many low-lying island nations in the face of rising sea-levels driven by climate change.[10] The Nasheed government actively considered the extreme step of relocation of the population. Indeed, the vulnerability of SIDS to climate-change-driven economic and environmental hazards, makes them likely sources for climate-driven migration. A 2018 World Bank report[11] highlights how the climate migrants are projected to increase by a factor of six between 2020 and 2050, and within South Asia alone, internal climate migrants could number over 40 million, constituting around 1.8 per cent of the region's total population. Protectionist fears are already being fanned and there is a growing movement that stridently opposes any government policy that might encourage 'climate refugees'[12] from island-states being accepted.[13]

In 2013, President Abdulla Yameen Abdul Gayoom succeeded President Nasheed and the Maldivian Government abandoned his predecessor's 'relocation policy'.[14] Instead, it formulated a new 'land-reclamation' policy aimed at raising the islands to well above the anticipated rise in sea levels. Indeed, several marine scientists in the Maldives feel that the process of reclaiming islands is perhaps the only real solution to the climate-change-driven existential threat facing the country. According to Shiham Adam, Director, Maldives Marine Research Centre, *"all you have to do is bring the dredgers, suck and pump it on the low-lying land in shallow waters...it takes* *four weeks to build the island and a couple more to put boulders around to stabilise it…to survive, we just need money.”*[15] The Maldives has been on a construction/reclamation spree for quite some time now. The City of Hope in Hulhumalé, an island right next to the capital city of Malé, was built by pumping sand from surrounding atolls, depositing it on shallow reefs, and then fortifying it with walls that stand 3-metres above sea level. Foreign investment was considered to be an essential prerequisite for the success of this policy. Foreign investors were invited to invest at least US$ 1 billion each, and demonstrate that 70% of their project-site would consist of land reclaimed from the sea. China's interest in such projects caused alarm bells to ring in New Delhi, for reasons already outlined above.

However, a major environmental concern arising from such reclamation activities is the harm caused to surrounding corals due to the pumping of sand onto the reefs. The coral reefs which are already facing extinction from ocean warming, are further endangered by this indiscriminate dumping of sand upon them. This, in turn, leads to bleaching and the destruction of the corals. In 2016, more than 60 per cent of the corals at Hulhumalé experienced bleaching due to the effect of the El Niño weather phenomenon. Likewise, as a consequence of the severe 1998 El Niño, reefs in the Maldives, as also in Seychelles and Chagos Islands, were amongst those most impacted by bleaching.[16] Studies also show that coral recovery is most likely to occur in the absence of direct human impact. Therefore, the process of reclamation of islands, in the face of the growing perils of climate change is quite untenable from the environmental perspective. This is particularly applicable in the Maldives even in the immediate-term, since that country's economy is largely driven by tourism. The loss of the archipelago's coral reef habitat would also have a severely detrimental impact upon coastal fisheries.

Conclusion

The Maldives may not yet have been submerged, but sea-levels have already risen, and the Maldives is experiencing other consequential effects such as coastal erosion, salinization, and major changes in monsoon pattern, rainfall, and, hurricane-winds even though the archipelago does not lie in the traditional 'cyclone zone'.

Some proportion of the Maldivian population has begun to migrate to safer and economically more lucrative destinations such as the United Kingdom, Australia, and Malaysia. However, the challenge of this seemingly inevitable migration of islanders must be borne by the neighbouring nation-states, particularly South Asian ones. India, as the dominant power in South Asia, must demonstrate enlightened leadership in its ongoing efforts to integrate the region under the prime-ministerial vision of SAGAR (Security and Growth for All in the Region). While the Maldivian Government, on its part, has taken some adaptive steps, including the construction of sea walls, land reclamation, beach vegetation, raising island elevation, etc., it is far from certain whether any or all of these will suffice to stave off not just climate-change impacts, but geopolitical ones as well.

ENDNOTES

1. An atoll is a ring-shaped coral reef, island, or series of islets, surrounding a body of water which is referred to as a lagoon. For more details see https://www.nationalgeographic.org/encyclopedia/atoll/ (accessed 10 October 2019)

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Note

This article was first published on 03 April 2020 on the Website of the National Maritime Foundation

Need for Development of Adaptive Geostrategies to Address Climate Change: An Indian and an Israeli Perspective

Vice Admiral Pradeep Chauhan (Retd), Captain (Dr) Nitin Agarwala, and Semion Polinov

In recent years, there has been an increased discussion on climate change. While scientific facts have made enormous progress in increasing our understanding of climate change, and how it has changed the weather of a place, there are others, like President Donald Trump, who believe that *"the concept of global warming is a hoax and has been created by and for the Chinese in order to make U.S. manufacturing non-competitive."*[1]

So, which one of them is right? What is this climate change and what does it have to do with the weather of the place where we live? To understand this better, let us first develop our understanding of scientific facts as *"facts are stubborn things; and whatever may be our wishes, our inclinations, or the dictates of our passions, they cannot alter the state of facts and evidence."*[2]

To develop the requisite understanding, three definitions are considered important. First, the *weather,* which is nature's way of balancing the forces of precipitation, clouds, winds, humidity, temperature, etc. in the atmosphere. Second, *climate*, which is the statistics about the weather and is usually the average weather pattern over a long period of time, say 100 years, and finally, *climate change*, which is the significant change in the statistics of weather patterns, glaciers, sea level rise over years, decades, or even centuries, say 100,000 years.

In recent years, enormous knowledge and understanding has been developed about climate change and its causes. This has provided humanity with a clearer picture of the current and future impacts and of the possible actions necessary to limit the magnitude of climate change and allow adaptation to its impacts. However, since these changes are expected to continue, it is definite that in many respects the climate of the future will be different from the climate of the past. Similarly, another accepted fact is that climate change is capable of creating stress on the economic, social, and political system of a nation state. When the institutions and governments of these States are unable to absorb the applied stress, these States and societies would face a long-term security risk both internal and external that would eventually have an impact on the overall stability of the world.[3]

This has thus allowed various nation-states to move on from the traditional view of military security to a far more holistic approach of maritime security, which is defined as freedom from threats arising in- or –from- or –through the sea.[4] These threats could be due to causes that may be natural, man-made, or interplay of one with the other. Sometimes when these threats address the regional fabric itself, nation-states find themselves increasingly enmeshed in a complex web of regionally focused security interdependence, with a robust regional initiative as a logical outcome.[5]

Since *military* maritime security incorporates an interlinked military, political, economic, societal and environmental dimension of security, none of them can be adequately addressed in isolation. Thus, threats to human-security, such as religious extremism; international terrorism; drug and arms smuggling; demographic shifts — whether caused by migration or by other factors; human trafficking; environmental degradation; energy, food and water shortages; all now figure prominently as threats that are inseparable from military ones,[6] and are all as a direct result of climate change. Ironically, despite their utter pervasiveness across both space and time, the security- impacts of climate-change are amongst the least studied in most nation-states including India. Consequently, genuine mitigating and/ or coping strategies are either absent in their entirety, or are hopelessly inadequate.

It is with this understanding that this chapter aims to look at the issues of climate change that affect the world in general and the Indian Ocean and the Israeli region in particular. It further aims to look at how each of these affects the geopolitics of the countries in the region and what geostrategies need to be implemented by

India and Israel to ensure the well-being of its people. The chapter will further explore common areas where collaborative mechanisms between India and Israel can be established.

Background

Of all the issues on the global political agenda, global warming and the associated, climate change, are topics that do not require an introduction because they are so well-known.[7] Climate change has always happened on Earth, which is clearly seen in the geological records of the Earth. However, it is the rapid rate and the magnitude of these changes occurring presently, which are of great concern worldwide.[8] The Intergovernmental Panel on Climate Change (IPCC) report of 2013[9] shows that global warming has been accelerated by anthropogenic activities, and is likely to have massive impacts by altering the basic conditions of life on Earth.[10] There is a growing understanding that, among other things, the international legal system, access to essential resources and the integrity of critical infrastructure are all at risk. Hence, like all global problems, the climate-change-related issue will need global solutions.[11] Today, the understanding and effect of climate change vary according to the existing economic, political and social structures of a nation in different world regions.[12] One of the main misconceptions is regarding the use of the term 'climate change' when in fact it means 'environmental change'. This complexity is due to the fact that the detection of changes in such a complex phenomenon is far from easy to analyse. This is because of the need for necessary averaging and adjustment of various data sources.[13] However, environmental geostrategies are being evolved due to climate change as they appear to be the new way a growing number of governments and non-state actors are starting to adapt to its complex consequences.[14]

It is now an accepted fact that economic and socio-political interactions between countries can have major impacts on transboundary conservation decisions and outcomes. Hence, successful transboundary collaboration in the field of climate change depends on meeting different environmental objectives and enhancing the economic ties and necessary political cooperation and will between nations.[15] But, there are roadblocks to finding effective answers. For example, as the result of a long-standing trust deficit, many leaders in the developing world are suspicious when the West pushes for global emission cuts. Some see it as hypocritical, and a way to impede growing economies. Furthermore, some partners in the West are less willing than others to look at solutions.[16]

Climate change is part of today's reality (see Figure 1). During the 21st century, significant changes are expected in the climate around the world. The Earth's temperature has risen by an average of 0.6-0.3°C since 1860 and is expected to rise by another 1.8°C by 2100.[17] Changes of such nature lead to significant harm to flora, fauna, and live-stock including human beings. Today, there is a global consensus that climate change is indeed taking place, it is man-made and its effect on individual regions will vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change. It is pertinent to mention that global economic loss due to an increase in temperature of 4°C is estimated at approximately 5 per cent of the world's annual GDP, while the economic cost of reducing GHG emissions is currently about 1 per cent of the global annual GDP. However, this cost is expected to increase over time if disregard for the environment continues as usual either by both 'natural' and 'anthropogenic' (human- induced) factors.

As the human population disregards and pushes the boundaries of the carrying capacity of the planet, as seen in Figure 2, a small degree of environmental variation

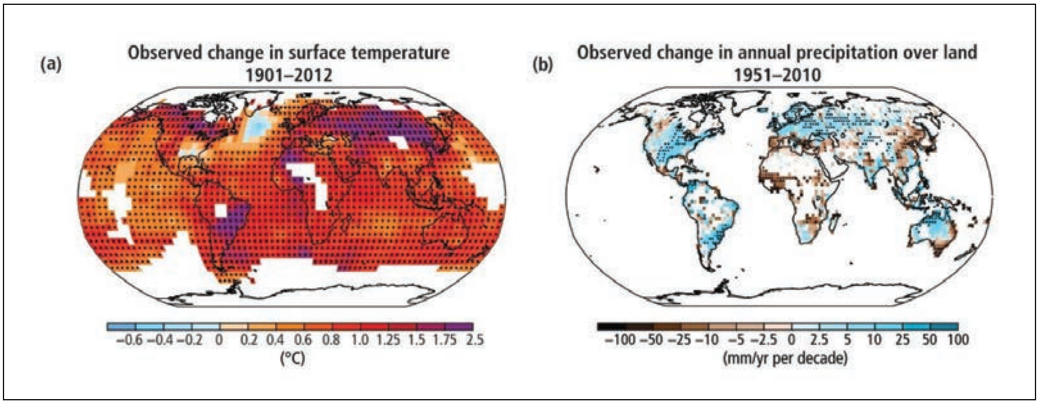

Figure 1: (a) Map of the observed surface temperature change, from 1901 to 2012; (b) Map of observed precipitation change, from 1951 to 2010 (IPCC, 2014).

has larger implications[18] resulting in significant exacerbation of the existing problems. It is understood that climate change is unlikely to lead to an increase in conflicts in the short- to medium-term, but, a long-term development marked by unmitigated climate change could very well have serious consequences for international security.

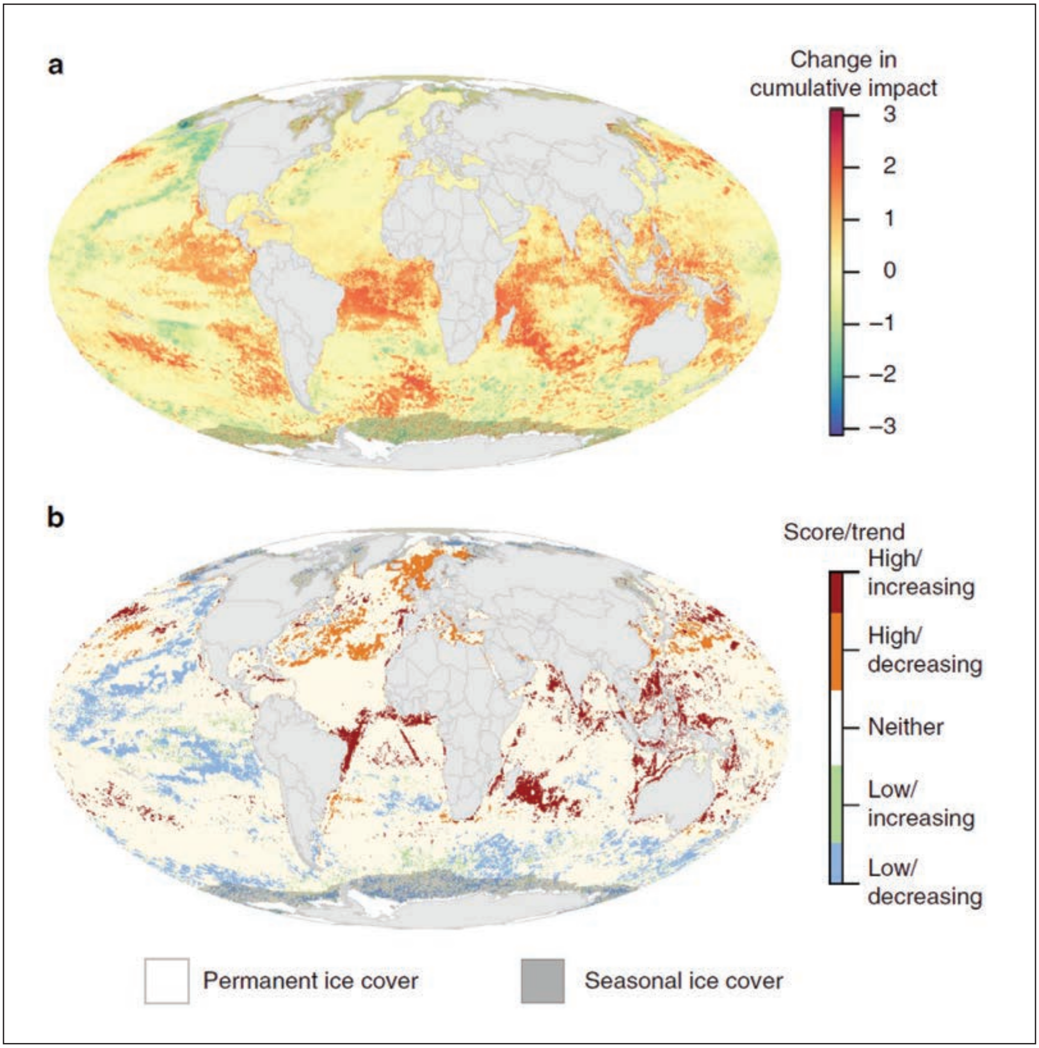

Figure 2: Change in cumulative human impact on marine ecosystems.
(a) Change in human impact between 2008-2013 based on 12 anthropogenic stressors;
(b) Combinations of cumulative impact and impact trend.[19]

Understanding Geopolitics and Geostrategy

With global climatic changes, a growing number of governments and non-state actors are beginning to adapt to the complex consequences of climate change. As a result, new approaches are being developed that focus on strategic thinking and an understanding of how climate change is resulting in tensions, armed conflicts, etc. However, many countries do not have a national maritime strategy based on scientific conclusions about climate change and its impacts on nations and states. Since climate change occurs 'fast' and in some cases is unpredictable, it alters the balance and 'order of things' on which the security of nations is based. Today, such changes have taken the dimension of being a powerful strategic force that needs to be fully understood. This in return is strongly influenced by international relations, future conflicts, and wars, etc. needing one to understand how and when new tensions and armed conflicts can arise through the convergence of environmental, social, political, and economic tensions. For example, an enhanced interest in the strategic implications of water scarcity in the Eastern Mediterranean may initiate the next 'battle for resource' in the coming years and start a new 'all resources race' in the region.

It is hence essential, before delving into the details of the adaptive geostrategies to address climate change, that we clearly understand the terms 'geopolitics' and 'geostrategy' and their relations with each other.

To understand these terms, it is essential to understand that the holistic-security of a nation is a function of two main features. The first comprises the policies, strategies, organisational structures, and the delivery-mechanisms that guide and shape her internal politics and determine her internal stability as a coherent *geopolitical* entity. The second feature consists of elements that define and shape the nation's interaction and interface with external structures — supranational and international organisations, nation-states, and, non-State entities, any of which may, at given points in time, be either supportive or inimical to a nation's geopolitical endeavours. Such geopolitical endeavours are known as the nation's *geostrategy*. These two features have numerous causal linkages with each other. Their infirmities as well as their strengths significantly impact each other. Hence, while considering geopolitics, it is a major conceptual error to place geopolitics, geoeconomics and geostrategy at the same hierarchical level. The correct conceptual hierarchical formulation to the conceptual level is as seen in Figure 3.

Components of Climate Change

Climate, as experienced at the surface of the earth, is a result of the interaction of five major components: the atmosphere, the hydrosphere, the cryosphere, the lithosphere and the biosphere. These interactions result in a balanced energy budget for the Earth. The resulting climate system evolves as a result of the influence of its internal dynamics and external forces such as volcanic eruptions, solar variations and anthropogenic forces. A balanced energy budget occurs when the incoming energy equals that of the outgoing. In case there is an imbalance, the Earth would experience

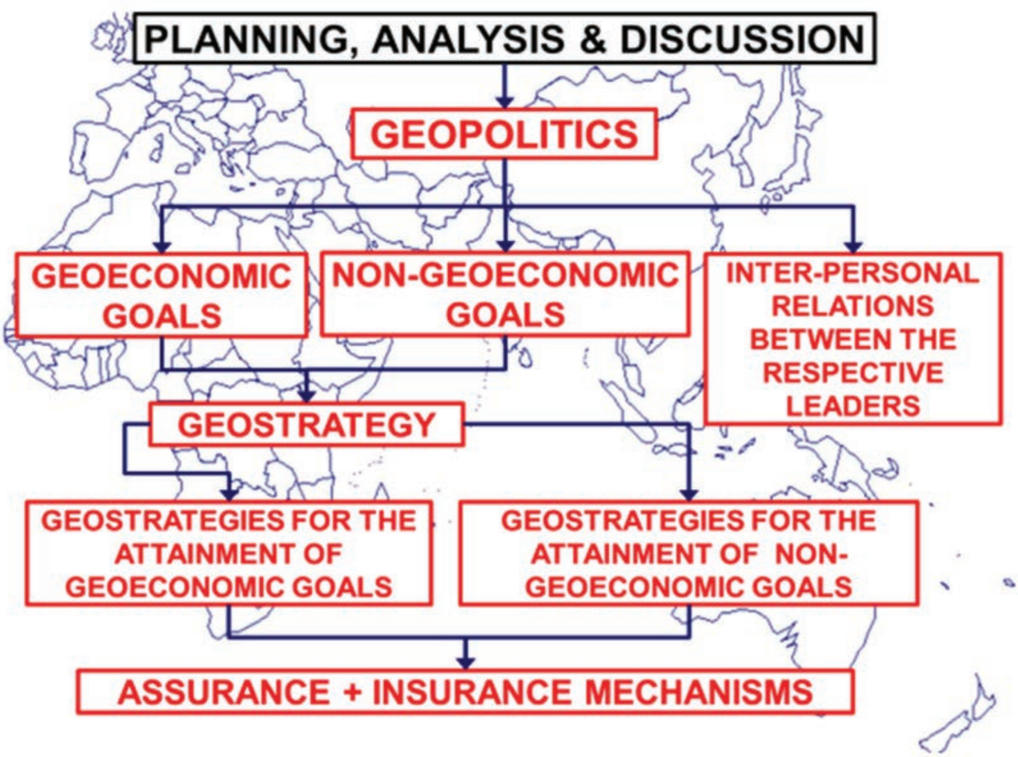

Figure 3: The correct hierarchical formulation of geopolitics, geoeconomics and geostrategy

heating or cooling depending on whether the incoming energy is greater or lesser than the outgoing energy respectively. This imbalance in the energy budget occurs if there is a change in the total radiative solar flux or the spectral distribution of the solar radiation or if there is a change in the concentration of the trace constituents in the atmosphere that affect the transfer of the radiative energy throughout the atmospheric column. Such a change in the energy budget results in a change of climate that is commonly known as 'climate change'.

It is an incontrovertible fact that adding energy to the Earth system will warm up the Earth, rising temperatures, melting ice, resulting in raising of sea levels, droughts, floods, etc. What is not known is just how fast or how much the planet will warm. Consequently, the multitude of associated changes that will take place cannot be accurately predicted. That said, global scientific consensus does exist on five 'climate certainties' due to anthropogenic activities that are in abundant evidence:

(a) Enhanced emission of Greenhouse Gases (GHG)

(b) Higher surface, tropospheric, and ocean temperatures

(c) Precipitation extremes leading to floods or droughts

(d) Melting of mountain glaciers, Arctic sea-ice, and ice sheets

(e) Rising sea levels

Enhanced emission of Greenhouse Gases (GHG). Greenhouse Gases (GHG) are those that absorb and emit radiant energy within the thermal infrared range. The main GHG in the Earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide and ozone. Without GHG the Earth's temperature would be -18°C. However, due to an imbalance in the number and quantity of these gases in the atmosphere, the temperature is +15°C (Cohn, 2008; PWC, 2007).

This GHG is an overarching climate certainty, for it directly contributes to the remaining four climate certainties mentioned above. It has been accepted that as long as CO_2 emissions continue (even if they do not accelerate any further), the temperatures will continue to rise as seen in Figure 4 and Figure 5.

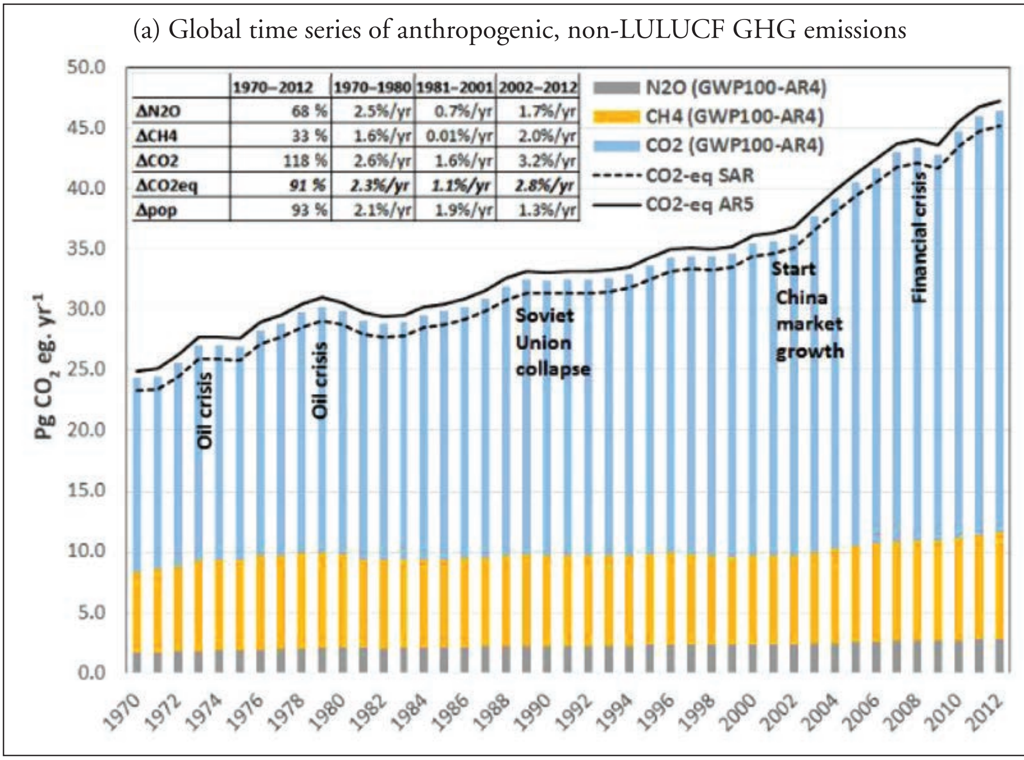

Figure 4: Global time series of anthropogenic. Non-LULUCF GHG emissions 1970–2012.[20]

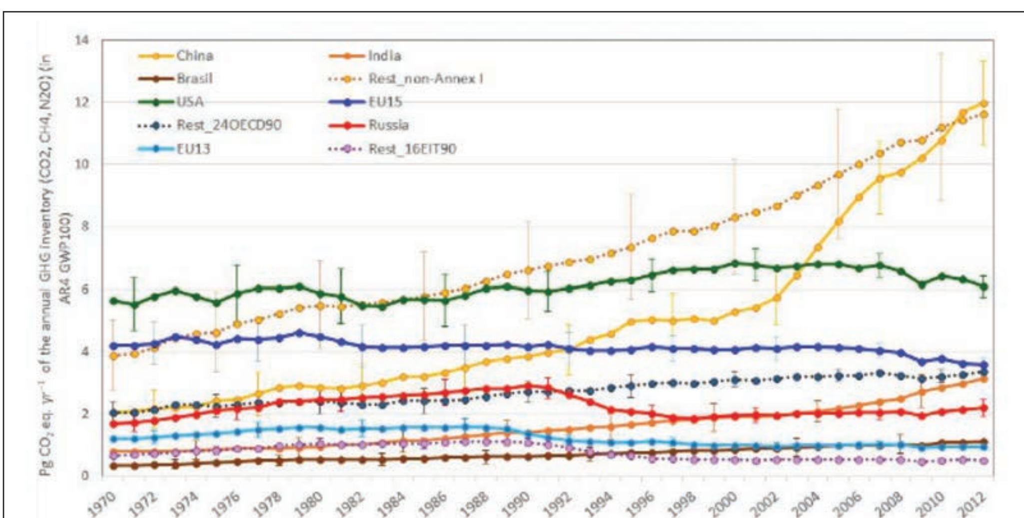

Figure 5: GHG emission trends for the different types of world countries (1970–2012).[21]

As per the World Meteorological Organisation (WMO), 16 of the 17 warmest years on record have occurred in this current century and 2011-2015 was the hottest five-year period on record. 2016 was even hotter, with a global average temperature of 1.2°C above the long-term average as seen in Figure 1. It is hence appropriate to dilate upon just how each of the remaining four of these climate certainties impacts the geopolitics of nations and hence the holistic security in general and the maritime security in particular, thereby creating a need for adaptive geostrategies.

Higher Surface, Tropospheric, and Ocean Temperatures. Both human beings and crops have very limited tolerance for heat. If GHG and surface temperatures continue to rise as shown in Figure 1, people in several countries of West Asia, and some in South Asia as well as the likes of Afghanistan and north-western Pakistan, will begin to experience intolerable levels of heat stress. This will generate a significantly reduced work-efficiency and a corresponding risk of heat-stroke for people especially those who routinely work outdoors. This would result in migration as a response to recurring situations such as drought and desertification that destroy agriculture and other natural resources upon which communities depend for their livelihood. Such waves of heat-induced human migration will be a significant factor in the context of both, internal security (due to migration internal to the country) and external security (due to migration across the borders) and hence the associated strategies to cope with such migration will be an important geopolitical driver.

An immediate result of widespread heat-stress and a decrease in precipitation is the scarcity of water that is used to sustain life and livelihood and is referred to as 'water-stress'.[22] Although thresholds for water stress are largely arbitrary, thresholds of 'moderate', 'chronic' and 'extreme' water-shortage are widely used, based on the per-capita availability of water. Studies indicate that the number of people exposed to extreme water shortage is projected to double, globally, by the middle of the current century due to population growth alone,[23] as seen in Figure 6.

One of the most commonly encountered security-impacts of temperature-rise and water-stress has been the occurrence of protracted and frequent *droughts*. Drought is a major challenge for people, agriculture and economies across the world. Though drought is a difficult phenomenon to predict in terms of the occurrence, frequency

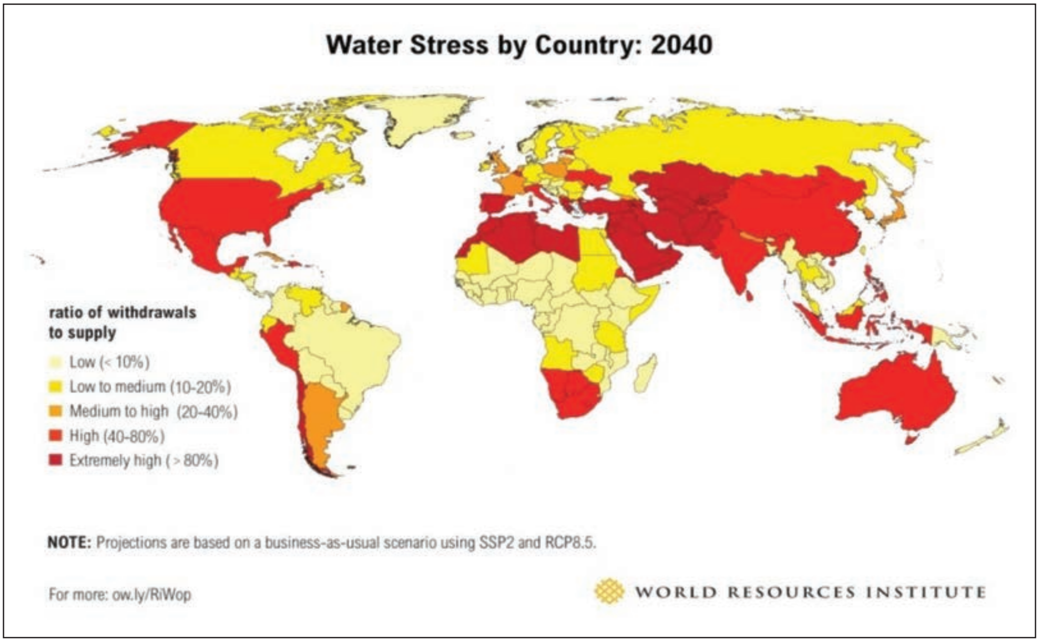

Figure 6: Water stress (as a function of water withdrawals to water-supply) in 2040.

and impact, one ubiquitous consequence of drought is that it causes crops that are already under heat stress to undergo more extensive withering and food-security to plummet as a consequence of large-scale crop failure.

Such droughts contribute to instability throughout the world, as populations migrate across borders, creating conditions for social or political upheaval along the way. More immediately, it will promote violent actions by an increasing number of malevolent non-State actors and terrorist organizations and would exacerbate other socio-political and socio-economic causes. For instance, although it cannot be said that climate-change created ISIS, its rise in 2011 was certainly facilitated by the preceding four years of drought in Syria that sent hundreds of thousands of Syrians into extreme poverty and food insecurity and generated a huge exodus from the rural areas of Syria towards Damascus.[24] The resulting brutal actions by the security forces were repressive and draconian that resulted in the rise of the *Daesh/Islamic State* (IS).[25] Similarly, the food and water shortages resulting from the drought conditions caused by climate change, made worse by incoherent and ineffective policies by weak governments of Chad, have provided a ripe recruiting ground for the *Boko Haram* terrorist group operating out of Nigeria.[26] These very conditions similarly facilitated the rise of the *al-Shabaab* terrorist group in Somalia and subsequently as sea-pirates from Somalia into the maritime domain.[27]

Closer to India, Afghanistan, a country with negligible food security and more than half of all her local conflicts being over arable-land and water, diminishing rainfall and advancing desertification is likely to spark further violent clashes between nomads and pastoralists over access to pastures, water and food. Farther south, Pakistan, too, is extremely vulnerable to heat and water stress and the possibility of climate change and environmental factors destabilising Karachi is now recognized as being real and temporally proximate if not imminent.

As the climate-driven migrant population from Afghanistan pushes into Pakistan, this would force subsequent migration of Pakistan's own population, thereby increasing the strain upon India to a point where the 'weaponization' of water — despite agreements such as the Indus Water Treaty of 1960 — could become a cause for serious conflict. The present treaty is increasingly strained as both sides pursue hydro-development projects to mitigate water and energy shortages; and to take pre-emptive action against flooding or drought, which are becoming more frequent and intense with climate change. Climate change is expected to further challenge water distribution and hydro-development in Pakistan and India, thereby significantly impacting security, especially as this inherent suspicion and mistrust between the two States is used by terrorist groups to provoke anti-Indian sentiment in Pakistan, providing fertile ground for conflict.

Water Surfeit or More Precipitation or Floods. If heat- and water- stress constitute one face of the adverse security-impact of climate change, water surfeit is its opposite face, but it, too, has an equally adverse security- implication. An increase in rainfall can be a blessing for a country that can capture, store, and distribute the additional water, but is a curse for a country that does not have adequate land management practices or infrastructure. Even where it is a blessing, the 'blessing' is likely to be a mixed one, because regions that benefit from additional rainfall will also need to cope with waterborne health issues and an influx of migrants from water-scarce areas, thereby aggravating existing national and/ or inter-State tensions.

Within India, extensive flooding caused by heavy rainfall has become endemic in large portions of the country. In 2017, Gujarat, Bihar, J&K, Maharashtra (including Mumbai) and even parts of Rajasthan of India were unable to handle increased rainfall, requiring the intervention of the defence services for in-country Humanitarian-Assistance and Disaster- Relief (HADR) operations in aid of civil power. Where the rainfall is both heavy and unseasonal, the call for HADR from the defence services is even more strident, as was the recent case in Uttarakhand (2013), J&K (2014), Tamil Nadu (2015), Kerala (2018) and Orissa (2019).

This inability to deal with increased rainfall extends across much of India's neighbourhood, with Sri Lanka, Nepal and, further afield, the Philippines, all offering recurring examples. In the civilian world, 'humanitarian logistics', which forms the core of HADR operations, is less well-established than 'commercial logistics' while that of the defence services is better established thereby experiencing a sharp increase in 'operational stretch' precisely because of the increased demand for HADR. As the adverse effects of climate change increase, the operational load on security forces due to HADR would increase thereby having an increasing impact on other facets of national security that they are actually expected to provide.[28]

Another security-impact of climate change that is grossly underestimated is that caused by changing/ stronger disease vectors that arrive in its wake and cause water-borne and vector-borne diseases, such as malaria and dengue fever.[29] Conversely, many airborne diseases thrive in those areas that become arider due to drought and higher temperatures. Further, the shortage of food and/or fresh drinking water renders human populations more susceptible to illness and less capable of rapid recovery. The risk of a pandemic is heightened too when deteriorating conditions prompt human migration.[30]

The resulting security impact on the geopolitical landscape is not hard to imagine. It is easy enough to comprehend the threat posed to human security by more frequent and vigorous outbreaks of diseases, epidemics and pandemics. In the face of an epidemic, it is not uncommon to find countries imposing varying degrees of restrictions upon the free movement of people from affected countries into their own. However, should these restrictions or total bans be applied to merchandise that is traded in bulk, and form a significant part of a country's GDP, the geopolitical ramifications can be very serious.

Glacial Lake Outburst Flood (GLOF). When talking of glacial lake outbursts, the first thing that strikes the mind is the polar ice caps. Though this is not directly applicable to the Asian continent, what is relevant is the Himalayan range that has a spread of over 2,900 square kilometres and feeds all the major water bodies of the continent, and supports nearly 1.3 billion people that account for over 20 per cent of the world population.

The security impact upon India due to the receding of the Himalayan glaciers as a result of climate change is evident in Nepal, where frequent, devastating floods are seen as a result of the bursting of glacial lakes. A glacial lake outburst flood (GLOF) is a result of a combination of increased heat from the emission of greenhouse gases, and a sudden water- surfeit causing flooding due to a glacier retreat and the conversion of the residual ice sheet into water.[31]

Several GLOFs have trans-boundary impacts. Many floods in Nepal have originated in Tibet, while floods from Nepal have run into India and even Bangladesh.[32] A GLOF event destroys downstream settlements, dams, bridges, and other infrastructure with waves nearly 15 metres high. Where Nepal is concerned, this puts further stress on a country already struggling to preserve a fragile peace and reintegrate tens of thousands of the Maoist insurgents — the failure of which could destabilise much of India and even South Asia at large.[33] Further, China's geopolitical gameplays in Nepal too, act as a source of frequent Sino-India tension and have security implications at the strategic level of very significant proportions.

Melting of the Polar Ice-Sheet. There have been speculations about the impact upon the maritime security of the melting of the Arctic ice-sheet and the potential opening of new routes for maritime trade as a result of this melting. Since the Arctic is warming at twice the rate of anywhere else on earth, due to high carbon concentration, the resulting ice-melt could well result in an ice- free Arctic Region in the latter half of the present century.[34] The opening of the Northern Sea Route (NSR) will certainly affect seaborne trade and International Sea Lanes in the northern 'east-west' reaches of Eurasia, although the effect upon the southern 'east-west' stretch of the Eurasian littoral will be far less. As a consequence, the geopolitical importance of ports such as those in the Koreas and in Japan will significantly increase. Since China has both components of this geography in large measure, it is frantically developing port-infrastructure in its relatively under-developed coast north of the Yangtze River. Such export-oriented northern Chinese ports, catering to shipping along the NSR would save about 25 per cent in transit time — provided they were trading with northern Europe, which at present is just under 3 per cent of her total international trade. Asia's big exporters — Japan, South Korea and China — are all investing in ice-capable vessels. So, quite clearly, changes in shipping patterns may be expected over the medium to long term. Every such new 'International Sea Lane' would need to have intermediate ports and shore-based multi-modal transportation infrastructure to provide access to hinterland areas thereby redefining the geopolitics of the region.[35]

Sea–level Rise. Turning to the impact upon the maritime security of the melting of the polar ice sheets, the situation is gradually approaching criticality. The percentage contribution of the melting of land ice to sea level rise is some 52 per cent, while another 38 per cent is contributed by the thermal expansion of the oceans as a result of surface and tropospheric warming.[36] Rising sea levels are thus a far more immediate problem than most Indian analysts realise. India was ranked 'Number One' in 2008 and is projected to retain this dubious honour even in 2050[37] based on the total number of people who would be at severe risk from a rise in sea level.

An immediate impact of sea-level rise in areas close to the coast is that of salinization of freshwater as seen in Figure 7. While this impact may not be noticed on the surface, it would affect groundwater. This will result in the loss of arable land, and hence desertification leading to the migration of coastal population causing both internal and external ramifications.[38]

Impact on Maritime Forces

As seen in the developing world, even a relatively small climatic-shift can trigger or exacerbate food shortages, water scarcity, destructive weather events, the spread

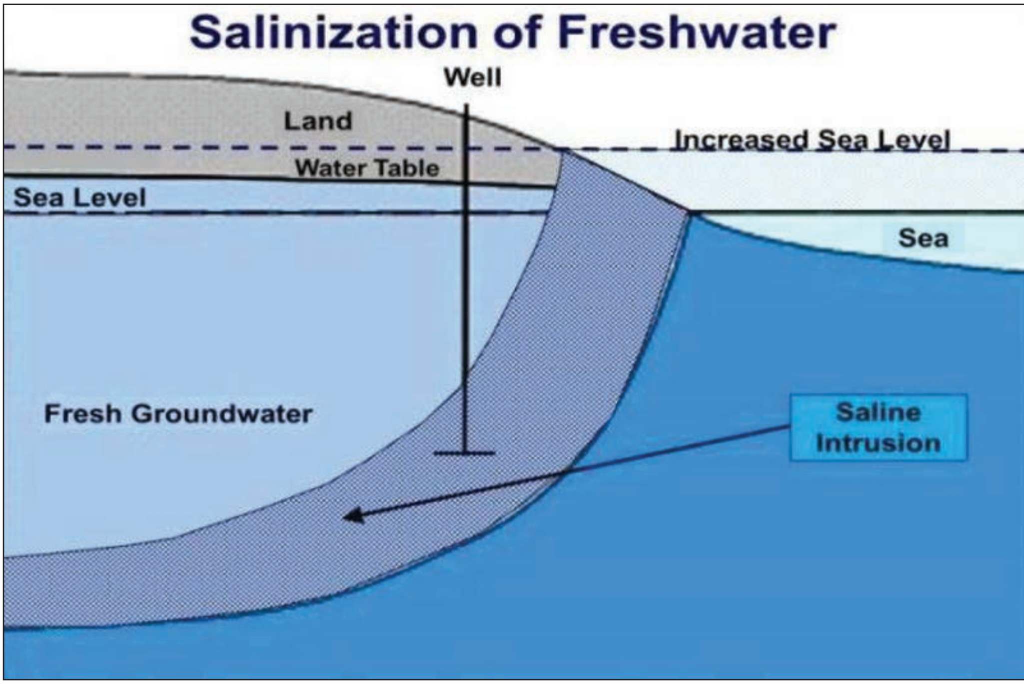

Figure 7: Immediate impact of sea-level rise on the salinization of freshwater

of disease, human migration, and natural resource competition, and, perhaps most ominous of all, can lead to partial or total 'State-failure'. Since whatever happens on the land has a direct bearing on what happens at sea, several security-related risks inherent to climate change come to the fore. Issues relating to maritime security may be direct or indirect. These are:

(a) **Indirect Security Issues**. The security-impacts of climate change are felt particularly strongly within the maritime domain — upon, below and above the seas, as also within the coastal areas of littoral countries. Rising surface temperatures have a direct effect of increasing the frequency, severity, and path-unpredictability of cyclones for the coastal areas. Future projections based on high-resolution dynamical models indicate that GHG-induced surface warming will cause globally averaged intensity of tropical cyclones to decidedly shift towards stronger storms, with intensity increases of 2 to 11 per cent by 2100.[39] These increased frequencies of disasters due to climate-change-induced cyclones and floods, would increase the already high operational strain upon the maritime forces and on the defence and naval budgets. This would inevitably impact the readiness to meet other maritime threats and challenges, including those arising from other State challengers, and/ or malevolent State-sponsored non-State actors.

(b) **Direct Impact on Naval Missions**. A range of naval missions and war-fighting capabilities are impacted by the changing salinity of the oceans due to climate- change. This salinity of seawater has changed measurably from 1950 to 2000.[40] The consequences of such a change upon a submarine and anti-submarine operations are both obvious and significant. Apart from naval combat due to inter-State armed conflict, climate change will significantly strain military transportation resources and supporting force structures in respect of coastal security, anti-piracy and counterterrorism, and HADR missions.[41]

'Hot-Spots' for Climate change and Human Impact

The Indian Ocean. The Indian Ocean is the warmest ocean of the world. Studies of the Indian Ocean, for the period 1901-2012 reveals that the Indian Ocean is warming at a rate much larger than any other ocean in the Tropics. This warming scenario and the related climate dynamics are factors to be vigilant of, while assessing long-term climate change[42] as the Ocean drives the region's climate, including extreme events such as cyclones, droughts, severe rains and waves. To add to this the Asian continent is a diverse continent with complex geography, economy, demography and political characteristics. This in return influences the different climates within Asia that vary from dry deserts to wet and humid tropical regions; hot and warm continental temperatures to cold polar and mountainous temperatures.[43]

Evidence indicates that annual temperatures in the Asian continent have increased with increasing warm days and warm nights. These temperatures are expected to continue to rise and will lead to accelerated glacier melts, a higher risk of droughts and lower rainfall periods. Such extreme weather events will result in significant loss and damage in a larger part of Asia as seen in Figure 8. The resulting 'climate certainties' in this region include:

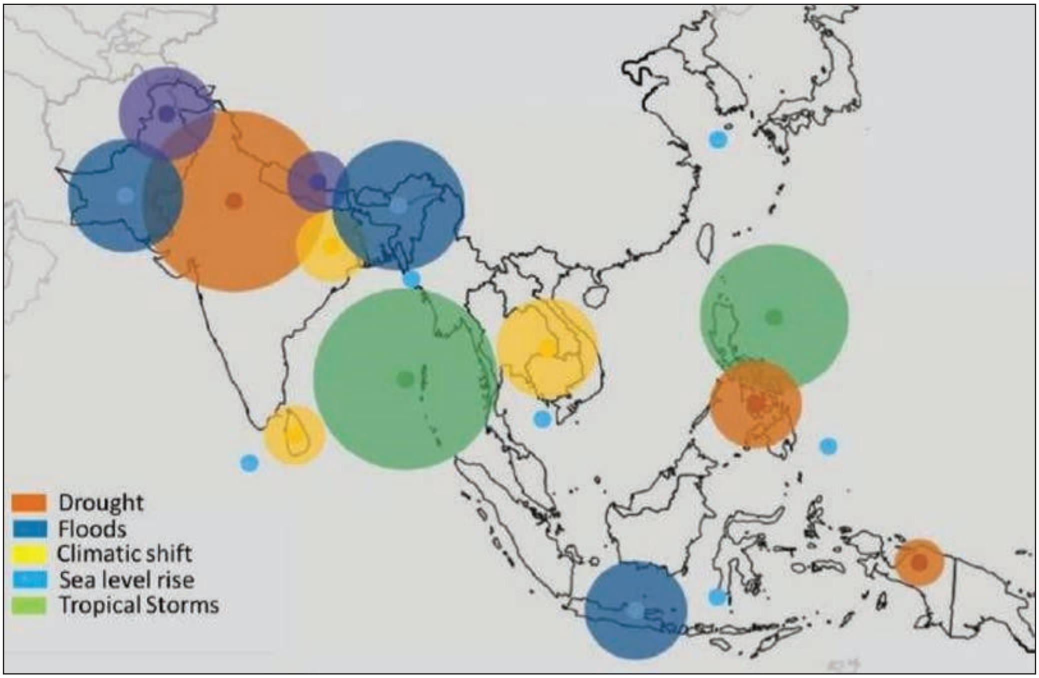

Figure 8: Climate-related risks in Asia.
Source: Modified from Krishnamurthy *et al.*, 2015

(a) **Droughts** that occur as a result of a combination of insufficient rainfall and high temperatures impact agricultural production. The currently available models suggest higher intensity and duration of drought in parts of South Asia, Indonesia, and the Philippines.

(b) **Floods** have become more frequent and intense in this region since the 1960s as a result of heavy precipitation events. More frequent and intense floods are expected in large parts of Asia. Glacier melt, sea-level rise, and more intense tropical storms are likely to increase the risk of floods.

(c) **Tropical storms** that have the potential to devastate large areas will become less frequent but more intense under climate change as suggested by climate models.

(d) **A climatic shift** that occurs due to changing rainfall and temperature patterns is expected over large parts of Asia, including the Mekong basin and parts of South

Asia. Such shifts may render traditional, climate-sensitive livelihoods such as farming and fishing unsustainable.

(e) **Glacier melt** which feeds water to rivers in the Indus and Ganges-Brahmaputra basin when accelerated due to increased temperature would result in non-availability of water and hence droughts in the long run and floods in the short-to-medium-term.

(f) **A sea-level rise** that is another serious area of concern is expected to rise by 57-100 cm by the end of the century, thereby exacerbating coastal flooding risk as well as the impact of storm surges.

The Mediterranean Sea. The Mediterranean Sea is a marine biodiversity hotspot and the surrounding region is undergoing rapid local and global climatic changes.[44] Currently, the main climate changes in the Mediterranean Region consist of a pronounced decrease in precipitation and an increase in air and sea warming. This region, which has been identified as a 'hotspot' for climate change, is expected to experience environmental impacts that are considerably greater than those in many other places around the world (see Figure 6).[45] Many of these impacts have already influenced the water, food, environmental and political security of the region and can potentially lead to conflicts (see Figure 10) caused partly by climate change between and within the Mediterranean countries. All indicators point to an increase in environmental problems in the Mediterranean Sea such as water scarcity, water pollution, destruction of coastline, increase in population density, night-time lights pollution, overfishing, habitat degradation, invasive species, and shipping with negative implications towards current and future sustainability.

Quantification and mapping of the cumulative impact of 22 drivers to 17 marine ecosystems[46] reveal that 20 per cent of the entire Mediterranean basin and 60–99 per cent of the territorial waters of EU member states are heavily impacted, with high human impact occurring in all ecoregions and territorial waters (see Figure 9). This high impact results from multiple drivers of them; climatic drivers such as increasing temperature and UV, and acidification are the major contributors. These results show that coordinated management of key areas and activities could significantly improve the condition of these marine ecosystems.

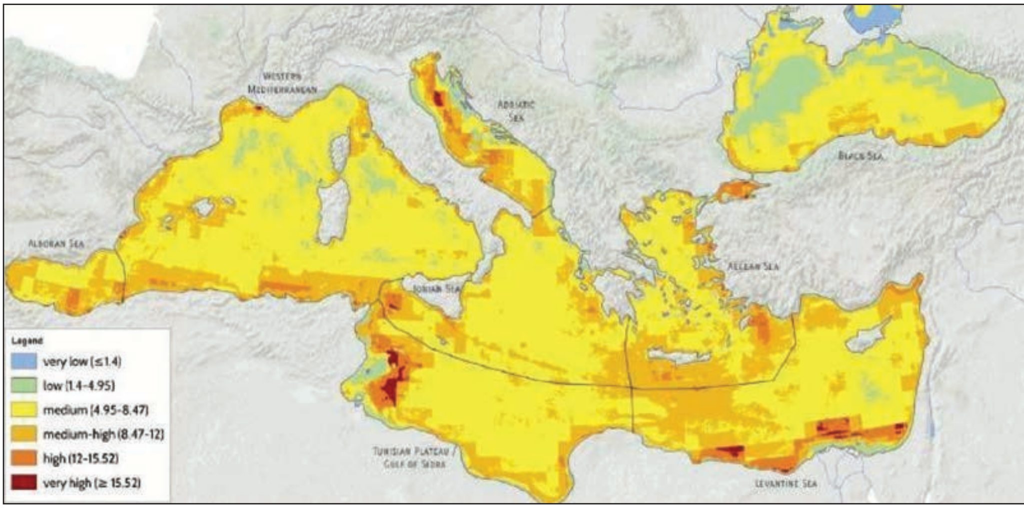

Figure 9: Spatial distribution of cumulative impacts to marine ecosystems of the Mediterranean.[47]

Environmental management by Mediterranean countries is challenging these pressures and needs to evolve to reach the target of increasing population with reliable access to freshwater, food, recreation and tourism etc. Currently, the majority of conservation programs are applied at national and subnational scales, but global and regional coordination is becoming more common. These global regional coordination demand higher transaction costs and resources beyond what is required in national programs.[48] The Mediterranean countries have different perspectives, towards economic development, social structure, climate change and its rates, and the state's ability to adapt to changes, such as the availability of water, infrastructure, and various other daily resources. However, in many regions, rapid social and environmental changes are taking place. These changes have negative consequences on the current and future human stability and security both within the country and the entire Mediterranean region, for which solutions have not been worked out. This is especially true for the food and water security of the Mediterranean region, where, according to forecasts, pressure and impact on water, soil and natural resources increases in the face of climate-change and various conflicts.

The inherent geopolitical complexity and disputes over marine borders and jurisdictions (see Figure 10) have raised obstacles to transboundary collaboration efforts in the Mediterranean. This situation poses both a challenge to large-scale conservation planning in the Mediterranean region and a unique opportunity for the development of coordinated regional conservation efforts. The integration of Mediterranean-wide and local conservation efforts, the facilitation of transboundary collaboration, and the establishment of regional funds for conservation will further enhance opportunities for marine conservation in this region.[49]

How Climate Change is Altering the Geostrategy of a Nation

India. India is amongst the most vulnerable countries to climate change because of its large population that depends on natural resources for their livelihoods. By 2020, pressure on India's water, air, soil, and forests is expected to become the highest in the world with water resources having the largest impact. The potential mechanism that is likely to cause this is:

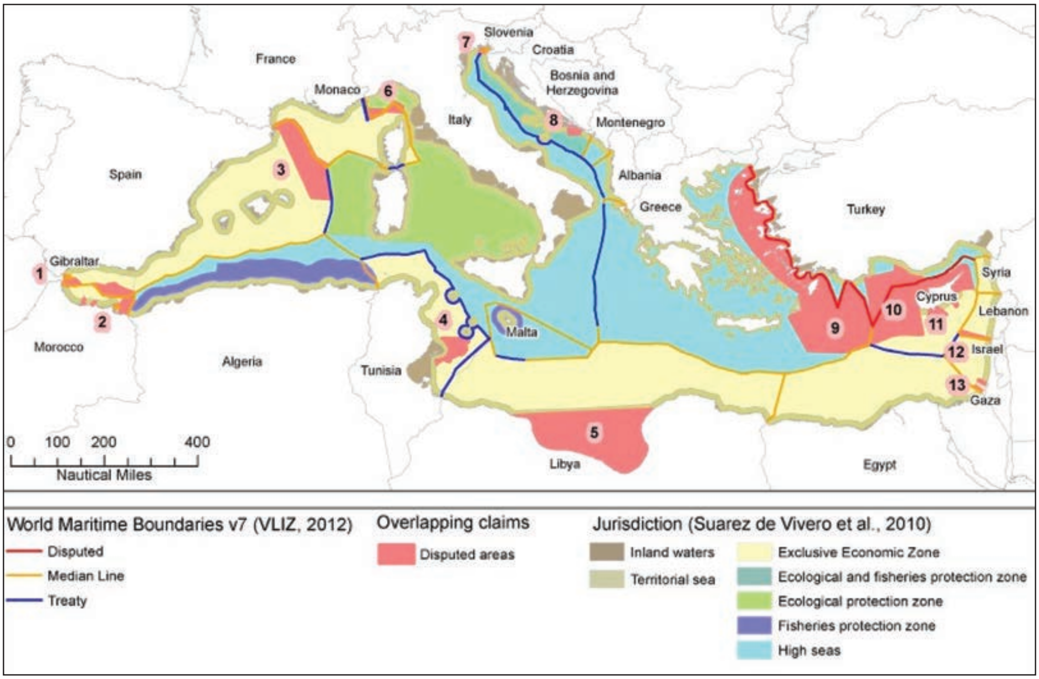

Figure 10: Marine boundaries and disputes in the Mediterranean Sea.[50]

(a) **Glacial recession**. The Himalayan glaciers are the water source for Asia in general and India in particular. As the Earth's temperature increases, these glaciers experience increased melting resulting in increased water content in the rivers. However, over the time as these glaciers disappear there would be a lack or no water for the people currently dependent on them. This would lead to the Himalayan river system to end up as seasonal, monsoon-fed rivers, making water availability for human sustenance round the year critical.

(b) **Rising sea levels**. The rise in sea levels in this region will result in the submergence of low-lying areas, river deltas, coastlines and small islands. In this region, the highly populated cities of Karachi, Dhaka, Mumbai, Kochi and Mangalore face the maximum risk due to submergence with the coastline advancing inland in many populated parts of Bangladesh, Sri Lanka, Myanmar, Pakistan and several parts of India. This would lead to forced migration leading to food and water stress and security issues to the regions where these people will migrate to.

(c) **Extreme weather**. Climate-change would worsen the impact of natural disasters by increasing their intensity and frequency and make adaptation efforts difficult.

Such changes would change the dynamics of conflict with little or no respect for political frontiers as States will be forced to react with self-interest that will complicate the existing unresolved inter-State disputes. Some of these are as shown in Table 1.

Table 1: Impact of climate change in the Indian subcontinent.

Conflict region	Water scarcity	Rising sea levels	Extreme weather	Resulting effect
Jammu and Kashmir	High	–	Medium	Risk of war with water being the prime cause
Indo-China border	High	–	Medium	Risk of natural disasters
Bangladesh	High	High	High	Mass migration
Pakistan	High	Medium	Medium	Ethnic conflict
Sri Lanka	–	High	Medium	Risk of mass migration and ethnic conflict
Nepal	High	–	High	Risk of natural disasters and mass migration

Israel. The estimated impacts of climate change on the geostrategy of the Mediterranean nation are still under investigation and not clear for most countries of the region. In the short- and medium-term, climate change is unlikely to significantly change and affect the geostrategy and nation security structures. However, depending on the severity of climatic changes in any specific area or site, these conditions may change and affect long-term prospects as they have a direct and serious impact on security perspectives.

The three main areas of concern for Israel as a result of climate change are: water scarcity (evident), the approximate rising of sea level by 6-8 cm since 1960, rising sea and air temperatures (evident) and complex problems caused by the cumulative effects of climate change in the fields of tourism, transportation, energy and national infrastructures, food security, fires, migration and geopolitics.

The impact affects a wide range of geostrategic issues depending on a number of geographic areas: the inner circle (Israel), the circle of neighbouring countries, the circle of Muslim-Arab countries adjacent to neighboring countries, and other countries. Among the most important points in this regard are: a change in the geostrategic balance of forces in the Middle East, water management problems, increasing energy consumption, and the food sector. The main conclusion is that Israel must turn fears and threats from climate change into a lever for advancing projects that Israeli society must promote. These include increasing water supply (desalination), completing the construction of dividing fences between Israel and all its neighbours to prevent illegal immigration, and enhancing the protection of existing and potential agricultural land to ensure food supply. The resources that are presently being challenged by climate change are:

Energy. Climate change trends observed throughout the world in recent decades are mainly reflected in changes in the temperature of air and water, rain patterns and an increase in the frequency and intensity of extreme weather events, including seawater heat waves. These scenarios have a major impact on various areas of the Israeli energy sector. Among the problems that the energy system is already facing is the need to cope with the growing losses in production and transmission due to rising temperatures, unexpected waves of jellyfish, and damage to the energy infrastructure on the coastline along which more than 80 per cent of all Israel's electricity is produced (see Figure 11).

Biodiversity. In terms of biodiversity, climate change is one of two major threats in Israel. The second threat is, accelerated growth of the population of Israel, especially along the coastline. In most cases, the effects of climate change are slower than those directly related to human activity, and therefore the impact of human activity on natural systems is more rapid. This is particularly noticeable in the coastal zone, where developmental pressures lead to habitat destruction and competition for water resources put freshwater habitats under threat. Therefore, the most important tool for biodiversity conservation is to manage policies aimed at reducing sources of harm that are not related to climate-change.

Maritime Policy. For several decades, marine spaces (EEZs) have been undergoing significant geopolitical and environmental/ climatic change. Demographic growth

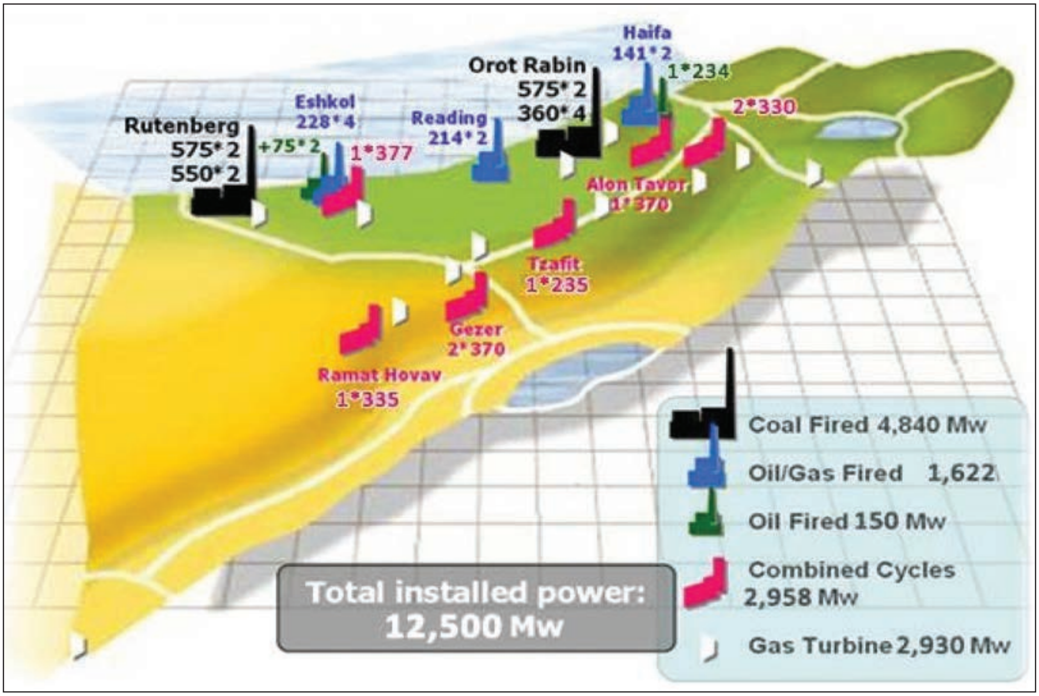

Figure 11: Location of Israel power stations.
Source: Israel Electric Company Limited[51]

and rising standard of living have increased the pressure on humanity to generate resources and facilitate a shift away from the oceans and from terrestrial resources with a realisation that investing in preparing for climate change will cost much less today than in the future, and that such a preparedness will bring much greater benefits and reduce damage. With this understanding, the Israeli Planning Administration, responsible for determining the national planning policy, identified the need to formulate an integrated policy for the preservation and development of the maritime space.[52] This requires a clear policy both at the central government level and at the local government level to minimise economic and social damage on a large scale, for developing technological innovations and as a source for exporting knowledge and technologies to countries at risk of climate- change, including developed countries. As of 2019, there is still no regulated government body that will manage Israel's EEZ.

Water Resource and Supply. Since the establishment of Israel, the water sector has been confronted with the need for reliable water supply, its quality and quantity. The water sector in Israel has been built over many years due to water shortages, population growth and a significant reduction in the drainage basin of the Sea of Galilee which led to the development of extensive knowledge in the field of water and the development of technologies in the field of land reclamation, desalination, etc. As a result of climate change, increased temperature leading to increased evaporation of surface water bodies, dehydration of springs and streams, and much more are creating a higher water stress on the already scanty water resource for Israel. While desalination and advanced wastewater treatment for agricultural reuse are helping to close the gap between the water supply and demand in Israel (see Table 2), they are expensive and energy intensive, resulting in increased emissions of pollutants and greenhouse gases.[53] However, Israel's energy sector is more reliant on natural gas,[54] from 12 per cent in 2004 to 54 per cent in 2017, while renewable energy constitutes 3 per cent for 2017.[55]

Coastal Infrastructure and Sea Level Rise. The impact of climate change on Israeli infrastructure is complicated to quantify, but it is expected that the impact will increase in extreme events like sea storms and floods on land as a result of the

Table 2: Desalination plants in Israel and their production (2019)

Location	Annual water supply (mcm/year)
Ashqelon	115
Palmachim	90
Hadera	127
Sorek	150
Ashdod	100
Eilat	20

Source: Desalination facilities in Israel, http://www.water.gov.il/Hebrew/Planning-and-Development/Desalination/Pages/desalination-%20stractures.aspx

inability of drainage systems to accept rain volumes. Currently, most of the Israeli cities located on the Mediterranean coastline are not prepared for climate change impacts such as rising sea levels and increased sea storms. Unless protection measures are taken, rising sea levels are expected to increase the rate of:

(i) *Salinization of the coastal aquifer*. The coastal aquifers of Israel have already been damaged by the infiltration of the intermediate aquifers to the east, and any further eastward progress will only worsen the situation.

(ii) *The retreat of the coastline*. The retreat of the coastline will harm tourism, vacation and kite activity and will necessitate diverting activities and structures eastward to the current coastline.

(iii) *Reinforcing coastline*. Due to receding coastlines, resources and efforts would need to be invested in protecting coastal buildings and elevation of ports.

(iv) *Reduced river flow gradient*. Due to increasing sea levels, the flow gradient would reduce which would increase the sedimentation rates in river deltas. This would require investment to rectify the situation.

(v) *Loss of coastal sand*. The natural resource of coastal sand is expected to be lost to an extent of 2-100 metres for each 10 cm rise in sea level.

Need for Geostrategies to Counter Climate Change

There is global unanimity in the understanding that South Asia will be among the hardest hit by climate change. Higher temperatures, more extreme weather, rising sea levels, increasing cyclonic activity in the Bay of Bengal and the Arabian Sea, as well as floods in the region's complex river systems will complicate existing development and poverty reduction initiatives. Coupled with high population density levels in this region, these climate shifts have the potential to create complex environmental, humanitarian, and security challenges.

The impact of this increased frequency of cyclones, a higher storm activity, and the *extensive attendant flooding* will be particularly severe upon Bangladesh and upon India's east coast. This would radically alter living conditions and seriously undermine livelihoods. The increase in the frequency of such extreme events and deteriorating conditions is likely to force many to leave their homes temporarily or even permanently and become climate- induced human migrants.

When considering the rise in mean sea levels, the Republic of the Maldives seems to be the most affected. With an average elevation above the current Mean Sea Level of just five feet (the highest elevation is a mere 2.4 m (eight feet) and with the 5th report of the Intergovernmental Panel on Climate Change,[56] predicting a global rise by 52- 98 cm (20.47 to 36.22 inches) by the year 2100, the country is extremely susceptible to the dangers of increasing sea levels because of global warming. This would be disastrous for Maldives whose 336,000 people could suddenly become 'boat people'!

An even more intriguing set of totally unexplored issues are thrown up by the loss of arable land in the deltaic coastal stretches such as those found in Bangladesh. According to a 2013 report of the World Bank, *"40 percent of productive land is projected to be lost in the southern region of Bangladesh to a 65 cm sea level rise, by the 2080s"*.[57] In such an eventuality, what will happen to the baselines of Bangladesh, which have currently been drawn up in accordance with the principles of UNCLOS? Will they now lie some 30-40 nm to seaward of the receded (new) coastline? If they are to be adjusted, what will happen to the Exclusive Economic Zone of

Bangladesh? How will that adjustment affect India? What will happen to the ruling by the International Tribunal on the Law of the Sea (ITLOS)? Is there a mechanism for ITLOS to revise its earlier ruling? What will happen to UNCLOS, which is already facing some robust criticism for the several ambiguities and harshly exposed by the imbroglios in the South China Sea and elsewhere? These are questions that have profound security implications and demand the closest attention and detailed scholarship by concerned departments and agencies of the government as well as maritime-domain experts.

The security implication arising due to the issues discussed herein need little elaboration. President Donald Trump's views cannot be taken as an excuse for inaction. These security implications demand a multi-dimensional contingency-planning at not just the strategic level, but also the operational and tactical ones. Accordingly, some geostrategies that can be considered as a possible way ahead are:

(a) **Spread Awareness amongst Governmental Echelons**. Though the 'brains-trust' of governments is a robust and invaluable resource, however, most governmental echelons are beset with innumerable challenges germane to the day-to-day minutiae of their departments and/ or ministries and have little or no opportunity to even become sufficiently aware of the security-implications of climate change. It is hence essential that creating awareness for the whole-of-government, both the central and the state is, therefore, a sine-qua-non for the formulation of mitigating and adaptive strategies against these adverse impacts.

(b) **Involve Multiple Stakeholders**. Governmental echelons are not the sole source of the originality and innovation required to determine optimal mitigating and adaptive strategies. It is, therefore, very important to widen the input-base by involving as many stakeholders as possible. It is particularly important to capitalise upon the idealism, exuberance and commitment of the country's youth and, in particular, the female population amongst them.

(c) **Commission Focused Studies**. Specialised think-tanks could — and should — be commissioned to undertake a series of focused studies that would formulate specific preventive, curative, mitigating and adaptive strategies to deal with the impact of climate change. While the National Maritime Foundation (NMF) could produce focused-outputs relevant to the impact of climate change upon maritime security, the IDSA, CLAWS and the USI can address holistic land-based security.

(d) **Vigorously involve the Private Sector**. India's private sector has deep stakes in adaptive and mitigating strategies designed to protect the investments made by it in national development. There are thus clearly business opportunities in each preventive, curative, mitigating and adaptive strategy. There is also much that can be gained from harnessing the carefully developed efficiencies that can exist within the private sector.

(e) **'Brand-position' Climate Change in India's Collective Consciousness**. Without correct 'branding', the disruptive and adverse impacts of climate change upon the day-to-day lives of the citizenry will not garner the requisite public (and hence 'political') support. This branding cannot be sustained as a generalist approach by one or more governmental echelon/structures and hence requires well-planned publicity and information-plan. It, therefore, requires a specialised professional/ agglomerate.

(f) **Create a 'Climate-Change-and-Security Contingency Planning Group'**. The Government needs an inter-ministerial group — perhaps under the rubric of the NITI Aayog, or the EAC to the PMO, or the NDMA (National Disaster-Management Authority) — to evolve contingency-based coping-and-adaptive strategies, plans, and responses to the security-impacts of climate change.

(g) **Vigorously pursue the proliferation of OTEC-LTTD**. Given the high capital, running expenses and environmental issues associated with Reverse Osmosis (RO), OTEC (Ocean Thermal Energy Conversion)- LTTD (Low-temperature thermal desalination) offers a highly viable solution to water-stress in India's Lakshadweep and Andaman and Nicobar Island chains, as also in specific areas along the country's East Coast. The proliferation of OTEC-LTTD plants lends itself admirably to capacity-building at a pan-regional level, especially in water-stressed Small and Developing Island States (SIDS) of the IOR and, must be incorporated as a major thrust line within an Indian geopolitical strategy, under the rubric of SAGAR and IORA.

(h) **Build Adaptive and Coping Infrastructure in SIDS throughout the Indo-Pacific.** Heightened regional maritime demands for capacity-building and capability-enhancement in Small Island Developing States of the IOR and the South Pacific, as a function of the IPCC's climate change scenarios, offer an excellent opportunity for India to underscore its position as a net security-provider with particular emphasis on non-traditional security.

(i) **Build Adaptive and Coping Infrastructure against GLOF-Events in Nepal**. The positive spin-offs of manifestations of Indian resolve in Nepal by way of coping and adaptive strategies against GLOF (Glacial Lake Outburst Flood) events are likely to be disproportionately large. If this is supported by a strong brand-building exercise, it would greatly help in countering the growing influence of China in Nepal.

(j) **Tasking of the Maritime Security Forces**. Task the maritime security forces (Indian Navy, Indian Coast Guard) to draw-up and submit to the PMO:

(i) Plans to meet the increased strain on its 'capacity' as well as its 'capabilities' due to the strong likelihood of frequent and more complex HADR missions, at both.

(ii) A vulnerability-assessment and mitigation-options in respect of coastal (both naval and civilian) installations in the face of anticipated sea-level rise and increased storm-surges.

(iii) A detailed assessment of the salinity-changes and the impact of these changes upon ASW surveillance operations, as also naval force-capabilities.

(iv) A vulnerability-assessment and mitigation-options in respect of human migration, trafficking and IUU as a likely outcome of climate change.

(v) Plans to address heightened regional maritime demands for capacity-building and capability-enhancement in Small Island Developing States of the IOR and the South Pacific, as a function of the IPCC's climate change scenario.

(k) **Ensure increased capacity and financing for adaptation**. Adaptation to climate change helps individuals, communities, organisations and natural systems deal with those consequences of climate change that cannot be avoided. It involves taking practical actions to manage risks from climate impacts, protect communities and strengthen the resilience of the economy. In practice, adaptation should be integrated with sustainable development and this requires both capacity and finance, which needs to be increased in the financial outlays of the country.

(l) **Create a global consensus on the principles of equity and common but differentiated responsibilities**. Since the right to sustainable development and eradication of poverty is considered a fundamental goal by SDG-2030, poor and developing countries need to be supported by the rich and the developed nations through the principles of equity and common but differentiated responsibilities, thereby needing to provide both finance and technology for achieving this goal.

(m) **Updating technology in older equipment**. In order to be able to achieve a reduction in GHG, which is the main cause of climate change, the need exists to spread and use new technologies and renewable energy in older equipment to make them more energy-efficient and eco-friendly. To support the cause, the government should:

(i) Encourage consumers and suppliers to use low carbon measures or to deal with a low carbon economy.

(ii) Enhance energy efficiency policy in power plants to reduce coal dependency and to improve the national economy.

(iii) Encourage players to set up new and more efficient and clean coal technologies programs. This will help to achieve our 20 per cent CO_2 reduction target by 2020.

(iv) Encourage fair and adequate public participation in decision-making and implementation.

(n) **Creating a regional cooperative mechanism**. Mitigating the deleterious effects of the 'operational stretch' while dealing proactively with the facet of climate change is, perhaps, best done through regional cooperative mechanisms, in which several countries can contribute, as has been seen from the experience of the United States Pacific Command (PACOM) in building upon the effectiveness of the humanitarian relief by the hospital ship, the USNS *Mercy* in the aftermath of the *tsunami- earthquakes* of 2004 (Indo-Pacific) and 2005 (Java, Indonesia). Subsequently, HADR missions, termed *"Pacific Partnership"* were successfully launched to provide succour and relief across the PACOM 'Area of Operations' (AOR). The USNS *Mercy* is deployed on these missions every alternate year, while the US Navy deploys an LPD in the 'gap' years. PACOM invites the militaries of all nations within its AOR to partner with it in these annual humanitarian missions. Similar constructs could be:

(i) The Indian Ocean Rim Association (IORA) offers an extant and mature structure for the dissemination of political direction with respect to maritime HADR.

(ii) The Western Pacific Naval Symposium (WPNS)[58] and the Indian Ocean Naval Symposium (IONS)[59] provide the functional instruments through which such regional approaches can optimally be made within the Indo-Pacific.

(iii) IONS can provide a possible security structure for the maritime domain in the Indian Ocean.

Perspective towards Climate change

India. India has not been a significant contributor to climate change in the past, at present, or likely to be in the near future, as revealed by actual empirical data, and modelling results on future carbon intensities. However, India is among the worst sufferers of climate change caused by industrialised countries.[60] In per capita terms, India's emissions of greenhouse gases are *one-third* of the global average and far lower than those of richer Western countries like the US or Asian peers such as China.[61] But in absolute terms, it is one of the major emitters, accounting for over 4.5 per cent of global GHG concentrations, behind only China, the United States and the 28-nation European Union bloc.

This debate on emission figures, notwithstanding, the topmost priority for India is economic development, poverty alleviation, ensuring energy security and developing infrastructure[10] for its people. Currently, nearly 600 million Indians do not have access to electricity and nearly 700 million use biomass as a primary energy resource for cooking. Ensuring a regular supply of clean energy is essential for nurturing these priorities, meeting the millennium development goals and raising India's human development index. However, since all these imperatives require energy, it would lead to increased carbon emissions and to ensure that the GHG emissions are kept under control is a challenge.

Since India is at the top of the list of nations expected to be worst hit by the adverse effects of climate change, it is striving to overcome the challenges posed by climate change. Hence, it has put the following in place:

(a) A number of policies and measures to address both mitigation and adaptation and has prepared a *National Action Plan on Climate Change* (NAPCC) in 2008. This NAPCC has eight subsidiaries "Missions" (see Figure 12); State Action Plans for Climate Change (SAPCC) at the State level with recommendations on how mitigation and adaptation could be mainstreamed into development policy; and an "Expert Group on Low Carbon Strategies for Inclusive Growth" at the central level.

(b) It established the Indian Network for Climate Change Assessment (INCCA) in 2010 to publish peer-reviewed findings on climate change in India.

(c) India is investing massively in renewable energy.

(d) It is setting aggressive goals for the automotive market, with plans to allow the sale of only electric and hybrid vehicles starting from 2030.

(e) Encourage development and use of Mass Rapid Transit Systems and improving the quality of available fuel.

(f) Has been supporting the use and sharing of technology for solar energy with the tropical countries of the region as a founder member of the International Solar Alliance and as a 'globally responsible actor'.

(g) Focusing on adaptation efforts that include (PIB, 2015):

(i) Developing sustainable habitats.

(ii) Optimising water use efficiency.

(iii) Creating an ecologically sustainable climate-resilient agricultural production system.

(iv) Safeguarding the Himalayan glaciers and mountain ecosystem.

(v) Enhancing carbon sinks in sustainably managed forests and implementing adaptation measures for vulnerable species, forest-dependent communities and ecosystems.

Despite all these efforts, India has long opposed signing any international moves aimed at imposing a cap on its GHG emissions, arguing that it would hurt its

Figure 12: Eight subsidiary "Missions" of NAPCC

economic development and attempts to pull millions of its impoverished citizens out of poverty. India has repeatedly maintained that its per-capita emissions are lower than those of the advanced countries and that it bears little responsibility for the enormous rise in GHG emissions since the industrial revolution. In order to provide a way ahead, India has argued for the principles of equity and common but differentiated responsibilities for cuts in GHG emissions and has called on the rich, industrialised nations to support poor countries with US $100 billion (85.86 billion Euros) a year from 2020 to help cope with climate change. Another demand has been to provide green technology transfers from developed countries (Mazumdaru, 2017). In addition, India has declared the following quantifiable Nationally Determined Contributions (NDC) goals (GoI, 2006):

(a) Reduce the emission-intensity of its gross domestic product (GDP) by 33 to 35 per cent (vis-à-vis 2005) by 2030.

(b) Achieve 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030.

(c) Create an additional carbon sink of 2.5 – 3 billion tons of CO_2 equivalent by 2030 through additional forest and tree cover.

Israel. The State of Israel recognizes the presence of global climate change and understands the need to prepare for this (ICCIC, 2014). The State of Israel is already acting to adapt to climate change, by reducing potential damage and exploiting the opportunities and potential benefits associated with climate change. Adaptation to climate change requires a national strategy and action plans between ministries. Willingness and adaptation are long-term processes that require commitment and flexibility to respond to emerging reality and to new information gained from ongoing research.

Organised and institutionalised management of a national climate change adaptation plan and leading technological innovations can lead to an economy to adapt to climate change, promote energy efficiency, green building, and the use of water technology and renewable energy. Currently, most of Israel's energy is produced by coastal power stations that presently use fossil fuel and require clean seawater to cool reactors. Some steps that Israel can look at to improve its maritime security in response to climate change are:

(a) Develop adopted thresholds for pollution/ impacts at the local level.

(b) Monitor entrance of ships with high air/ water pollution history.

(c) Undertake research and dedicated development of scientific methods for a better understanding of the changes and impact of climate change, especially in the marine environment due to the geographical location of Israel.

(d) Promote education and discussion of climate change and the environmental impacts of these changes.

(e) Establish scientific database-principles/methodology of long term analysis of climate change.

As a small, densely populated country characterised by population and economic growth against a backdrop of land and water scarcity, Israel recognizes the importance of preparing for climate change. Israel is sensitive to the potential impacts of the phenomenon due to its location. Thus, it is making efforts to reduce greenhouse gas emissions, while at the same time doing everything possible to reduce the expected damage that would occur if climate change is not stopped.[62]

The preparation of a vulnerability assessment to climate change and an adaptation plan to confront and minimise the risk is of vital importance to Israel, especially in issues related to the seaside. Therefore, in 2009, Israel's government decided to prepare a national climate change policy and action plan that includes both 'mitigation' and 'adaptation' measures. In the wake of the decision, an Israeli Climate Change Information CentreCenter (ICCIC) was set up by the Ministry of Environmental Protection in 2011 to compile the existing knowledge in Israel and abroad, to identify knowledge gaps, and to submit recommendations to the government on national and local adaptation measures. Based on the findings, an inter ministerial committee on climate change adaptation, which is headed by the Director-General of the Ministry of Environmental Protection, has finished its recommendations on a climate change adaptation plan for Israel, on both the national and local levels.[63]

Protecting Israel's environment from the impacts of climate change requires regional and international cooperation. Therefore, Israel has partnered with regional and global organisations to better identify the impacts of climate change and to identify options for mitigation and adaptation. The important link between science and policymaking has been especially prominent within the framework of Climate Impact Research and Response Coordination for a larger Europe, in which Israel has been an active member. This regional network has been committed to funding research and sharing knowledge on climate impacts, vulnerability, and adaptation.

Cooperation between India and Israel to Counter Climate change

The importance of global and regional coordination on security risks due to climate change cannot be overlooked. From the foregoing discussions, it is clear that the associated security risks due to climate change pose a multifaceted obstacle that does not fit neatly into any particular department portfolio and hence is not solvable by one country alone. This necessarily means that a cooperative mechanism between countries needs to be established that would allow some radical steps to be taken to counter the threats being posed by climate change. It is essential to mention that multinational programs incur transaction costs and resources beyond what is required in the national programs.

Though India and Israel have different focus areas as far as the resulting threats from climate change is concerned, the need of the hour is 'global solutions' and not 'local solutions' as the challenge at hand is more global than local. Hence, collaborative mechanisms to counter climate change are essential. Scientific cooperation between the two countries in the field of climate change research needs to be encouraged in the field of sharing information, costs and efforts that can accelerate and facilitate technical change towards more favourable technologies for creating a more appropriate climate. A collaboration between the countries should also encourage governments to intensify their efforts, especially in supporting basic research and development in the field of climate change. Some areas of cooperation that are considered viable are:

(a) **Cooperation in desalination**. Both India and Israel are water deficient nations and need to 'produce' water to meet the water requirement of their population. While Israel has made major advancements in developing Reverse Osmosis (RO) technology, India has developed a Low-temperature thermal desalination (LTTD) process for desalination. In order to make the entire process sustainable while moving away from the emission of GHG both India and Israel need to cooperate to ensure the use and further development of LTTD/ OTEC technology not only for their own use, but also as a means of 'diplomacy' and for projection as 'a global responsible actors'.[64]

(b) **Cooperation in solar energy technology**. India is a founding member of the International Solar Alliance with a mandate of promoting the use of solar energy as an alternative to carbon fuels for energy. Though the use of solar energy is increasing in West Asia[65] and Israel,[66] there is a need for concerted efforts in supporting the development and establishing of solar- voltaic plants in these countries. A collaborative arrangement between Israel and India to take advantage of the International Solar alliance would only help the spread of the use of solar energy faster and would ensure that the production of GHG gases in these countries can be reduced. The technology can then be shared with other developing nations to make an impact on the overall GHG produced in generating electricity.

(c) **Cooperation in other renewable energy sources**. Reduction of GHG is considered to be an essential step in limiting climate change as GHG affects all the other four 'climate certainties'. It is hence essential that both India and Israel cooperate in developing the necessary technology and studies in other areas of renewable energy that include wind energy, offshore wind energy, tidal power energy to name a few. This would furthermore help Israel to develop its wind energy farms at Golan Heights.

(d) **Undertake joint studies**. Though geographically separated, the concerns of climate change are universal. While some of them can be addressed by creating awareness, others need academic and technical collaborations by means of joint studies that develop technology and recommend actionable and doable steps. These studies could provide the necessary inputs to policymakers and the stakeholders that include private and public entrepreneurs.

(e) **Undertake joint workshops**. More often than none, the major problem with mitigation of issues related to climate change is lack of awareness, which can only be addressed by conducting workshops and lecture series for a spectrum of people. Towards this a series of joint workshops by the National Maritime Foundation (NMF), India and the Maritime Policy and Strategic Research Centre (HMS), Haifa, Israel, may go a long way in creating awareness amongst the stakeholders and the policymakers.

(f) **Technological developments**. Increase technological developments between the two countries in the field of:

(i) *Observation* – For development, improvement and integration of observational systems to manage global and regional climate change.

(ii) *Forecasting* – For an assessment of the usefulness of forecasts of future climate changes and their geostrategic consequences.

(iii) *Confining* – For the development of scientific methods and tools of how to determine and to anticipate, recognize, avoid and manage global and local climatic changes and their impacts on maritime geostrategy.

(iv) *Responding* – To determine what institutional, economic and behavioural changes can enable effective steps towards countries' maritime sustainability.

(v) *Innovating* – To encourage innovation in developing technology, policy and social response tools to achieve sustainability due to climate change.

Conclusion

The foregoing arguments in regard to climate change and the effect it has on issues of human health, water, food, economy, infrastructure and maritime security of the region have thrown up many questions that need to be contemplated if not answered. The key question however is - how can the capacity to assess and respond to climate-related maritime security risks in the international system continue to be enhanced? Since neither the ownership of the problem, nor the solutions to the problem are simple, they need further introspection and debate. As the point of departure for the policy responses within a government or an intergovernmental organisation is often unclear, it complicates the problem further. With the associated security risks due to climate change posing a multifaceted obstacle, that has relevance to more than one country, and at times to more than one working agency in a country, it is clear that climate change is not solvable by one country or one agency alone and hence demands collaboration.

With every passing day the urgency of action to be taken in mitigating the adverse security-impacts of climate change becomes more acute. We are rapidly approaching the point where our coping and adaptive strategies to ensure holistic security for our people will fall under the category of "too-little-too-late". This is something that resurgent nations like India and Israel cannot afford. It is hence imperative that collaborative mechanisms between countries are explored. To do so, this chapter has brought out some such collaborative mechanisms between India and Israel and has highlighted some geostrategies of India to address the effect of climate change.

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This article was first published on 12 August 2021 on the Website of the National Maritime Foundation

Climate Risks to India's Holistic Maritime Security: Rising Sea Level, Intensifying Extreme Weather, and Collapsing Ocean Biodiversity

Dr Pushp Bajaj

In recent decades, climate change has evolved from a supposed distant problem for future generations to a major imminent security threat for all nations worldwide.[1] Climate-change-induced food and water shortages, combined with sea level rise and extreme weather shocks, are potentially powerful destabilising forces within countries and across international borders. The increasing frequency and intensity of extreme weather events including heatwaves, floods, droughts, and tropical storms, driven by climate change, are threatening ways of life for billions of people on the planet. Moreover, climate change often acts as a threat multiplier by amplifying existing stresses, and, could push already unstable and ill-equipped regions over the edge.[2] In this context, the National Maritime Foundation has undertaken a new research endeavour to study the impacts of climate change on India's holistic maritime security. This chapter will address some of the key security-threats posed by climate change, namely, rising sea-level, intensifying extreme weather, and collapsing ocean biodiversity, and the vulnerabilities in India's maritime domain.

Rising Sea-Level

Past, Present, and Future

Our planet has had a remarkable climate history, during which the sea level has changed by hundreds of metres to even a kilometre over periods of hundreds to thousands of years.[3] In the most dramatic case, around 635 million years ago, when the planet was coming out of a 'deep freeze' state, scientists estimate that sea level rose at an extraordinary rate of 0.2-0.3 metres (m) per year. This was during what is known as the Neoproterozoic deglaciation.[4] Most recently, after the last glacial period[5] nearly 20,000 years ago, global mean sea level is estimated to have risen by as much as 135 m before it reached current levels. These indirectly observed historical sea-level changes (through the study of ice cores, ocean sediments, cave rock samples, and fossils) suggest that the Earth has undergone astonishing transformations, in some cases at relatively fast geological timescales. Periods of warm climates in the past also provide insights into what we can expect in the future as global warming continues. During the last interglacial period, around 129-116 thousand years ago, the global average temperature was about 0.5° C to 1.0° C warmer than today and the sea level is estimated to have been around 6-9 m higher than today's levels. Going further back, during the mid-Pliocene Warm Period, around 3.3-3.0 million years ago when global average temperature was 2°-4° C higher than today, sea level is estimated to have been around 25 m higher than today.

Current trends, based on satellite and tide-gauge measurements, irrefutably show that the global mean sea level (GMSL) is rising, and that the rate of rise is accelerating (see Figure 1). The pace of sea-level rise increased from 1.4 mm/year over the period 1901-1990 to 2.1 mm/year over 1970-2015 to 3.2 mm/year to 3.6 mm/year over the period 2005-2015.[6] Overwhelming scientific evidence confirms that anthropogenic climate change is the primary driver of sea level rise since 1970. There are two main sources of current sea level rise: (1) Thermal expansion of the ocean due to increasing ocean temperatures, and (2) The melting of land-based ice sheets in Greenland and in Antarctica, and the glaciers in high altitude regions around the world. The latter is presently the dominating contribution to global mean sea level rise. Greenland and Antarctic ice sheets together hold most of the freshwater on the planet. Greenland holds enough ice to raise sea level by nearly 7 m, if all of it were to melt. The Antarctic ice sheet, on the other hand, contains nearly eight times more ice than Greenland, and if this ice were to melt completely, it would cause around 60 m of sea level rise. Although it is unlikely that either of them will melt completely anytime soon, any significant changes will have huge repercussions.

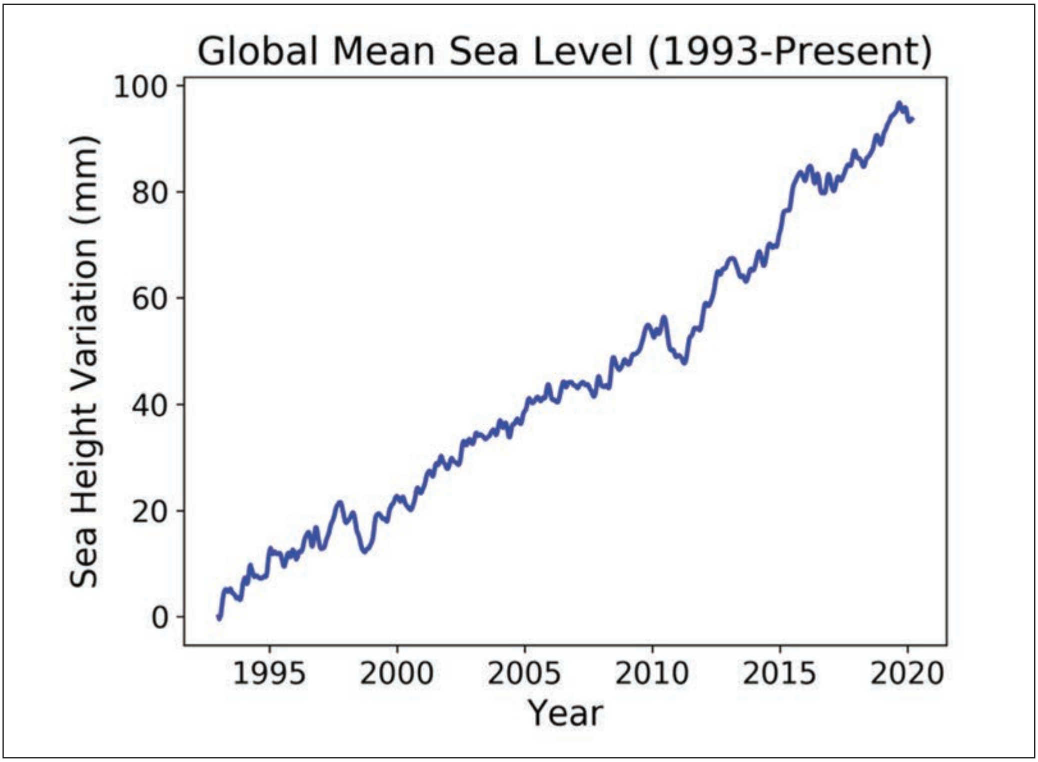

Figure 1: Trends in global mean sea level from 1993 to 2020. Image created by author. *Data Source*: GSFC. 2017. Global Mean Sea Level Trend from Integrated Multi-Mission Ocean Altimeters TOPEX/Poseidon, Jason-1, OSTM/Jason-2 Version 4.2 Ver. 4.2 PO.DAAC, CA, USA. Dataset accessed [2020-06-20] at http://dx.doi.org/10.5067/GMSLM-TJ42

The GMSL is expected to continue to rise at an accelerating pace through the 21st century and beyond, if climate change continues unabated. In its latest Special Report on *"The Ocean and Cryosphere in a Changing Climate"*, published in 2019, the United Nations Intergovernmental Panel on Climate Change (IPCC) projects that the GMSL could rise by around 0.84 m (likely range 0.61-1.10 m), by the year 2100, if no mitigating action is taken (a scenario denoted as Representative Concentration Pathway 8.5 or RCP8.5). With aggressive and transformative action to reduce global greenhouse gas emissions (a scenario denoted as RCP2.6) the potential sea-level rise could be brought down to around 0.39 m (likely range 0.29-0.59 m), (see Figure 2). The report also states that "*extreme sea level events that are historically rare (once per*

Global mean sea level (m)

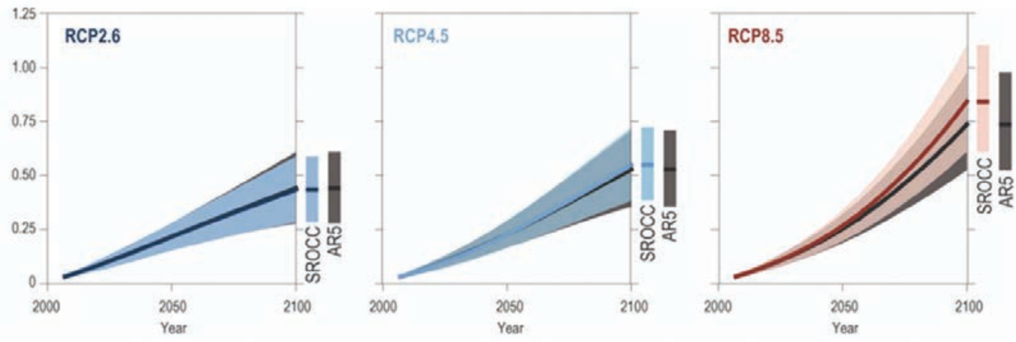

Figure 2: Future projections through 2100 of global mean sea level rise for the RCP2.6, RCP4.5, and RCP8.5, as defined by the IPCC. Comparisons are made between the SROCC (2019) and the AR5 (2013)

Source: Image taken from UN IPCC Special Report on the Ocean and the Cryosphere in a Changing Climate (2019).

century in the recent past) are projected to occur frequently (at least once per year) at many locations by 2050 in all RCP scenarios, especially in tropical regions." The predictions are primarily based on computer simulations using sophisticated climate models and while they certainly serve as a guide to policy makers and governments to make appropriate strategies, any model-based predictions must be understood within the context of observational trends, and inherent limitations of climate models, while simultaneously acknowledging the possibility of abrupt changes in the future.

Contrary to common intuition, sea level does not and will not rise uniformly around the planet. Although the major climate-change assessment studies and reports focus on GMSL change, it is the regional variations that are of greater concern to India s national security. Regional sea level can be significantly different from the global average, due to varying ocean temperature and salinity (both of which alter the density of water), ocean dynamics, local subsidence caused by groundwater extraction, and change in tidal heights and periods. A recent climate-change assessment report produced by the Ministry of Earth Sciences of the Government of India notes that sea level of the North Indian Ocean rose at a rate of 1.06-1.75 mm/year during 1874-2004 and has accelerated to 3.3 mm/year during 1993-2017,[7] which happens to be comparable to the rate of global sea level rise. However, unlike current global sea-level rise, the regional sea-level rise in the Indian Ocean has been driven primarily by thermal expansion of the ocean due to increasing temperatures.

Implications for India's Maritime Security

Sea-level rise affects nearly all aspects of India's maritime security, either directly or indirectly. Every fraction of a metre of rise in sea level, compounded by an increase in probability of extreme sea-level events (such as high tides, storm surges, and cyclones), poses a direct threat to the infrastructure and population along India's 7516 km long coastline. A 2019 study on global vulnerability to sea-level rise and coastal flooding estimates that nearly 35 million Indians will be exposed to annual flooding by the year 2050 and that number will grow to 51 million Indians by 2100 (based on 2010 census), in the absence of effective mitigation and/or adaptive measures.[8] The study also estimates that parts of the coastal regions that are currently home to 21 million Indians will be permanently inundated by sea-level rise by mid-century, and regions inhabited by nearly 38 million Indians will be permanently inundated by the end of the current century. According to another recent global study, the annual economic losses due to coastal flooding in India could be anywhere between 1.5-2 per cent of the annual GDP by the end of the century, depending on how much the global average temperature rises.[9]

In addition to economic security, sea-level rise threatens India s food- and water-security as well. Amongst other impacts of higher flood levels, storm surges, and land erosion, salt-water intrusion into coastal lands due to sea-level rise increases salinity levels in agricultural soils damaging crops and contaminating underground drinking water aquifers.[10] In this context, sugarcane and rice are two particularly important crops grown in low-lying coastal regions, which are highly vulnerable to the impacts of sea-level rise. Compounding the effects of increasing temperatures, changing rainfall patterns, and extreme weather events, sea-level rise poses a unique challenge to coastal agriculture.

The affected population will eventually be displaced and forced to migrate inland due to frequent flooding, coastal erosion, agricultural failure, and increasing extreme weather events. This is already happening in nearly all coastal states of India. The coastal population of Odisha and Andhra Pradesh are increasingly facing powerful cyclones against the backdrop of continually rising sea level. The Lakshadweep island group, with an elevation of 1-2 m, is very much at the frontlines of vulnerability to sea level rise. In an ongoing pattern of heavy monsoonal rainfall, Kerala was battered for two consecutive years in 2018 and 2019,[11] questioning the resolve of the residents to stay their ground. Nowhere in India is forced migration becoming a more serious concern than in the Sundarbans region in the Bengal Delta where sea level is rising much faster than the national average, and the region is frequently hit by powerful cyclones. Just this year in May, the region was struck by the monstrous Category 4 Cyclone *Amphan* that killed nearly 100 people, destroyed hundreds of thousands of homes, and affected millions of Indians.[12] The Sundarbans area is shared between India and Bangladesh, with millions of Bangladeshis living in the region facing the same threats and being pushed out of their homes.[13] As sea level continues to rise, more and more coastal residents in India and the neighbouring countries will have to make the difficult choice between staying put and dealing with the consequences of frequent flooding or leaving their homes in search of safer living conditions.

The island nations in the Indo-Pacific are extremely susceptible to sea level rise. These include the Democratic Socialist Republic of Sri Lanka, the Republic of Maldives, the Republic of Seychelles, the Republic of Indonesia, the Republic of Philippines, etc., all of which lie within India s maritime areas of interest. Over 80 per cent of the land area of the Maldives is less than one metre above sea level. Even small changes in sea level would be disastrous for the population of Maldives. This fact is not lost on the national government, which has been exploring creative options for the future, including building fortified artificial islands at higher elevations, and purchasing land in other countries to relocate its population. Given that the Maldives is located a mere 250 nm south-west of India, it is not hard to imagine that a significant proportion of the population of that country, and other island nations in the region, may seek refuge in India. In addition to the possibility of an influx of migrants, deteriorating conditions in the Maldives and other small island nations in the Indian Ocean Region will have geopolitical implications for India as they are important components of India's geostrategies.[14] The internal struggles of individual nations could potentially spill over to the broader Indo-Pacific region. Whether the affected nations then come together harmoniously and support each other to secure their common interests, or, increasing competition for dwindling resources translates into political instability and subsequently into conflicts, will very much depend on the geopolitical relations we establish today.

In the midst of the growing security challenges arising from accelerating climate change, the role of India's maritime security agencies, especially the Indian Navy and the Indian Coast Guard, will be of paramount importance.[15] The Indian Navy and the Indian Coast Guard are the primary responders in times of emergencies and humanitarian crises within India. Beyond the Maritime Zones of India (MZI), the Indian Navy is the primary first-responder for the region at large. With climate change loading the dice for extreme weather events such as floods and cyclones, both services will have to participate in increasing numbers of humanitarian assistance, disaster relief and evacuation operations. It is important to remember, however, that the Indian Navy and Indian Coast Guard are themselves vulnerable to the impacts of sea level rise. A vast majority of the Indian Navy s and the Indian Coast Guard s bases, headquarters, and hospitals are located in high-risk regions along the coastlines of Mumbai, Goa, Karwar, Kochi, Chennai, Visakhapatnam, Kolkata, as also in islands of the Lakshadweep and the A&N chains. Any damage incurred by critical infrastructure or support facilities such as power and communication lines, will seriously hamper the ability of the Indian Navy and the Indian Coast Guard to provide timely and effective assistance.[16] Without concrete short-term and long-term strategies to mitigate and adapt to climate change-induced sea level rise, all the aforementioned security threats could easily become overwhelming.

Avoiding the Intractable while Adapting to the Inevitable

Sea-level rise is not a one-time event, but a continuous and accelerating process. While some degree of sea-level rise is already "locked-in" due to the climatic changes that have occurred so far, any future warming will further add to the misery at an accelerating pace. More importantly, scientists warn that there are certain "thresholds" or "points-of-no-return", in terms of the global average temperature, which, if crossed, will commit the planet to irreversible multi-metre sea-level rise over a period of decades or centuries. What is not clear, however, is where exactly these thresholds lie, whether at 1.5° C or 2° C or 3° C of global warming above pre-industrial levels. Consequently, it is in our best interest to limit future warming as much as we can in order to avoid these worst-case scenarios. It is imperative for India to take drastic measures to mitigate its carbon emissions and, through international negotiations, apply pressure on other countries to do the same. India's current pledges to the global Paris Climate Agreement signed in 2015 include: (1) A 33-35 per cent reduction in emissions intensity below 2005 levels by 2030; (2) An increase in non-fossil share of cumulative power generation capacity to 40 per cent by 2030, and (3) The creation of additional carbon-sink capacity of 2.5-3 Gt CO_2 equivalent by 2030. Promisingly, current trends suggest that India will meet these targets, and might even surpass them. As per the Paris Agreement, member nations are expected to ratchet-up their pledges and submit revised and more ambitious targets every five years. The first such revision is due in 2020 itself, but India is yet to submit its revised targets to the UNFCCC. This could be an excellent opportunity for India to display its continued commitment to climate change mitigation by raising its ambition, and lead the global climate action movement.

Mitigation, although absolutely essential, is not, in and of itself, enough. Any comprehensive action plan should include dynamic and adaptive measures to manage the impacts of sea-level rise that have already occurred and that are projected to occur in the near future. In this regard, India is grossly underprepared to protect even its most developed coastal cities.[17] In order to be effective, adaptation policies must be informed by the latest and best available climate science and include a national-, state-, and regional-level vulnerability assessment of the short-term and long-term impacts of sea-level rise. A number of different responses could be considered, such as, protecting the coast using dykes, seawalls, barriers, etc., boosting the resilience of coastal infrastructure, advancing seaward by land-fill, using sand or other material or by planting vegetation, and, retreating and relocating from areas that cannot be protected. Additionally, ecosystem-based adaptation measures that focus on the conservation and restoration of natural coastal ecosystems, such as wetlands and reefs, are essential to any adaptation plans.[18] These ecosystems are extremely effective natural defences against storm-surges and coastal erosion. Of course, the feasibility and practicality of a particular approach will depend on the geographical limitations of the particular region and the associated economic, technological, and human costs.

India must simultaneously brace for the eventuality of sea-level-rise induced human migration of unparalleled proportions, both within India and from neighbouring nations, and the geopolitical chaos that will follow. It is crucial that an appropriate policy framework is put into place now, so as to prepare for the consequences of sea-level rise in the future. Currently, there is no legal or institutional framework that explicitly addresses inter-state or international migration due to climate change or other environmental reasons. While India does have a National Action Plan on Climate Change (NAPCC), that was published in 2008, and all coastal states have policies at the state-level called the State Action Plan on Climate Change (SAPCC) which stem from the NAPCC, these plans barely examine the impacts of human displacement due to sea level rise.[19] As discussed above, a climate action plan should be dynamic in order to keep up with the accelerating changes in the climate. Therefore, there is much need for the NAPCC of 2008 to be updated to reflect current scientific understanding. India must also strengthen relations with its maritime partners in the Indo-Pacific and adopt policies to address climate-change induced migration in the future to ensure security in its maritime neighbourhood.

Intensifying Extreme Weather

The terms 'global warming' and 'climate change' are often, but quite incorrectly nevertheless, used interchangeably in media-driven public discourse. 'Global warming', in the present context, refers to the ongoing rise in global average temperature due to the increasing concentration of greenhouse gases in the atmosphere, primarily driven by human activities. Rising planetary temperature subsequently alters the fundamental natural cycles of our planet. The broader term, 'climate change', describes the long-term changes in the air and ocean circulation patterns, hydrological cycle, carbon cycle, weather patterns, etc., that define the local, regional, and global climates, and is a consequence of rising global average temperature (global warming).[20]

'Weather' and 'Climate'

It is often easily forgotten that weather and climate, although closely related, are not one and the same thing. 'Weather', at any given time, describes the atmospheric conditions at that particular time in a particular location. It can change significantly over a period of minutes to hours or days, or across a distance of a few metres to several kilometres. 'Climate', on the other hand, refers to the long-term regional or global average of "weather conditions" such as temperature, humidity, and rainfall patterns, over seasons, years, or decades.[21] In the scientific community studying anthropogenic climate change, the "climate" of a region refers to decadal-scale averages of weather, usually over three decades. In other words, 'climate' encompasses 'weather'.

A region's climate determines the types of weather one can expect, depending on the time of the year. Each weather event has a 'probability' (likelihood of occurrence) associated with it. For instance, India has a hot and humid tropical climate; in the summer months (April-June), it is highly likely that the Indo-Gangetic Plains of India will experience very hot daily temperatures in the range of 30°-40° C. During a heatwave, however, which would be classified as an extreme weather event, temperatures could reach up to 45°-50° C in some parts of the Indo-Gangetic plain. An 'extreme weather event', therefore, refers to atmospheric conditions that are outside the typical range of near-average conditions expected for a particular climate type, at a particular time. A heatwave in the Arctic, for instance, would constitute sustained temperatures of say, around 20° C, which would be considered extreme for the Arctic climate. Now, due to global warming, as the average temperature (which determines average weather conditions and in turn, the climate) is rising, the entire distribution of possible temperatures (or weather conditions) is changing along with it. Consequently, what used to be 'extreme' and low-probability events in the past are becoming increasingly common, and the extremes that previously did not exist are now showing up as 'extreme' and rare events.

Changing Odds of Extremes

In recent years, a growing number of peer-reviewed scientific studies have shown that climate change is altering the probability of extreme weather events worldwide. According to a report released in July of 2020 by the Ministry of Earth Sciences of the Government of India, titled *"Assessment of Climate Change over the Indian Region"*,[22] there has been a decrease in the overall annual-frequency of tropical cyclones in the

North Indian Ocean since the middle of last century (1951-2018). However, the report adds that "*the frequency of very severe cyclonic storms (VSCSs) during the post-monsoon season has increased significantly (+1 event per decade) during the last two decades (2000-2018).*" Observational trends also show an increase in the frequency of Extremely Severe Cyclonic Storms (ESCSs) in the post-monsoon season over the Arabian Sea during 1998-2018. Table 1 shows the different categories of Tropical Revolving Storms' (TRS) or as they are known in India and its environs, 'cyclones', as defined by the Indian Meteorological Department. A cyclone with sustained winds of 118-165 km/h is known as a 'Very Severe Cyclonic Storm', while a cyclone with sustained winds of 166-220 km/h is called an 'Extremely Severe Cyclonic Storm'. Climate-models-based projections suggest that the frequency and severity of tropical cyclones will increase in the future, largely due to anthropogenic climate change, particularly for the more extreme cyclonic storms (VSCSs and higher).[23]

Observational records of annual maximum precipitation and number of extreme events show that the frequency and intensity of extreme rainfall events over India, which often lead to floods, have increased during the last few decades. The changes are found to be more dramatic in Southern India compared to Northern India. This trend is expected to continue throughout the 21st century.[24] At the most basic scientific level, this is an expected consequence of increasing atmospheric temperatures, because warm air holds more moisture (with every 1° C increase in temperature,

Table 1: Tropical Cyclone Intensity Scale.

Category	Sustained Winds (3-min average)
Super Cyclonic Storm	≥ 221 km/h
Extremely Severe Cyclonic Storm	166 – 220 km/h
Very Severe Cyclonic Storm	118 – 165 km/h
Severe Cyclonic Storm	89 – 117 km/h
Cyclonic Storm	63 – 88 km/h
Deep Depression	51 – 62 km/h
Depression	31 – 50 km/h

Source: Indian Meteorological Department the air can hold around 7 per cent more water vapour). It follows that nowadays, when it rains, it will *pour-down* far more aggressively than was the case in the past, due to the increased air-moisture content. A corollary to this is that when there is a drought, it will be more extreme because of increased heat and higher capacity of the atmosphere to take-up more water vapour before it reaches saturation. Beyond this fundamental physical aspect, there are other, more complex factors. For instance, the decreasing gradient between the temperature over the Indian Ocean and that over mainland India affects air-circulation patterns and makes monsoonal rains more erratic and unpredictable. In combination with changing rainfall patterns, other factors that are exacerbated by climate change, such as sea-level rise, coastal erosion, melting glaciers, cloud-burst events, and human-induced secondary factors such as deforestation, urbanisation, poor drainage facilities, etc., are causing an overall increase in the number of severe flooding events over India (see Figure 3).

In its latest Special Report on *"The Ocean and Cryosphere in a Changing Climate"*, published in 2019, the UN's Intergovernmental Panel on Climate Change (IPCC) notes that upper ocean temperatures have increased significantly in most regions of the world over the last few decades, leading to more frequent, extensive, and intense 'marine heat waves'.[25] A 'marine heat wave' is defined as a period of abnormally high

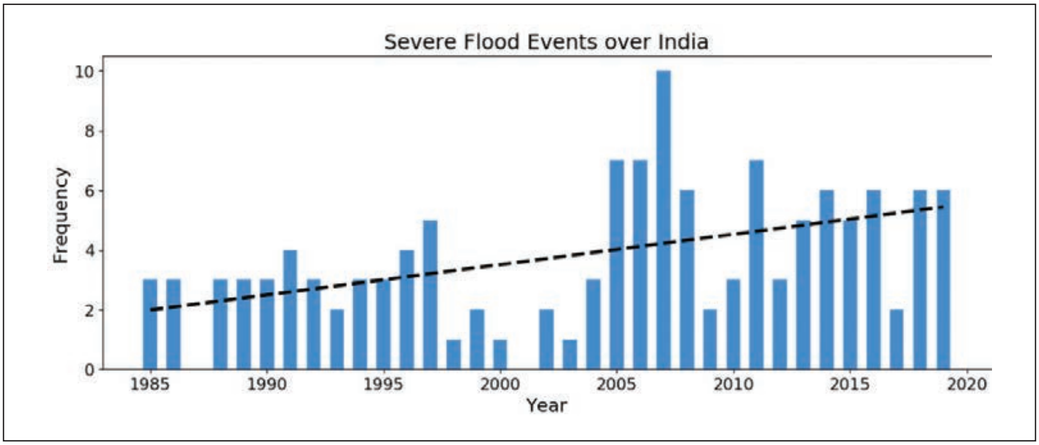

Figure 3: Time Series of Severe Flood-events over India, during 1985-2019. (The black pecked line shows a linear trend fitted to the frequency data)
Source: Image adapted from Fig. 6.5b of "Assessment of Climate Change over the Indian Region", a report of the MoES, GoI. https://www.springer.com/gp/book/9789811543265

ocean temperatures over days or months. It can extend up to thousands of kilometres and can penetrate the ocean to depths of the order of hundreds of metres into. The ocean absorbs around 90 per cent of the excess heat generated from the increasing concentration of greenhouse gases in the atmosphere, and this takes decades to be gradually redistributed into the atmosphere. This fact is glaringly evident in the relentlessly growing 'ocean heat content' in recent decades. In other words, the global ocean acts as a primary protective shield against warming on land and in the atmosphere. Clearly, this comes at a heavy cost. Future projections, based on widely-accepted climate models, not only show a significant global increase in both, the marine-heat-wave intensity and the count of annual marine-heat-wave days, but also show this to be occurring at an accelerating pace throughout this century.[26] This increase is largely caused by anthropogenic (human-induced) warming due to increasing emissions of greenhouse gases. It is also projected that many parts of the ocean will reach a near-permanent heat-wave-state (compared to the 1982-2005 base climatic conditions) during the course of this century, which essentially implies that ocean temperatures that currently considered 'extreme' will soon become 'average'.[27]

The examples mentioned above are, of course, only a subset of the full range of extreme weather events that are threatening India's national security. Other important examples that deserve careful assessment include heat waves over land, droughts, forest fires, and flash floods leading to landslides. All of them pose major threats to the economic, material, and societal well-being of the people of India. However, in order to limit the discussion to extreme weather affecting the 'maritime domain' in particular, these threats are not discussed further here.

Implications for India's Maritime Security

Heatwaves, cyclones, floods, and heavy precipitation events, typically result in heavy socio-economic losses over a short period of time. These losses manifest themselves in terms of damage to infrastructure, damage to natural ecosystems, damage to agricultural crops, and, loss of life. Moreover, disaster-affected regions become vulnerable, at least temporarily, to health hazards such as infectious diseases, falling debris, exposed power lines, etc., as also other cascading resultant effects such as civil unrest and conflicts. Complete recovery from such events often takes several months or even years. If current trends continue, climate change is expected to decrease the 'return-period' of such events, implying that what used to be '1-in-100-years' storms could become '1-in-10-years' storms or even annual ones.

In the wake of this year's monstrous cyclone *Amphan*, the state of West Bengal suffered tremendous damage of the order of Rs 1.02 lakh crore. Nearly 100 people lost their lives, 28.6 lakh houses and 17 lakh hectares of agricultural crops were damaged along with critical infrastructure such as roads, irrigation canals, drinking-water facilities, education and health infrastructure.[28] *Amphan* was soon followed by the Severe Cyclonic Storm *Nisarga*, this time on the West Coast of India. *Nisarga* was the strongest tropical cyclone to hit the state of Maharashtra in the month of June since 1891. Although it was less severe than *Amphan*, Cyclone *Nisarga* damaged over 5 lakh structures, destroyed 8000 hectares of crops, killed 6 people and injured 16.[29] In 2018, the state of Kerala saw its worst floods in a century resulting from incessant monsoonal rainfall between the 8th and the 15th of August, which was 250 per cent more than the average. Reportedly, 15,632 houses were destroyed, 3,06,766 houses were damaged, 140,000 hectares of agricultural land was submerged, 453 people were killed, and another 140 were reported missing. In financial terms, the damage was of the order of Rs 31,000 crore.[30] Even before it could recover from this unparalleled disaster, Kerala was hit once again by heavy monsoon rains in 2019, in the same month of August and with similar consequences. Hundreds of lives lost, thousands of homes damaged, and thousands of crores of rupees of incurred losses.

While the individual state that is directly impacted by a particular event bears the full brunt of the immediate damages, extreme weather events taken in aggregate, pose a monumental threat to the security of the country as a whole. Arguably, the most worrisome long-term impact of increasingly frequent extreme weather events is the widespread damage to agricultural yields and, in turn, to India's economic-security, and particularly its food-security. Even today, the Indian economy and a vast majority of the population are heavily reliant on the agriculture sector. Around 50 per cent of agriculture in India is solely dependent on natural rainfall (over 70 per cent of which is received in the monsoon months), and has little or no access to artificial irrigation facilities. This system has worked so far because of the historically robust monsoon-season which has returned year on year, without fail. However, as discussed above, this is no longer the case. The onset, intensity and duration of the Indian monsoon has already been significantly altered as a result of climate change. It will continue to become even more erratic, riddled with more extreme events, and more unpredictable, in times to come. Any deviation from the average will lead to heavy losses in Indian agriculture, which is already facing multiple stresses from rising temperatures, water shortages, and more frequent pest attacks.[31] While agricultural practices may be able to adapt to slower, long-term changes in temperature and precipitation, the sudden and unpredictable nature of heatwaves, floods, and cyclones, makes it difficult to adapt to them.[32] Moreover, experts warn of the growing risk of simultaneous collapse of the major global 'breadbaskets' in the event that a series of multiple extreme-weather events are experienced simultaneously, in a short period of time.[33]

The fisheries and aquaculture sectors face a similar predicament. Rising ocean temperatures and more frequent marine heat waves will have an adverse impact on the biodiversity in the Indian Ocean. For instance, the Great Barrier Reef along the north-eastern coast of Australia has faced three severe marine heat waves (2015-2016, 2016-2017, and 2019-2020) in the last five years. all three of which led to mass coral bleaching and fish die-offs.[34] Indian coral reefs in the Gulf of Mannar, the Gulf of Kachchh, the Palk Bay, the Andaman Sea, and, the Lakshadweep Sea, have similarly experienced as many as 29 widespread bleaching-events since 1989. Coral reefs provide an essential habitat for thousands of marine species and support nearly a quarter of all marine life. Current climate-projections suggest that all of the world's coral reefs may be lost by 2100, if we continue with business-as-usual.[35] Fish populations are trying to cope in their own ways to increasing ocean temperatures, sea-level rise, deoxygenation, and ocean acidification, by changing their migration patterns, their reproduction cycles, and, even their geographical distribution.

Naturally, this will have a significant impact on the fisheries industry and seafood security of India. In order to maintain their catch, fishers will have to adapt accordingly, whenever possible, by extending their reach or acquiring new equipment and resources, or, focussing upon other fish that may now become available in their region.[36]

It takes only a minor stretch of imagination to realise that the compounding economic- and societal-threats posed by extreme weather events driven by climate change, could easily destabilise the national or even the global *status-quo*. Recent history is riddled with examples of extreme climatic events, such as long-term droughts, leading to crop failure or economic collapse, followed by civil unrest that eventually transforms into conflict. In a future characterised by the accelerating impacts of climate change, the risk of simultaneous or consecutive 'state-failures' becomes a real possibility, not only for India, but worldwide as well.[37]

Brace for Impact

It would be an understatement to say that we are currently not prepared for repeated strikes of increasingly extreme weather-shocks. While a few economically-developed countries may be able to cope with a few consecutive weather disasters, most developing nations and least-developed ones would quickly reach the limits of their economic, infrastructural, and human capacity. The sheer range of impacts of the ongoing COVID-19 global pandemic and the vulnerabilities that they have exposed, are a stark reminder of the fragile state of the world order. Increasing instances of extreme weather events, each one costing millions to billions of dollars, will likely have a similar, if not worse, socio-economic impact.

Therefore, it is essential that we prepare our existing systems for a changing climate and an erratic distribution of extreme weather events. Enhancing the resilience of coastal and mainland infrastructure against floods and storms is essential in order to limit economic losses. In this context, appropriate policies and safety standards must be urgently put in place so as to ensure that at least all new buildings, roads, power, and communication lines, are designed and constructed in a manner and to a standard that will address the threats from extreme weather, while enhancing the resilience of existing ones to the extent feasible. In order to be effective, this needs to be addressed at the state- and local-levels, depending on the specific risks, vulnerabilities, and opportunities relevant to the region or area under consideration. At the same time, there is a dire need to enhance the resilience of the human populations through emergency-preparedness drills at the community-, regional-, and state-level, both for the general public, and for the first responders, as well. This is particularly so in regions that are assessed to be more vulnerable than others.

Weather forecasts and early public-warning services also play a crucial role in the run-up to natural disasters, as also during their occurrence. Weather-prediction is by no means a perfect science. It is an inherently challenging problem, due to the high variability of weather conditions, the limited understanding of atmospheric processes such as cloud dynamics, and insufficient data- and monitoring-stations. It is true that the technological capacity to predict weather conditions days in advance has increased significantly in recent decades, which has led to tangible results in terms of reduced fatalities and injuries. However, there is far more that needs to be done. The Government of India needs to catalyse future technological measures aimed at enhancing the country's predictive, adaptive, and curative abilities, by actively promoting and investing in scientific research-and-development (R & D). Particular attention needs to be paid to improving weather-forecasting services. India must also establish a nationwide emergency surveillance system to provide real-time information on extreme events in a way that is efficient and easily accessible.

Collapsing Ocean Biodiversity

The health of human civilisations is inextricably linked with the health of ecosystems. Declining biodiversity and collapsing ecosystems pose a serious threat to economies, food-security, livelihoods, and human health, globally. In May of last year (2019), in a landmark event, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), an organ of the United Nations, published its global assessment report,[38] in which it unequivocally warned that natural biodiversity was declining rapidly due to changes in land- and sea-use, the exploitation of organisms, climate change, pollution, and the introduction of invasive alien species through the discharge of ballast-water from merchant ships. In a striking conclusion, the report stated that around one million plant and animal species were now at risk of extinction, many within decades, at a rate unprecedented in human history.

Nowhere are the impacts of climate change more apparent than in the ocean. Carbon dioxide concentration in the atmosphere has been increasing at an alarming rate since the industrial revolution (whose year of occurrence is taken to be 1850). According to scientific estimates, nearly a third of all human-caused emissions of carbon dioxide have been absorbed by the oceans, which has, inevitably, led to increased acidity of ocean water. The pH (a measure of acidity, wherein a lower pH value corresponds to higher acidity) of surface ocean-water has been declining steadily since the late 1980s, at a rate of 0.017-0.027 units per decade.[39] As mentioned before, the oceans have also absorbed around 90 per cent of the excess heat generated by the increasing concentration of greenhouse gases in the atmosphere, leading to significant warming of the global ocean. In the Indian Ocean, sea surface temperature (SST) has increased, on average, by 1.0° C during the period from 1951 to 2015, which is much higher than the global average SST rise of 0.7° C in the same period.[40] Increasing ocean temperatures are, in turn, leading to a loss of oxygen in some parts of the ocean, as warmer temperatures reduce the solubility of oxygen in seawater, creating new 'dead zones' and expanding existing ones. This combination, of ocean acidification, rising temperatures, and deoxygenation, is causing major disruptions to marine life and destabilising entire ecosystems.

Marine Life Bears the Brunt of Climate Change

Significant changes have been observed in marine species due to the ongoing physical and chemical transformation of the oceans. From microscopic phytoplankton and small pelagic fish, all the way to multi-tonne whales, all ocean inhabitants are bearing the brunt of climate change. In contrast to land animals, most marine species are highly sensitive to temperature changes and can only survive in a very narrow range of optimum temperatures.[41] Consequently, with increasing temperatures, many species are moving either to higher latitudes or deeper waters in order to avoid the rising heat. Changes have also been observed in biological functions such as metabolism, growth and reproduction.[42]

At the very bottom of the marine food-chain are tiny organisms called phytoplankton. They sustain not only millions of marine species but also all land-based animals, as they are the primary producers of oxygen on the planet. Phytoplankton are microscopic marine plants that take-up carbon dioxide and utilise sunlight to generate oxygen (and carbohydrates), through photosynthesis, amounting to as much as 80 per cent of the total atmospheric oxygen.[43] One of the largest growths of phytoplankton (also called 'phytoplankton blooms') occurs in the western Indian Ocean.[44] Recent studies show that rising temperatures are leading to a decrease in phytoplankton populations. As the surface water is warming up rapidly, the temperature difference between surface and deep waters is increasing, resulting in enhanced ocean stratification, which prevents the mixing of water and, in turn, nutrients in the ocean. This mixing of nutrients is essential for phytoplankton blooms. The more the stratification and the less the mixing, the less the phytoplankton. According to a recent estimate based on long-term records, phytoplankton numbers decreased by 20 per cent in the western Indian Ocean over the past six decades.[45] The decline in phytoplankton has a ripple effect all across the marine food web, particularly for the species that rely upon it as a primary food-source, adding to the growing stresses from ocean acidification, rising temperatures, and deoxygenation.

In addition to primary productivity, the health of several marine ecosystems that provide critical habitats to marine species is also declining due to the adverse impact of climate change. Coral reefs that provide habitat to nearly a quarter of all marine life are arguably the most vulnerable ecosystem and face a high risk of disappearing completely from the world's oceans, perhaps as soon as the end of the present century.[46] During marine heatwaves, corals experience a phenomenon called 'bleaching'. They expel the microscopic algae that live within them symbiotically, and which provide the corals with nutrition (and colouration). Without the algae, the corals cannot survive. Bleaching is a common natural phenomenon and corals typically recover completely as the algae return when temperatures cool down. However, due to relentlessly rising ocean temperatures, bleaching events are becoming longer and occurring more frequently, not allowing enough time for corals to recover completely. The devastating impacts of climate change on the world's largest coral ecosystem called the Great Barrier Reef came under the spotlight of global media following the consecutive months-long marine heatwaves in 2015-2016 and 2016-2017 that wiped out nearly 50 per cent of the reef. Indian coral reefs have experienced similar widespread bleaching events in recent decades, but these have largely gone unnoticed in the Indian and global public discourse. According to a 2009 study, *"bleaching would become an annual or biannual event for almost all reef regions along the Indian coast in the next 30-50 years."*[47] Moreover, the impacts of bleaching are and will continue to be amplified by increasing ocean acidity, which hinders growth and degrades the structural integrity of the coral exoskeleton.

Another critical coastal ecosystem in India that is under threat from climate change is the Sundarbans, the largest mangrove forest on the planet. Mangroves are tropical plants that grow at the land-sea boundary. In addition to providing a native habitat to myriad land-based animals (perhaps the most famous being the Bengal Tiger) and bird species, mangroves provide an equally critical habitat to a variety of marine species as well. The Sundarbans, for instance, support nearly 400 fish species, with many species using them as nursery grounds. The mangroves of the Sundarbans also act as the primary line of defence against tropical storms and floods. Increasing temperatures, sea-level rise, coastal flooding, and increasingly frequent cyclonic storms, due to climate change, pose a major threat to this crucial ecosystem. While mangroves are resilient to seawater to some extent, seawater is now intruding for longer durations and encroaching into areas that it did not earlier reach. Excess salinity-levels in the soil can hinder plant growth and damage the ecosystem and, in turn, adversely impact the biodiversity in the region.[48]

At the individual level, species are responding in a number of different ways in order to adapt to the changes in the oceans, with some doing better than others. The most common responses include horizontal and vertical movement, changes in the time of spawning, changes in growth rate, reduction in size, and reduction in number of eggs, amongst a host of others. For instance, Hilsa, which is a highly migratory fish found in large numbers in the Upper Bay of Bengal (largely because of the riverine systems in the Sundarbans), is changing its migratory routes and spawning grounds. Studies show that its fertility rates are declining and populations are gradually moving from inland to marine water, due to human exploitation, climate change, increased siltation, etc.[49] Not all species are adversely impacted by rising ocean temperatures, however, and some species, particularly tropical (warm water) fish, are actually gaining new territories and expanding into previously inhospitable (colder) waters.[50]

The chances of a species surviving the dramatic changes in the oceans will depend on how efficiently and how quickly it can adapt. Naturally, those species that are not able to keep up will perish, while the ones that are able to adapt will thrive, albeit with altered distributions and behaviour. Arguably, small-sized (low value) fish with high turnover numbers will enjoy better odds of survival compared to large-sized (high value) fish that are already threatened by overfishing. Taken in aggregate, the aforementioned changes indicate that there may be a grand reorganisation of the marine food-web in the offing, resulting in changes in the structure and function of marine ecosystems, with huge socio-economic consequences. Indeed, some studies have shown that the trophic level (position in the food chain) of fish has been decreasing since the 1950s, with small pelagics increasing in abundance and large pelagics declining at steady rates.[51]

Consequences for India's Economic and Food Security

The fisheries (including aquaculture) industry, which forms a major part of India's economy, is inherently dependent on the health of marine and coastal ecosystems and marine species. In 2014, India's total marine fish catch was approximately 3.59 million tonnes, valued at nearly 5.6 billion USD. Together with fish produce from aquaculture practices, India exported fish worth 5 billion USD in 2014.[52] According to the National Fisheries Development Board of the Ministry of Fisheries, Animal Husbandry and Dairying, the fisheries and aquaculture industry employs around 14 million people. Around 30 per cent of India's total population lives in coastal areas and relies heavily on the fisheries industry as an important food source. Therefore, any significant losses in marine ecosystems and fish populations will inevitably impact India's economic and food security.

Of course, declining fish populations due to die-offs in extreme events and/or reduced reproduction rates, are not the sole concern. India's legal access and right to exploit marine fisheries is limited to its own maritime zones (specifically the Exclusive Economic Zone). However, as marine species continue to move, they may cross India's EEZ and move into the 'high seas', or worse, into another nation's EEZ. Such relocations of populations are equally detrimental to Indian fisheries and will inevitably lead to geopolitical complications as well — not only for India but also for nations within the Indian Ocean Region as a whole. There have been several examples of international disputes over fish stocks in recent history. Most notably, in 2007, a conflict erupted over stocks of the northeast Atlantic mackerel, which had shifted from waters managed by the European Union, Norway and Faroe Islands, into Icelandic and Greenland waters, leading to the so-called "mackerel war".[53] Increased competition and lack of a decisive agreement between the stakeholders eventually led to the available stock being overfished. Given the enhanced competition for fishing grounds and depleted fish stocks in almost all fishing areas, climate-change driven geographic shifts of marine species will make such conflicts more likely, as the future unfolds. According to a recent estimate, as much as 35 per cent of the global EEZs could receive new transboundary stocks by 2100 if climate change continues unabated.[54]

In the economic context, marine and coastal tourism (often clubbed together and referred to as 'ocean tourism') industry, which accounts for nearly 26 per cent of the total global ocean economy,[55] will also be impacted by declining ocean biodiversity. Ocean tourism is a source of livelihood for millions of people in developing coastal nations. Within that, coral reef tourism is a major component, including activities such as diving, recreational fishing, and snorkelling.[56] The deteriorating state of coral reef ecosystems worldwide will have a direct impact on this sector. India under its Swadesh Darshan scheme is promoting coastal tourism under its theme-based circuits.[57] It has selected six states, and two union territories, namely, Puducherry and Andaman & Nicobar Islands, of which the latter has one of the major coral reef formations in India. The conservation and protection of ocean biodiversity is, therefore, essential to safeguard the economic benefits of coastal tourism as well.

Protecting and Preserving Ocean Biodiversity

In India, climate-change mitigation and adaptation is largely restricted to a top-down approach. It encompasses the national policy at the Centre and sub-national policies formulated by the respective state governments. The National Action Plan on Climate Change (NAPCC) adopted by the Government of India in 2008 gave a formidable thrust towards India's climate change mitigation initiatives. The policy was largely based on India's internal challenges and efforts to tackle climate change, but it also implicitly encompassed India's international commitments to the United Nations Framework Convention on Climate Change (UNFCCC) and its provisions.[58] It is a long-term policy consisting of eight 'national missions', which represent the core of the NAPCC. These are the 'National Solar Mission', the 'National Mission for Enhanced Energy Efficiency', the 'National Water Mission', the 'National Mission for Green India', the 'National Mission on Sustainable Habitat', the 'National Mission for Sustaining the Himalayan Ecosystem', and, the 'National Mission on Strategic Knowledge for Climate Change'.

Each of these missions contains a number of subordinate missions/policies within them, such as the Swachh Bharat Mission which falls under the 'National Mission on Sustainable Habitat'. The NAPCC thus invokes the participation of India's civil society at large and encourages public-private partnerships (PPP) in order to achieve key climate-goals. It is important to note that as of now, the NAPCC does not include a dedicated 'mission' for the protection and conservation of the oceans. As established through the foregoing paragraphs, there is an urgent need to create a targeted national-level policy to protect marine ecosystems and species for sustained economic and food security.

Promisingly, the Ministry of Earth Sciences (MoES), in its thirteenth report of the Committee on Estimates (2018-2019), acknowledged the need for a 'ninth' mission to be added to the NAPCC. The MoES has proposed 'National Coastal Mission' to be included within the NAPCC, which will address climate-change threats to coastal zones, mangroves, corals and seawater intrusion into fresh-water systems.[59] However, in order to be comprehensive, this mission must also cover deep-sea systems, pelagic ecosystems, and, indeed, the entire ocean ecosystem. Moreover, participation of individual states and local governments in addressing the challenges to ocean biodiversity is crucial to bring about any meaningful and tangible change.

In this context, the states of Odisha and Maharashtra are key players, largely due to their rich biodiversity, which is facing extreme pressure in supporting the livelihood of millions of the citizens of these two states. Their long coastlines are categorised by the Coastal Vulnerability Atlas of India as being highly vulnerable to climate change.[60] Ocean biodiversity is collapsing particularly sharply in the state of Odisha. One of the key indicators is the decline of dolphins which is a 'keystone species' essential to the marine ecosystem in the region. According to the state's annual census of dolphins in 2019, the total dolphin population has experienced a significant decline, with numbers dropping from 469 in 2018 to 259 in 2019.[61] This 45 per cent drop in the numbers is indicative of the overall decline in ocean biodiversity in Odisha, threatening the entire marine food chain. According to the Coastal Vulnerability Index (CVI) formulated by the Indian National Centre for Ocean Information Services (INCOIS), a total of 407 km of the coastal area of Odisha comes under 'medium' and 'high' vulnerability categories.[62]

It must be admitted that the state government of Odisha is, indeed, alive to the precariousness of its situation and is actively pursuing measures to address the declining ocean biodiversity. Yet, all such measures must accommodate the impacts on coastal communities. For instance, in protecting the turtle congregation area in Odisha, the livelihood of thousands of marine fishermen will be affected due to the ban on fishing within 20 kilometres of a sanctuary such as the Bhitarkanika National Park.[63] To its credit, the Odisha government has provided 'marine cards' to the affected fishermen's families as compensation, under which 25 kg of rice is provided at a nominal cost of just one rupee per kilogram, every month.[64] This initiative was a part of the Integrated Coastal Zone Management Programme (ICZMP) funded by the World Bank. This highlights the need for 'holistic' conservation strategies, which share equitable benefits among the community and ecosystem.

In the case of Maharashtra, the 750-kilometre length of the state's coastline hosts a variety of fisheries, mangroves, salt marshes, and corals. Maharashtra's ocean biodiversity and its vulnerability are inextricably linked with India's overall food security. In terms of fish species diversity, Maharashtra ranks third among Indian coastal states.[65] In this regard, the State Action Plan for Climate Change (SAPCC) of Maharashtra calls for a regional model for assessing the implications of climate change, such as the dispersal, spatial, and temporal patterns of various fish species.[66] The present data used to estimate how climate change or environmental factors affect fisheries is collected from external sources within temperate regions. For a more accurate assessment, there is a clear need for specific data in respect of tropical fish, so as to understand how they are affected, and in order to consequently formulate effective state- and national-level policies. Considering this, a bottom-up approach, through strong public participation, including back and forth dissemination of information and constructive feedback, will be an excellent guide for the decision makers to construct future strategies.[67]

Along these very lines, the UN Food and Agriculture Organisation (FAO) recommends a stepwise process involving identification, planning, and effective resilience through Early Warning Systems (EWS) and local efforts.[68]

For the protection of marine and coastal biodiversity, establishing and expanding Marine Protected Areas (MPA) is an effective approach that has been recognised by the International Union for Conservation of Nature (IUCN) since 1999.[69] MPAs cover a wide array of protections from human exploitation to the maintenance of productivity and the enhancement of oceanic biomass. There are about 25 MPAs located in Peninsular India and 106 MPAs in the island territories of India. The three oldest ones — the Haliday Island Wildlife Sanctuary, the Sajnekhali Wildlife Sanctuary, and, the Lothian Island Wildlife Sanctuary — are all in the state of West Bengal and were declared protected sanctuaries way back in 1976.[70] Contemporary developments in research, and technological advancements, have enabled the adoption of innovative solutions to ocean conservation. Novel 'dynamic ocean management strategies',[71] driven by real-time data, are being explored to protect highly mobile marine species such as whales, sharks, sea turtles, sea birds, etc.[72]

Addressing the collapsing ocean biodiversity and its impacts on the economic and food security of India will require a dynamic and holistic approach that encompasses local/community-led efforts that are encouraged and supported by national/state-level policies. Local governments should be strengthened by institutional capacity-building, capability-enhancement, and financial-support, so as to realise the national-level goals and meet India's international commitments. Moreover, any and all mitigation and adaptation policies must be directed by the best available science and utilise the latest and most effective technologies.

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Note

The author acknowledges the extensive contributions of Mr Akshay Honmane in the section on Collapsing Ocean Biodiversity

This chapter was first published as a three-part article series (on 22 June 2020, 23 July 2020, and 04 November 2020) on the Website of the National Maritime Foundation

Protecting and Conserving Coastal and Marine Ecosystems

Kunming COP15: Mapping Linkages Between Biodiversity and Climate Change

Dr Saurabh Thakur

The birth of the current climate change regime was a product of a series of events that unfolded with the end of the Cold War and the simultaneous rise of the era of globalisation. On the heels of an evolving understanding of the threat of anthropogenic climate change and a persistent grassroots movement that raised the banners of Sustainable Development and ecological justice, countries came together at the Rio Earth Summit in 1992 to chart a new path towards tackling the environmental issues. The signing of the Rio Conventions – the United Nations Convention on Biological Diversity (CBD), the United Nations Convention to Combat Desertification (UNCCD), and the United Nations Framework Convention on Climate Change (UNFCCC), was a landmark step towards the development of a collective approach, which was based on principles of "Equity" and the "Precautionary Principle".[1]

While the UNFCCC has since managed to carve a significant space in the mainstream political discourse, most visibly through its annual iterative meetings known as the Conference of Parties (COP), which entered its 26th year this year, the other two conventions have had to struggle for similar space. The recently held COP26 meeting garnered world's attention and is being seen as a critical watershed moment in the history of the regime in its post-Paris phase of negotiations. The recent months also saw another important event unfolding — the first part of the 15th meeting of the Conference of the Parties to the Convention on Biological Diversity (COP15).[2] This meeting, and its second phase, which is to be held in Kunming, China, in 2022, will be critical for a number of reasons, among them the adoption of a Post 2020 global biodiversity target that has been delayed due to the ongoing COVID19 pandemic. Next year (2022), the parties to the Convention will also meet in Côte d'Ivoire for a different COP15 meeting, addressing the third Convention, namely, the United Nations Convention to Combat Desertification (UNCCD).[3]

Earlier this year, in his address at the build-up event to Kunming COP15, the UN Secretary- General emphasised the importance of biodiversity targets for a sustainable planet, stating that: *"A healthy planet is critical for achieving the Sustainable Development Goals. Yet biodiversity is declining at an unprecedented and alarming rate, and the pressures are intensifying. We have failed to meet any of our internationally agreed biodiversity targets. One million species are at risk of extinction. Ecosystems are disappearing before our eyes. Deserts are spreading. Wetlands are being lost. Every year, we lose 10 million hectares of forests. Oceans are overfished and choking with plastic waste. The carbon dioxide they absorb is acidifying the seas. Coral reefs are bleaching and dying. We are depleting resources faster than nature can replenish them."*[4] Given the wickedly entangled nature of the climate change challenge and its deep interconnections with biodiversity and sustainable development goals as enshrined in the 1992 Convention, it is important for countries to start addressing the biodiversity question with an equal amount of urgency and concern.

The 'Other' COP: The United Nations Convention on Biological Diversity

The "Convention on Biological Diversity" was opened for signatures at the Earth Summit in 1992 and came into force in 1993. It was further expanded with the addition of two supplementary agreements, namely, the Cartagena Protocol on Biosafety in 2000, and the Nagoya Protocol on Access and Benefit Sharing, 2010. The CBD has evolved as an institution in the years that have elapsed since its inception, with the formation, in 2001, of a "Joint Liaison Group" between the secretariats of the three conventions. This step is aimed at enhancing coordination and cooperation. The linkage between climate change and biodiversity has been a key point of discussion within the convention. The "Ad Hoc Technical Expert Group" (AHTEG) on biodiversity and climate change met several times between 2002-2005 to discuss the issue, and the first round-table, which was held in 2007, was aimed at building knowledge regarding this complex interlinkage.

The "Nagoya Protocol on Access to Genetic Resources and Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity" was a critical milestone in the history of CBD. It saw the adoption of 20 biodiversity targets, also known as the "Aichi Biodiversity targets" (See Figure 1), which were expected to provide a roadmap for the protection of diverse land based and marine biodiversity resources. The recently published global outlook report by the UN has drawn an alarming picture, highlighting the fact that only six out of twenty targets have been fulfilled, that too, only partially. The 14 remaining targets have been entirely missed by the 200 signatories.[5] One of key reasons for this dismal performance is the persistence of harmful subsidies in key sectors like fossil fuels, fisheries, and agriculture. Globally, fish stocks are on the verge of collapse due to the deleterious effects of climate change and overfishing.[6] Since the end of the second World War, the unchecked expansion of industrial fishing and IUU fishing activities have depleted fish stocks, endangering both marine biodiversity and food security for millions. In China alone, the world's largest seafood producer, fuel subsidies made up 94 per cent of the $6.4 billion that the country provides to its fleets.[7]

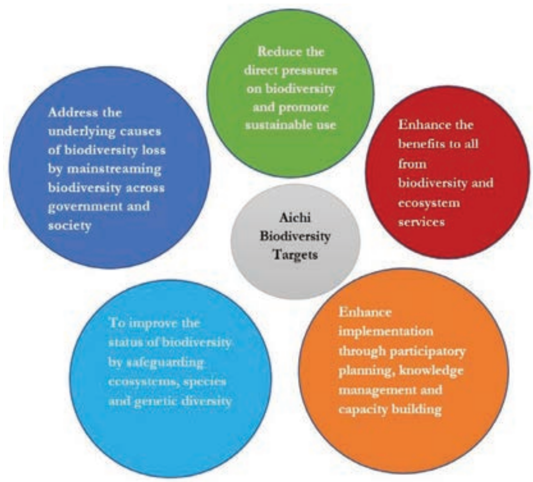

Figure 1: Aichi Biodiversity Targets.
Source: Author

Mapping Linkages: A Review

The complex interconnections between climate change and biodiversity loss have been the subject of several key studies and reports in recent years. Among them, the *Special Report on Global Warming of 1.5°C* of the Intergovernmental Panel on Climate Change (IPCC) is the most significant indictment of the desultory nature of the efforts of States towards the achievement of objectives set in the Paris Agreement.

The report notes, "*by 2100, global sea level rise would be 10 cm lower with global warming of 1.5°C compared with 2°C. The likelihood of an Arctic Ocean free of sea ice in summer would be once per century with global warming of 1.5°C, compared with at least once per decade with 2°C. Coral reefs would decline by 70-90 percent with global warming of 1.5°C, whereas virtually all (> 99 percent) would be lost with 2°C.*"[8]

The "Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services" (IPBES) has published its global assessment and highlights nature's contribution to people through its biodiversity and ecosystem services and its accelerated decline in the recent decades. The report warns that current trajectories and goals are inadequate to meet the goals of sustainable development: *"Except in scenarios that include transformative change, negative trends in nature, in ecosystem functions and in many of nature's contributions to people are projected to continue to 2050 and beyond, due to the projected impacts of increasing land-/and sea-use change, exploitation of organisms and climate change."* [9] The report makes a case for nature-based solutions as the most cost-effective strategy to meet the SDGs in cities and prescribes a coordinated mix of interventions, across stakeholders, on land, oceans, and freshwater to tackle the questions of sustainable fisheries and marine biodiversity protection.

The Food and Agriculture Organisation (FAO) published its report titled *The State of The World's Biodiversity the State of The World's Biodiversity for Food and Agriculture* and notes that small land-holders and landless rural dwellers manage 75 per cent of the India's reported livestock resources and receive nearly half of their total income from these resources, species and ecosystems which are in sharp decline. The report highlights the importance of building knowledge about interaction of different variables of biodiversity, in particular micro-organisms and invertebrates, and of its roles in the supply of ecosystem services because, "*while a range of drivers of change are having major negative impacts on biodiversity for food and agriculture and the ecosystem services it delivers, some provide opportunities to promote more sustainable management.*"[10]

In the run-up to COP15 in Kunming in 2022, the UN Environment Programme (UNEP) has released its own strategy,[11] which outlines the essential steps that need to be taken towards the adoption of post-2020 global biodiversity targets. This strategy prescribes a holistic view of sustainable development in which biodiversity is not a standalone issue. Rather, what it recommends is the mainstreaming of biodiversity into national development plans as a cross- cutting matter and strengthening of, *"coherence, synergies and governance, legal frameworks and enforcement of the rule of law."*[12]

Kunming COP15: Pitfalls & Possibilities

The Kunming COP15 meeting will be a critical point in the history of CBD negotiations for several reasons:

First Meeting Outcomes. The first session of the negotiations was conducted in a hybrid format in the month of October 2021, wherein world leaders came together to pave the path for the post-2020 targets. Given the abject failure of States to achieve the Aichi targets, and the looming climate crisis, which is worsening each day, as made clear with the publication of the latest IPCC report, the meeting was a welcome step forward after two years of delay due to the COVID19 pandemic. The meeting resulted in the publication of the Kunming Declaration, a vision document that adheres to the "Agenda 2030 for Sustainable Development" and the UNEP's 2050 vision for biodiversity: "Living in Harmony with Nature". The document acknowledges, *"with grave concern that the unprecedented and interrelated crises of biodiversity loss, climate change, land degradation and desertification, ocean degradation, and pollution, and increasing risks to human health and food security, pose an existential threat to our society, our culture, our prosperity and our planet."*[13] The declaration, therefore, is an open acknowledgement of the deeply entangled nature of post-pandemic recovery, which will require States to align their priorities, which are currently falling under the separate banners of the "UN Decade of Action for Sustainable Development", the "UN Decade on Ecosystem Restoration", and the "UN Decade for Ocean Science for Sustainable Development", and adopt a transformative path towards biodiversity conservation.[14]

30 x 30 Target: An Ambitious Bet. While the first session was aimed at creating political ground, the upcoming meeting in 2022 will be the real test for countries as they deliberate a whole gamut of complex issues. Among them, the '30 x 30 Target' has gained the most attention and even found mention in the "zero draft" of the CBD COP15. The "30 x 30 Target" is aims at conserving 30 per cent of Earth's landmass and seas by 2030. The IPBES report notes that about 15 per cent of land and freshwater resources and 7 per cent of the sea areas are currently under protection — a dismal figure compared to the scale of the crisis. Yet, despite the catchiness of the "target", there are important questions that need to be answered. *"First, 30% of what exactly? Of the world's entire surface? Or must it be both 30% of the land and 30% of the ocean? Or would each country protect 30% of its territory? The draft as it stands is not clear, and the matter will need to be thrashed out over the negotiating table."*[15]

Ocean Biodiversity: A Divided House. The COP26 negotiations have seen convergence on the goals related to ending deforestation, but the same cannot be said for the oceans. Currently, 61 per cent of the world's ocean falls under the category of international waters and the Aichi targets were largely vague on the jurisdictional issues related Marine Protected Areas (MPAs). This makes the 30 per cent conservation-target at Kunming particularly problematic as this will require States to protect 80 per cent of their domestic waters. The creation of MPAs on the high seas is another contentious topic that will require States to invest in new and innovative mechanisms. Following the 2012 Rio +20 Conference, the UNGA instituted a two-year Preparatory Committee Process (Resolution 72/249), which was assigned the task of developing an international legally binding instrument on marine biodiversity in areas beyond national jurisdiction (BBNJ).[16] BBNJ constitutes some of the rarest biodiversity resources on Earth, which provide critical ecosystem-services such as carbon storage. In 2017, the "Intergovernmental Conference on Marine Biodiversity of Areas Beyond National Jurisdiction" was formally created to promote the idea of a BBNJ Treaty and bring the oceans to the core of the climate-change negotiations. Although the formal negotiations began in earnest in 2018, the BBNJ Treaty remains an unfulfilled project, mired in the questions of national sovereignty, the effectiveness of UNCLOS and, *"a broader philosophical divide: Developing nations insist that the high seas and their resources constitute "the common heritage of mankind," whereas developed nations, including the U.S., tend to invoke the "freedom of the seas" and resist being bound by international obligations."*[17]

The Question of Leadership. The question of leadership will also be an important topic of interest at the COP15. China's role as the host means that expectations will generate interest, as has been the case with the COP26 negotiations, which President Jinping has chosen to skip, much to the consternation of the United States. COP15 will also be a battleground of ideas, with President Biden establishing a national goal that mirrors the '30 x 30 Target', while China, which has remained hesitant on the question, would be looking to promote its own idea of 'ecological civilisation' as the core idea at the negotiations. China is also promoting biodiversity targets outside of the CBD process, through bilateral initiatives and the proposal to build world's largest national park system.[18]

Amidst all these different questions, CBD COP15 will be a political hotspot in the coming months. While it will be an ideological battleground for competing claims regarding conservation, fairness and equitable burden sharing, it is also an opportunity for countries to chart a transformative path towards biodiversity conservation.

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Note

This article was first published on 30 December 2021 on the Website of the National Maritime Foundation

Implications for India of *Noctiluca Scintillans* in the Maritime Domain

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In October 2020, bright blue sparkling waters were reported on the shores of the western Indian coasts, which were presented with excitement by residents of coastal cities and tourists in the face of the cold and demeaning fervour of the ongoing pandemic meltdown, restrictions and losses. The blue 'bioluminescence' along the western coastal shores of India, which was much bigger in regional expanse, duration, and visibility, than the previous year, was, however, noted with dismay and nervous documentation by field biologists, climate scientists, fishers and policymakers.

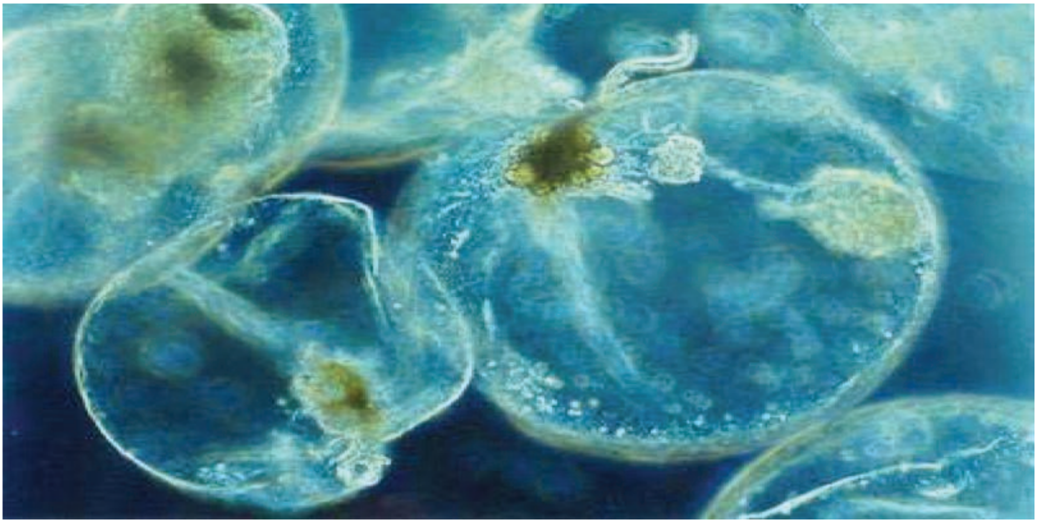

Figure 1: Green Noctiluca S. cells under a microscope.
Source: Maria Antónia Sampayo, Instituto de Oceanografia, Faculdade Ciências da Universidade de Lisboa - http://planktonnet.awi.de (provided under a Creative Commons Attribution 3.0 License)

Noctiluca Scintillans, depicted in Figure 1, is a large dinoflagellate– a type of phytoplankton, whose sightings date back to 500 BC and is responsible for creating prominent green-murky tides by day and phosphorescent blue tides by night, during winter months in the eastern Arabian Sea (West Coast of India).[1] Marine bioluminescence is mainly blue in colour, and is produced by a few organisms such as the green *Noctiluca Scintillans*, which have light producing organs that harbour symbiotic bioluminescent cells (see Figure 1). The light is produced in response to mechanical stimulation, and is commonly referred to as 'sea sparkle' due to its nocturnal appearance.[2] These organisms are opportunistic and evolving, with strong resilience to changing conditions and exhibit high rates of growth and reproductivity in a single given season.[3] The green and red types of *Noctiluca Scintillans* are known to create cascading negative impacts on the marine food web by eliminating healthy traditional populations of diatoms and aggressively feeding on a variety of nutrients and available food supply such as fish eggs.[4] Environmental alterations, caused by anthropogenic influences in the face of climate change, have provided favourable conditions for *noctiluca scintillans* to exponentially grow and expand across the Arabian Sea and several other tropical regions in the world.[5]

Fish are known to avoid regions with a high presence of noctiluca blooms, probably due to the presence of low levels of dissolved oxygen from the decay and death of the bloom or metabolites released by lysing cells.[6] Moreover, excessive sewage and industrial effluent run-offs lead to conditions suitable for eutrophication in the Arabian Sea. The untreated outflow provides for the nutrient and food supply for noctiluca to thrive better than other phytoplankton and fish species. The subsequent impacts of these outbreaks are reported through dead shoals of fish being washed ashore, reduced quality of fish catch, damage to coastal infrastructure and machinery, and, challenges to biodiversity management in marine protected areas.[7] These causes, which lead to a conducive environment for *Noctiluca* to increase exponentially in the Arabian Sea, have been linked to climate change — more specifically the melting of the glaciers in the Himalayan Tibetan plateau, the expanding and quasi-permanent Oxygen Minimum Zone (OMZ) of the Arabian Sea, and, human factors such as the impact of air pollution and the outflow of high quantities of untreated domestic sewage, as also industrial effluent-discharge from bordering countries.[8]

The social, economic, and security importance of the Arabian Sea to India's Gross Domestic Product (GDP) highlights the need to scientifically evaluate the causes of *Noctiluca Scintillans* blooms/ outbreaks and their impacts upon India's maritime domain. This chapter will focus on the current scientific understanding of the characteristics and causes leading to the unprecedented outbreak of green *Noctiluca Scintillans* (hereafter referred to as *Noctiluca*) and its present and predicted implications for and impacts upon the different maritime sectors of interest to India.

Unique/ Invasive Characteristics of *Noctiluca Scintillans*

As already stated above, *Noctiluca Scintillans* is a large and conspicuous dinoflagellate, about 0.2 millimetres (mm) in diameter, which is common in coastal and marine environments around the world.[9] Dinoflagellates, along with diatoms, are a type of phytoplankton commonly found in aquatic and marine systems bearing a single cell and two dissimilar flagella, and have characteristics of both plants and animals.[10] They are free-moving organisms of red and green varieties and are distributed among tropical and subtropical waters. Recent outbreaks of the green *Noctiluca Scintillans*, which is famously known to cause incidences of bright blue bioluminescence (the production and emission of light by a living organism) at night, has sparked the interest of the scientific and strategic communities, as well as local coastal communities, due to the significant, wide-ranging impacts that these organisms have on the marine food-web and on the different sectors of the coastal economy, directly or indirectly.[11]

The cell wall of a dinoflagellate is made of cellulose, while diatoms have a cell wall comprising silica.[12] Dinoflagellates, like noctiluca, result in widespread blooms, leading to cascading impacts on the marine food web and coastal sectors.[13] *Noctiluca* are voracious, invasive mixotrophs and can feed on a large variety of organisms like bacteria, algae, fish eggs, and their commonly-found phytoplankton relatives, namely, diatoms. Their growth rate and subsequent outbreak depend upon the availability of food, nutrients, and, atmospheric and oceanic conditions such as wind speed, salinity and temperature. *Noctiluca* is known to feed on traditional diatoms — phytoplankton that form the basis of the marine food chain — and can invade entire populations of diatom-rich waters, with an established predator-prey relationship.

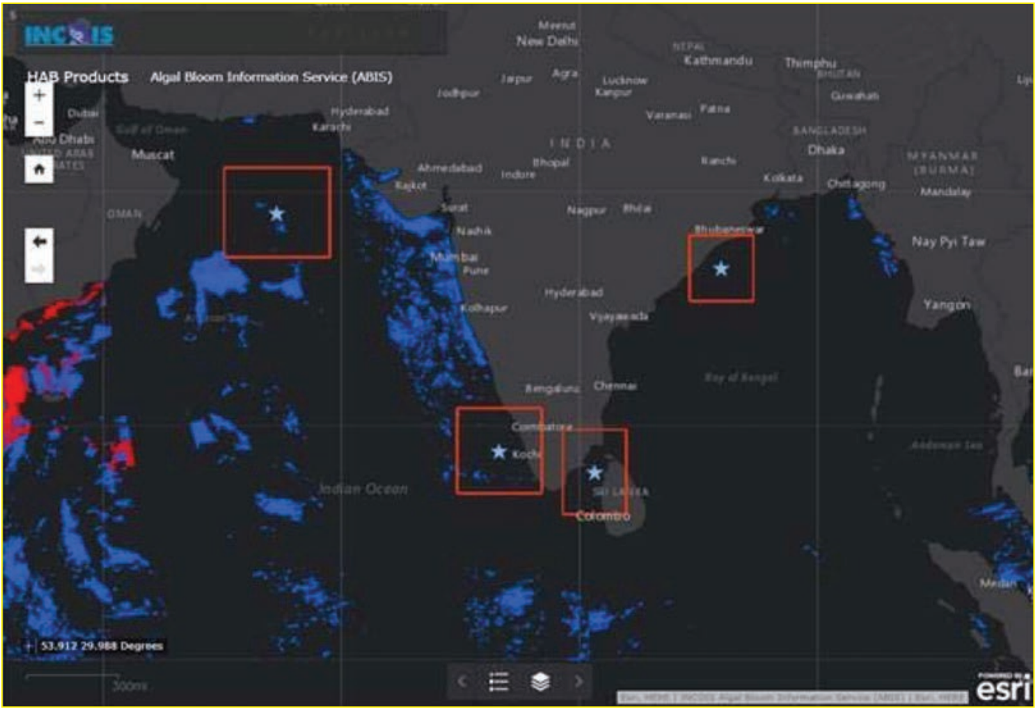

Figure 2: Detection of *Noctiluca Scintillans* in the Arabian Sea.
Source: INCOIS (2020) https://incois.gov.in/portal/hab.jsp

Additionally, in the absence of prey, green *Noctiluca* is known to photosynthesise and produce its own food. This allows the organism to survive even in the winter monsoon months of enhanced stratification, during which the availability of prey like diatoms and other varieties of organisms is low. A recent study found that *Noctiluca* can survive in hypoxic conditions, enabling the species to thrive in the 'dead' OMZs of the Arabian Sea (see Figure 2).[14]

Due to their large size and high concentration of ammonia, green *Noctiluca Scintillans* are avoided by other predators within the marine food web. They are mostly consumed by gelatinous zooplankton — mainly jellyfish and salps. Located further up the marine food chain, jellyfish have high reproduction rates and experience very few predators. Sea turtles do prey upon jellyfish but their own populations are severely endangered.[15]

Climate-change Connections in the Arabian Sea

If there is one factor — other than the ongoing COVID-19 pandemic — that exemplifies the interconnectedness of our planetary and societal systems, it is climate change. All natural processes beyond our sight, whether occurring on land, in the oceans, or in the atmosphere that envelops our planet, are intertwined with one another, often through complex mechanisms. One example of this is the manner in which mountain glaciers in the Himalayan region regulate the annual Indian monsoon, which, in turn, regulates the flora across South Asia and the primary productivity and, subsequently, the marine species across the Northern Indian Ocean.[16] For thousands of years, millions of inhabitants of this region have relied on these connections for freshwater (from the mountain glaciers), agriculture (supported by monsoon rains), seafood (dependent upon healthy ocean biodiversity), and the myriad other benefits provided by these natural systems. However, these mechanisms are now being increasingly altered and disrupted by human interventions, directly through overexploitation, pollution and industrial activity, and, indirectly through anthropogenic climate change.

In recent decades, the Himalayan region, also known as the "third pole" of the planet, has been warming at an accelerating pace, primarily due to increasing greenhouse gas emissions into the atmosphere, generated by human activity. Rising temperatures are leading to the increased melting of the mountain glaciers. As the glaciers melt, the snow-covered white surface is replaced by dark- coloured rocks or vegetation, which absorb more solar radiation, resulting in more warming which causes more melting of the snow caps, thus entering a self-reinforcing cycle of melting snow and rising temperatures.[17] This melting is further exacerbated by other human-engendered factors, such as the deposition onto the surface of the glaciers of black soot particles originating from the industrial and vehicular pollution or forest fires in South and East Asia. These soot particles darken the surface of the glacier, causing it to absorb more solar radiation, which leads to more severe and rapid melting of the glaciers.[18] The rapid warming of the Himalayan region has a number of knock- on effects with significant socio-economic consequences. In the context of this article, the changing land-air-sea dynamics, triggered by the loss of snow cover in the Himalayas, may be responsible for the proliferation of *Noctiluca Scintillans.* in the Arabian Sea in recent years.

In general, during summer months, the South Asian landmass gets much warmer than the Indian Ocean, creating a low-pressure region over the landmass and a high-pressure region over the ocean. This leads to 'monsoon winds' flowing from the south-west to the north-east direction. The strength of the winds depends upon the temperature gradient between the land and the ocean. An emerging scientific theory argues that due to declining snow cover and increasing temperatures over the landmass, the land-ocean temperature gradient is increasing, leading to stronger winds which, in turn, lead to more upwelling in the ocean and nutrient-rich surface waters.[19]

All autotrophic plankton species need these nutrients, such as nitrogen and phosphorous, which are dissolved in the water, for photosynthesis. Nutrient-rich waters should, therefore, in principle, support all plankton species, but, *Noctiluca* ends up dominating the others because it can actually feed on other phytoplankton as well, and also the generally oxygen-depleted waters of the Arabian Sea give it an edge in terms of survival.

During the winter months, the situation is reversed. As temperatures begin to drop, the landmass cools down faster than the ocean due to the relatively slower process of heat exchange between different layers in the ocean. As a result, the landmass ends up being relatively cooler than the ocean which means the temperature gradient and the wind direction is reversed in the winter months. Now, the winter monsoon winds flow from the north-east to the south-west. Over the Arabian Sea, these winds are typically far weaker than the summer monsoon winds, and therefore, there is much less upwelling but much more stratification. This stratification is accentuated by the increasing temperature of the Himalayan region due to increased loss of snow cover, which further reduces the land-sea temperature gradient. However, even in these relatively unfavourable conditions, *Noctiluca* still thrives because it can rely on its heterotrophic properties to grow, while suppressing its autotrophic properties in the face of the unavailability of nutrients in surface waters.

Impact of Oceanic Pollution

Human activities have a widespread impact on the world's oceans. The burning of biomass and industrial development in countries of South and East Asia have led to an increase in aerosol and dust pollutants — with satellite imagery detecting the coverage of aerosol and dust pollution extending from China to the foothills of the Himalayan plateau and all the way to the southern reaches of the Arabian Sea.[20] The South Asian and East Asian regions are the largest sources of black soot in the world and this unhappy situation is predicted to persist into the near-term future. The land temperature pressure-gradient has altered the intensity-characteristics of India's South- West monsoon wind, largely due to the accelerated melting of glacial ice caused by soot and dust deposition from bordering Asian countries. This increase of air pollution in South Asia has been documented in several studies, using measurement methods such as MODIS (Moderate Resolution Imaging Spectroradiometer), CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation) and GEOS (NASA Goddard Earth Observing System).[21]

In 1988, a team of scientists from India's "National Institute of Oceanography" (NIO), which is headquartered in Goa, conducted several studies aboard the research vessel, *Sagar Kanya*, to monitor the status of marine pollution along India's coast and its exclusive economic zone.[22] The results of their study confirmed high concentrations of domestic sewage, metal concentration, pesticide run-off and oil spills. A decade later, in July of 2018, the NCCR (National Centre for Coastal Research), through their flagship projects COMAPS (Coastal Ocean Monitoring and Prediction System) and SWQM (Sea Water Quality Monitoring Program), monitored the quality of seawater around India's coastline over the period from 1990 to 2015.[23] The study found that the estimated sewage generated from domestic sources in India was about 61,754 million litres per day (MLD), of which only 22,963 MLD was treated sewage, while a staggering 38,791 MLD was untreated sewage released directly into the sea. 66 per cent of India's domestic sewage reaches the country's marine and aquatic systems – untreated.

The study also found high concentrations of Ammonia-N as the dominant contributor of dissolved inorganic nitrogen on India's coastal stretches. Of particular relevance to this paper, the NCCR-COMAPS-SWQM study indicated an alarming abundance of phytoplankton along India's north-western coast. The rising trend of high levels of nutrients, such as ammonia and phosphate concentrations from sewage and agricultural-pesticide run-offs, will increase incidences of eutrophication and fuel phytoplankton blooms such as *Noctiluca*, while increasing hypoxia and anoxia in the Arabian Sea as a whole.

Expansion of the Permanent Oxygen Minimum Zone (OMZ) in the Arabian Sea

OMZs are regions within the marine system that have permanent suboxic (oxygen lower than normal concentrations) conditions, leading to a decline in primary productivity. The Arabian Sea is one of the few oceanic regions in the world that has quasi-permanent OMZs that stretch for several hundreds of meters, both vertically and horizontally, wherein oxygen values are below 0.1 millilitres per litre of seawater (ml/L).[24] These naturally occurring, oxygen-deficient waters are seasonally influenced and it is very important to map and study them, as these conditions allow the process of denitrification, where dissolved nitrate in the ocean is converted to nitrogen gas, making it readily available for plants, algae, and microbes, thus balancing the nitrogen cycle. The suboxic zones in the Arabian Sea are one of the three major water column denitrification sites in the world's oceans.[25] The Arabian Sea OMZs have a delicate biological response-relationship between pelagic species of fish and other organism distributions. It would be obvious that the extent of changes in such zones needs to be actively monitored.

Recent reports confirm that the OMZ in the Arabian Sea is expanding at a greater pace due to climate change and human pressures. These human pressures result in increased organic matter and nutrient overload, leading to eutrophication from untreated sewage and industrial outflow from not just India, but also from bordering countries of the Arabian Sea. It is reiterated that this further enhances the competitive edge of *Noctiluca* over other species in the region due to the capability of the former to survive even in hypoxic conditions.

Maritime Implications for India

The increasing range of *Noctiluca* is observed and, further, predicted, to have significantly deleterious impacts upon a number of important coastal and maritime economic sectors such as aquaculture, fisheries and tourism.[26] Green *Noctiluca Scintillans* outbreaks, commonly referred to as *'Noctiluca blooms'*, are known to occur prominently in the winter-monsoon months when the temperature- pressure gradient of the Arabian Sea is reversed, and enhanced stratification is observed. The observations of these outbreaks are marked by the increased extent of bioluminescence and have been documented by several institutions and coastal monitoring system services including the ABIS (Algal Bloom Information Service) and INCOIS (Indian National Centre for Ocean Information Services). The domino effect created by the blooms has current and future implications for the health of the Arabian Sea and the ecosystems and services that it provides to human beings.

Fisheries. The impact of green *Noctiluca Scintillans* in the Arabian has been widely reported. Fishermen report avoiding regions where the blooms occur because fish themselves are known to avoid these regions due to the low dissolved oxygen presence from death and decay of the bloom. There is insufficient scientific evidence to definitively establish the correlation between the rates of overall fish catch and *Noctiluca* blooms in the Arabian Sea, but empirical and anecdotal reports from fishermen and other observers indicate that the quality and quantity of certain species of fish have reduced due to these recurring events, not to mention the net damage to nets caused by the subsequent jellyfish bloom.[27] The causes for a reduction in overall fish catch can be debated between *Noctiluca* blooms and plain overfishing within the coastal stretches of the Arabian Sea. One the one hand, a study conducted in 2010 by the Space Applications Centre (SAC) of the Indian Space Research Organisation (ISRO), National Institute of Oceanography (NIO) and Central Institute of Fishery Technology (Kochi) found no adverse impacts of *Noctiluca* blooms on the ecosystem. The study noted enhanced fish populations and tuna catches using longline fishing, even during the blooming stages of *Noctiluca*.[28] On the other, the study also mentioned seasonal reports and observations of dead shoals of fish washing ashore and attributed them to the low dissolved oxygen from the decay of *Noctiluca* due to seasonal-climatic shifts. Other studies have reported the clogging of fish gills due to the large size of *Noctiluca* and its subsequent impact on the quality and quantity of the fish catch.[29] Such discrepancies in recent observations indicate that more studies, with more rigorous measurements, and more robust data-analyses, would be required to understand the linkages and the degree of impact that *Noctiluca* blooms have on the marine biodiversity of the region and, in turn, on the broader fisheries sector.

Coastal Tourism. The bright blue bioluminescence seawater of the Matsu archipelago, also known as the sea of 'blue tears' due to the annual bloom of the large green *Noctiluca Scintillans*, has become an infamous tourist attraction in the distant waters of the East China Sea. However, even much closer home, *Noctiluca* could cause cascading impacts on the coastal tourism industry in terms of reduced water quality, hazards from subsequent jellyfish blooms, and the unseemliness of the murky green colour of nearshore waters during the day. The subsequent increase in jellyfish populations are reported to cause painful stings to beach goers, tourists and the diving community. In December of 2020, 385 cases of jellyfish stings were officially reported by lifeguards in Goa.[30] Alongside jellyfish stings, the murky green waters reduce the shore's visibility and aesthetics, further impacting local livelihoods and activities such as diving by local operators. These factors also affect marine protected areas (MPAs) and pose challenges in the management of biodiversity and habitat.

Maritime Security. Maritime security is essential to ensure a holistic approach towards the governance, use and maintenance of the oceans. The security challenges that a nation can face are divided into traditional and non-traditional threats. Glowing phytoplanktons have a long naval history. In 1918, the German U-boat *U-34* was sunk by allied forces in the Strait of Gibraltar, when it encountered a school of bioluminescent plankton, and revealed itself to a major enemy base.[31] Marine scientists, in the United States and Russia, have long tried to study the power of bioluminescence in detecting the location of submarines. A submarine wake can trigger surface phytoplankton, especially *Noctiluca* blooms, to glow and increase the chances of detection (see Figure 4).[32] In June 1999, Ukrainian border guards confiscated a poster presentation, created by a group of marine biologists, describing the mapping of phytoplankton by bioluminescence for a symposium in Lithuania.[33]

Figure 4: Noctiluca S. blooms detected through the naked eye.
Source: Ricky –Flickr/Aqua Views Online Scuba Magazine https://www.leisurepro.com/blog/explore-the-blue/marine-bioluminescence/

However, due to the unpredictable nature and occurrence of blooms, opportunities in the study of bioluminescence, for underwater detection, often hits a brick wall.

Maritime security agencies are prepared to counter traditional threats but also face frontiers of non- traditional threats that have traits of unpredictability. Non-traditional maritime threats include impacts of climate change such as increasing ocean temperatures, ocean acidification and sea-level rise, marine pollution, declining marine ecology, lack of marine data and information, etc. These non-traditional security risks affect India's maritime strategy, policy, operations, capacity building, and management.[34] According to one study, *Noctiluca* could also bloom in the summer months of upwelling in coastal stretches of Oman, Yemen and Somalia. This would impact the traditional summer bloom of diatom populations due to the invasive mixotrophic characteristics of *Noctiluca*, and impact regional-artisanal fisheries.[35] This would then, in turn, further impact the food-security of these regions, especially for countries such as Yemen and Somalia, where fish is a major source of protein and income, further exacerbating socio-economic loss and turmoil. The non-traditional threats emanating from the impacts of *Noctiluca*, and their cascading implications for coastal sectors like fisheries, maritime infrastructure and tourism in the Arabian Sea need to be monitored and comprehensively assessed in India.

Long-term Implications. Current trends and climate-model-based future projections suggest that climate change will continue at an accelerating pace for many decades or even centuries unless we take urgent, transformative action. This implies that the biophysical changes, described earlier in this chapter, occurring in the marine environment as a result of climate change, will also continue to worsen. Similarly, with growing population, urbanisation and industrialisation, the human impacts on the marine environment will, in all likelihood, continue to grow unless we, as a global civilisation, take significant measures to address the root causes of the problem. These human impacts will, in turn, continue to make environmental conditions even more conducive for *Noctiluca* to flourish. Due to their own invasive nature and in the absence of a prominent predator, the natural tendency of species such as *Noctiluca Scintillans* is to keep expanding and consuming as much as they can, until they exhaust the resources available in the region. The expanding *Noctiluca* blooms and the potentially colossal shift in traditional (diatom-maintained) ecosystems will have long term ramifications on food and economic security, the Blue Economy, incidences of IUU (Illegal, Unregulated, and Unreported) fishing, and, critical maritime infrastructure. In the medium to long term, these impacts could lead to a significant loss of livelihood in key economic sectors such as tourism and fisheries, which would increase pressures on economic and food security, leading to a rise in poaching, illegal fishing, and allied activities. These medium to long-term implications pose a major challenge and warrant greater attention in the planning and implementation of India's Blue Economy model.

Policy Recommendations and Mitigation Pathways

The discovery of *Noctiluca* blooms in the Arabian Sea is relatively recent (the early 2000s). Consequently, scientific understanding of the causes and impacts of these blooms in this particular region is also at a very nascent stage where new hypotheses are frequently being proposed by scientists. Considering the potentially widespread, wide-ranging and significant knock-on impacts that *Noctiluca* blooms could have on the maritime domain, there is a need to conduct many more studies incorporating multiple perspectives (science, policy, economy, marine biodiversity, and security).

While the exact mechanisms through which climatic changes and human exploitation may be contributing to the increased proliferation of *Noctiluca* may be open to debate, it is clear that climate change and human-caused marine pollution are leading to changes in the physical, chemical and biological conditions in the Arabian Sea, and these changed conditions are, in turn, becoming more conducive to invasive species such as *Noctiluca*. This adds another strong reason to the already long list of reasons for why we should act urgently and drastically to tackle the issues of climate change and growing marine pollution and overexploitation of marine living resources. Climate change related impacts will be continual, with low availability of quick-fix mitigation options. The prevailing understanding of *Noctiluca* blooms is still in a nascent stage and requires a wider and more profound range of regional studies and rigorous monitoring efforts to comprehend and find methods to predict the high bloom periods in the Arabian Sea and their subsequent impacts.

Policy and mitigation steps could be explored for human-led impacts concerning pollution and resource management. However, this would require inter-disciplinary and multi-stakeholder approaches to ensure bottom-up implementation processes.

Addressing Research and Technological Gaps. Available methods of studying mechanisms that trigger the bloom and seasonal variations of *Noctiluca Scintillans* are poorly investigated. The relationship between *Noctiluca* outbreaks and jellyfish blooms should certainly be investigated further and incorporated into existing monitoring systems, so as to alert stakeholders of high-risk coastal sectors (which includes most of all sectors along India's West Coast) that are vulnerable to such blooms. Interagency and interdisciplinary approaches with institutions, agencies in maritime governance, and local actors, have considerable potential in terms of addressing gaps within data and technological deficits.

A case in point is the impact on India's maritime infrastructure. A study undertaken on the coastline of Oman has highlighted the damage that *Noctiluca* and the subsequent jellyfish blooms cause to desalination plants, oil refineries, and natural gas plants, to the point where they have been forced to shut down during high bloom episodes. The implications for India's maritime infrastructure and damage caused by *Noctiluca* and jellyfish blooms have simply not been assessed thus far. The combined value of several sectors and their current and predicted infrastructure requirements, such as port-development, fisheries, trade, tourism, and related sectors, need to be assessed to understand the cumulative impact of *Noctiluca* and subsequent impacts of jellyfish blooms on critical maritime infrastructure.

Opportunities within the Blue Economy. The objectives of the Blue Economy in addressing pollution, and climate-change mitigation measures, such as the restoration of degraded ecosystems, enhanced sustainability of fishing and tourism practices, and overall marine resource- management, all require further deliberation towards determining the optimal steps that could enable India to establish itself as a regional leader and exemplar in maintaining the health of the Arabian Sea. These opportunities require the articulation of high-risk sectors and regions in the Arabian Sea impacted by seasonal noctiluca blooms.

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Note

This article was first published on 06 May 2021 on the Website of the National Maritime Foundation

Climate Change Impact on Mangrove Ecosystems in India's Coastal Regions

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Mangroves form a unique ecosystem that exists along the coastline, on the margin between land and sea in tropical and subtropical areas. Mangroves are considered to be amongst the most productive, diverse, and crucial bio-resource in the coastal environment. They have tremendous socio-economic and ecological value as they provide goods and services to human societies and coastal and marine species. For instance, they offer several vital ecosystem services such as regulating water quality, providing a breeding ground for fish species, and are a source for fuelwood, charcoal, timber, and wood chips. They have several unique features, such as aerial breathing roots and extensive supporting roots. They play a significant role in stabilising the shoreline and providing physical protection by serving as a natural ecological barrier against ocean currents, storms, and cyclones. They also help in flood-attenuation since their roots and organic matter trap sediments and act as sponges, absorbing floodwater. As a result of these characteristics, they protect the most vulnerable coastal communities from the devastating impacts of climate change-induced sea-level-rise and extreme-weather events Mangrove forests also store large amounts of carbon — more than any other type of forest. Therefore, they play an important role in mitigating climate change. However, due to rampant human exploitation in coastal regions and the accelerating impacts of climate change including rising sea-levels, altered weather patterns, and the acidification of the oceans, the health of mangrove forests around the world is deteriorating at an alarming rate.[1]

Mangrove Cover in India

Mangrove forests cover just 0.1 per cent of the world's land area and just 15 countries account for more than 75 per cent of the total global mangrove forest area.[2] India has a total mangrove cover of 4,975 sq km, which is 0.15 per cent of the country's total land area but amounts to 3 per cent of the global mangrove forest area and 8 per cent of Asia's mangrove forest area.[3] Of this, about 60 per cent is located along the country's eastern coast (abutting the Bay of Bengal), 27 per cent is located along the western coast (abutting the Arabian Sea), while the remaining 13 per cent is found in the Andaman and Nicobar Islands. The mangrove distribution among maritime states differs quite extensively.

West Bengal has the largest mangrove forest and accounts for 42.45 per cent of the total mangroves cover, followed by Gujarat with 23.66 per cent. The mangrove forest cover of other maritime states is marginal compared to that of these two states. Daman and Diu, for instance, accountaccounts for just 0.03 per cent (3 sq km), Puducherry 0.06 per cent (2 sq km), Goa 0.52 per cent (26 sq km), Kerala 0.20 per cent (9 sq km), Karnataka 0.205 per cent (10 sq km), and Tamil Nadu 0.09 per cent (45 sq km).

Within the states themselves, the density of mangrove forests is not uniform, as very dense mangrove comprises 1476 sq km (29.66%) of the mangrove cover and are limited to just three coastal states, namely, West Bengal (996 sq km), Andaman and Nicobar Islands (398 sq km) and Odisha (81 sq km) (see Table 1). Globally, too, mangroves are disappearing at a rate of 1 to 2 per cent per year, which is even faster than coral reefs and tropical rainforests.[4] Since the 1950s, about 50 per cent of the mangroves biome has degraded due to inadequate protection and extensive alteration of their habitat.[5] At the current rate, all the world's mangroves will be lost by the end of this century.[6] India itself has lost as much as 40 per cent of its mangroves during the last century alone.[7] India had a mangrove cover of about 6,749 sq km (the fourth largest mangrove area in the world), which dropped by nearly 59.18 sq km between 1972-75 and 1980- 82, as per the 2019 report of the National Remote Sensing Agency, India.[8]

Table 1: Mangrove Cover across India in 2019

Ser	State/UT	Very Dense	Moderately Dense	Open	Total (sq km)
1.	Andhra Pradesh	0.00	213.00	191.00	404.00
2.	Goa	0.00	20.00	6.00	26.00
3.	Gujarat	0.00	169.00	1,008.00	1,177.00
4.	Karnataka	0.00	2.00	8.00	10.00
5.	Kerala	0.00	5.00	4.00	9.00
6.	Maharashtra	0.00	88.00	232.00	320.00
7.	Odisha	81.00	94.00	76.00	251.00
8.	Tamil Nadu	1.00	27.00	17.00	45.00
9.	West Bengal	996.00	692.00	424.00	2,112.00
10.	A&N Islands	398.00	169.00	49.00	616.00
11.	Daman & Diu	0.00	0.00	3.00	3.00
12.	Puducherry	0.00	0.00	2.00	2.00
Total		1,476.00	1,479.00	2,020.00	4,975.00

Source: India State of Forest Report 20199

The density and diversity of mangroves are affected by temperature and moisture to a very significant degree.[10] Increasing temperature causes heat stress and increase in ocean salinity. The problem of salinity of water is exacerbated by rising sea-levels, as also by other factors such as changes in the flow of fresh water from rivers, and, the growth of human activities such as shrimp-farming and expansion of salt pans along the coast.[11] In fact, the expansion of salt pans along the coast is one of the major causes of decline of mangrove species. For instance, Gujarat is the single largest producer of salt in India and contributes 80 per cent to the total marine salt production of the country. Large portions of mangrove areas were leased to industries for the creation of salt pans. As a result, the salinity level in Gujarat's soil and water is very high and this is reducing the natural regeneration of mangrove forests. The State government of Gujarat has recorded that over 14 species of mangroves have already become extinct.

"No major rivers, except Indus with its reduced annual flows, pour fresh water into the Gulf of Kachchh. As a result, only hardy species like Avicennia Marina, with high salt tolerance, have survived. Similarly, in the Gulf of Khambhat, freshwater inflows from some of the major rivers like Sabarmati and Mahi have reduced due to construction of dams for irrigation in the upstream areas." [12]

Despite the cases of degradation of mangroves in Gujarat, the 2019 edition of the "India State of Forest Report" (IFSR) states that the mangrove forests cover area in Gujarat (1,177 sq km) has increased "substantively" — by about 750 sq km — since 1987, which is almost a three-fold increase. In general, government data shows a long-term increase in mangrove cover in India, particularly in the category of open mangrove forests. This is perplexing, to say the least. There is some possibility that localised conservation efforts are at least partially responsible for this apparent reversal, but the dichotomy remains largely unaddressed. A more likely reason for the seemingly increasing trend could be ineptitude or inaccuracies in the methods used for mapping and monitoring mangroves. Even though satellite data analysis and geographical information systems are the most effective methods available for monitoring "forest cover", they cannot be used to gauge the health of the forests. Assessing the health of mangroves would require additional field surveys to complement satellite data. Coastal states are generally the most industrialised, and, in such states, the reclamation of mangrove areas to support human settlements, aquaculture and the rampant discharge of industrial effluents and toxic substances, are all major factors that lead to the destruction and degradation of mangrove health and cover. Most coastal states that are vulnerable to the adverse impacts of climate change, such as Tamil Nadu, West Bengal, and the Andaman and Nicobar Islands, are the very ones that continue to experience loss of mangrove cover.

Major Challenges Facing Mangroves: Climate Change and Natural Factors

The mangrove forest ecosystem in general shows "*exceptional morphological and physiological adaptation skills to counter the environmental and natural stress associated with their intertidal habitat.*"[13] However, sea-level rise is among the more critical of the various factors that contribute to the degradation of mangrove habitats. According to recent projections, global mean sea-level could rise by an estimated 0.61-1.1 metres by the year 2100, which would place most Indian coastal cities at high risk of complete submergence or, at the very least, of experiencing frequent inundation during high tide conditions.[14] Changes in sea-level impact the structure, growth, and areal extent of the mangroves, while increase in temperature affects their density.[15] In an assessment conducted by Gilman et al. in 2015, it has been suggested that sea-level rise will be the primary driver of future mangrove area losses in the Sunderbans.[16] The Sundarbans area, straddling India and Bangladesh, has the world's largest mangrove ecosystem, which is recognised as the largest land-based carbon sink in South Asia. The Sundarbans mangrove forest was declared a 'reserve forest' in 1996, and a UNESCO World Heritage Site', in 1997, because of its crucial environmental and socio-economic role.[17] As per the latest India State of Forest survey report, Sunderbans lost 2 sq km of mangrove cover, going from 2214 sq km to 2112.11 sq km, between 2017 and 2019. This loss was primarily driven by erosion and sea-level rise in the Bay of Bengal.[18]

Besides sea-level rise, storms and tropical cyclones also have significant impacts on the coast, directly through damage caused by extreme winds, and indirectly through storm surges and high tides.[19] For instance, following the *tsunami* that occurred in the Indian Ocean in 2004, it was reported that around 62-70 per cent of the mangrove forest in the Nicobar Islands was damaged and uprooted,[20] and Pichavaram mangroves suffered 5–10 per cent damage.[21] In the case of the 1999 Orissa Super Cyclone (IMD designation BOB 06 — cyclones began to be named only from the following year), the Forest Survey of India assessed that at least 50 per cent and 40 per cent of the mangroves had been lost in two districts of Orissa, namely, Jagatsinghpur and Kendrapara, respectively, which hold a significant share of the Mahanadi mangroves. Similarly, Cyclone *Amphan*, in 2020, damaged vast swaths (an area of some 1, 600 sq km) of the mangrove forest in the Indian Sundarbans that accounts for nearly 40 per cent of the total area of 4,000 sq km.[22]

Although, as has been mentioned earlier, mangroves are well adapted, both morphologically and physiologically, to saline conditions, this is true only up to a finite threshold. A great degree of variation in water and soil salinity has been recorded in Indian coastal states in recent decades, with some regions experiencing significant increases. For instance, salinity in the Pichavaram mangrove of Tamil Nadu, varied between 0.6 per cent and 36.2 per cent during 2004-2005.[23] Dr V Selvam, the lead researcher who is looking into the depletion of mangrove cover in Tamil Nadu, noted in an interview in 2019 that the wetlands in Pichavaram and Muthupet have lost five species of mangrove trees over just 70 years, due to the sharp increase in salinity levels.[24] High salinity has severe and entirely adverse impacts on the species-diversity of mangroves and on even marine animal species. A notable decrease of gastropods (snails, slugs, etc.) in the Pichavaram mangroves was reported and, similarly, migratory water birds' populations were also shown to decline, due to increases in salinity.[25] Extreme saline conditions have also led to a 90 per cent reduction in freshwater flow.[26] When the supply of freshwater decreases, afforestation of mangrove in highly saline coastal wetlands becomes challenging.

Anthropogenic Factors that Impact Mangroves

Another major cause for the impairment of mangrove forests in India is due to anthropogenic activities such as the conversion of mangrove habitats into agricultural land or for the promotion of aquaculture, tourism, and urban development in general.[27] A majority of India's coastal communities are dependent on agriculture for their livelihood. It has been recorded that over the past 100 years, about 1,50,000 hectares[28] of mangroves have been destroyed in India and Bangladesh in order to make land available for agricultural purposes.[29] Further, Indian coastal cities are experiencing rapid urbanisation and the concomitant development of urban infrastructure, whereby the majority of mangrove forests on Indian coastlines have been lost to land-reclamation and other supposedly 'developmental' projects. Mumbai city is a perfect example, as it was built on a cluster of seven islands each of which was surrounded by mangroves. In the case of the Mumbai suburban region, a total mangrove area of 36.54 sq km was lost during a period of just 11 years, from 1990 to 2001, which accounted for a 39.32 per cent decrease in the mangrove cover area.[30] Even more recently, hundreds of acres of mangroves have been cleared for the construction of the Navi Mumbai International airport. This can be seen in the satellite images shown in Figure 1.

Figure 1: Google Earth image of the vicinity of Navi Mumbai International Airport. Left panel corresponds to 12 November 2003, right panel corresponds to 12 November 2019. *Source*: Sushmita Pathak, "Mangroves Help Fight the Effects of Climate Change. So Why is Mumbai Destroying them?", *NPR*, 25 November 2019, https://www.npr.org/sections/goatsandsoda/2019/11/25/781990792/mangroves-help-fight- the-effects-of-climate-change-so-why-is-mumbai-destroying-them

The image on the left was taken on 12 November 2003, where the green areas correspond to the forest cover that was then available. The image on the right corresponds to 12 November 2019, which clearly shows that hundreds of acres of mangroves were destroyed over these 16 years.[31] Tragically, urban-development projects continue to endanger mangrove forests. Last year (2019), Maharashtra's Transport Minister blandly stated that around 32,044 mangroves would be cleared for the Mumbai-Ahmedabad bullet train project.[32] Achal Khare, Managing Director of the National High-Speed Rail Corporation Limited (NHSRCL), claimed that *"if 32,044 mangroves are cut, then around 1,60,000 new mangroves will be planted, and the entire financial expense will be borne by NHSRCL."*[33] However, even as the Maharashtra government promises to replant mangroves to substitute those that were cleared, there is no land available within the city to replant the mangroves, as was pointed out by Debi Goenka, the executive trustee of a Mumbai-based non-profit organisation, the 'Conservation Action Trust'. Goenka pointed out that even if mangrove restoration did, by some miracle, take place, most of the planted saplings would not survive. Presently, Mumbai city has only 2 sq km of mangrove forests in all. This is a huge loss for this megapolis, if only because mangroves are highly efficient natural defences against sea-level-rise and cyclonic storms, both of which have already begun to ravage the city.

The seemingly ceaseless development of ports and harbours is also contributing to mangrove degradation. For instance, the port of Mundra, in Gujarat, has been roundly condemned globally for severely degrading Indus delta mangroves. Likewise, Paradip Port in Odisha has also been reported to have built over dense patches of Mahanadi delta mangroves.[34]

Pollution is yet another big challenge for the mangrove ecosystem, especially in megacities such as Mumbai and Kolkata. Large amounts of solid waste and effluents from various sources are being callously dumped into the mangrove ecosystems. Oil spills, when they happen in coastal waters, severely impact mangrove ecosystems. If all this were not enough, the construction of dams on rivers also leads to reduced flow of freshwater, which adversely affects the growth of mangroves.

Implications of Loss of Mangroves

The acceleration of unsustainable human activities, coupled with the adverse impacts of climate change, are threatening the mangrove ecosystem, placing the lives and livelihoods of millions of coastal residents at high levels of risk. Any further loss of mangrove forests would leave coastal communities without a vital line of defence against extreme-weather events that are becoming more frequent and more intense. Numerous studies have shown that mangroves play a critical role in protecting coastal communities from the impact of large storms. For instance, when Cyclone *Bulbul* hit Odisha and West Bengal on 9 Nov 2019, it was reported that the wind speed of Cyclone *Bulbul* was reduced by 20 km an hour because of the Sunderbans mangrove forest. This saved the rest of southern West Bengal from the disastrous storm, which might otherwise have proven to be cataclysmic for Kolkata and its environs.[35] On the other hand, the catastrophic impact of the unprecedented flooding in Mumbai, in 2005, was exacerbated by the lack of mangroves along the 18 km long *Mithi* river. These mangroves had earlier been cleared for construction purposes. Consequently, Mumbai was left without any natural buffer against flood surges.

More often than not, biodiversity and the functioning of marine ecosystems are closely interlinked. A loss of biodiversity could limit the functioning of ecosystems, which subsequently reduces their capacity to provide goods and services to coastal communities. Roughly 560 million people live along India's coastline and the vast majority of them are dependent on marine and coastal ecosystems, even if they and their elected representatives seem largely oblivious of this fact.

Mangroves serve as a critical breeding ground and nursery habitat for a wide range of marine organisms, including shrimps and fishes. Importantly, commercial marine fish species such as cuttlefish, squid, lobster, shrimp, and certain types of finfish, contribute enormously to India's seafood exports.[36] India ranks second, globally, in fish-production; the fisheries sector employs 145 million people and contributes 1.07 per cent to the GDP, as per a recent estimate of the National Fisheries Development Board.[37] If conserved, mangroves have the potential to significantly enhance the productivity of fisheries. On the other hand, a continuing loss of mangrove forests will significantly and adversely impact the health and quantity of fisheries and hence the economic productivity of coastal communities.

The role of mangrove forest ecosystems, particularly in the tropics, in mitigating climate change through carbon sequestration can hardly be overstated, given that these ecosystems constitute one of the largest carbon sinks.[38] Conversely, when these mangroves are cut down, they release significant quantities of stored carbon, accelerating global warming. India is currently the eighth- largest carbon emitter in the world in terms of the total amount of annual CO_2 emissions and is likely to become the second-largest carbon emitter by 2050. Therefore, mangroves are more critical now than ever to counteract the rise in carbon emissions from human activities and mitigate global climate change.

Way Forward: Conservation of Mangroves

There has been some success in restoration of mangrove forests in India, but it is nowhere near enough, given the rate of loss of mangroves during the last few decades. A far more inclusive framework for understanding, predicting, and managing interactions between climate change, human activities, and coastal ecosystems needs to be formulated. At the most basic level, efforts must be made to create awareness and educate the public regarding the vital role that mangroves play and provide community training to generate the requisite skills and knowledge to conserve and restore mangrove ecosystems.

In recent years, some policies and conservation efforts from the government, NGOs, and local communities in India, have played an important role in sustaining and restoring mangrove forests. For instance, a community-based restoration programme was carried out by local communities in the Krishna district of Andhra Pradesh, where the community innovated new techniques for cultivation and plantation of mangroves, created a village-level Forest Conservation Council, and planted 6000 mangrove saplings in the district.[39] In Gujarat, the mangrove conservation strategy involves large-scale plantation, development of new mangrove habitats at suitable areas, and capacity-building of managers and staff. Different approaches, strategies, and methods must be studied and promoted and the success stories shared.

Conservation of mangroves can be enhanced by devising well-balanced coastal land-use plans, such as maintaining sustainable limits in logging and other harvesting activities. Mangroves also hold religious, cultural, and sentimental value to the local communities, which is another reason to protect and preserve them. The inland mangrove forests in Shravan Kavadia, Kachchh, are considered sacred and the locals in that area strictly regulate any exploitation of the forests as such activities are believed to be inauspicious. Similarly, the Kagekanu forest patch, which is dominated by species such as *Rhizophora mucronata*, *Avicennia officinalis* and *Kandelia candel,* off the coast of Karwar in Karnataka, is one of the examples of traditional conservation through sacred groves.[40] In a way, the resource-dependent community of Karwar protects its forest from destruction as they associate nature with sacred deities. Therefore, traditional conservation strategies and inclusion of local and resource-dependent communities should be given priority in policy making.

Participation of the local community in the conservation and prevention of illegal clearing and encroachment of mangrove areas is crucial. There are a few cases where resource-dependent communities have fought against illegal activities. For instance, Sahjeevan, an NGO based in Kachchh initiated a photo story campaign to raise funds for the Camel Breeders Association of Kutch (*Kutch Unt Ucherak Maldhari Sangathan*

(KUUMS)) to “Save the Mangroves of Kandla from Salt Making Industries”. It was stated that in February 2018, *“Hitachi machines and tractors illegally cleared more than 4 sq km of pristine mangrove forest for salt industries”.* Camel breeders and camels are dependent on the mangroves for their livelihood. The Camel Breeder association members saw the threat and protested against the destruction; and have started the process to revive the mangroves that were destroyed for ostensibly ‘developmental’ purposes. In such a situation, local authorities and other concerned stakeholders need to support the community and provide it with necessary resources, be these monetary or legal assistance. Therefore, existing forest rules must be strictly enforced to prevent unlawful entry/encroachment and indiscriminate exploitation.

In the face of rapid urbanisation of coastal cities, urban development policies should vigorously address the issue of livelihoods of slum dwellers and urban poverty in India. As Seema Adgaonkar, who until recently was one of the four Range Forest Officers at the Mumbai Mangrove Conservation Unit, and has been guarding the city’s vital coastal ecosystem has said, *“it’s very difficult to demolish illegal structures and slums encroaching mangrove areas. There are social and political pressures from all sides on us.”*[41] Ensuring urban poor with shelter and access to basic urban infrastructure and services would address some of the problems of the urban poor in the encroachment of the mangrove ecosystem.

While conservation of mangroves in the context of anthropogenic activities and pollution is discussed at least occasionally, even if not frequently enough, there is very little discussion on protection of mangroves from climate change. As has already been explained, the health, growth, survival, and productivity of mangroves are largely influenced by the rise in salinity in soil. Extreme climate change is a looming danger for the entire mangrove ecosystem. Since degradation of mangrove ecosystem is caused by a wide range of factors, which cannot be treated in isolation, it is necessary to adopt an integrated management approach by taking into consideration all the factors such as sea-level rise, extreme weather, and human exploitation, and involve all the stakeholders to protect and conserve mangroves.

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Note

The author would like to acknowledge Vice Admiral Pradeep Chauhan (DG NMF), Dr Pushp Bajaj, and Mrs Sunanda Khanna, for their valuable inputs

This article was first published on 12 October 2020 on the Website of the National Maritime Foundation

Towards a Sustainable and Secure Blue Economy

Towards a Comprehensive Climate Adaptation Framework for India's Port Infrastructure and Operations: Lessons from Global Best Practices

Dr Pushp Bajaj and Dr Chime Youdon

Coastal areas around the world are among the most vulnerable geographical areas to climate change. In addition to the generic impacts such as rising temperatures, extreme heatwaves, erratic rainfall patterns, etc., that are common to all land areas, coastal areas are exposed to two more dramatic impacts of climate change: a) sea level rise and b) increasingly frequent and intense tropical revolving storms.[1] They are typically also densely populated, primarily due to the myriad economic opportunities that are afforded simply by being in the vicinity of the ocean and having access to the rich marine resources. Approximately 40 per cent of the world's population lives within 100 kilometers (km) of the coast. Coastal zones around the world are also experiencing the fastest rates of urbanization and growth and undergoing remarkable socio-economic and environmental transformations in the process. As a result, even more people are moving to coastal areas from the hinterland to take advantage of the growth trends.

In recent years, India, recognizing the immense potential of its maritime space, has launched a slew of measures to expand and enhance the maritime sectors of the economy and facilitate the transition from a *'Brown Economy'* to a *'Blue Economy'*. The latest and most comprehensive development plan, in this regard, is the Maritime India Vision 2030 (MIV-2030), launched by the Prime Minister in March 2021 on the inaugural day of the Maritime India Summit 2021.[2] Under the aegis of the Ministry of Ports, Shipping and Waterways (MoPSW), the port-led development model outlined in the MIV-2030 is focused on building world-class greenfield ports, creating 'smart ports' and modernizing existing ports, reducing logistics by enhancing land-connectivity, promoting port-led industrialization and public-private partnerships. Over 150 initiatives have been identified so far under the 10-year plan which is expected to generate over INR 3 trillion in investment and 2 million new jobs. The plan also lays emphasis on building a *sustainable* and *green* maritime sector by increasing the use of renewable energy at ports, improving air quality at ports, reducing water consumption and improving health and safety standards. Notably, no explicit targets for reduction of greenhouse gas (GHG) emissions have been defined yet. Similarly, no mechanisms have been mentioned to calculate the life-cycle GHG emissions of the greenfield ports that will be constructed. Nonetheless, the commitment towards improving energy efficiency and increasing renewable energy usage in the vision document denotes a significant step towards a sustainable transition.

Even though the motivation for sustainability measures such as improving efficiency and using technology may be rooted in the economics, to save on fuel costs and time, they could, in principle, be considered a part of the climate change mitigation strategy. However, there are no plans in this port-led development model to adapt to the impacts of climate change that have already occurred or those that are projected to occur in the near- and long-term future. Currently, while almost all Indian ports have extensive 'Disaster Management Strategies' for natural disasters such as earthquakes, cyclones, floods, fires, etc., these disaster management strategies do not account for the ongoing changes that are occurring in the frequency, intensity, and behavior of these disasters due to climate change. None of the major Indian ports have a dedicated 'Climate Change Adaptation' strategy. This is, in fact, a common theme across most coastal States in the world, there is little emphasis on enhancing the resilience of the ports and shipping infrastructure and the critical supply chains to the impacts of climate change compared to the emphasis given to climate change mitigation by reducing carbon emissions from ports and shipping. As discussed in detail in the next section, everything from rising temperatures to flash floods to sea level rise and more frequent cyclones, will adversely impact port infrastructure and the personnel which could seriously hamper the ability of the ports to carry out their operations and meet their targets. This would, at best, result in frequent localized, short-term economic losses and, at worst, lead to increasing instances of shutdowns of one or more ports for weeks or even months causing crippling damage to the country's economy.

Currently, India has 12 major ports (see Figure 1), that are managed by the MoPSW of the central government, and 205 minor ports, that are managed by the state governments of the states in which the port is located.[3] India's maritime transport sector accounts for 95 per cent of the country's total trade by volume corresponding to 70 per cent of total trade by value. The absolute volume of trade is expected to continue to grow significantly under the MIV-2030, in fact, capacity augmentation for maritime trade is one of the core objectives of MIV-2030. Of course, trade forms a significant portion of the Indian economy. In 2020, India's trade-to-GDP ratio was 36.47 per cent; at its highest point, in 2012, the trade-to-GDP ratio was 55.79 per cent.[4] In order to ensure the long-term security and sustainability of its maritime transport sector, India must make its ports 'future-ready' by making them 'climate-resilient'.

This paper aims to provide a comprehensive overview of the steps and guidelines that need to be followed to develop an exhaustive climate adaptation strategy for seaports in India, based on a discussion of international best practices. To set the context, the next section provides a literature review and highlights the observed and projected impacts of climate change on Indian ports and the urgent need for an adaptation strategy. Of course, the first essential step towards climate adaptation and building climate resilience is a robust 'risk assessment' which must include a study of the climate hazards to a particular region and type of infrastructure, the ways in which the region and infrastructure are exposed to those hazards, and the degree of damage that could potentially be caused by those hazards. The chapter discusses these elements and how they may be determined, through a review of risk assessment frameworks that have been utilised in recent years. Following that, the chapter provides an overview of the current and proposed adaptation measures by ports around the world to enhance their resilience to the impacts of climate change. Then the chapter outlines a way forward for Indian ports and analyzes how these best practices can be molded-to and utilized-in the Indian context. Finally, the main conclusions of the paper are collated at the end.

Literature Review

Impact of Climate Change on Indian ports

Before assessing the impacts of climate change on ports, it is critical to realize that the influence and interlinkages of ports extend well beyond their physical location. The road and railway networks in the hinterland are just as important for port operations as the maritime shipping network. Industries, small businesses, and local communities, in far-away regions in the hinterland are dependent on the efficient functioning of the ports for their own operations. Several port infrastructure assets, including the support infrastructure and supply chains, and human personnel, are vulnerable to climate-change-induced events such as sea level rise and climate-change-altered events such as extreme precipitation, tropical revolving storms, storm surges, and heatwaves. Flooding due to extreme precipitation or after a cyclone could cause damage to radio and radar equipment, storage facilities, and inundate inland road and rail networks resulting in delay in operations. High speed winds during cyclones could affect loading/unloading crane operations and cause damage to communication and navigation equipment, in addition to generic damage to buildings and warehouses. In many cases, ports halt all operations during cyclonic storms, particularly during severe cyclonic storms, to minimize damage. However, with more frequent and intense cyclones being predicted in the Indian Ocean due to climate change, the average annual economic loss caused by direct infrastructure damage or due to operational downtime, will likely increase in the coming decades. Frequent and more extreme heatwaves and overall increase in high-temperature days could lead to significant increase in energy consumption of cold storage equipment and refrigerated containers, as also for air conditioning of office buildings. Additionally, sustained periods of extreme heat could lead to damage to road and rail infrastructure and affect the health and productivity of human personnel due to harsher working conditions.

In May 2021, when Cyclone *Tauktae* (which made landfall as an Extremely Severe Cyclonic Storm) hit the west coast of India, it caused significant disruptions in operations at the Jawaharlal Nehru Port Trust (JNPT) in Navi Mumbai in Maharashtra. The JNPT is one of the youngest ports and the top container port

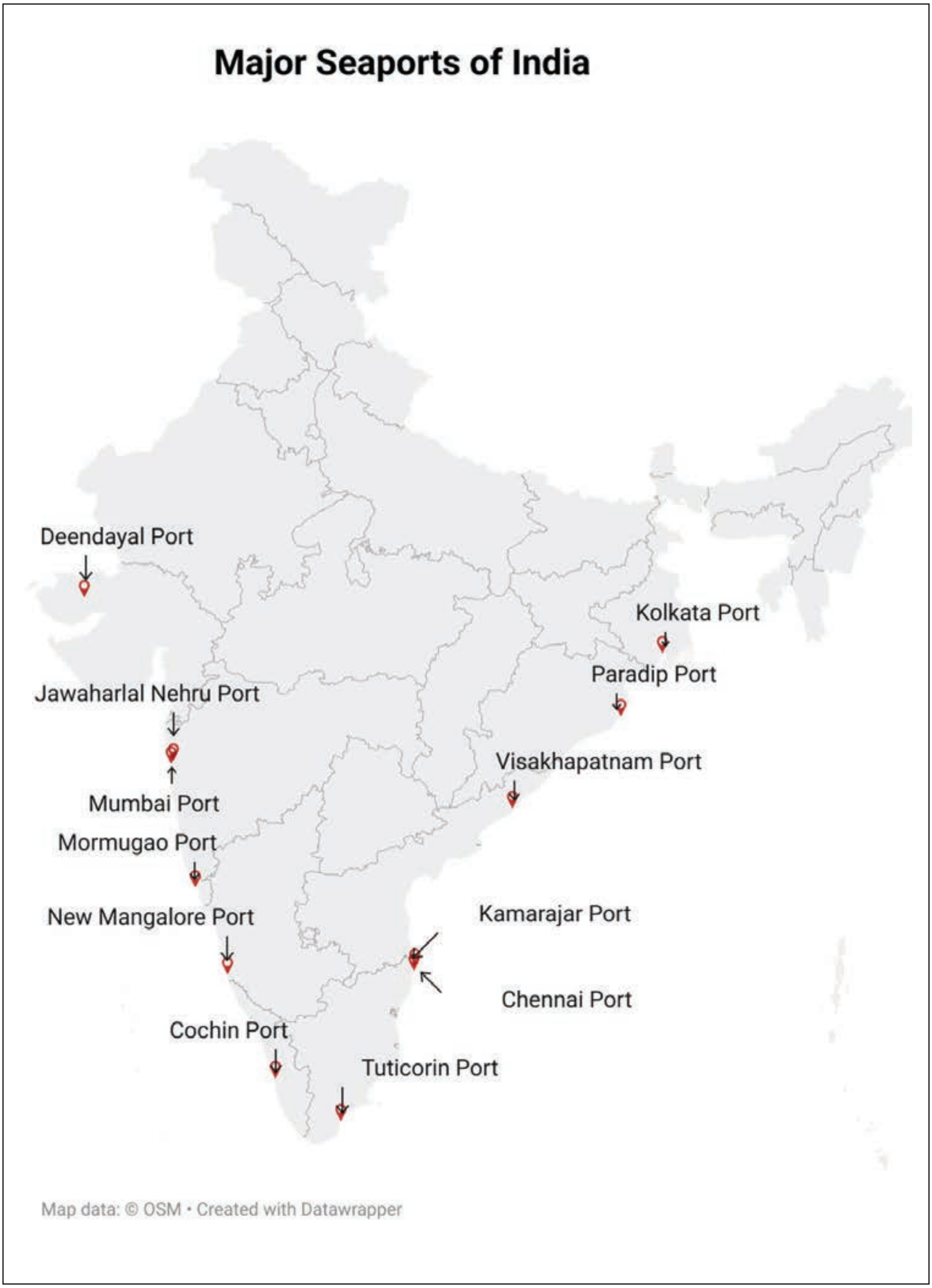

Figure 1: Location of India's 12 major seaports.

in India. The port has a 39.54 km long main harbor channel with a draught of 14 km. The container traffic at JNPT constitutes about 50 per cent of total container traffic handled by all the Indian Major Ports (around 9 million TEUs).[1] Following standard protocols, the port took preventive measures by evacuating most port areas before *Tauktae* made landfall. Only the control rooms at the ports were kept active for monitoring purposes for three days (15 to 17 May 2021). Many vessels which were scheduled to route through the west coast were called off from berthing. JNPT has four dry port or dry dock sites in Wardha, Jalna, Nasik and Sangli that facilitate cargo aggregation in the hinterland away from the port; the roadblocks and cancellation of railway lines during the cyclone led to significant delays for shipping lines. Overall, suspending all the operations at the JNPT resulted in congestion at the port and severely affected the supply chain. Other non-major ports in the areas hit by *Tauktae* were affected even more badly and operations were suspended for several weeks.[2] This setback, of course, added to the losses incurred due to the ongoing COVID-19 pandemic which had already caused a slow-down in port operations and disrupted supply chains due to labor shortages and *force majeure* during the global travel restrictions.

Additionally, more erratic and extreme monsoon rains and strong winds, due to climate change, are becoming an annual nuisance for the city of Mumbai and the state of Maharashtra, in general. Frequent, heavy monsoonal flooding also affects port operations. In 2020, during a record-setting monsoon season, Mumbai recorded a total rainfall of over 1,240 mm in the month of August, which was more than double the average rainfall of 585 mm for that month (Pinto, 2020). In the same month, three high-capacity cranes deployed at the JNPT collapsed due to heavy rains and strong winds. However, no injuries or casualties were reported since operations were already halted, and personnel evacuated due to bad weather.[3] The year before that, 2019 also broke several records for monsoon rainfall in Mumbai.[4] Such events are expected to become more common all along the West Coast as climate change continues unmitigated.

In October 2014, Cyclone *Hudhud* hit the coast near Visakhapatnam as an Extremely Severe Cyclonic Storm (ESCS) with a wind speed of 175 km/h, causing extensive damage to the city and its neighboring districts. *Hudhud* was one of the two strongest tropical cyclones of 2014 within the Bay of Bengal.[5] Over 250,000 people were affected, and the city of Visakhapatnam suffered billions in damages. Within a few hours of hitting the coast, the cyclone caused significant impacts on the Naval Dockyard, Vizag Steel Plant, Hindustan Petroleum Limited, and other critical assets. An estimated four hundred boats conducting fishing and related activities were damaged and seventy-two were sunk without trace; thirty-eight trains were cancelled on 12 October 2014.[6] Around 2,250 km of roads were damaged, and the total loss incurred by the local industries was estimated to be around INR 100 billion. The Indian Navy suffered economic losses of around INR 20 billion. The estimated damages faced by the Visakhapatnam Port Trust was around INR 3 billion.[7] Several port services remained on hold even days after the cyclone. The damages to the road and railway infrastructure caused significant hindrance to the movement of trucks to the port, vital internet services remained unavailable, and consequent supply-chain disruptions posed considerable delays in providing essential services.

These are just a few of the recorded examples of the ways in climate-change-related events are adversely affecting the port infrastructure and operations in India. Unfortunately, the true extent of the damages caused by climatic events to Indian ports cannot be accurately estimated due to the lack of robust data collection, monitoring and reporting in the public domain. Lack of data records is, in fact, one of the major challenges in the efforts to analyse and create awareness about these impacts and the growing trends. According to the 2020 climate change assessment report of the Ministry of Earth Sciences of the Government of India, there has been a significant increase in the number of heavy precipitation events and severe cyclonic storms over India since 1950.[8] The climate-models-based projections suggest that frequency and intensity of these events are expected to continue to increase throughout the 21st century primarily driven by the warming of the atmosphere and the ocean which is creating favorable conditions for heavy precipitation events and rapid intensification of tropical cyclones.[9]

Dimensions of Climate Risk

The first and most critical step towards any climate adaptation strategy or policy is a comprehensive 'climate risk assessment'. In the present context, the term 'climate risk' corresponds to risks or threats, arising as a result of contemporary anthropogenic climate change, to human lives, livelihoods, infrastructure and operations, and natural ecosystems and resources. This definition becomes more and more specific as the scope is narrowed down either in terms of the stakeholders or the specific impacts of climate change or a specific timeline. The Fifth Assessment Report (AR5) of the UN IPCC, released in 2014, laid great emphasis on and attempted to quantify the concept of 'risk' which is crucial for making decisions with respect to managing the effects of climate change. The report described the risk posed by climate change as a combination of 'hazard', 'vulnerability', and 'exposure'. Wherein, Hazard corresponds to a singular event or a changing trend that could have an adverse impact, Exposure corresponds to the elements (people, infrastructure, livelihoods, ecosystems, etc.) that may be exposed to the adverse impacts of the aforementioned hazard(s), and Vulnerability corresponds to the degree to which the adverse impacts can cause damage and the lack of capacity to cope with those damages. Almost all climate risk assessment frameworks follow essentially the same general approach to measuring risk, however, they may use different terminologies and they may have different methods to quantify hazards, exposures, and vulnerabilities.[10] While global scientific analyses, such as those published by the UN IPCC, provide a broad overview of the major threats arising from climate change at the global scale, what are more relevant for policy-making are the national and local level manifestations of these threats.

All three of these factors and the resultant climate risk vary widely across temporal and spatial scales and depend on a wide range of social, economic, demographic, geographic, cultural, institutional, political, and environmental parameters. These parameters are typically not easily quantifiable. Even if they are quantifiable, they may not be recorded frequently and accurately enough to provide robust insights. This makes rigorous, quantitative climate risk assessment an extremely challenging problem. The task becomes even more difficult when analysing future climate risks, several decades or even a century into the future, where the number of possible scenarios-of and uncertainties-in climate hazards, exposures, and vulnerabilities, grow exponentially.[11] Therefore, in many cases, climate risk assessments, instead, rely heavily upon the stakeholders' 'perceptions' of risk that are typically recorded through a series of surveys/ interviews which are then transformed to a numerical index or to risk-categories to facilitate comparative analysis.

In the context of seaports, climate change risk assessments and adaptation planning are relatively novel areas of research. Most of the literature in the area has come out in the last one to two decades, a majority of that has emerged from the more developed parts of the world.[12] In an attempt to fill the gaps in data and information availability for risk assessments and adaptation planning, Asariotis et al (2017), under the aegis of the United Nations Conference on Trade and Development (UNCTAD) secretariat, conducted a comprehensive online survey of stakeholders in the port-industry to understand the impacts of climate change and weather-related events on the ports around the world.[13] A total of 44 ports (73 per cent of which were located in developed countries), from 29 countries, participated in the survey which comprised questions related to the profile of the port, the history of climate and weather-related events that impacts the ports, the availability of information for a vulnerability assessment, and the level of preparedness. About 70 per cent of the ports that participated reported that they had been impacted by climate- or weather-related events in the past, in terms of operations and delays, and some of them also experienced physical damage to infrastructure. A significant number of them indicated that future infrastructure investment plans would consider weather/ climate-related factors, however, this result should be interpreted with the caveat that most of the ports that were surveyed were located in developed countries which are better equipped financially and better informed than the developing and least-developed countries. The survey also found that there is a significant lack of data availability in terms of local-level future projections of climatic changes and the port operational and infrastructure design parameters which would play a critical role in adaptation planning.

While the global-level studies/ surveys such as those conducted by UNCTAD provide critical insights into the broader issues and an international perspective, more nuanced risk assessment studies with national- and local-level details are necessary to inform adaptation decisions for individual ports. Nursey-Bray et al (2013), conducted a national-level climate vulnerability assessment of ports in Australia, through a systematic literature analysis and two stakeholder workshops.[14] The authors followed the IPCC-prescribed definition of 'vulnerability' and focused on determining "*(1) real or potential [climate change] impacts on the system [the port ecosystem]; (2) the systems'* *ability to cope and adapt to these impacts; and (3) the extent to which coping capacity may be constrained by environmental or societal conditions.*" The participants in the workshops comprised ports managers, workers and administrators within Australia's port-industry. The workshops were also supported by a survey questionnaire before and after the workshop to gather the participants opinions on how climate change has and will affect the ports. Based on the literature review, the broader impacts of climate change on ports were divided in five key areas: (1) Environmental impact, (2) Infrastructure, (3) Ports and people, (4) Occupational health and safety impacts, and (5) Supply chain impacts. The expert surveys were then used to assess *"the ability of the systems to cope and adapt to these impacts"*, and the constraints that may limit the ability to build adaptive capacity as seen by the port authorities. As one would expect, the study found that while all ports will indeed be affected by the impacts of climate change, the vulnerability varies significantly between the different sections of port infrastructure and operations. Importantly, the surveys revealed that most port authorities displayed high levels of confidence in their ability to adapt to the ongoing and projected changes. The authors called for a standardized national-level framework which can be applied to individual ports to assess the climate vulnerability of Australia's port infrastructure. The semi-quantitative yet robust methodology of the study provides a blueprint for researchers in other countries on how to break down climate vulnerability into its critical components and systematically evaluate it through perception surveys.

Port-specific case-studies have also been conducted in the recent past. To mention a few, Stenek et al (2011), published a comprehensive climate-risk assessment report, including financial impacts estimates and suggested adaptive measures for the Terminal Maritimo Muelles el Bosque (MEB) in Colombia.[15] The authors categorized the impacts across a wide range of operational, financial, reputational, legal, environmental and social categories and across different future climate change scenarios. The study was accomplished through a combination of desk-research and modelling, and discussions with the port authorities, local government and climate change experts. The study also laid great emphasis on the interdependencies between the port operations and hinterland industrial activities and local businesses. Following a similar methodology, Cox et al (2013), conducted a climate risk assessment for the

Avatiu port in the Cook Islands.[16] Building upon previous studies the authors took specific steps to address the interconnectedness of port operations with the broader city infrastructure and included multiple stakeholders for a more holistic assessment. Messner et al (2013), used the port of San Diego as a case study to understand the impacts of climate change, sea level rise in particular, on ports and provided an evaluation framework for risk and vulnerability;[17] Chettri et al (2015), also studied the impacts of sea level rise on port infrastructure and operations using Port Kembla in New South Wales as the case-study.[18] All of the aforementioned vulnerability/ risk assessment studies utilize some combination of 'desk-research' and 'expert interviews/ surveys' or 'stakeholder workshops'. The ratio of this combination may vary significantly depending on accessibility of data and port personnel. As discussed later, expert interviews/ surveys become particularly relevant for developing countries, such as India, where robust, long-term data records may not be available.

It is important to remember that at the national or regional level all the ports taken together form the larger maritime transport network of a country. By corollary, it is also true that some ports may be more critical to the broader maritime sector than the others. Arguing for a holistic, multi-port approach to climate risk assessment and adaptation planning, McIntosh and Becker (2017) stated that *"at the single port scale, decision makers such as port managers may consider the uninterrupted functioning of their port the number one priority. But, at the multi-port (regional or national) scale, policy-makers will need to prioritize competing port climate-adaptation needs in order to maximize the efficiency of limited physical and financial resources and maximize the resilience of marine transportation system as a whole."*[19] Towards this end, the authors highlighted the lack of multi-port assessment studies and provided a critical review of the few indicator-based multi-port vulnerability assessments that have been published in recent years. The 'indicators' used in such studies typically include quantifiable, observable quantities, for instance, projected sea level rise, storm surge level, value of port assets, port efficiency measures such as turnaround time, etc., that can collectively be used to determine the vulnerability or risk of the system. One of the limitations of indicator-based assessments at multi-port level is the fact that the indicators need to be generic enough that they can be applied to all ports under consideration. While this may allow for a comparative analysis to be conducted which would generate a relative ranking of the ports according to their risk level, it limits of the scope of the indicators which may lead to an incomplete assessment of the risk. Nonetheless, a standardized approach to multi-port assessment would be highly relevant for India, since India has 12 major and over 200 non-major ports, and more ports are being planned under the central government's long-term development plans. Considering the limited financial and technological capacity of the country, it would have to prioritize the more vulnerable ports in the adaptation plans which would require a comparative multi-port assessment.

State-of-the-art in Climate Adaptation Measures for Seaports

With growing literature and increased awareness of the ways in which climate change impacts will affect coastal regions, coastal state/ city planners are increasingly acknowledging the need for implementing adaptive measures to minimize damages to infrastructure. However, in the port industry very few ports globally have actually taken appropriate adaptive measures.[20] Some studies have noted that this could partly be attributed to the difference in timeframes of port planning activities, which typically ranges between 5-15 years and the timeframes in which climate change impacts play out which could be over multiple decades, particularly in the case of sea level rise.[21] This myopic approach to infrastructure planning is, of course, a hinderance to climate adaptation planning in all sectors and at all levels of governments. In almost all cases, the critical maritime transport infrastructure has a lifetime of many decades and therefore their planning and maintenance processes must ensure resilience to medium- and long-term threats arising from climate change.

A wide range of adaptation measures for seaports have been proposed, analysed, and some have been implemented, in recent years. Adaptation measures could range from 'soft measures' such as changes in standard operating procedures, adaptation policies, emergency preparedness exercises, generating more accurate local-level climate projections, etc., to 'hard measures' which include infrastructural changes such as building seawalls/ storm surge barriers, expanding the dimensions of breakwaters, upgrading drainage systems, increasing elevation of infrastructure, etc., and everything in between. In this context, the city of Rotterdam in Netherlands provides an example of a holistic approach. The city set up the "Rotterdam Climate Proof (RCP)" programme, as part of the broader "Rotterdam Climate Initiative" of 2008, which aims to make Rotterdam resilient to climate change by 2025 while simultaneously generating opportunities to make the city more attractive.[22] The RCP is focused on five major aspects- flood management, accessibility, adaptive building, the urban water system and the urban climate. The RCP has laid specific emphasis on knowledge sharing, creating awareness, and promoting innovation in science and technology. The city founded the "Connecting Delta Cities" knowledge network, in 2009, as a part of its initiatives under the C40 climate leadership group. Some of the members of the knowledge network include Tokyo, Jakarta, Hong Kong, New York, New Orleans, London, Ho Chi Minh City, Melbourne, and Copenhagen. In 2021, the Port of Rotterdam Authority and the Municipality of Rotterdam jointly launched the "Flood Management Adaptation Strategy Programme" to protect the port and associated industries from the impacts of climate change including sea level rise, storm surges and increased likelihood of tidal flooding.[23]

The Port Authority of New York and New Jersey (PANYNJ) had integrated climate change mitigation and adaptation into their environmental sustainability policy in 2008 which recognized safety, resilience and environmental sustainability as its primary objectives. In 2009, the PANYNJ Engineering Department released the Climate Resilience Design Guidelines that demand climate risk factors to be incorporated into the design and construction of ports' buildings and other infrastructure. The design guidelines were further updated in 2015 and again in 2018.[24] The Port Authority completed the climate risk assessment focusing on flood-related risks across all port facilities in 2020. The follow-up multi-year programme was initiated in 2021 focusing on applying rigorous, engineering-based assessment techniques at the local level. Notably, the PANYNJ was the first public transportation agency in the USA that promulgated carbon emissions reduction targets to align themselves with the goals of the 2015 Paris Climate Agreement. It made commitments to reduce its carbon emissions by 35 per cent by 2030 and by 80 per cent by 2050.[25]

The city of Kaohsiung in ROC (Taiwan) which hosts the Port of Kaohsiung, ROC's largest international port, is highly vulnerable to the impacts of climate change including rising temperatures and frequent bouts of extreme weather events. In response to these growing threats, a number of measures have been taken by the city to enhance the resilience of its physical and social infrastructure, including large-scale restoration of wetlands to protect its coastline, upgrades to water management and drainage systems to mitigating urban flooding, construction of energy efficient 'green buildings', among others.[26] Notably, the Port of Kaohsiung received the 2021 World Ports Sustainability Program (WPSP) award for Resilient Physical Infrastructure. In Australia, several ports have undertaken extensive climate risk assessment studies in recent years and incorporated measures to mitigate socio-economic damages from the impacts of climate change. For instance, the Port of Melbourne adopted corporate climate change policy in 2007, a climate change action strategy in 2009 and became a signatory to the World Ports' Climate Declaration.[27] Other ports in Western Australia, Northern Territory and New South Wales have taken adaptive measures against flooding from cyclonic storms and sea level rise.[28]

The city of Jakarta in Indonesia is one of the largest coastal megacities in the world which is also considered to be one of the most vulnerable cities to coastal flooding, large parts of the city are already below sea level. Studies have shown that the primary cause for increasing flooding events in Jakarta is land subsidence being caused mainly by unsustainable and unmanaged extraction of groundwater for various industrial and domestic purposes.[29] The extent and frequency of coastal flooding will be worsened by accelerating sea level rise in the coming decades. According to model-based projections, the potential flood area extent is estimated to increase by 110.5 sq km by 2050 relative to 2000 levels.[30] The simulations also indicated that the rate of flood area expansion during the 2025-2050 would be 3.4 times faster than that in the 2000-2025 period.

The ports of Jakarta are severely affected frequently by tidal floods and storm surges. The Sunda Kelpa port is the oldest port in Jakarta spanning 52 hectares of land area. Some estimates suggest that the port is currently experiencing 5-10 cm of land subsidence per year, over the last two decades. According to port authorities, around 20 per cent of the annual income is spent on adaptation measures including protective dikes and raising the elevation of port infrastructure which is being done in a section-by-section manner.[31] Similarly, the Pelabuhan Perikanan Samudera

Nizam Zaham port which is the largest fishing port in Indonesia is experiencing 7-12 cm of subsidence annually. Consequently, the port elevation was raised in 2002 and then again in 2012 by +1.4 m. The Muara Angke port was also raised three times, in 2006, 2011 and 2014, by 40-50 cm each time using sheet piles.[32] Other studies have argued that the protective dikes that have been built are themselves vulnerable to sea level rise and increased frequency and intensity of tropical storms.[33] Moreover, measures such as increasing the elevation of port infrastructure are akin to "band-aid solutions", and very expensive ones at that, which focus on short-term adaptation rather than increasing long-term resilience of the infrastructure.

Moulding to the Indian Circumstances

As alluded to before, India has initiated a number of measures in recent years to expand its maritime transport sector and the broader Blue Economy. There is one thing that is common across all of these initiatives, that is the overwhelming emphasis on capacity augmentation and modernization. While that is commendable and necessary for economic growth, it is crucial to acknowledge and prepare-for current and projected threats arising from the impacts of climate change which may otherwise derail the ambitious expansion plans. There is an urgent need for a holistic and dynamic climate change adaptation strategy to ensure the protection and continued operation of the existing and planned port infrastructure. Clearly, this adaptation strategy will have to be based on a series of risk assessment studies at the national-, state- and local-levels. In this regard, the amount of literature in India is relatively sparse. For the first time in 2020, a comprehensive 'climate change assessment report' for India was published by the Ministry of Earth Sciences (MoES).[34] This much-needed report highlighted the observed and future projections of temperature, precipitation, sea level, extreme weather events and the Indian monsoon system, among other parameters, over the Indian region. In 2021, the Department of Science and Technology of the Government of India published a report entitled, "Climate Vulnerability Assessment for Adaptation Planning in India Using a Common Framework", which mapped all-India state-level and district-level vulnerability to climate change.[35] However, the report provided an incomplete picture because it was solely focused on determining vulnerability based on an analysis of the current state of infrastructure and state- and national-level policies. The report did not account for the current and projected evolution of climate-change related 'hazards' and the level of 'exposure' of the districts and states, which are necessary for quantifying 'risk'. The authors acknowledged this caveat and mentioned that additional studies will be conducted on these aspects in the future.

This lack of robust and reliable long-term data records and analyses of climate variables and local-level climate projections poses a major hurdle towards a quantitative climate risk assessment of ports in India. As discussed earlier, this limitation is often remediated, at least partially, by conducting interviews and workshops with domain experts and stakeholders to collect qualitative information-on and perceptions-of risk to infrastructure and operations. Insofar as adaptation measures are concerned, India would have to work within the national financial and technological limitations which may preclude the possibility of adopting the cost-intensive hard infrastructure solutions that have been adopted by the more developed cities/ countries, such as Rotterdam, some of which were discussed in the previous section. Consequently, India would have to utilize a creative combination of hard- and soft-measures, in other words, a combination of capacity building (that is the generation of material wherewithal) and capability enhancement (that is enhancing the human ability to manage the impacts), to build resilience against climate change.

Considering the national circumstances described above, the following interventions are recommended for policy makers in India at the national- and state-level governments to enhance the resilience of the country's port infrastructure:

Conduct comprehensive climate risk assessments of India's major and non-major brownfield ports, including asset- or area-specific details, in consultation with all relevant stakeholders including climate scientists, engineers, port authorities, local government officials, industry members, local businesses, and local community members including the fisherfolk. This could be incorporated as an actionable under the 'port-modernisation' goal of the Maritime India Vision 2030 (MIV-2030) to ensure security and continued functioning of existing ports. Additionally, pre-emptive climate risk assessments and adaptation planning for the current and projected impacts of climate change should be mandated for all greenfield projects proposed under MIV-2030.

A standardised framework is needed which can be applied to all ports to produce a comparative analysis of climate risk, which could then be compiled into a national-level assessment of the broader maritime transport sector of the country. This would allow the central and state governments, private entities, and port management authorities to identify the most vulnerable ports and the most vulnerable sections or assets within individual ports which should be prioritised for adaptation actions.

Climate change adaptation measures for ports could include 'hard measures' or 'soft measures' or a combination of the two. Due to limited financial resources in India, hard measures (which may include creation of protective infrastructure or retrofitting or relocating existing infrastructure) would require cost-benefit analyses to be conducted to identify the most viable options. Nature-based protective solutions such as creation of coastal dunes, conservation and plantation of mangrove forests, etc., should be seriously considered, in combination with the man-made protective infrastructure, which would provide cost-effective ways to reduce the impacts of floods and storm surges. The protection and conservation of such ecosystems would also provide additional ecological and socio-economic benefits for coastal regions. Conservation efforts are already being pursued by some of the coastal states in India; these efforts could be integrated with port planning and development to maximise the benefits.

Since ports form integral components of the city, state, and country's economy, and are inextricably linked with hinterland activities, there is a need for greater cooperation at these levels to generate a cohesive adaptation strategy. For instance, the resilience (or the lack of resilience) of hinterland road and railway networks, energy infrastructure, fisheries infrastructure, and other industries, against climate-change-induced hazards would have direct consequeces for port operations and efficiency. Therefore, city-wide or state-wide adaptation strategies that address the broader socio-economic systems would have to be developed accordingly. The examples of New York and New Jersey in the USA and Kaohsiung City in ROC discussed in Section 4 provide insights into combined port and city climate adaptation strategies that have been attempted.

Importantly, the adaptation strategy must account for the dynamic nature of climate change. The impacts of climate change are expected to continue to grow at an accelerating rate even in the more optimistic future scenarios. Moreover, there are new phenomena that are being discovered constantly that challenge our past predictions, especially with regard to sea-level rise and the intensification of extreme weather events. Therefore, the adaptation measures cannot be short-sighted, one-time efforts but should leave room for further changes and updates as we learn more about these natural processes and their interactions with human activities. This is also important because protective measures that involve construction of hard-infrastructure such as seawalls, breakwaters or support structures to increase the elevation of port infrastructure are capital- and time-intensive and, therefore, require careful planning to ensure long term sustainability. Along the same lines, it is necessary to put in place mechanisms for monitoring and evaluation of the adopted measures and re-assess the risks at regular intervals, every five to ten years. Devising and implementing a holistic and dynamic climate adaptation strategy for seaports will not only ensure a secure and sustainable maritime transport sector but also facilitate India's ambitions of becoming a leading Blue Economy of the world.

Finally, it must be recognised that some regions may be beyond adaptation and would be completely inundated by sea level rise in the coming decades. In India, this is particularly relevant for the Bay of Bengal region and the Sundarbans delta in particular which is experiencing a much faster rate of sea level rise than the global average due to a combination of geographical and anthropogenic factors. The ports in such regions would have to be systematically decommissioned or relocated to other regions. Therefore, planned retreat should also be considered as an adaptation action that may become increasingly necessary in the future.

Conclusion

As global warming continues unabated, the knock-on effects of rising atmospheric and oceanic temperatures such as more frequent and intense extreme weather events (heatwaves, heavy precipitation and tropical cyclones) and accelerating sea level rise pose major threats to coastal regions around the planet. For the maritime trade sector, these climatic changes will have direct impacts on the port infrastructure and the ability of the ports to maintain maximum operational efficiency. As discussed in detail in the paper, in India, more frequent extreme weather events are already affecting port operations which lead to downtime ranging from a few hours to several days. Collectively, these operational downtimes can add-up to major economic losses for the country. In the coming decades, climate-change-induced sea level rise will significantly worsen the impact of cyclonic storms and tidal flooding and will emerge as an irreversible threat to the port infrastructure. Adapting brownfield ports to sea level rise may require significant modifications to the existing infrastructure (such as raising elevation) or building protective infrastructure such as breakwaters or storm surge barriers, all of which will require long-term planning and huge financial costs.

While India has taken several measures in recent years to expand its maritime sector, there are no national- or local-level strategies to protect the port infrastructure and operations against the growing impacts of climate change. A stark example of this is the lack of emphasis on climate change adaptation in the Maritime India Vision 2030 which is the guiding document from the Ministry of Ports, Shipping and Waterways for the maritime trade sector for the next decade. In this context, this paper highlights the need for a holistic and dynamic climate change adaptation strategy for India's port ecosystems and provides recommendations for a way forward based on a comprehensive literature review of international best practices. The adaptation strategy must be built upon rigorous and comprehensive climate risk assessments of the ports and interdependent supply chains to determine the internal and external vulnerabilities to the impacts of climate change. A standardized national-level risk assessment framework would be critical to conduct a comparative vulnerability analysis of India's major and non-major ports to identify the most vulnerable ports which may require priority action from the central government (in the case of major ports) or respective state governments (in the case of non-major ports).

Moreover, considering the dependencies of the port on the broader city activities and vice versa, the adaptation strategy must take an integrated approach and incorporate the needs and limitations of all stakeholders including the city authorities, industries, local communities and businesses. As discussed in the paper, the ideal adaptation strategy should be based on a combination of infrastructure-level and operational-level solutions which considers not only capacity-building but also capability-enhancement measures. Devising and implementing a holistic and dynamic climate adaptation strategy for seaports will not only ensure a secure and sustainable maritime transport sector but also facilitate India's ambitions of becoming a leading Blue Economy of the world.

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Note

This research was supported by the 2021-22 Fellowship of the Coalition for Disaster Resilient Infrastructure (CDRI), Application ID 201104207. The authors would like to thank Mr Kevin Jose and Ms Sakshi Savita for their contributions in analysing the impacts of climate change on India's major ports

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Ports and Climate Uncertainty: An Economic Imperative for India

Dr Saurabh Thakur

Ports are the critical nodal points in globalised trade and commerce. They act as the threshold space that links the vast hinterlands with critical supply chains of an interconnected and interdependent world market. Further, they act as catalysts for growth and sustenance of nearby industries and communities, and provide an ecosystem for the growth of domestic markets and stakeholders.[1] Historically, port cities have been the epicentre of human economic productivity and socio-cultural exchange; and the port itself, by dint of its geographical location, has acted as the mediating space between the land and the sea.

Ports have played a critical role in shaping the political and economic destinies of nations. Currently, 90 per cent of trade by volume in India docks at its 12 major and nearly 200 minor and intermediate ports.[2] Over the past a few decades, the People's Republic of China has witnessed a staggering rise in its port cargo throughput, which, much like the pattern of its overall economic growth, has risen from 0.40 to 8.08 billion tonnes, with coastal provinces like Zhejiang, Fujian, Jiangsu, and Guangdong as the epicentres of this growth.[3] In the case of the United States (U.S.), the total economic impact of port sector exceeds US$4.5 trillion annually and the maritime transport sector provides nearly 23 million jobs.[4]

As the port industry undergoes rapid transformational changes, including artificial intelligence, big data analytics, information technology-driven infrastructure, smart grids, changes in trade routes, demographic shifts, and sustainability challenges, the future global port landscape appears to be on a markedly different path.[5] A critical component of this change will include attitudinal and policy shifts on the questions of nature of climate risks, adjustments for future uncertainty, and investments into climate resilience strategies of ports. A 2017 survey by the United Nations Conference on Trade and Development (UNCTAD) reported that 72 per cent of the responding port authorities were impacted by extreme events, which led to delays (60 per cent), operations disruptions (76 per cent), or physical infrastructural damages (45 per cent).[6] Given a port's vital role in the global supply chains and their deep backward linkages, rise in the frequency and scale of port disruptions, such as extreme weather events and pandemics, may prove to be a critical threat to national and international economy (see Figure 1).

Accuracy of predictions and forecasting of trends are a fundamental basis for the planning of ports and port-led development. Future trends in the shipping and port sectors are going to see a complex interplay of technological shifts, hinterland politics, health of oceans, and global competition. Therefore, the tools and techniques of forecasting must be updated to incorporate all new and emerging factors. The climate crisis is one such factor which is rife with uncertainty, and the emerging scientific evidence as well as information gaps and imperfections in the understanding of its interactions with the wider socio-economic systems make it the most complex challenge for vital sectors of economy such as ports and shipping.[7] This chapter will shed light on the nature of this climate uncertainty and the economic

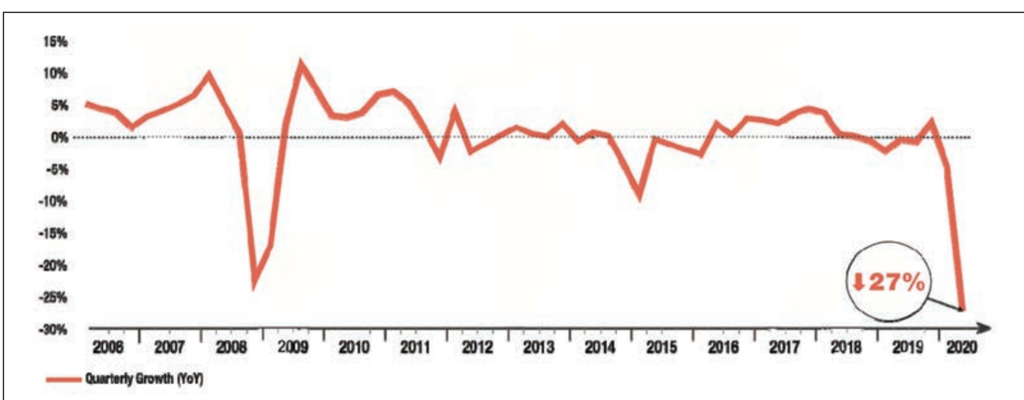

Figure 1: Trends in global trade (percentage change).
Source: UNCTAD, "COVID-19 and Maritime Transport Impact and Responses", *Transport and Trade Facilitation Series* No 15, 2021, https://unctad.org/system/files/official-document/dtltlb2021d1_en.pdf

impacts of climate change on the ports sector. The first part of the chapter will focus on examining climate uncertainty, tipping points, and social cost of carbon (SCC), which are critical part of the current economic thinking and debates on climate change. The second part will focus on port economics and the rising threat of climate change to port infrastructure, supply chains, and future business prospects. The main argument presented in the chapter is that there is a strong economic case for India to err on the side of pre-emptive planning and climate-resilient port development in order to secure against future uncertainty.

Ports and Climate Disruption

Natural disasters and anthropogenic climate change, which are accelerating the frequency and scale of such disasters, are affecting the ports in multiple ways. Given the critical role that port infrastructure, operations, and supply chains play in the interconnected global markets, the heightened vulnerability to future changes to water, oceanic, and atmospheric conditions will be an important point of concern. A port disruption can lead to severe economic and infrastructural losses, as has been the case with multiple cyclones hitting the shorelines of tropical nations. For instance, India's busiest port, Jawaharlal Nehru Port in Mumbai, which handles almost 52 per cent of all cargo traffic in India (see Figure 2), had to suspend vessel berthing operations for almost two days due to the landfall of Cyclone Tauktae in May, which resulted in delays at Nhava Sheva;[8] and this upward trend is further expected to result in higher instances of port disruptions and blank sailings. The delays also led to greater congestion at the port, which directly impacted the importers who had to pay higher rates for demurrage – a cost that will finally have a cascading impact on the customers.

A similar story unfolded at the port of Pipavav in Gujarat, run by a private enterprise, where the port authorities declared force majeure due to the disruption in critical infrastructure of power supply and communication that led to operational delays and diversion of cargo traffic.[9] Further, disruptive events like cyclones and flooding have caused damages to the breakwater, and also led to other construction-related delays, at the upcoming international multipurpose deep-water seaport project

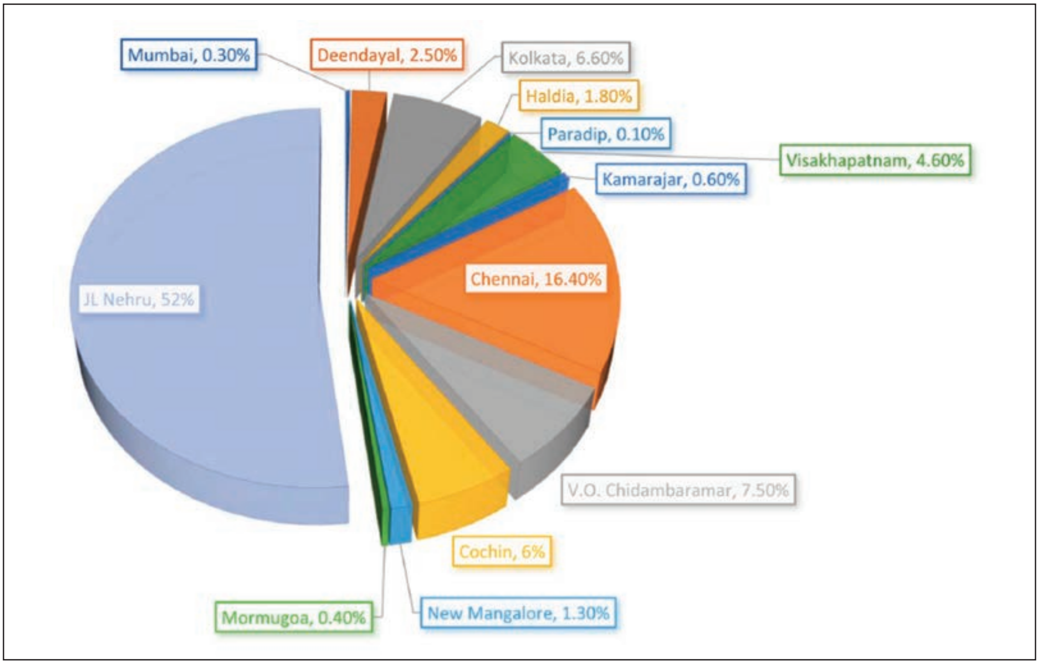

Figure 2: Share of major port container traffic in 2018-2019.
Source: Basic Port Statistics of India (2018-19), Ministry of Shipping, GoI, 2020, https://shipmin.gov.in/transport-reseach/basic-port-statistics

at Vizhinjam in Kerala, which is expected to compete with Sri Lankan port as the preferred port of call for transhipment. Currently, the ports in Colombo, Singapore, and Jebel Ali (Dubai) handle 62 per cent of India's transhipment cargo, which adds to both the costs as well as transit time of the cargo.[10]

The first-ever regional climate assessment report published by the Ministry of Earth

Sciences, Government of India, notes: *"There has been a significant reduction in the annual frequency of tropical cyclones over the NIO basin since the middle of the twentieth century (1951–2018). In contrast, the frequency of very severe cyclonic storms (VSCSs) during the post-monsoon season has increased significantly (+1 event per decade) during the last two decades (2000–2018)."*[11] In recent decades, rainfall occurrences of unprecedented intensity have also been witnessed during the Indian summer monsoon season, which has brought major coastal cities – Mumbai (2005, 2014, 2017), Chennai (2002, 2004, 2005, 2006, 2007, 2015), and Kolkata (2007, 2017) – to a crippling standstill.[12]

The Right Time for Climate Action?

Today, how should ports weigh the value of costs and benefits that will accrue in future? The cost–benefit analysis of climate action has been a long-standing debate which can be understood through the concept of SCC, which, essentially, *"tries to add up all the quantifiable costs and benefits of emitting one additional tonne of CO2, in monetary terms. This value can then be used to weigh the benefits of reduced warming against the costs of cutting emissions."*[13]

This vexing question of SCC has been traditionally addressed by the economists through the method of discounting.[14] Social discount rates (SDRs) are used to assign a present value on costs and benefits that will occur in future. The debate between Lord Nicholas Stern, the author of the Stern Review: The Economics of Climate Change,[15] and William Nordhaus, the 2018 winner of Nobel Prize in Economics, essentially dealt with this broad question: whether we should act on climate incrementally or should one opt for immediate precautionary efforts to avoid catastrophic and irredeemable losses in the future? The Stern Review assumed: *"a dollar of economic damage prevented a century from now (adjusted for inflation) is roughly as valuable as a dollar spent reducing emissions today."*[16] Nordhaus challenged this assumption, arguing that the burdens of climate change can be discounted in the present as it will only have a marginal impact on the global gross domestic product (GDP) and the future generations will be richer and better equipped to handle the crisis. Nordhaus developed the integrated assessment models (IAMs), particularly the Dynamic Integrated Climate Economy (DICE) model, which allowed scientists to assess divergent economic pathways and their implication for climate change and well-being of future generations.[17] The smooth relationship that Nordhaus predicts between the economic impacts and increasing temperatures has been critiqued extensively. Also, the underlying assumptions within the DICE model, particularly its choice of high discount rate, which is a critical element in determining the pace of decarbonisation, have raised concerns in recent years.[18]

Stern, on the other hand, suggests a lower discount rate, which makes it easier to rationalise a higher investment in costly technological changes in the present. Unlike Nordhaus, Stern rests greater faith in bottom-up technological progress which, he argues, can cut down costs of climate mitigation drastically by the year 2050 for an abatement level up to 75 per cent.[19] Nordhaus critiqued the Stern Review as "political in nature", which essentially has "advocacy" at its main purpose.[20] The ideas such as SCC and discount rates remain hotly debated and there may be a temptation on the part of non-economists to dismiss their practical utility, but it is clear that IAMs, such as the DICE model, are now an integral part of decision making.[21] In the case of ports and port-led development models, the economic question is of paramount concern. Much like in the case of shipping sector – which was excluded from the 2015 Paris Agreement on account of the international nature of the activity, which is difficult to address through a framework of national commitments alone – the ports sector too has paid little attention to the climate question. The performance of ports is heavily reliant on the health of oceans and port authorities will find themselves increasingly under pressure to wrestle with the question of climate uncertainty and its impact on economic performance of ports and resilience of port infrastructure and operations. However, the task of incorporating elements of climate uncertainty into decision-making processes, such as the future of port development, remains an uphill challenge.

Understanding Climate Uncertainty: Risks and Tipping Points

Martin Weitzman, an economist, describes the most striking characteristic of climate economics to be its extreme downside, which, he argues, remains non-negligible. He notes, *"deep structural uncertainty about the unknown unknowns of what might go very wrong is coupled with essentially unlimited downside liability on possible planetary damages."*[22]

The lexicon of climate change economics has always carried the weight of risk, uncertainty, and liability as its core concern; and this is reflected in the United Nations Climate Change Conference of the Parties negotiations, which are currently stalled on the outcomes of Article 6 that deals with carbon markets.[23] Within the specific context of climate change economics, the notion of uncertainty is not limited to the classical understanding of risk, where the probability of a certain event occurrence is known. It has to take into account the notion of future risk, which is largely unknown and uncertain. It further lacks any clear consensus on the assignment of probability due to a lack of information or vastly different predictions and opinions derived from different scientific models and data sets.[24] The scientific models serve as an important and incisive tool to organise knowledge, predict outcomes, and map out the relationship between multiple variables.[25] In the environmental economics domain, models can be categorised into scientific and economic models. The former concentrate on the ecological and biophysical impacts and long-term consequences of rising greenhouse gas (GHG) concentrations and emissions, while the latter concentrate on cost–benefit analysis and assessment of alternative strategies, such as renewable transition.[26] The IAMs, a hybrid form of these two models, are commonly used to assess the SCC, as discussed in the previous section.[27]

These models provide a map of different pathways to the future, which can guide policy changes. However, they lack the precision that can entirely overcome uncertainty, which, for example, in the case of scientific models of temperature projections may "differ by the lead time of the prediction, and even by geographical region".[28] Similarly, in economic models, the objective probability remains a crucial hurdle, along with the difficult task of assigning economic value to indicators, such as health of the future generations, reducing health of ecosystems, biodiversity, and cost–benefit analysis. The 2007 Intergovernmental Panel on Climate Change (IPCC) report notes: "*Where we cannot measure risks and consequences precisely, we cannot simply maximize net benefits mechanically. This does not mean that we should abandon the usefulness of cost-benefit analysis, but it should be used as an input, among others in climate change policy decisions.*"[29]

The IPCC had introduced the idea of tipping points two decades ago, which has gained greater traction among policymakers in recent years. The idea was largely mooted as a precautionary approach against a low probability scenario, rather than a definite threshold. At the time of its conception, the scientific predictions regarding large-scale discontinuities in the climate system were limited to future scenario where global warming would exceed 5°C above pre-industrial levels. This prediction has sharply changed in the recent years, especially with the publication of IPCC special reports, which suggest that erring on the side of inaction would be inadvisable as tipping points could now be exceeded between 1°C and 2°C of global warming.[30]

While the future uncertainty and SCC are important ways to understand climate change economic risks, it is also equally important to observe the recent historical trends to understand the business risks of climate change. A rating agency's recent paper highlights the credit implications of physical climate change: *"While our sovereign bond rating methodology does not account separately or explicitly for the credit risks posed by climate change, climate risks are already broadly captured in the four key risk factors we use in our analysis – economic strength, fiscal strength, institutional strength and susceptibility to event risk – either directly or indirectly through a variety of indicators."*[31]

Ports and climate change: Impacts and strategies

The rate of increase in synoptic-scale weather disturbances, like tropical cyclones and coastal flooding, that last for a few days and rising trends for sea surface temperatures and sea level rise in the Indian Ocean Region carry severe consequences for port operations and supply chain management. These relate to the chain of external systems and internal assets and activities on which a port's commercial success relies.

Trade patterns and demand

(1) Climate change is a planetary-scale phenomenon that is increasingly shaping the geophysical and geopolitical state of the world. Its impact on the global economy will be disruptive and, in most cases, damaging. Commercial ports are dependent on the vitality of the shipping sector and the overall GDP of the country. The Stern Review estimated that the average costs of climate change could be up to 1.25 per cent of global per capita consumption by the 2050s, which will mean heavy annual revenue losses for the ports. The high-risk, low-probability events, the unknown unknowns, will also affect the port

sector heavily, as has been the experience during the COVID-19 pandemic and the 2008 economic downturn. Economic losses, which includes direct loss in the form of critical infrastructure and operational disruptions/delays, will affect the tropical countries the most due to high instances of cyclones, storm surges, and waves.

(2) The Northern Sea Route, which runs from the Barents Sea to the Bering Strait between Siberia and Alaska, is increasingly becoming accessible due to the melting of ice in the region. The new sea route, which will be 4000 nautical miles shorter compared to the Suez Canal, will carry severe ecological implications: for instance, black carbon from ships could lead to loss of reflective capacity of the earth, which would be "*equivalent to adding one trillion tons of CO_2 to the atmosphere, on top of the 2.4 trillion tons emitted since the Industrial Age.*"[32] Apart from contributing to the global sea level rise and acceleration of global warming, this new sea route will lead to "*remarkable shifts in trade flows between Asia and Europe, diversion of trade within Europe, heavy shipping traffic in the Arctic and a substantial drop in Suez traffic.*"[33]

(3) Climate disruption may also lead to supply-side disruptions. The supply of raw material, especially agricultural products, is highly vulnerable to changes in climatic patterns and will directly impact the supply flows to the ports where the agricultural items of trade are a critical source of revenue. Changes in the pattern of economic development may have an impact on the location of economic clusters, which will further affect the port–hinterland connections. Notteboom et al., in a comparative study of the impact of the 2008 recession and COVID-19 on shipping, note: Changes (declines) in consumption patterns (demand) are related to the type of goods and related services.…Basic goods (also labeled essential goods such as food and household items) and luxury goods (fashion items) tend to be the most resilient. …However, recessionary forces can have significant impact on the demand for durable goods (e.g. cars, appliances, computers), discretionary goods (e.g. electronics, apparel), and capital equipment (e.g. ships, trucks, machinery, and port infrastructure).[34]

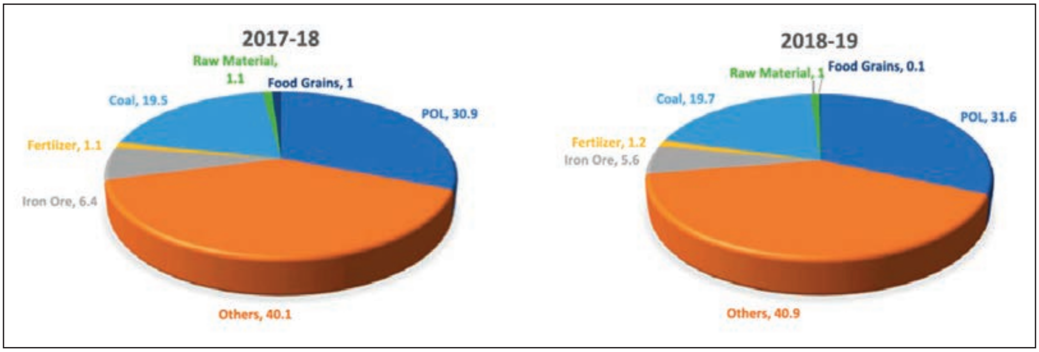

Figure 3: Percentage share of commodity-wise traffic handled at major ports of India (2017-2018 and 2018-2019).
Source: Ministry of Shipping, Basic Ports Statistics of India (2018-19).
Note: POL: petroleum, oil, lubricant

(4) Rick Bosman et al. define transition as a radical, structural change of a societal (sub)- system that is the result of the co-evolution of economic, cultural, technological, ecological, and institutional developments at different scale levels. It comes about through the simultaneous build-up of sustainable alternatives and the breakdown of existing unsustainable practices.[35]

A blue–green transition will require weaning off the fossil fuels, which are the major commodities of trade at ports in India (see Figure 3). Port authorities will have to take into consideration such transformative changes in the global economy to stay relevant and ahead of the curve. Trade will be the major concern for ports from the perspective of climate change and, therefore, it merits further research.[36]

Port Infrastructure and Operations

(1) Biophysical changes, such as the average sea level rise, will affect port operations and infrastructural demands in the long term.[37] The rise in sea levels can prove useful in some cases: for example, the dredging requirements at the port would go down, thereby lowering the marine traffic congestion and reducing operational expenditure on maintenance of navigable waterways.[38] However, longer and frequent spells of precipitation, drought, and tropical cyclones will reduce the capacity of ports to function without disruption and delays. Damages to the cargo and port infrastructure from such incremental

and abrupt high-impact events will cause changes to the coastline, such as inundation and wave regime changes. Franco-Ochoa et al. Note: Currently, the global mean sea level and wave energy are increasing at rates of 3.26 mm and 0.4 per cent per year, respectively. However, a precise quantification of regional rates is much harder and depends on factors such as the local wind energy, the sea water temperature and tectonic uplift/subsidence motions, among others.[39]

Consequently, it is critical that each port carries out its regional climate risk assessments, and also invest in technologies and infrastructure for downscaling of climate data to make effective operational forecasting at local scales.[40] This will facilitate ports to counter incremental and abrupt changes, as well as anticipate high-impact, low-probability events more effectively.

(2) A container terminal can be described as: *"open systems of material flow with two external interfaces. These interfaces are the quayside, with loading and unloading of ships, and the landside, where containers are loaded and unloaded on/off trucks and trains."*[41] High winds, droughts, and high waves pose a direct risk to port terminal operations and safety, especially navigability and berthability of ships. This is likely to increase maintenance costs, dredging expenditures, risks of spoilage of cargo, demurrage, operational delays, along with reducing port access and operability range of equipment like quay cranes, which cannot be used above certain wind speeds and precipitation levels. The port is also heavily dependent on its hinterland connections through roads, railways, and inland waterways networks, which are critically exposed to extreme weather events. Therefore, the catchment area of concern for port operations falls well beyond its location and must take into account the emerging climate risks in both the foreland as well as the hinterland.[42]

(3) The critical infrastructure of ports, that includes its power supply, transport, data communication network, and marine traffic service towers, is increasingly at risk due to disruptive events. Such disruption leads to terminal closure and heavy revenue losses. Climate resilience and adaptation measures, therefore, acquire a critical importance in maintaining operability of ports

and enhancing their capacity to bounce back from extreme conditions. The COVID-19 experience has catapulted adaptative management strategies to the forefront as the "new normal" sets in the global trade and shipping. There are multiple examples of such approaches that were taken up during the pandemic. In the ports of Rotterdam and Hamburg, a submission of Maritime Declaration of Health (MDoH) was made mandatory before arrival or exit from the port. The Hamburg Port Authority also decided to defer rents and charges for operations at the port. The Northern Corridor and the East Africa Community (EAC) created an online platform for exchange of information, practices, and experiences during COVID-19 to enhance the resilience of supply chains and minimise losses.[43] Future adaptation strategies must include investments in climate-resilient infrastructures, such as allowances for sea level rise;[44] upgradation and regular review of dredging programmes and drainage systems; redesigning flood response plans taking into account the latest scientific data; development of closed systems for handling goods; investments in wind speed monitoring and prediction systems; and development of guidelines and protocols for extreme weather events which will improve and safeguard the safety and security of staff and labour.[45]

(4) Apart from trading operations, ports are also knowledge hubs which facilitate several economic activities and influence lives and livelihoods of people who live in their vicinity. Initiatives such as port-led development models of growth are going to be central to the development of blue economy. The harbours are critical source of employment generation for local fishing communities, labour, and mechanics who depend on port facilities. A resilient port strategy must ensure that the health and safety of its workforce is enhanced to maintain productivity and community participation.[46]

(5) Apart from the capacity-led arguments in favour of climate-resilient ports, which includes grey and green infrastructures as well as operational and adaptation strategies, there is also a need to acknowledge the critical distinction between ports in developed and developing countries and the higher vulnerability of states, particularly small island states, to climate extremes.

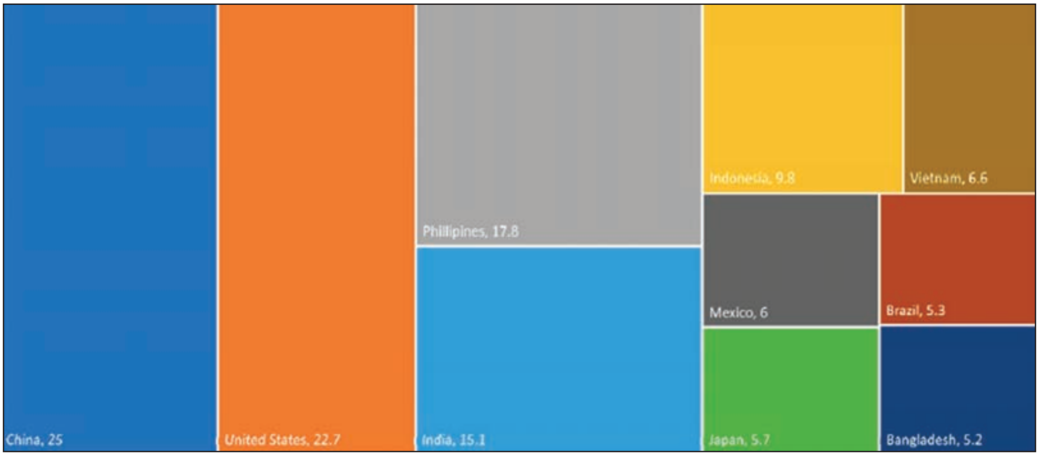

Figure 4: Number of climate-related disasters (average 10 years).
Source: Compiled by author from "How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issues", Moody's Investors Service, 07 November 2016, https://www.eticanews.it/wp-content/uploads/2017/01/Moodys-climate-change-and-sovereigns-November-7.pdf

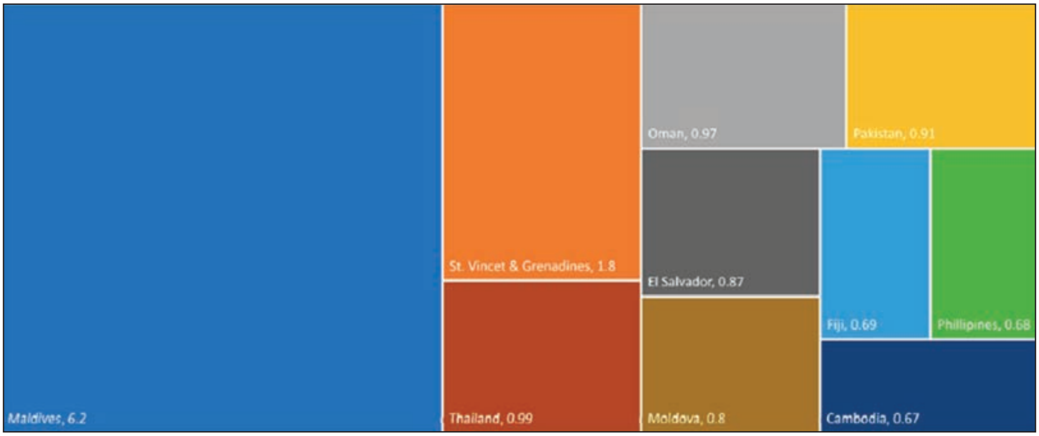

Figure 5: Economic damage (percentage of GDP; average 10 years).
Source: Compiled by author from "How Moody's Assesses the Physical Effects of Climate Change on Sovereign Issues", Moody's Investors Service, 07 November 2016, https://www.eticanews.it/wp-content/uploads/2017/01/Moodys-climate-change-and-sovereigns-November-7.pdf

The simple comparison of statistics regarding countries experiencing highest number of climate-related disasters (see Figure 4) and the countries with maximum economic damages as a percentage of GDP (see Figure 5) brings out the contrasts between nations to the fore. Countries like the U.S., India, and China face a higher percentage of climate-related disasters, but it is the countries with lesser capabilities and capacities, such as the Maldives, which are the least economically resilient to face such disasters.

Conclusion

The following paragraphs address some of the major strategies that Indian ports must adopt in order to counter the threats of climate change. Future proofing port infrastructure, as has been outlined earlier in the chapter, is a complex interplay of range of factors including assessment of future risks, political and economic feasibility of interventions, and potential negative effects of climate interventions. Some key strategies to counter these impacts are discussed below.

Climate proofing of ports

The initial sections of the chapter have highlighted the critical importance of understanding climate uncertainty. Scientific and economic models facilitate a road map to the future. Foresight has been a key characteristic of global trade, and accurate forecasts have managed to improve the functioning of ports, save lives, mitigate the impacts of extreme weather events, and prevent economic losses. Therefore, it is critical that port authorities and governments invest in new approaches to tackle climate uncertainty.[47] There are a number of approaches and policy experiments that have been employed to tackle uncertainty, such as dynamic strategic planning approach,[48] multi-criteria analysis,[49] adaptive port planning,[50] assumption-based planning,[51] and what-if analysis and scenario analysis.[52] The ports in India are highly vulnerable to extreme weather events in short, medium, and long term. While the short-term planning, where the climate risk is determinable, can be based on predictive models of forecasting, the long-term risks remain uncertain and unknown and require adaptative planning as well as multiple scenarios planning to develop alternatives. Climate proofing the port infrastructure will require a holistic risk-based approach to planning, which entails *"identifying risks to a development project, or any other specified natural or human asset, as a consequence of both current and future* *climate variability and extremes, and ensuring that those risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable, and socially acceptable changes implemented at one or more of the following stages in the project cycle: planning, design, construction, operation, and decommissioning."*[53]

While the precautionary principle remains central to dealing with the unknown unknowns, it is equally important for stakeholders to invest in building resilience, that is, the ability to bounce back, and adaptive robustness, which implies that states must be prepared to change their plans and strategies in case the conditions change.[54]

Mainstreaming of blue–green solutions

The process of mainstreaming green solutions as part of long-term adaptive strategy remains a pipeline dream. One key way of mainstreaming adaptative measures is to treat ports as liminal spaces rather than fixed infrastructural assets. This requires greater synergies between the specific port development models, subnational level governance and planning, and national-level strategic vision. Therefore, in the case of India, initiatives such as the Sagarmala and Maritime India Vision 2030 must align with other key goals, such as the Security and Growth for All in the Region (SAGAR), blue economy, Sendai Framework for Disaster Risk Reduction 2015–2030, Sustainable Development Goals, and nationally determined commitments under the Paris Agreement.

A contextual approach

Dupuis and Biesbroek made an important intervention in adaptation studies by highlighting the "dependent variable problem", which they define as *"the indistinctness of the phenomenon that is being measured and the fuzziness of its scope and boundaries, which leads to contradictory results and difficult comparisons between studies…if comparative research on adaptation policy is to evolve toward more explanatory ambitions, the dependent variable problem should be considered and addressed."*[55]

They critique the comparative methods utilised to study adaptation policies at a national level for its conceptual indistinctness, inadequate research design, and unclear indicators. Adaptation is predominantly understood as a context-dependent problem. Its operationalisation on the ground has been idiosyncratic, which tends to fluctuate from one country to another, one state to another, and one port to another. Therefore, a holistic approach to climate adaptation of ports cannot merely be adoption of best practices from another country. It must meet two critical parameters. The first parameter is "intentionality", which implies that port authorities in India must treat climate change policy as a distinct problem, both as a mitigation as well as adaptation challenge, pre-empt and prepare for its future implications, and adopt decision-making approaches that allows for the incorporation of the phenomenon of climate change in their short to long-term planning. The second key parameter is "substantiality", which implies that adaptation measures taken up by ports must directly contribute towards a reduction in vulnerability of ports.[56] This requires the Indian port authorities to carry out substantial climate risk assessments, which can provide a more substantial view of climate risks and facilitate the transition of Indian ports to a new climate regime.

Framing the climate change crisis

While sustainability and environmental monitoring measures at India's major ports have increased in recent years, particularly pollution control, ambient air monitoring, marine water quality, and plastic management, there is a conspicuous absence of adaptation framing of the issue, which relates to the threats that climate change impacts pose to the port infrastructure, workforce, and operations. Therefore, the challenge of climate change uncertainty for the Indian port authorities is a question of framing of the issue itself, which will give equal weightage to both mitigation and adaptation outcomes. The climate resilience of ports is intricately linked with economic viability of sustainability measures and regulations, and the government's willingness and effectiveness in making the process of blue and green transitions just and economically viable for all the stakeholders who are involved in this industry.

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Note

The author would like to thank Dr Pushp Bajaj and Dr Chime Youdon for their valuable comments and suggestions. This research was supported by the 2021–2022 fellowship of the Coalition for Disaster Resilient Infrastructure (CDRI), Application ID: 201104207

This article was first published online on 03 February 2022 in Maritime Affairs: Journal of the National Maritime Foundation of India, Vol 17, Issue 2 and is reproduced here with due permissions from the Publisher. The format of the article and the references have been modified in accordance with the formatting style of the book. The main text of the article remains unchanged

Offshore Wind Energy, Sagarmala, and the Blue Economy

Priyanka Choudhury, Akshay Honmane, Dr Sameer Guduru, and Dr Pushp Bajaj

The SAGARMALA Project and Predicted Energy-Requirements

Launched in 2015, the SAGARMALA Project (SP) is a contemporary, mega undertaking of the Government of India (GoI) that is aimed at 'port-led' comprehensive and holistic development of the country as a whole. Its stated vision is to *"reduce logistics cost[s] for both domestic and EXIM cargo with minimal infrastructure investment."*[1] The four principal pillars of the project are: (1) port modernisation, (2) port connectivity, (3) port-led industrialisation, and (4) coastal-community development. The first three pillars and the thrust-lines along which they are developed are almost entirely focussed upon one or another facet of 'ports'. The follow-through mechanisms in respect of these three pillars all seek to improve efficiency and productivity (recognising, of course, that these are not synonymous terms). The more these factors of efficiency and productivity are aligned to the UN Sustainable Development Goals (SDGs), the 'bluer' the Indian economy will become.[2]

Port modernisation entails incorporation of emerging technologies related to "Industry 4.0" such as Internet of Things, 5G, digitalisation of port infrastructure, etc., while port-connectivity encompass the multi-modal transportation of goods, involving the creation or enhancement of rail, road, pipeline, and inland waterway networks. New (Greenfield) ports and improvements in connectivity attract new investment and fuel the growth of industrial clusters to support all three models relevant to port-led industrialisation, viz., the energy-based model, the materials-based model, and, the export-oriented discrete-manufacturing model. The existence and growth of these clusters, in turn, leads to the migration of people to coastal areas in search of employment and better opportunities. Irrespective of which of the three models of port-led industrialisation is predominant, the clusters themselves require substantial inputs of energy in one or another form. Consequently, it is fairly common to find thermal power plants and petrochemical complexes being located in coastal areas due to the proximity of the port, which ensures easy access to raw materials such as coal, natural gas, and crude oil that are typically transported by ships.

India, being one of the biggest consumers of energy resources, is also the third biggest polluter in the world and contributes significantly to greenhouse gas (GHG) emissions. Around 98 per cent of the country's transportation sector and over 60 per cent of electricity production is dependent on fossil fuels.[3] For a lower-middle-income country that is highly vulnerable to the impacts of climate change and with a per capita GDP of approximately USD 2000,[4] reduction in greenhouse gas (GHG) emissions must be an integral part of any major development plans. This is especially relevant in the context of development in coastal areas which are likely to face the brunt of climate change in the form of sea-level rise and increasing extreme-weather events, such as cyclones and tidal floods. While on the one hand, the SAGARMALA project aspires to reduce carbon emissions by an estimated 12.5 million tonnes (MT) annually,[5] ironically, the project also envisages cheaper transportation of coal through coastal shipping and the development of thermal power plants and petrochemical refinery projects in its planned industrial-corridors such as the Vizag-Chennai Industrial Corridor (VCIC). In order to be sustainable and reduce India's long-term carbon emissions, there is a need to incorporate provisions to facilitate clean, renewable energy in the SAGARMALA doctrine. In addition, the carbon footprint of ports is either explicitly or implicitly related to cargo-handling operations, exhaust from ships, power plants providing energy for ports, harbour crafts, rail locomotives, trucks, etc.[6] This chapter establishes reasons for exploring Offshore Wind Energy (OffWE) to power the SAGARMALA vision. The authors advocate the use of OffWE, particularly in the vicinity of India's minor and upcoming ports. OffWE has the potential to power ports, shore-based industry, coastal communities as well as the tourism sector, and, thereby, further India's endeavour to transition to Blue

Economy. The chapter concludes by discussing the key challenges both in terms of practicality and policy in the wider adoption of OffWE in India.

India's Ambitious Climate Targets

In progressing a global strategy to mitigate climate change, the 2015 Paris Agreement mandated the member States of the United Nations Framework Convention on Climate Change (UNFCCC) to provide individual proposals to reduce their GHG emissions through 'Intended Nationally Determined Contributions' (INDCs). India intends to reduce its 'emissions intensity' (emissions per unit GDP) by 33-35 per cent from the 2005 levels, and to produce 40 per cent of cumulative power from non-fossil fuel based energy resources by 2030.[7] In its movement towards this goal, India aims to achieve 175 gigawatts (GW) of clean energy capacity by 2022, of which 100 GW would be of solar energy and 60 GW of wind energy.[8] The long-term targets that have been set by India are the production of 450 GW from renewables by the year 2030, with 300 GW exclusively from solar and 140 GW from wind power.[9] These targets have also been motivated by the UN SDG #7, which aims to provide affordable, reliable, sustainable, and clean energy for all. These targets are highly ambitious and India may well fall short of achieving them due to various reasons. As on 30 April 2020, 87 GW of renewable capacity addition had been achieved with the share of Solar being 35 GW and that of Onshore Wind Energy (OnWE) being 37 GW. Insofar as solar photovoltaics are concerned, due to the lack of indigenous manufacturing, India is primarily dependent on cheap imports from China. The heightened tensions between the two nations along the Himalayan frontier could lead to increases in import costs and customs duties.[10] The ensuing section discusses in detail the challenges associated with solar and OnWE adoption in India.

Challenges Associated with Conventional Onshore Wind and Solar Energy

India's energy demand is persistently increasing with the primary energy demand reaching 906 million tonnes of oil equivalent (MTOE) in 2019.[11] According to the

NITI Aayog, India's energy demand will double by 2040 and the electricity demand, specifically, will increase three-fold.[12] Current trends show great momentum towards the expansion of renewable energy capacity in India, driven primarily by solar and wind capacity addition. Solar photovoltaics development has gained momentum and offers wide investment opportunities in India. According to the International Energy Agency (IEA), India's investment in solar energy, in 2018, was greater than all fossil-fuel sources of electricity generation, put together.[13] The creation of the International Solar Alliance (ISA), led jointly by India and France, is a prime example of Prime Minister Modi's resolve as far as solar energy capacity augmentation is concerned. The ISA is headquartered at Gurugram in Haryana, while the National Institute of Solar Energy (NISE) will be devoted towards its research and development which is also situated in Gurugram, Haryana.[14]

India has some of the world's largest solar installations. With a capacity of 2245 megawatts (MW), the Bhadla Solar Park, located in Rajasthan, is the world's second largest solar power station.[15] The world's largest single-location solar power plant with a capacity of 648 MW is located in the state of Tamil Nadu. Other large solar power plants in India are the Kamuthi Solar Power Project (648 MW), the Charanka Solar Park (600 MW), the Sakri Solar Plant (150 MW), and, the Welspun Solar MP Project (151 MW), in the states of Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh, respectively.[16]

In terms of OnWE development, India's installed capacity is an impressive 37.5 GW, making the country the fourth largest producer of OnWE power in the world after China, the USA, and Germany.[17] Yet, there is scope for growth as OnWE constitutes just 10 per cent of India's total installed electricity generation capacity. The GoI is, therefore, providing several incentives in developing wind parks/farms. Amongst the more prominent and larger OnWE parks in India are Tamil Nadu's Muppandal Wind Farm (1500 MW), Rajasthan's Jaisalmer Wind Park (1064 MW), and, Maharashtra's three mega wind-parks in Brahmanvel (528 MW), Dhalgaon (278 MW), and, Vankusawade (259 MW).[18]

Even though the thrust towards expansion of solar and OnWE is proceeding apace, there are, nevertheless, a few major challenges which impede an expedited and expanded adoption of OnWE. First, both solar and OnWE are highly land intensive. According to a 2017 report by The Energy and Resources Institute (TERI) entitled, "*Addressing Land Issues for Utility Scale Renewable Energy Deployment in India*", around 1,50,000 hectares of land is needed for 50 GW of solar and 30 GW of OnWE production, which translates to 3000 hectares per GW for solar and 5000 hectares per GW for wind energy.[19] In a densely populated country such as India, land is a highly-prized commodity and land-acquisition is, consequently, a major hurdle for the expansion of solar and OnWE parks to cater to the country's rising demand. This paucity of land further leads to improper land- management practices by OnWE farms, causing large scale erosion and landslides that causes rubble to flow into the fertile farmlands and river systems, causing significant environmental degradation.[20] Another major problem associated with solar and wind energy is the issue of intermittency. Solar energy, for instance, is available only during daylight hours, implying that an electricity-grid operator has to adjust its 'day-ahead', 'hour-ahead', and 'real-time operating' procedures.[21] This leads directly to the challenge of storing electricity that is produced from renewable sources. The storage of electricity remains a significant issue as batteries tend to become bulky with increasing storage capacity and are, therefore, cumbersome to handle, require considerable maintenance, and, need frequent replacement.[22] OnWE farms also face several issues such as spatial-crowding caused by the erection of urban structures in the vicinity, which affect the speed and pattern of the wind, and lower the efficiency of the farms. The best locations for OnWE and solar-energy development are remote, sparsely- populated areas, but such areas often lie within one or another protected-area network, such as the Western Ghats, in Maharashtra.[23] This brings them into conflict with environmental law and increases the cost of production.

It is in this context that ocean-based renewable energy can play a crucial role in not just reducing the dependence on fossil-fuel-generated power, but also in avoiding the challenges associated with onshore renewable energy sources. Among the various ocean renewable energy resources, Offshore Wind Energy (OffWE) offers a particularly promising solution due to the technological maturity that it has achieved over the past couple of decades. OffWE is a unique case as it is considered an Ocean Renewable Energy Resource (ORER), even though its functioning mechanism is dependent on the kinetic energy of wind blowing over oceanic areas, rather than being generated by the ocean itself.

Harnessing OffWE Potential in India's Coastal Areas

In order to realise the SAGARMALA vision while significantly 'blueing' India's economy, it is essential for India to develop MARPOL-compliant non-major ports that adopt high and modern standards of functional efficiency. In the Financial Year 2019-20, between 01 April and 31 December 2019, India's twelve major ports handled a total cargo traffic of 704.82 million tonnes (MT), while the 200-odd non-major ones handled 447.21 MT.[24] The 12 major ports in India can handle a combined capacity of 1524.91 MT, which translates into a current capacity-utilisation of less than 50%.[25] This results from a combination of factors — lack of adequate infrastructure, inefficient operations at berths, slow rates of loading and unloading cargo, poor movement of logistics, etc., especially in the non-major ports.[26]

In any attempt to enhance capacity-utilisation, the power supply is a major issue that needs to be addressed. The availability of continuous, stable, and reliable electricity in ports is essential not only for port operations themselves, but also for providing external power to ships at the port's berths.

Electric power for all twelve of India's major ports already has a significant contribution from solar and wind power facilities. This, however, is far from being the case with the non-major ports. In addition, with MARPOL regulations now in force, and with the drive towards reducing carbon emissions from berthed ships, ports are now being urged to provide shore-generated power to ships berthed alongside the various wharves, jetties, and piers in the various terminals of the port. This provision of shore-based supply is termed "cold ironing".[27] As a consequence of these MARPOL- induced measures and the genuine desire to 'blue' the ports by aiming for an eventual state of carbon-neutrality, there is a pressing need to equip these ports with power generated from renewables, which will, of course, require the setting-up of more solar and OnWE facilities.

However, as discussed previously, there are several impediments — including land usage and intermittency — to the adoption of these land-based renewable-energy technologies and facilities. This is where OffWE can be pursued and integrated into SAGARMALA.

India's long coastline has immense potential for OffWE. According to a study conducted by the National Institute of Wind Energy (NIWE), the potential of all forms of wind energy in India is around 302 GW at 100-metre hub height (i.e., the distance from the turbine platform to the rotor of an installed wind turbine). That said, issues with OnWE, as discussed earlier, preclude this potential from being fully realised. Encouragingly, however, according to the Ministry of New and Renewable Energy (MNRE), OffWE potential is an estimated 127 GW. Of this potential, as much as 70 GW can be exploited off the coasts of Gujarat and Tamil Nadu, alone.[28] The 'Facilitating Offshore Wind in India' (FOWIND) project — an 'Indo-European Cooperation on Renewable Energy' programme[29] — has identified Gujarat and Tamil Nadu as the most feasible locations for future OffWE development.[30] The OffWE development potential is underexplored in India and requires serious consideration, duly supported by financial investment. Brijesh Lohia, Managing Director of the Ocean Group is of the view that, "*India offers great potential for developing offshore renewable energy and the government has accorded due priority to attract investment in this area. The power generated will feed the coastal activity and also contribute to the national grid.*"[31]

In June 2018, guided by the FOWIND report, the MNRE set mid-term and long-term targets for OffWE. The plan is to install a capacity of 5 GW by 2022, and 30 GW by 2030. OffWE has several benefits over OnWE as the wind farms are situated at sea and, hence, do not have to compete with urban coastal agglomerations for space. The open ocean provides, in principle, a large amount of area, for big wind-turbine installations and, therefore, the scope of expansion is tremendous. Since there is no obstruction to wind at sea, the quality of wind is better for energy production. Also, its remote location, far from populated areas makes it less intrusive than OnWE.[32] It is, however, important to note that at the present state of development of engineering technology, the cost of OffWE in India is higher than that of onshore installations — about Rs 7-9 per unit compared to OnWE which costs Rs 2.8-2.9 per unit.[33] However, as mentioned before, OnWE installation projects typically have to go through a strenuous process due to the paucity of land and other logistical issues related to community impacts. OffWE — even though it is high on capital investment — can be developed on a large scale that will provide long-term energy-security to the non-major ports and, as the infrastructure is put into place, and with additional capacity, as also with the advance of engineering technology, the costs will inevitably come down, particularly in the long-run.[34]

The inclusion of OffWE deployment within the various projects under SAGARMALA can greatly facilitate GoI's efforts towards modernisation, industrialisation, and infrastructural development of ports. With the immense potential of OffWE thanks to the presence of abundant OffWE resources in the nation, this renewable can cater to the power requirements of new installations and development activities in coastal areas. The powering of ports and related activities from such installations will significantly reduce the carbon footprint and 'blue' India's port-led developmental efforts to boost the country's economy. Figure 1 displays India's major ports and some select non- major ports, along with the proposed coastal corridors under the SAGARMALA mega-project.

As has already been mentioned, a major pillar of the SAGARMALA vision involves port modernisation. This, *inter alia*, involves automation of several port-processes and this, in turn, requires a substantial amount of dedicated power, and uninterrupted power supply.[35] Further, the ongoing process of digitalisation of Indian ports and the incorporation of 'Industry 4.0' to lift the county's port sector to 'Port 4.0' standards, a whole slew of contemporary and near-future practices would be required, all of which will require dedicated, stable and uninterrupted power supply.[36] This is what OffWE will be able to provide.

Powering Ancillary Industry and Coastal Community Development with OffWE

It would be recalled from the preceding paragraphs that the third pillar of the SAGARMALA mega- project concentrates on port-led industrialisation, along three focal-models — energy, materials, and discrete-manufacturing. The locations of industries are 'clustered' such that they are in the vicinity of ports (both, 'major'

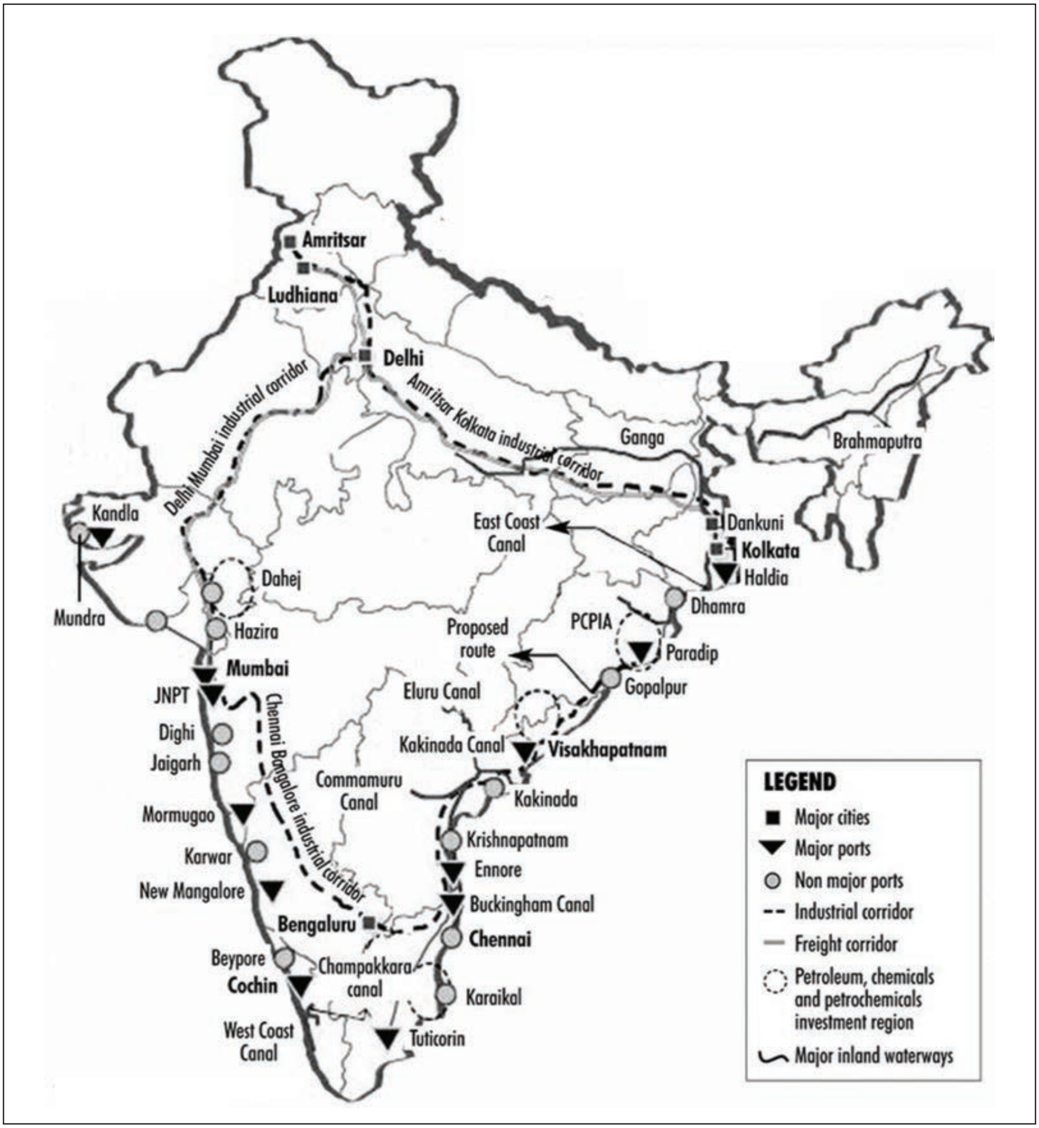

Figure 1: The corridors envisaged under the SAGARMALA Project as well as select major and non-major ports of India.
Source: https://www.rajras.in/sagarmala-program-port-led-development/

as well as 'non-major' ones) in order to facilitate movement-of and access-to cargo. These clusters, collectively termed Coastal Economic Zones (CEZs), also synergise with the planned industrial corridors such as the Delhi-Mumbai Industrial Corridor

(DMIC), the Visakhapatnam-Chennai Industrial Corridor (VCIC), etc.[37] The one factor that is glaringly common in all three models of port-led industrialisation is that the industries that are sought to be 'clustered' are all highly electricity-intensive. Hence, OffWE will be able to assist in a significant manner by supplying energy for the development of CEZs, as also providing electricity for the functioning of optimal utilisation of the ports themselves.[38] This will have the cascading effect of attracting not only large firms but also a whole host of ancillary industries that provide raw materials to the former, as also to the ports themselves, bringing with them technology, capital, job opportunities, and links to global value and supply chains.[39] The linkage of non-major ports to industrial units — both powered by OffWE — will result in expedited development of the coastal regions, while at the same time moving in the direction of eventually achieving net-zero carbon emissions.

In India, approximately 18 per cent of the population call the 72 coastal districts 'home'. As a result, Coastal Community Development is the fourth pillar of SAGARMALA. This can be undertaken by providing employment opportunities, skill development, and affordable, stable and uninterrupted electricity. The OffWE industry has the potential to provide these benefits to the population in coastal regions. In the life cycle of an OffWE farm, diverse skills are required in the planning, construction, and maintenance stages. According to Lauran Morton, Director of American Wind Energy Association, "*to build and operate an offshore wind farm requires a diverse workforce of 74 different occupations*."[40]

This showcases the scope of jobs that can be generated by OffWE deployment. The demand for skilled human resources will naturally lead to skill-development within coastal communities.[41] For instance, in the European Union (EU), it is predicted that by 2030 almost 215,000 people will be employed in the OffWE sector, exceeding by far the jobs provided by the OnWE farms themselves.[42] Likewise, in India, the OffWE sector would provide extremely substantial employment-opportunities, ranging from the manufacture of wind turbines, their installation and maintenance, to the multiplier-effects in terms of employment in related ancillary industries and the secondary and tertiary jobs (school teachers, health-workers, barbers, tailors, shopkeepers, hardware- suppliers, vehicle-repairers, stationers... the list is endless) that come in the wake of such port-led processes.

A very large number of ancillary industries that are more directly related to the activities of Indian ports — such as fishing, shipbuilding, coastal tourism, etc., are already present. Of these, fishing — as a sector that has sea-going and shore-based segments — is one that is of particular significance to coastal communities, and plays an important role in furthering India's Blue Economy endeavours. However, its products are perishable and require cold storage stocking and warehousing facilities.[43] Right from the time the fish is caught, it needs proper storage and preservation, usually under low temperature. This 'cold-chain' calls for a variety of refrigeration devices and facilities, all of which, once again, consume large amounts of electricity. Depending on their capacity handled and the outside temperature, such cold storage facilities consume between 30 and 50 kWh/m^3/year of electricity.[44] In the absence of captive renewable power, this power has to be drawn from electricity grids fed by traditional, fossil-fuel-run power plants. OffWE, if installed so as to feed non-major ports, will be able to provide clean, renewable energy to such facilities.

Sustainable coastal tourism is another sector that will contribute to India's Blue Economy. India's Ministry of Tourism aims to build coastal tourist-circuits so as to enhance the country's attractiveness to Indian and foreign tourists.[45] As coastal tourism is centred upon ports, OffWE will be able to cater to the power requirements of the tourism sector, as well. In addition, with the introduction of coastal ferries, cruises, etc., there is a need to develop new jetties and berths to facilitate the embarkation and disembarkation of tourists, and these, once again, can be entirely powered using OffWE. A well-established tourism sector can provide local employment in the hospitality and service sectors and can also enhance the associated small-scale industries.

Shipbuilding is another critical industry that demonstrates the technological capabilities of any nation. It is often referred-to as the "Mother Industry"[46] as it supports a very large range of associated ancillary industries. The shipbuilding sector as a whole is very sensitive to uninterrupted power-supply, as any delay in delivery of orders translates into heavy financial losses and, more importantly, loss of the reputation of the concerned shipyard or boatyard. India plans to further its shipbuilding capabilities in terms of both naval vessels and mercantile ones catering to the transportation of cargo and bulk products. This is especially relevant today with PM Modi's clarion call of "Make in India"[47] and "*Atmanirbhar Bharat*" (Self-Reliant India).[48] Given the emphasis being laid on the expansion of trade along India's national waterways, the demand for a whole slew of new vessels whose shape, form and number is contextualised to the requirements of various connectivity options, often involving multi-modal transportation, will increase significantly. Within this paradigm of growth, the use of OffWE would significantly reduce the shipping industry's overall carbon emissions whichthat are primarily driven by the high energy usage.

Challenges and the Way Ahead

For all that, there is no gainsaying that India's path to developing OffWE is strewn with several foundational challenges which include, amongst others, those summarised below.

(a) Even though policies related to OffWE were framed in 2015,[49] no OffWE farm has physically materialised as yet in India. Developing OffWE plants in India will have high capital (installation) costs. This is due, *inter alia*, to the lack of support vessels and port facilities for OffWE installation, the lack of local sub-structure manufacturers, and the lack of skilled employees.

(b) Considerable research and data collection mechanisms need to be created so as to make them available along with historical data such as resource maps, bathymetric data, etc., all of which are crucial for determining the location, design, and feasibility of a given OffWE project.[50]

(c) The use of submarine cables for such projects is essential so as to establish integration with shore-based electricity grids. However, submarine cables are much more expensive compared to normal cables and, therefore, increase the unit cost of electricity produced by an OffWE project.[51]

(d) OffWE development in India should be viewed as a long-term opportunity and be managed efficiently with timely investments. A synergetic approach is accordingly proposed involving the Ministry of New and Renewable Energy, the Ministry of Earth Sciences, the Ministry of Shipping and Ministry of Skill Development and Entrepreneurship. With such political, financial, and social coordination and cooperation, the SP will greatly benefit from OffWE while significantly empowering the Blue Economy of India.

(e) OffWE turbine manufacturing requires technical expertise as well as a local base for production. Given that indigenous capacities and capabilities are in their infancy, it is necessary to seek technology-transfer to support and advance local manufacturing. Relying solely upon foreign suppliers for the finished product is not only a significant burden on the nation's exchequer, such import-dependence is also the antithesis of the 'Make in India' initiative. These imperatives require a horizontal proliferation of awareness and some degree of knowledge, if not expertise, across a number of vertically-specialised organisational structures of the government as well as private industry. The breaking down of these vertical silos and the comfort zones that they have been established over protracted periods of time, will be a challenge of major proportions.

(f) Determining how to minimise the potential threat that each OffWE project might pose to the marine environment in the vicinity of the installation, whether at the construction, operation, or maintenance stages, is another challenge that needs to be addressed squarely. OffWE projects must, therefore, include environmental impact assessments to identify and minimise these impacts.[52]

(g) Given that the OffWE plant will be situated offshore (i.e., in the sea) there are likely to be challenges (each with its own cost-contribution) related to restrictions and limitations in terms of accessibility to a given OffWE site, during its construction, operation and maintenance.[53]

(h) OffWE installations will invariably form part of the nation's critical maritime infrastructure. While India has adequate organisational structures to address the challenges of offshore security, the fact that OffWE farms would be vulnerable to sea-borne attacks from malevolent State-sponsored (and other) non-State actors will add to the burden of the Flag Officer Offshore Defence and Advisor to the Government of India (FODAG) who is the designated authority for the defence and security of OffWE projects, in addition to being similarly responsible for the security of offshore oil installations.[54] An attack on an OffWE installation would impose a cascade of downstream economic losses. In addition, as the advantages of Industry 4.0 are incorporated and adopted, the vulnerability to cyberattacks will increase.[55] While such cyber-vulnerability is not unique to OffWE installations, their location and difficulties in physical accessibility certainly add to the challenge.

(i) Being largely located in the tropics, peninsular India is prone to severe cyclonic weather, which could result in damage to installed wind turbines and their associated infrastructure, causing severe interruptions and disruptions to power-supply, thereby imposing significant losses upon the ports and port-fed industries located in coastal areas.

Amidst these challenges, one clear advantage of OffWE is its high value in India's archipelagic island chains — the Lakshadweep Islands off the western coast, and the more distant Andaman & Nicobar Islands off the country's eastern coast. In both these island-chains, electrical energy is currently being provided by localised diesel generators, despite the adverse impact that these fossil-fuel-driven installations have upon the ecosystems and the biodiversity of these ecologically sensitive islands.

While the costs associated with OffWE, at least at the present point in time, are three times greater than those associated with solar or wind or fossil fuel power, a wide adoption of OffWE yields several advantages, especially over the long run. As technologies mature and become more efficient the 'levelized cost of electricity' will go down and, in a country such as India, with a perennial growth in demand, low tariffs can easily be achieved simply due to the enormous size of the market. In addition, OffWE can play a major role in furthering India's transition to clean (blue) energy in the maritime sector, especially in terms of shipping. Encouragingly, there are already examples that can be emulated. For instance, the use of OffWE for the production of 'green' hydrogen — a clean, zero-carbon-emission alternative fuel (suitable for large cargo ships) — is already being exploited in Hamburg, Germany.[56] Moreover, with the increase of commercial vessels propelled by hydrogen and methane, as well as autonomous electric vehicles, there is increasing scope for development of offshore refuelling infrastructure in the future, which can be carried out using power generated by OffWE.

The creation of such offshore infrastructure can be leveraged to enhance underwater domain awareness — something that is undoubtedly of interest to the Indian Navy. Finally, if the technology is mastered with a sufficiently sophisticated indigenous base for production, it can be transformed into a tool for foreign policy and be shared with nations in the Indian Ocean Region (IOR), furthering India's standing as a net provider of security in the region under the twin visions of 'Security and Growth for All in the Region' (SAGAR), as also the 'Indo- Pacific Oceans Initiative' (IPOI).

Conclusion

Large developing countries such as India, with their burgeoning populations, are increasingly the hubs of rapid economic growth and development. This growth is propelled primarily by the consumption of energy and, therefore, the demand for energy is constantly on the rise. For maritime nations such as India, this growth encompasses a number of aspects related to her endeavour to transition from a 'brown' economy into a 'blue' one. Consequently, the vision of port-led national development — of which SAGARMALA is a prominent manifestation — cannot afford to neglect or minimise the enormity of its contribution to the 'blueing' of the economy as a whole. While economic growth is crucial, it is critical to incorporate within the chosen growth- model, adaptive and mitigative strategies to reduce or minimise the potentially devastating consequences of climate change. Central to these endeavours is the adoption of clean energy. In India, the drive towards renewable sources of energy has, thus far, been limited to the adoption of solar energy and OnWE. However, limitations such as the unavailability of land, the intermittency of electrical energy generated by renewable sources such as solar and OnWE, the lack of local production capacity capability, etc., remain significant impediments. In order to optimally realise the SAGARMALA vision of port-led development, there is a need to continuously scout for alternative sources of renewable energy. An important one of these alternative sources is OffWE. Owing to their geographic location in the open ocean and the proximity to the coast, OffWE installations can play a major role in powering ports and various ancillary industries including shipbuilding, tourism, fishing, etc. It is, therefore, worthy of serious consideration as an option of choice for India, and can readily supplement the ongoing advocacy for the adoption of 'blue' hydrogen derived from Ocean Renewable Energy Resources — including OffWE.

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Note

This article was first published on 29 January 2021 on the Website of the National Maritime Foundation

India's Low Temperature Thermal Desalination Technology: Water Diplomacy with Small Island Developing States in the Indo-Pacific Region

Dr Sameer Guduru, Dr Pushp Bajaj, and Dr Oliver Nelson Gonsalves

Climate Change and Water Scarcity in Small Island Developing States

The 58 Small Island Developing States (SIDS), spread across the world's oceans, are at the frontlines of climate change. Several impacts of climate change such as extreme heat, sea-level rise, intensifying natural-disasters, droughts, and declining ocean-biodiversity, pose an imminent existential threat to the communities and the ecosystems in these nations. Notably, SIDS are among the least responsible nations for climate change, as can be seen in their marginal contribution to global greenhouse gas (GHG) emissions, and are, therefore, reliant on other nations to cut-down their GHG emissions to halt global warming. Among the challenges faced by SIDS, one problem that is extremely worrisome — and continually worsening — is freshwater-depletion.[1] Around 71 per cent of the SIDS are facing water stress (see Figure 1 and Figure 2).[2] Rapidly growing populations, combined with urbanisation and an increase in tourism, have led to a persistent rise in demand for freshwater in most SIDS. For instance, Maldives, Mauritius, and Seychelles, all of which are located in the Indian Ocean, are amongst the most popular tourist destinations in the world. While tourism forms an integral part of the economies of SIDS, it also contributes significantly to added water stress and environmental degradation.

Along with the rising demand, the available freshwater supply is declining. Climate change is already altering and will continue to alter the natural water cycle,

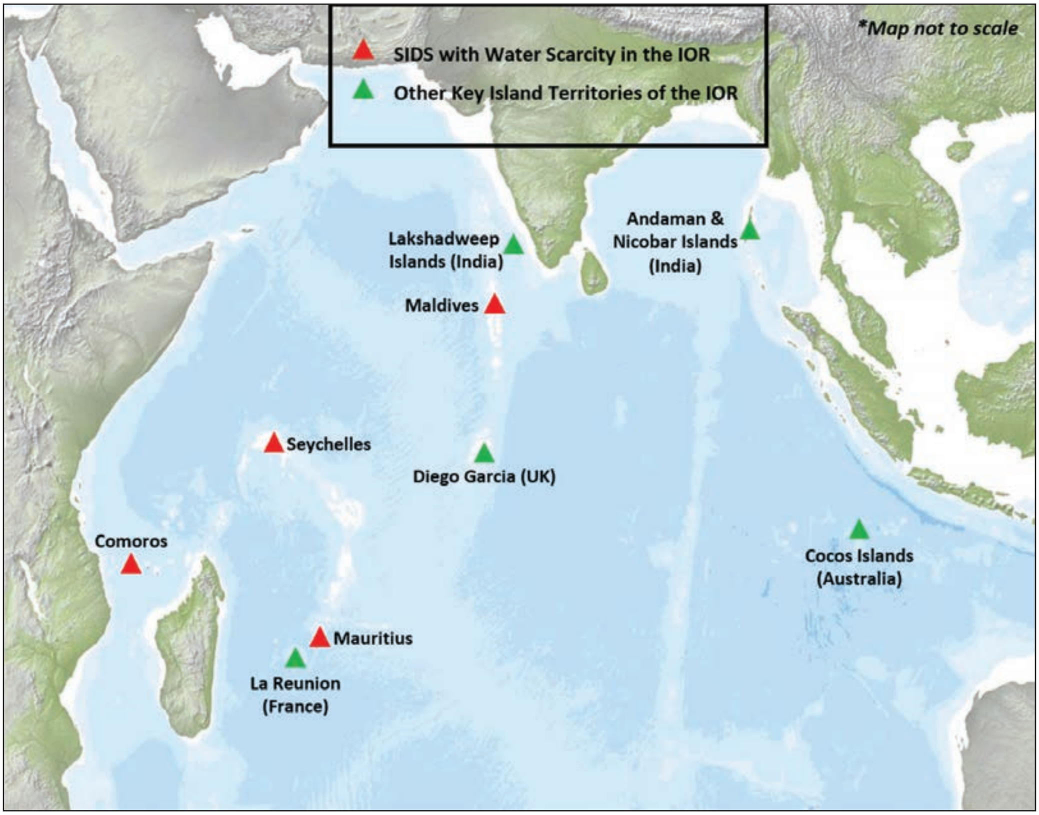


Figure 1: Small Island Developing States and Other Key Island Territories in the Indian Ocean Region Facing Climate Change Induced Water Scarcity.
Source: Created by Dr Sameer Guduru with Data Obtained from J Ghuenes et al, "Disaster-Risk, Water Security Challenges and Strategies in Small Island Developing States (SIDS)", Water 2019, 11(4), 637; https://doi.org/10.3390/w11040637, and Map Obtained from https://www.freeworldmaps.net/

resulting in erratic rainfall patterns manifesting as abrupt, heavy precipitation in some areas and droughts in other areas.[3] While normal, consistent rainfall contributes to replenishing groundwater tables, water from heavy rainfall over a short time period, if unmanaged, ends up in run-off and does not percolate into underground aquifers. On the other extreme, climate-change-induced droughts are consuming surface and underground freshwater resources. Moreover, saltwater intrusion into agricultural lands, rivers, and underground aquifers, due to sea-level rise, is an ever-present and growing threat to food- and water-security in SIDS. Pacific islands, in particular, have shallow, permeable groundwater aquifers, which serve as their primary freshwater source, but are at high risk from long periods of drought and contamination from surrounding seawater.[4] Water pollution and poor sewage-water management, exacerbated by urbanisation in many SIDS, also contribute to freshwater-contamination in some islands. For instance, the Pacific islands of Papua New Guinea, Kiribati, and Solomon Islands, have severely limited water-treatment capacities, impeding access to sanitation and clean drinking-water.

Water security is inextricably linked to the socio-economic development and the political stability of a nation. UN-Water defines water security as, *"the capacity of*

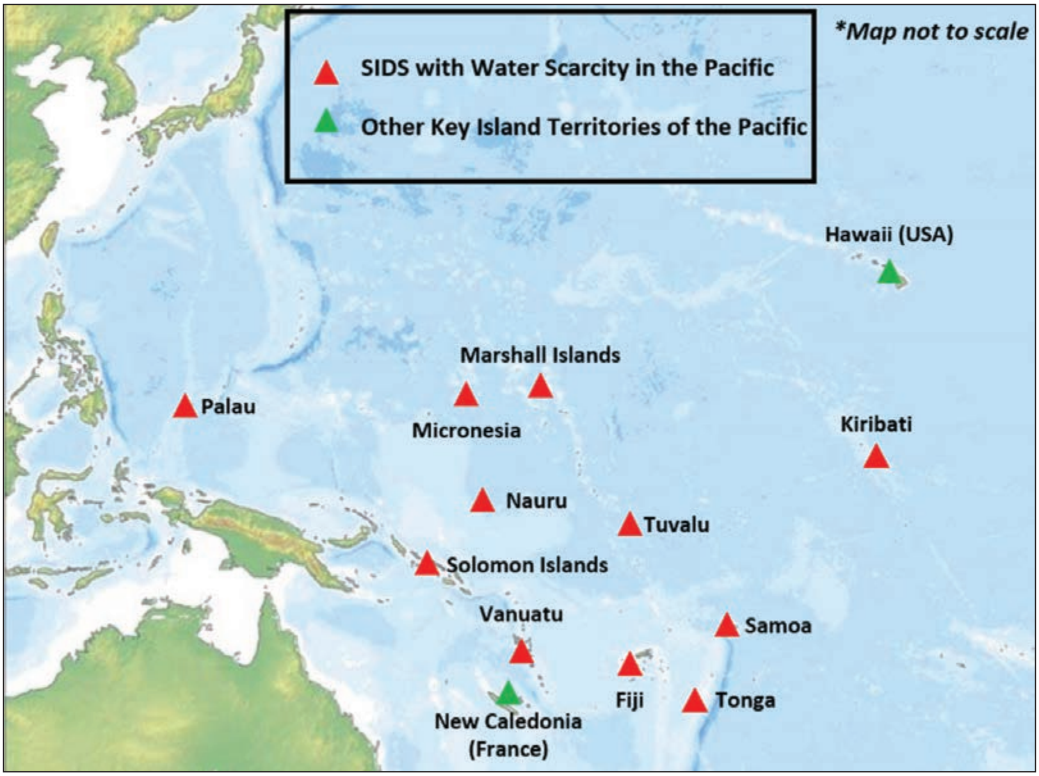


Figure 2: Small Island Developing States and Other Key Island Territories in the Pacific Ocean Region Facing Climate Change Induced Water Scarcity.
Source: Created by Dr Sameer Guduru with Data Obtained from J Ghuenes et al, "Disaster-Risk, Water Security Challenges and Strategies in Small Island Developing States (SIDS)", Water 2019, 11(4), 637; https://doi.org/10.3390/w11040637, and Map Obtained from https://www.freeworldmaps.net/

a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability."[5]

Growing water scarcity is already adversely impacting economic sectors such as health, agriculture, fisheries, and tourism, amongst others. In 2011, the island nation of Tuvalu declared a state of emergency and imposed strict water rationing on Funafuti and Nakulaelae atolls for several months following a severe drought.[6] Mauritius and Comoros islands are expected to become 'water-stressed' and 'water-scarce', respectively, by 2025, due to changing rainfall-patterns and saline intrusion into groundwater.[7] In an interview in 2018, Amjad Abdulla, Director-General of the Ministry of Environment and Energy of the Maldives, and Chief Negotiator for the Alliance of Small Island States (AOSIS), emphasised the seriousness of the issue, *"climate change carries significant challenges that we simply cannot address without help from the international community. The biggest emergency has probably been water shortages in some of our outlying atolls that now experience long periods of drought. We had to ship drinking water at great expenses and it will be difficult to sustain it over the long term."*[8]

In recent decades, several island-nations have invested heavily in desalination plants in an effort to mitigate water-scarcity and build long-term self-reliance. Desalination does, of course, offer a promising solution. However, conventional membrane-based reverse-osmosis techniques have significant inherent disadvantages. Further, the use of fossil-fuels to power desalination plants leads to the production of greenhouse gases and exacerbates global warming. In view of this, many SIDS are now considering harnessing the abundance of natural wind and sunlight to combine renewable energy with desalination to produce clean water without increasing their carbon emissions.[9] While novel, this approach, too, has its own limitations. For instance, land-paucity in SIDS is a major hindrance to any serious expansion of capacity in terms of onshore wind energy as well as solar energy.

It is against this backdrop that the subsequent paragraphs explore the potential of India's development of Low Temperature Thermal Desalination (LTTD) technology combined with Ocean Renewable Energy Resources (ORERs), specifically Ocean

Thermal Energy Conversion (OTEC), and present this as a near-ideal solution to mitigate water scarcity by using an essentially carbon-free technology. The geopolitical significance of SIDS and the role of technology in geopolitics is first addressed. Thereafter, the chapter delves into the need for India's proactive engagement with SIDS in combating climate change by offering technological solutions, as a part of New Delhi's soft power ('water diplomacy') to combat emerging threats and to evolve a new brand of geopolitics in the Indo-Pacific Region (IPR). A comparison of existing seawater desalination techniques is undertaken thereafter, highlighting their advantages and disadvantages. The final segment of the chapter seeks to explore the possibility of aiding SIDS in the IPR under the ambit of existing multilateral mechanisms, as a tool for soft power and furthering water diplomacy, while at the same time addressing non-traditional aspects of security, encompassing, *inter-alia,* human security and climate change.

Geopolitical Significance of Small Island Developing States and the Role Played by Technological Assistance

Geopolitical Significance of SIDS

The strategic value of the SIDS within the IPR was highlighted during the ferocious battles of the two World Wars, when the belligerents sought to dominate the seas using island bases. The onset of independence to these SIDS was adversely impacted by the Cold War that followed on the heels of the Second World War. Great Power interest was aroused in several of these territories, which were pivotal in promoting the political objectives of the new belligerents onto the adjoining Asian and African continents. Naval bases played an important role in asserting the West's strategy to protect vital energy supplies from West Asia, while countering Soviet attempts to effect sea-denial.[10] Even today, with the Cold War now a part of history, the geographical proximity of many of these SIDS to International Shipping Lanes (ISLs) — particularly given the ongoing global shift in world trade from the traditional markets of North America and Europe to the emerging economies of Asia — guarantees a contunuation of this strategic significance.[11] However, their geographical isolation is a double-edged sword that prevents the SIDS themselves from capitalising on their strategic value to gain economic advantages. Further, the diminutive economic standing of the majority of SIDS increases their vulnerability to external economic shocks, which in turn constrains their political value and their ability to manage environmental challenges.[12] Such an inability to challenge economic and environmental impediments to development may compel SIDS to seek a compromise with the dominant powers of the region in exchange for monetary and political concessions. Such arrangements further the geopolitical objectives of the dominant power while eroding the sovereignty of the SIDS.[13] For instance, China's pattern of extending massive loans for infrastructure projects in economically-sensitive countries has pushed several of them into a debt trap. In the case of Sri Lanka's port of Hambantota, the failure by Sri Lanka to repay an estimated US$ 301 million — at an interest rate of 6.3 per cent — compelled it to hand over control of the port to China Merchants Port Holdings Company for a 99-year lease, in December 2017.[14] Similarly, it is speculated that Djibouti — situated on the strategic Horn of Africa — acquiesced to the development of China's first overseas military base in exchange for large infrastructure loans, which included a free-trade zone, a railway line connecting Djibouti with Ethiopia, and, a container port.[15] Interestingly, despite increasing Chinese maritime assertiveness, India does not have a single naval base/installation anywhere in the world. Instead, it has opted to provide logistic assistance to enhance the internal capabilities of island states such as Maldives, Seychelles, Mauritius, and Sri Lanka. Manifestations of hard power, like the establishment of naval bases on sovereign island nations or the creation of artificial islands, are unsustainable without uninterrupted supply-networks, but these are themselves militarily and financially vulnerable. In the case of China's artificial islands across the South China Sea, until the introduction of desalination plants in 2016, freshwater had to be shipped from the mainland to supplement rain and limited groundwater supplies.[16] Further, hard power projections may face negative exposure from local communities, in addition to generating retaliatory measures from opponents.[17]

Role of Technology in Geopolitics

The technological prowess of a given nation is directly proportional to its political prowess. Historically, technology has given nations the necessary edge over other nations and led to prosperity as well as security. This was true even in ancient times. For example, shipbuilding capability led several Indian empires to pursue trade with nations in West Asia, the east coast of Africa, Southeast Asia and even the Roman Empire, on advantageous term.[18] On the other hand, technological advancement also led to colonisation and has increasingly led to power asymmetries among nations ever since the beginning of the first Industrial Revolution. With European powers competing to establish global dominance, the great wars of the last century have resulted in a rapid and exponential advancement of military capabilities, including the development of the nuclear bomb. The Cold War witnessed the advancement of space capabilities of the two superpowers and the advent of computers and digital technologies by East Asian nations such as China, Japan and South Korea, have become indispensable to global supply and value chains. Manufacturing prowess and education in technological skill development has resulted in economic prosperity, which in turn, has contributed to the expansion of hard-power (military) capabilities of nations.[19] For ambitious nations such as India, which envisage a significant role for themselves in shaping the global order, indigenous technological advancement is a game-changer. One has only to look at how the nuclear tests in 1998 by India completely changed the geopolitics of South Asia.[20] Hence, the ability to indigenously develop, manufacture, and export technology, can be leveraged in order to maintain the desired balance of power in an international system that is primarily run on the principles of realism.

In the context of the IPR, the increasing presence of China is undeniable over the last few years. For China, the IPR is a natural waypoint in its pursuit of global dominance. The Middle Kingdom, primarily a Pacific Ocean power, is challenging the existing global order through a variety of means, including the rapid development and expansion of naval combat platforms, all thanks to a robust and technologically advanced shipbuilding and port-development industry that sustain mega-projects such as those within the Belt and Road Initiative (BRI).[21] Chinese actions in the IPR are motivated not only by Beijing's quest for establishing itself as a superpower but also to secure and ensure China's access to energy-supplies from West Asia[22] and mineral resources from Africa.[23] However, Chinese interests in the region have, over the years, resulted in Beijing adopting an aggressive posture. This is evident by their establishment of a military base in Djibouti,[24] overlooking the strategically important strait of Bab-el-Mandeb, which leads into the Red Sea and thence to the Suez Canal, and, for southbound movement, provides access to the Arabian Sea. The Chinese have also proactively engaged with nations of the Indian Ocean Rim, as also those in India's neighborhood, such as Thailand, and provided military assistance, including submarines. Although that particular purchase has been cancelled following a backlash within Thailand and public protests post the COVID-19 global pandemic,[25] the general trend remains unaltered.

In the Indian Ocean Region (IOR), Comoros, which is an SIDS with low human development indices and frequent internal conflict, offers a stark example of how China leverages its influence. China was the first country to recognise Comoros as a newly independent nation, in 1975. With rival forces within the country, one seeking to maintain an independent *status quo* and the other arguing for rejoining the French Union, the country has witnessed a great deal of violence and civil unrest. With appeals for assistance to France having largely failed, Comoros has befriended Beijing, which immediately promised it assistance and aid — all of which can pave the way for the establishment of PLA base in the country. This could significantly change the existing geopolitics of the region considering Comoros' geographical location overlooking the Mozambique Channel through which some of the most important international shipping lanes (ISLs) pass. The region is important for India's energy and commodity exports and the risk of a Chinese military base should be viewed as a very serious one. Moreover, the recent discovery of massive offshore gas reserves off the coasts of Tanzania, Mozambique and Madagascar has increases the geopolitical importance of the Mozambique Channel manifold.[26]

Addressing these challenges requires novel approaches to providing aid, assistance, as well as, technological support to these SIDS. India already enjoys friendly ties with States such as Mauritius, Maldives, Seychelles, Sri Lanka, and others in the region.[27] Offering them technology to combat climate-change-induced water-scarcity, which represents an existential crisis to these island-states, as a major component of India's soft-power diplomacy will create additional goodwill among the populations of SIDS in the IPR. This resonates well with India's existing aid and assistance endeavours vis-à-vis these SIDS, and focuses primarily on 'human' rather than 'military' security. Thus, it is crucial for India to influence SIDS in the IPR using subtle soft power approaches that will not only benefit India's long-term foreign policy objectives but also provide a beneficial trickle-down effect for the citizens of these territories and enhance an enduring degree of people-to-people connectivity. Mitigating water scarcity within SIDS using LTTD technology will amplify India's image as a benign power that is sensitive to community needs as well as aware of the necessity to promote sustainability and self-reliance among these nations.

Assessing Existing Seawater Desalination Technologies

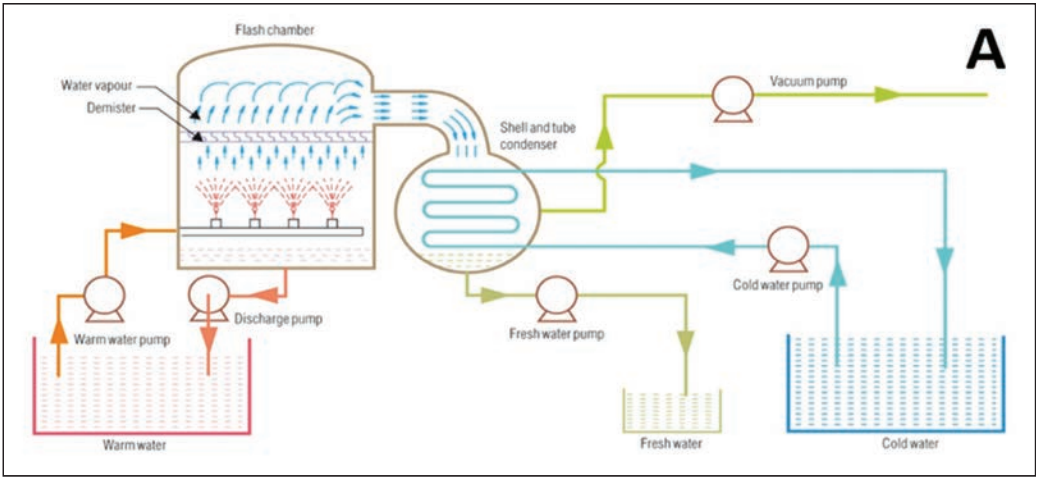
Water scarcity, as discussed earlier, is a major challenge that needs to be addressed, and one that is especially relevant to SIDS. Being surrounded by the ocean, these SIDS naturally view seawater as an abundant source of potable water, albeit with proper pre-treatment and desalination. Existing desalination technologies can be broadly classified into two categories: (1) membrane-based techniques, and (2) thermal distillation-based techniques.[28]

Membrane-based techniques, as the name suggests, involve a process of reverse osmosis through the use of semipermeable membranes. Here, seawater under a pressure of 70 atmospheres (atm) is forced to pass through a series of membranes which, at the microscopic level, are capable of blocking relatively larger salt particles while allowing the smaller water molecules to pass through.[29] Thermal distillation technologies, on the other hand, rely on heating seawater, which results in evaporation of pure water molecules, leaving the salt particles behind as residue. The steam is collected and then cooled to produce clean water, while the residual brine containing the salts is filtered out. The specific approach to thermal distillation that is of interest for this chapter is known as Low Temperature Thermal Desalination (LTTD).[30] LTTD operates on the same fundamental principle of distillation albeit in a slightly altered manner. It exploits the fact that water tends to boil under pressure resulting in its evaporation, at temperatures far below the normal boiling point of 100 degrees Celsius. The temperature differential between warm surface seawater and the cold deep seawater is exploited in this case. Warmer surface water in tropical areas is pumped into a chamber within which a pressure of 1013 millibar is maintained, causing the seawater to evaporate well below its regular boiling point. The vapour is then passed through a cooling chamber (condenser) which is filled with colder deep seawater (see Figure 3). The vapour cools and condenses, yielding clean water, which is recovered for human use. The technology was pioneered and indigenously developed by scientists at India's Chennai-based National Institute of Ocean Technology (NIOT), who demonstrated the principle in early 2000s. So far, three plants have been installed and are currently operational in the islands of the Lakshadweep archipelago, namely Kavaratti (2005), Agatti, and Minicoy (2011). Six more plants are to be set-up on the islands of Amini, Kadamat, Kalpeni, Androth, Kiltan, and Chetalath in the near future.[31]

Advantages and Disadvantages of Membrane and Thermal Distillation Techniques

As membrane-based desalination relies on filters at the microscopic level, the membranes are prone to biofouling. 'Biofouling' refers to the accumulation and growth of microorganisms that end up clogging the filters. This requires the membranes to undergo frequent maintenance, using expensive chemicals for cleaning. In addition, the use of pressure in order to filter seawater damages the membranes and requires them to be replaced frequently, which further contributes to the overall costs.[32] Furthermore, reverse-osmosis-based desalination plants are typically located onshore, which requires the usage of land resources, which is often scarce within SIDS. The technology achieves a purity of water with 500 parts per million (ppm) of salt. The biggest advantage of membrane based desalination plants is, of course, the recovery ratio — that is, the amount of water recovered as a percentage of the seawater input, which varies with water salinity and is typically around 20% for smaller plants, 40% for larger plants and with a maximal limit of 50%.[33]

Israel has emerged as one of the leading countries that exploits desalination technology, which has transformed the country from an arid, drought-prone land to one that has attained water self-sufficiency. Nevertheless, an analysis of the



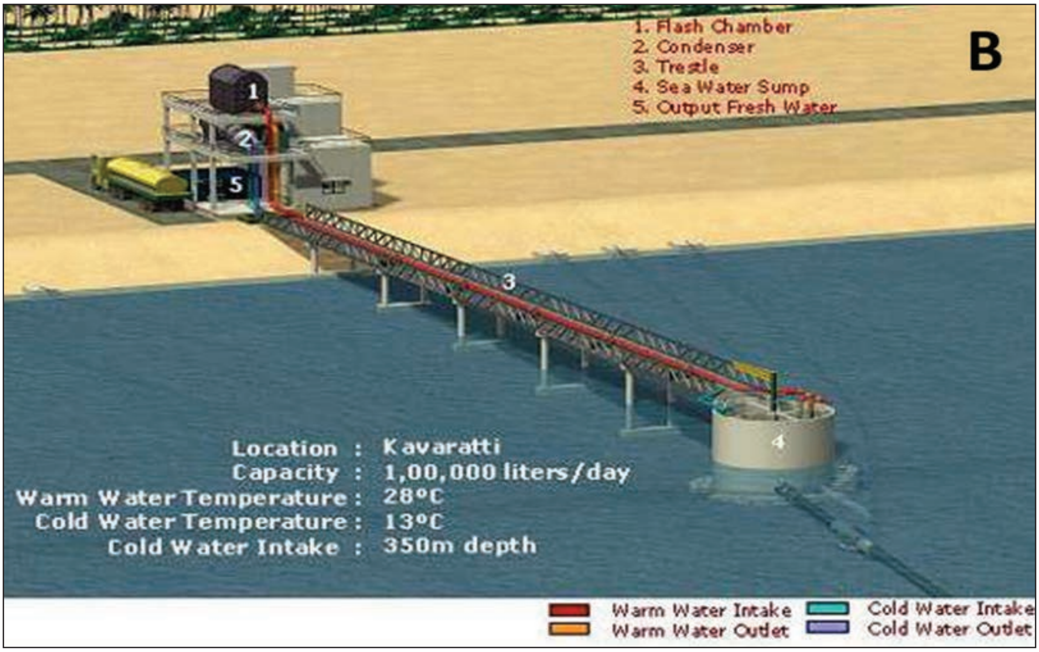


Figure 3A: The Working Principle of an LTTD Plant.
Figure 3B: The Schematic Layout of an LTTD Plant (Original links)
Source: Images adopted from (3A), "Desalination of Ocean Waters", https://geographyandyou.com/desalination-of-ocean-waters/ and (3B), "Now technology will help in conversion of 'Sea Water' into 'Drinking Water", https://m.dailyhunt.in/news/india/english/news+bharati-epaper-newsbhar/now+technology+will+help+in+conversion+of+sea+water+into+drinking+water-newsid-70529307

emissions associated with Israeli desalination plants found that the plants are run by onsite natural gas power stations, which have a fairly high carbon footprint.[34] LTTD technology, on the other hand, is capable of achieving a purity of 20-200 ppm which is much better compared to that from membrane techniques. The recovery rate is a function of the temperature differential between the surface and the deeper seawater, with optimum efficiency achieved at a temperature difference of ≥ 20 degrees Celsius. Consequently, recovery rates in LTTD plants are low and are usually in single digits, which is, of course, a drawback. The technology also requires the use of very long submerged pipes, close to 600 metres in length, to draw colder deep seawater, and these can be expensive.[35] One other disadvantage of an LTTD plant could be the excessive pumping of deep seawater which can result in the destruction of marine larvae and fauna.[36] Offsetting these disadvantages are five major advantages of LTTD technology: (1) The requirement of cold seawater means that the plants can be located offshore, thereby reducing the use of land. (2) The components used to create the plant are static and, therefore, have low maintenance and longer operability. (3) The brine-discharge associated with LTTD is negligible unlike membrane-based methods. (4) The post-treatment necessary for desalinated water from LTTD is inexpensive; and (5) the desalinated water must pass through limestone to achieve desired levels of purity. Even though the existing LTTD plant in Lakshadweep is powered by diesel power generators, it is eminently possible to bring the carbon footprint to a near zero value by switching to clean, renewable energy. In fact, LTTD technology can be seamlessly combined-with and viewed as a byproduct or an associated technology of Ocean Thermal Energy Conversion (OTEC), which, once again, is a technique that involves the generation of power from the ocean by exploiting the temperature differential between deep and shallow water. The vapour created using desalination is used to run a turbine and produce electric power. Hence, conceiving a technology that runs on self-generated power is an attractive option for producing desalinated water. LTTD can be ideally implemented in tropical conditions, where temperature differentials of ≥ 20 degrees Celsius are commonplace. This is a very significant facetbecause most inhabited SIDS are located in tropical regions. The discharge water from an LTTD plant is at a temperature of around 15-18 degree Celsius and can potentially find further application in air-conditioning. Moreover, deep seawater is rich in nutrients and this can be used for aquaculture resulting in enhanced fishing activity.

LTTD: An Opportunity for India's Soft Power Diplomacy Vis-à-Vis SIDS

As discussed in the initial portions of this paper India views herself as a "net provider of security" and the vision of Security and Growth for All in the Region (SAGAR)[37] substantiates this notion. Naturally, the element of security in SAGAR is viewed from a holistic point of view and incorporates both "traditional" and "non-traditional" aspects. The former includes military and hard power dimensions of security, while the latter is focussed on non-military aspects, including climate change, resource-scarcity, human security, food security, migration, health, etc. If India were to offer LTTD technology to SIDS in the IPR, this would be a natural extension of its diplomatic outreach and humanitarian assistance. New Delhi has always conducted humanitarian assistance and disaster relief (HADR) operations in the littorals of the IOR[38] in the aftermath of various calamities. Examples of this are numerous and include, amongst others, humanitarian assistance to Sri Lanka (Operation RAINBOW), Maldives (Operation CASTOR) and Indonesia (Operation GAMBHIR) following the devastating *tsunami* of December 2004; and, very recently, to Madagascar (Operation VANILLA)[39] in the aftermath of the tropical cyclone Diane in early 2020. As far as 'water diplomacy' is concerned, India assisted Maldives in 2014 by supplying huge amounts of drinking water after a devastating fire damaged the island nation's sewage-treatment infrastructure (Operation NEER).[40]

With climate change exacerbating the water crisis in SIDS, the promotion of LTTD technology to these States would emphasise India's commitment to adapt to, combat, and mitigate the consequences of climate change. As a responsible global player and by virtue of being a regional power, engaging proactively with vulnerable SIDS has far reaching strategic implications in an increasingly contested geopolitical space. Moreover, LTTD technology, as mentioned before, is ideally suited for tropical regions as the temperature gradient required for an efficient desalination process is naturally available. The low utilisation of land, resulting from the fact that the bulk of an LTTD plant lies offshore (see Figure 4) is another advantage, considering the limited land area of most SIDS.

A cost analysis of various desalination technologies carried out establishes that LTTD would be the preferred option of choice for standalone plants on remote islands,

Figure 4: An Operational LTTD Plant Installed on the Island of Agatti in the Lakshadweep Archipelago of India.
Source: Image Procured from "Indian scientists develop world's first low temperature thermal desalination plant", http://www.indiansciencejournal.in/r-d-news/indian-scientists-develop-worlds-first-low-temperature-thermal-desalination-plant-528341

as well as in conjunction with other desalination technologies for larger islands.[41] When combined with OTEC, the LTTD plant could be self-powered through clean renewable energy and would, therefore, not contribute to carbon emissions. Even if not combined with OTEC in particular, the plant can be powered by renewables such as solar photovoltaics, offshore wind and ocean wave-energy conversion (OWEC), which are increasingly being installed offshore for the production of electricity. The minimal maintenance requirement further reduces the costs and makes the technology even more attractive. With adequate skill development initiatives, the local population can be trained to operate the LTTD plant just as was done in the case of Lakshadweep Islands. As the technology is already benefitting India's islands – and with six other plants coming up soon – the technology is proven and mature and can, therefore, be utilised as a major tool of India's foreign policy.

Exploring Opportunities of Multilateral Cooperation through the Prism of Human Security and Climate Resilience

As discussed earlier, technology plays a very significant role in shaping geopolitics and, therefore, should be a tool-of-choice for the advancement of India's foreign policy. It also offers prospects for multilateral cooperation in terms of either developing a novel technology through cooperative and collaborative efforts, or, in terms of sharing and offering the technology to lesser developed countries that are dependent on external powers. With climate change being one of the global commons, mitigating the same requires concerted global efforts. It is in this context that the member-states of the United Nations Framework Convention on Climate Change (UNFCCC) pledged individual climate change targets in accordance with the Paris Climate Agreement of 2015. The focus, however, is largely restricted to developing novel technologies to combat greenhouse gas emissions and adopting non-fossil fuel based renewable sources of energy. This addresses only a part of the problem. The complicated dynamics of climate change and related effects require far greater efforts in all socio-economic sectors. Mitigating the knock-on effects of climate change, such as erratic rainfall patterns, droughts, water scarcity, sea-level rise, ocean acidification, etc., require independent focus alongside greenhouse gas-emission reduction-strategies. While some multilateral efforts — by the World Bank and the Asian Development Bank — to finance climate change resilience infrastructure exist, given the magnitude of the problems, such projects require a much bigger pool of financial resources.[42] The issue is complicated further considering the low GDP per capita and low Human Development Indices of the States that are most vulnerable to climate change. Therefore, exploring regional multilateral mechanisms involving various stakeholders including experts, private multinational companies, and governments is the need of the hour.

The Quadrilateral Security Dialogue (QUAD),[43] a grouping of four democracies — Japan, India, Australia, and the United States — is quickly emerging as a security provider in the region. Even though this has not been formally stated, Chinese aggressiveness in the region has intensified the QUAD's engagement of late. While hard-power capabilities of the QUAD's constuent States are likely to be at the forefront, the focus of the coalition and scope should be expanded to include non-traditional security threats as well. Since climate change is an existential threat, the QUAD's engagement with SIDS in the IPR can generate disproportionately large benefits. Establishing a financing mechanism through lines of credit to fund climate resilience infrastructure, under the ambit of human security, provides the coalition with an opportunity to better engage and negotiate with SIDS in the region. This can act as a mechanism that restores the existing *status quo*, prevents authoritarian regimes from extending their influence in the region, and restores the balance of power. This is particularly important considering China's expansionist moves in the region by means of projects within the BRI. For India, this is an opportunity to shift focus away from the disputed trans-Himalayan border with China and towards the maritime domain, where it enjoys an advantageous asymmetry of power. Water scarcity and climate change mitigation is an area of cooperation that also has the potential to provide a much-needed fillip to the Asia-Africa Growth Corridor (AAGC),[44] jointly led by India, Japan, and Indonesia. In fact, sustainability and disaster-resilience feature in the vision document of the AAGC. The AAGC seeks to fund development-projects in various African states and aid to SIDS in the IPR can certainly be taken-up in this context. Since LTTD is a proven technology with several advantages (as already established), the QUAD and the AAGC should explore the possibility of improving the technology to be offered to SIDS in the IPR. Developing LTTD plants powered by OTEC can provide access to clean desalinated water to the SIDS without adding to carbon emissions. Such an initiative would reinforce New Delhi'srole as a net provider of security in the IOR. It would also stimulate India's image as a responsible lead-player within the IPR as a whole, including the Australasian sub-region, where traditionally India's engagement has been limited except for engagement with States such as Fiji. It would also serve as a way of signalling to adversarial States that democratic coalitions in the IPR are serious about their role in maintaining the rules-based status quo in the region. With water-scarcity likely to get exacerbated in the coming years, the opportunities for both bilateral and multilateral partnerships with several SIDS as well as archipelagic nations such as Indonesia where the a number of remote islands exist, are immense. Technology-transfer also has the potential of increasing Indian exports in the IPR and can boost the national leadership's vision under the "Make in India" initiative. Perhaps more than merely an eastward looking policy or a westward looking one, the time is ripe for India to have a 'forward'-looking policy — one that can deal with climate change not only in India's own territory or limited to its immediate neighbourhood but in the broader IPR as well. This will establish India's credentials and cement her status as true a "net provider of security".

Conclusion

SIDS are at the frontline of climate change, bearing the full brunt of the impacts of extreme heat, sea-level rise, intensifying extreme-weather, droughts, and water-scarcity. Due to their geographical and topographical position, SIDS typically have limited freshwater resources in the form of underground aquifers and natural rainfall. Rising populations and an expanding tourism sector, combined with the impacts of climate change and pollution, are adding significant stress to the already-limited freshwater resources. Economic compulsions encumber local efforts to redress the impacts of climate change within SIDS. These, in turn, may compel them to compromise their sovereignty in their quest for monetary and political advantages, and transform them into mere pawns on the geopolitical chessboards of dominant powers. Advancing LTTD technology to provide freshwater supply to SIDS is a projection of India's soft power, which will also act as a counterbalance to the traditional hard power approaches of other players. Consequently, the endowment of this sustainable process will enhance self-sufficiency among SIDS, bequeath immense political capital to India's foreign policy objectives and legitimise India's climate change mitigation efforts in the IPR.

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Note

This article was first published online on 17 December 2020 in Maritime Affairs: Journal of the National Maritime Foundation of India, Vol 16, Issue 2 and is reproduced here with due permissions from the Publisher. The format of the article and the references have been modified in accordance with the formatting style of the book. The main text of the article remains unchanged

On Climate Change and Fisherwomen in India

Smriti Misra and Dr Pushp Bajaj

Many historical and contemporary events have aggravated the social inequalities that exist along the divisive lines of race, class, caste, gender, and religion. Although climate change is not often discussed in terms of social divides, it is, perhaps, the most important amongst these contemporary events. It is a global phenomenon whose effects are expected to disproportionately affect the 'less-privileged' populations across the world. Women, especially those belonging to these communities, are particularly vulnerable and most likely to disproportionately face the adverse impacts of climate change.[1]

Against this backdrop, this chapter begins by exploring the active interaction of women with the environment. It thereafter delves in some detail into the social, economic, and political disadvantages that fisherwomen continue to face which will be exacerbated by the impacts of climate change. The chapter concludes by discussing some of the initiatives being taken by the state and central governments of India, NGOs, and the fisherwomen themselves, to address these challenges, and argues that such initiatives must account for and adapt to the pressing reality of climate change.

Climate change is not only affecting the natural balance in the environment, but it is also altering the societal balance as well. According to the 2018 Special Report of the UN's Intergovernmental Panel on Climate Change (IPCC) on "*Global Warming of 1.5° C*",[2] global temperature and sea level are rising alongside frequent occurrences of extreme weather events. The average annual number of natural disasters has doubled over the past 25 years and their likelihood is increasing with every passing year. Climate change is adding to the existing environmental stresses of deforestation, land degradation, depleting freshwater resources, and air, water, and land pollution. As is often the case, the poorest communities across the world are likely to be the worst hit. Communities of fisherfolk, farmers, and labourers, etc., are highly dependent on natural resources and/or climatic conditions for their livelihoods, which are now at increased risk due to climate change.

Women and the Environment

Women living in developing or least-developed countries and especially those belonging to marginalised communities within such countries are intimately connected to nature and both land- based and marine natural resources. In many societies and cultures across the world, women derive their sense of identity and social wellbeing, as also their economic and food security, from the environment. It is not surprising, therefore, that Indian women have a long history of actively participating in environmental movements. In India, their participation dates as far back as the early 1730s, when the Bishnoi women started a movement to protect the Khejri trees in rural Rajasthan. Indian women participated actively in peasant ecological movements like that of the Champaran in 1917 in the early days of India's independence movement and in the Chipko movement of 1973, where women mobilised their communities to maintain the ecological balance of the Terai region in Uttarakhand.[3]

Indian women are still actively involved in the agriculture- and allied sectors. This is true for the fisheries sector as well. For fisherwomen, the sea is their collective mother who gives life to their fishing villages.[4] According to the 2018 edition of the "Handbook on Fisheries Statistics" produced by the Government of India's Department of Fisheries of the Ministry of Fisheries, Animal Husbandry and Dairying, published in September 2019, fisherwomen account for 34.6 per cent of the total fisherfolk population that engages in various fishing and fisheries-related activities.[5] The latest draft of the "National Fisheries Policy 2020", formulated by the National Fisheries Development Board (NFDB), claims to be "*based on the cardinal principles of equity and equality and adopts a people-centric and participatory approach; [which] mainstreams gender and maintains inter-generational equity.*"[6] In truth, however, the participation of fisherwomen is restricted throughout the various processes involving the fisheries sector, starting from the collection of fish and extending all the way to managerial and entrepreneurial positions. It seems clear that public policies and civil society support are not able to reach women in these communities effectively.

Fisherwomen participate in various activities of the fisheries industry, such as fish-drying, net-making, and shrimp-making, among others.[7] India holds the third position with respect to fisheries, and second with respect to aquaculture, globally.[8] The annual fish production of inland areas (ponds, tanks, etc.) and marine ones (the latter includes the exclusive economic zone, the continental shelf, etc.) is around 3.2 million tonnes and 3.8 million tonnes, respectively.[9] The fisheries sector in India employs about 16 million people and accounts for 6.58 per cent of the agricultural GDP, while contributing 1.03 per cent to the overall GDP (2017-18).[10] India is a leading exporter of seafood, with marine exports accounting for at 5% of the total exports of the country. According to the NFDB, India has the potential of producing 8.4 million tonnes of fish from an aggregate of inland and marine sources.[11]

Implications of Climate Change for Fisherwomen in India

These impressive statistics notwithstanding, the ground reality is that India fares very poorly in terms of empowering its women, especially those with inherent socio-economic and political disadvantages. Recent studies on gender and climate change have shown that vulnerabilities emerging in the aftermath of extreme-weather events induced by climate change (such as floods, cyclones, droughts, etc.) have a notable gender dimension.[12] In general, women and men experience the impacts of climate change differently because of differences in their roles and responsibilities at the household and community levels. According to "Women Watch Fact Sheet: Women, Gender Equality and Climate Change" produced by the United Nations, "*women are more vulnerable to the effects of climate change than men – primarily as they constitute the majority of the world's poor and are more dependent for their livelihood on natural resources that are threatened by climate change.*"[13]

Women are more exposed to climate change because of a variety of social, economic, and political reasons, which often influence and intersect with one another at the local and national levels. It is important to understand the vulnerabilities of fisherwomen in India in the context of their roles and identities, which are neither static nor homogenous across the various socio-economic interactions of caste, income, geographic location, age, and household membership.[14] Women experience gender- differentiated higher risks in their capacities as individuals, groups, and community members, in comparison to men.[15]

A recent study by the World Bank states that "*103 out of 141 countries have legal distinctions between men and women that are likely to hinder women's economic opportunities.*"[16] Fisherwomen in India face relatively harsher economic conditions and lack both, opportunities and access, in building economically sustainable livelihoods. Fishing, for instance, began as a purely traditional activity but has now become a decidedly commercial enterprise, with the dependence of traditional marine fisherfolk on marine capture-fisheries increasing just for sustaining livelihood. According to a case study published by the International Federation of Red Cross and Red Crescent Societies on fisherwomen in Andhra Pradesh, fisherfolk are relatively poor and often come from lower castes.[17] Moreover, they often get trapped in bad debts because most of the fisherwomen are landless and depend on local moneylenders for credit. The latter ruthlessly exploit the fish-supply value chain, run "*their businesses by essentially recycling the poor fishermen's capital*", and push the fishers into "*a vicious circle of debt and poverty.*"[18] Women are also dependent on their husbands, who control the finances and, in many instances, squander money on liquor. Fisherwomen do not have easy access to marketplaces — they often walk several kilometres to market their products.

Studies conducted by the 'Action Aid', and, the 'District Fishermen Youth Welfare Association', two NGOs based in Andhra Pradesh, highlight that fisherwomen "*face several hardships in the course of their backbreaking work*", which involves long working hours outdoors, which makes them unable to attend medical camps and they "*earn just Rs 100-200 a day*".[19] With climate change expected to make outdoor conditions worse due to rising temperatures and erratic rainfall patterns, fisherwomen will be exposed to greater health risks. Many of them already suffer from skin diseases, kidney problems, and sleep- deprivation caused by harsh working conditions and environments that do not provide even the most basic sanitary requirements. Their health is also impacted "*due to lack of toilets and drinking water facilities at the fishing harbour or other places where they sell their catch",* a problem that is coupled with lack of awareness about sanitation issues and their rights to hygienic working conditions.[20] They also bear the additional burden of unpaid care work and face gender discrimination and marginalisation. Many fisherwomen are anaemic, and often have to endure domestic violence in one form or the other.[21]

Women are also more dependent on natural resources for survival. In India, climate-change events have impacted marine resources across the country. The most severe impacts of climate change are manifested in the forms of resource-depletion, increasing natural disasters, changes in aquaculture, habitat- and species-loss, loss of livelihood for fishing communities, and, biophysical changes such as changes in water-salinity and the introduction of invasive species. Climate change impacts the livelihood and coping responses of fisherwomen, and, in some cases, may even lead to large-scale migrations.[22] Several studies suggest that women, as a group, are often neglected in relief efforts in the aftermath of natural disasters. A case in point is the relief and rehabilitation efforts made by the government and humanitarian organisations in the aftermath of the 2004 *tsunami*, which largely neglected fisherwomen as a target group that needed assistance for rebuilding their lives.[23]

Illiteracy and low levels of skill sets, amongst Indian women in general, and fisherwomen in particular, also contribute to their existing vulnerabilities because they impair their ability to make informed decisions in times of crises. Women are subjected to discriminatory cultural norms that restrict their participation in political and household decision-making processes, and the prevailing gender-differentiated socio-cultural ethos does not encourage women to learn skills (such as swimming, climbing trees, wilderness survival skills, etc.) that could better prepare them for natural disasters. The rate of illiteracy is the highest amongst fisherwomen who work in the unorganised fisheries sector.[24] Further, their knowledge of scientific subjects, including those directly related to the environment, is often severely lacking. All these existing systemic disadvantages for fisherwomen will inevitably be exacerbated by climate change.

There are virtually no rigorous, contemporary studies on a major, pan India level that focus upon the impacts of climate change on fisherwomen in India. There is, consequently, a lack of analysis of climate-change impacts on fisheries from a gender perspective. Some case studies, such as the "*Awareness, perceptions, and adaptation strategies of women in an urban fishing village in a climate change environment – a case study in Versova, Mumbai*", published in 2016 in the Indian Journal of Fisheries, have looked at the impacts of climate change on fisherwomen, but these are far and few between.[25] There is certainly no systematic pan-Indian study on the subject.

Alleviating Challenges and Empowering Indian Fisherwomen

Admittedly, the long-standing systemic challenges facing fisherwomen in India are beginning to get noticed, howsoever sporadically, and have become a topic of policy debate in recent years, even though explicit correlations with the impacts of climate change have not yet been made. This section will highlight some of the noteworthy measures that have been taken at the local and national policy level and by civil society groups to elevate the fisherwomen communities.

Since fisheries is a state subject, a few state governments in the coastal states of India have taken initiatives to support fishing communities. Odisha, for example, which is one of the major aquaculture and maritime states of India, has introduced the '*Matsyajibi Unnayana Yojana*' which extends financial assistance to fisherwomen, amongst other measures.[26] Odisha's Fisheries Policy is another of its state-level policy measures, and aims to give importance to education, vocational training, diversification of employment opportunities through capacity-building, market tie-ups, and social benefits, amongst its various measures for the state's fisherwomen. Likewise, Andhra Pradesh, in the execution of the "Fisheries Policy of Andhra Pradesh, 2015-2020" extends orientation-training and technical and financial assistance for ornamental fishing to women self-help groups, and provides subsidies to women belonging to fishing communities — subsidies that are at par with its industrial policy.[27] It is important to note that while the measures taken by Odisha and Andhra Pradesh are encouraging, they are certainly not being replicated across all the states and union territories of India. Moreover, there is little or no evidence that any significant emphasis has been given, within any of these initiatives, to the worsening impacts of climate change and their repercussions for fisherfolk, in general, and fisherwomen, in particular. That said, there are, nevertheless, some faint glimmerings of a more enlightened policy and these deserve to be highlighted.

At the national level, the 'National Institute of Fisheries Post Harvest Technology and Training' (NIFPHATT) has undertaken several initiatives to empower fisherwomen across Odisha, Andhra Pradesh, Lakshadweep, Tamil Nadu, and Kerala, through training programmes, restoration programmes, the proactive involvement of fisherwomen in product-development activities, and employment generation through self-help groups for fisherwomen. The NIFPHATT claims that, "*treading along the meaning of the famous saying "Give a man a fish and you feed him for a day: teach a man to fish and you feed him for a lifetime", this Institute has been providing the skill and techniques to fisherwomen which help them to get their daily bread.*"[28]

Staying at the national-policy level, the draft National Fisheries Policy (NFP) 2020 states that, "*necessary steps will be taken to encourage women in fish processing, value additions, marketing activities, fisheries management including creation of requisite amenities for improving workplace environment … current welfare, and social protection programs will be streamlined and further strengthened.*" To ensure gender equality, welfare, and mainstreaming of women in the fisheries and aquaculture sectors, the policy draft adds that, "*government will further enhance support to women cooperatives, women self-help groups and through women-friendly financial support schemes.*"[29] The NFP 2020 aims to achieve these targets by 2030. Alongside these policy measures, however, there is an urgent need for the governments of India's coastal states, as well as the central government, to work together with each other in the fisheries sector, so as to utilise the resources, particularly those resources that are presently underutilised, to offer opportunities for the development of livelihoods, and for ushering economic prosperity,[30] with special measures taken for the empowerment of fisherwomen. This is more critical now than ever before, because of the fast-changing climatic conditions and the adverse impacts that these will have on the livelihoods of fisherwomen.

A few notable NGOs, too, have been active. For instance, 'ActionAid India' and the 'District Fishermen Youth Welfare Association' (DFYWA), have initiated programmes (with some financial support from the UK and the European Commission) that focus on improving the living standards of fisherwomen in India by establishing market linkages, building sensitivity among families of fishermen about the contribution of fisherwomen, and, upgrading skills and leadership qualities of fisherwomen in rural areas.[31] They also aim at strengthening women collectives and cooperatives. The support received from these NGOs has yielded tangible and beneficial results on the ground – some women who formed part of their target group have become ward members, while others are headed to government offices or collectorates. Some have also learnt how to write, and, in some families, women are now supported by their male family members in their work.

Fisherwomen themselves have begun to participate proactively in improving their circumstances. For, instance, women's agencies, such as Kerala's 'Society for Assistance to Fisherwomen', and one of their microenterprises, 'Seafood Kitchen', are focused on empowering fisherwomen through small businesses.[32] In Odisha, a group of fisherwomen started an NGO called *"Samudram"*, which now comprises 4,000 members from 250 women's self-help groups.[33] *Samudram* enlisted the support of OXFAM in 2008, and, in 2010, received the UNDP Equator Prize for its efforts in biodiversity- conservation, and poverty-alleviation.[34] Such community-led efforts will play an increasingly important role in the future as climate-related challenges become more prominent. They must, therefore, be encouraged and supported by local and national governments. Additionally, there is a need to increase the reach of government-led welfare programmes to the less-economically- developed states and districts.

Conclusion

Gender issues have traditionally been sidelined in research that has been undertaken on major policy and academic issues, including those in the maritime domain, of which fishing and climate change form an integral part. Fisherwomen in India form an intrinsic part of the fisheries sector. However, their contribution, participation in the industry, and their vulnerabilities, are largely ignored both at the local community level and the national one.

Measures need to be taken at both the level of public policy, as also at the level of civil society at large, to incorporate the perspectives of fisherwomen in the larger policy framework of India. In this regard, there is an urgent need to undertake case studies, conduct field visits, and undertake primary research at the local/state level, so that a reliable pool of data is generated that could assist in formulating gender-sensitised policies for the fishing community in India.

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Note

This article was first published on 19 October 2020 on the Website of the National Maritime Foundation

Impact of Climate Change on Indian Coastal Cities and Communities: Need for an 'Integrated Adaptation' Approach

Dr Chime Youdon

A country's coastline is the epicentre of its business, commerce, transportation, and industry. It provides a majority of the global ecosystem goods and services that are central to the country's socio-cultural and economic development. The Indian coastline is one of the most vulnerable, risk-prone and densely populated regions in the world. Indian coastal cities have been altered profoundly in the last few decades due to their rapid growth in population and economic activities. With rapid urbanisation, it is likely that human dwelling-concentrations will increasingly extend to low-lying areas of the coast.

It is reliably estimated that the number of people living in Low-Elevation Coastal Zones (LECZ),[1] as also the total number of people exposed to climate change-related events such as flooding and storm surge events (1-in-100-year return period) are the highest in Asia; and coastal populations of India, China, Bangladesh, Indonesia and Vietnam are expected to have the highest exposure. In fact, available research findings indicate that India could experience a three-fold increase of its LECZ population between the baseline year 2000 (64 million; 6.1% of its total population) and the year 2060 (216 million; 10.3% of its total population) under a high-growth scenario.[2] Groups most at risk in a typical Indian city are slum dwellers, squatters and migrants. These include workers in the industrial and informal service sectors; whose occupations frequently place them at significant risk from natural hazards. More often than not, these groups live in traditional and informal settlements, often in locations that are extremely vulnerable to a variety of social and economic risks that are exacerbated by additional stressors such as climate change. Hence, the threat posed to coastal cities by a rise in the sea level caused by climate change is both, high and multi-dimensional.

The impact of climate change-induced sea-level rise is aggravated by unsustainable and unplanned development, and the growth of densely populated and unstructured settlements in coastal cities. Limited access to housing, public services and infrastructure for the poor, as also poverty itself, add to the vulnerability of coastal cities. Consequently, extreme climate-induced hazards weaken the resilience and coping-capacities of already poor and vulnerable communities, raising socio-economic costs. The impact of climate change on coastal cities is a vital strategic, economic and political issue as well.

The chapter focusses upon the manner in which urban expansion and encroachment have intensified vulnerability of coastal cities to climate-change-induced impacts. It also discusses how the most vulnerable and disadvantage section of the population is overlooked, and how the lack of fair equity in several dimensions of action and decision-making in terms of coastal adaptive measures ends-up reducing the adaptive capacity of coastal cities. As such, it tries to address the need to take into consideration of the adaptation needs of marginalized and vulnerable groups, several of whom are likely to be disproportionately affected because of structural and social disparities. It highlights how it is important to provide environmental justice and bottom-up solutions on the community level to tackle inequality and eliminate poverty. This chapter seeks to draw the attention of the Indian populace at large, but most particularly that of India's coastal communities and their governance structures, to the alarming and imminent challenge posed by climate-change-induced sea-level rise.

Exposure of Coastal Cities and Communities to Climate Hazards

On the one hand, coastlines in general are highly productive and critical elements of any country as they provide a globally-connected ecosystem of goods and services, which is central to socio-cultural and economic development. On the other hand, they are areas that are highly risk-prone vis-à-vis climatic impact. Perhaps the most serious risk, and one that is growing much faster than predicted, involves the adverse impact of climate-change in its several manifestations. These include extreme climatic events such as flooding, drastic changes in the precipitation cycle, a sharp and sustained rise in sea-surface temperature, and, tropical revolving storms (TRS) that are, of late, demonstrating a marked increase in frequency-of-occurrence and in ferocity/intensity, but an equally marked decrease in path-predictability. The occurrence of such extreme weather events is affecting both natural ecosystems and human systems severely and adversely, with socio-economic productivity being correspondingly impacted. Moreover, coastal cities already stand exposed to high and multi-dimensional risks induced by climate-change-related sea-level rise. Coastal cities are also highly vulnerable to anthropogenic climate change and have the least capacity to adapt. Yet, exposure to the impacts of climate hazards are expected to increase with growing population and economic relevance of coastal cities.[3]

Insofar as India is concerned, the country's coastline runs for some 7,516 kilometres (km) across nine states and four union territories (UTs) — two of the latter, namely, the Andaman and Nicobar island chain on the country's eastern seaboard, and the Lakshadweep chain on the western one, being archipelagos. This coastline is home to roughly 170 million people and, not only is it one of the most densely populated regions in the world, it is also extremely vulnerable to a multiplicity of sea-based threats and hazards, the more obvious of which have already been mentioned. The Indian coastline is studded by a number of human agglomerations, ranging from fishing hamlets and villages to megacities. Climate change and climate variability will produce an extremely complex web of interrelated and highly adverse impacts on all such human concentrations but will be most severely felt in large coastal cities. Amongst the most worrying of these effects concerns sea-level rise. Table 1 depicts how the warming of the globe will impact regional climatic variations such as temperature change, precipitation, and sea-level rise, in India.

Major factors that contribute to sea-level rise are ocean thermal expansion, the melting of glaciers and icecaps, glacier-melt from the Greenland and Antarctic ice-sheets, and, to a smaller extent, the melting of snow on land and permafrost. The sea-surface temperature (SST) of the tropical Indian Ocean rose by 1° C on average during 1951–2015, which was markedly higher than the global average SST warming of 0.7° C, over the same period. As a direct consequence, the sea-level rise experienced in

Table 1: Climate Change Projections for India based on Four Global Environmental Multiscale (GEM) Model Outputs

Year	Temperature Change (°C)			Precipitation Change (%)			Sea Level Rise (cm)
	Annual	Winter	Monsoon	Annual	Winter	Monsoon	
2020s	1.36±0.19	1.61±0.16	1.13±0.43	2.9±3.7	2.7±17.7	2.9±3.7	4 to 8
2050s	2.69±0.41	3.25±0.36	2.19±0.88	6.7±8.9	-2.9±26.3	6.7±8.9	15 to 38
2080s	3.84±0.76	4.52±0.49	3.19±1.42	11.0±12.3	5.3±34.4	11.0±12.3	46 to 59

Source: Aromar Revi 2008[4]

the northern Indian Ocean, has accelerated to 3.3 mm per year between 1993-2017.[5] This rate of sea-level rise will accelerate further with the rising mean temperature. Table 1 clearly depicts that increasing temperature is contributing to the sea-level rise and its impacts. For instance, the sea-level rise increased from 4-8 cm to 15-38 cm with an of temperature-rise of just 2° C. This sort of sea-level rise will inundate a very large number of low-lying areas. It is likely to aggravate flood situations, erode beaches and further impact coastal settlements in terms of population-displacement from presently densely-populated areas. As per studies undertaken by The Energy Institute (TERI), a one-metre rise in sea level would displace approximately 7.1 million people within the coastal population, and place about 5,764 sq km of land at risk of getting submerged. Several coastal areas — with their constituent population amounting to some 200 million people — are projected to be below the high-tide line by 2100.[6]

According to the Intergovernmental Panel on Climate Change (IPCC), climate models are consistent with the ocean temperature observations and indicate that thermal expansion will continue to contribute to sea-level rise over the next 100 years. Since deep-ocean temperatures change slowly, thermal expansion would continue for many centuries even if atmospheric concentrations of greenhouse gases were to be stabilized.[7] Therefore, increasing temperatures and sea-level rise are likely to continue to be major risk factors for coastal cities in India, where one-third of the population [which is nearly 40 million people] is located. This regional temperature-rise, along with the changes being experienced in both, the global climate system and the Indian Ocean monsoon system, may lead to a mean increase in annual precipitation of 12.3 per cent by 2080, up from the 3.7 per cent change forecast for the 2020s.

Even more worryingly, it is assessed that many regions in the semi-arid and drought-prone central part of India will also experience a simultaneous decline in precipitation of the order of 5-25 per cent. As if there were not challenge enough, a sharp decline in winter rainfall across northern India is also projected.[8] This lethal combination of severe disruptions to the country's precipitation cycle will severely affect food security and agriculture production. According to a 2011 study conducted by the Indian Agricultural Research Institute and the CGIAR Research Program on Climate Change, Agriculture and Food Security, climate change could lead to a 15-50 per cent decrease in the yield of irrigated maize and a 10 per cent drop in yields of irrigated paddy in the majority of coastal districts by 2030.[9]

Chronic flooding, too, should be expected in the future. The Climate Central study on global vulnerability to sea-level rise and coastal flooding estimates that 36 million Indians are at risk of chronic flooding by 2050 and estimated that number will grow to 51 million Indians by 2100 [See Figure 1]. It also predicted that extreme precipitation similar to the Mumbai floods in 2005 and Gujarat floods in 2006 could occur over other parts of the west coast in the absence of effective adaptive measures.[10]

Cyclones and storm surges are very likely to be devastating for coastal mega-cities such as Mumbai, Chennai, Visakhapatnam, Surat, Bharuch, Bhavnagar and Jamnagar,

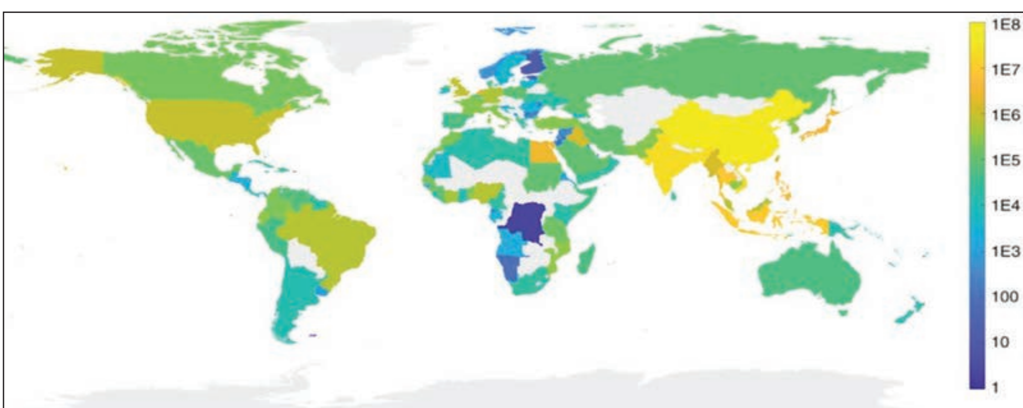

Figure 1: Number of People on Land Exposed to Sea-level Rise and Coastal Flooding by 2050.
Source: Scott A. Kulp and Benjamin H. Strauss, "New Elevation Data Triple Estimates of Global Vulnerability to Sea-Level Rise and Coastal Flooding", Nature Communication, 10, No 4844 (2019).

apart from causing critical bottlenecks in important ports such as Kandla.[11] It needs to be remembered that a storm surge, accompanied by coastal flooding and cyclonic winds, is the second most destructive, rapid onset hazard in Gujarat. It accounts for 12 per cent of the risk to the state and a potential loss of over 11,000 lives for a probabilistic 100-year event.[12] Increased migrations to the coast, drawn by huge investments in coastal infrastructure, settlements and enterprise would be disastrous as there are future risks involved, which have not been considered.

Another major big loss of climate change-induced changes on the coastal region is infrastructure, predominantly ports because India has 12 major and 205 notified minor and intermediate ports. Indian port operator handles significantly large number cargo movement and 95 per cent of the country's trade by volume and 70 per cent by value is done through the ports. Extreme weather events like tropical storm surges, waves, and sea level rise are all anticipated to have a significant impact on coastal transportation hubs and networks, including temporary or permanent flooding of seaports and the roads and rail lines that connect them.

The ongoing-and-accelerating rise in sea level poses a clear, direct and imminent threat to the populations of each such coastal city, and adversely impacts their livelihoods, the city's economy, its tourism, coastal infrastructure, and marine ecosystems. For instance, the degradation of coastal ecosystems, especially wetlands and coral reefs, has serious implications for the wellbeing. The ongoing-and-accelerating rise in sea level poses a clear, direct and imminent threat to the populations of each such coastal city, and adversely impacts their livelihoods, the city's economy, its tourism, coastal infrastructure, and marine ecosystems. For instance, the degradation of coastal ecosystems, especially wetlands and coral reefs, has serious implications for the wellbeing of coastal communities that are largely dependent on the coastal ecosystem for goods and services. It is fairly obvious that coastal flooding caused or accompanied-by sea-level rise will cause serious degradation of drinking-water sources and supply-systems, fishery resources, and, lead to the inundation of low-lying areas, impacting millions of people, with unpredictable consequential political fallouts as well.

A cause of considerable disquiet if not actual alarm is that even if Greenhouse Gas (GHG) emissions are stabilised in the near future, sea levels would continue to rise for many decades.[13] The adverse impact of greenhouse gas emissions and the associated global warming would be irreversible and devastating to the coastal cities, whose millions of economically-disadvantaged inhabitants, many of whom dwell in low-lying areas, are extremely vulnerable to the impact of anthropogenic climate induced hazards and also have least coping capacities. In many cases, these slums and informal settlements are built in low-lying areas that are flood-prone and geologically unstable. Hence, sea-level rise due to climate change is likely to pose not just a serious socio-economic, environmental and security threat to these segments of the population, but rather, an existential one.

Urban Expansion and Increasing Coastal Vulnerabilities

In India, as in several other littoral States, urban critical infrastructure within coastal cities is already vulnerable to extreme climatic events. Indeed, India has some of the world's most vulnerable coastal cities and simultaneously has amongst the least adaptive-capacity to face anthropogenic climate change. Rapid urbanisation is significantly adding to the problem. For example, there are already about 71 lakhs (hundred thousand) dwellings located within 100 metres of the Indian coastline.[14] Studies undertaken by the National Institute of Disaster Management estimate that by the year 2050, the Mumbai-Pune megapolis is likely to have a population of over 50 million. Likewise, Kolkata's population is expected to touch 20 million.[15] Investment in critical infrastructure to meet the demands of this exponential growth will, of course, increase dramatically but it is important to understand how much of this enhanced investment, will meaningfully address climate-change adaptation measures and enhance the resilience of coastal communities.

The already pitifully-inadequate natural 'green' areas are diminishing alarmingly in the face of uncontrolled development of built-up areas, with numerous water bodies and rivers being encroached upon. For instance, Chennai's Thamaraikeni lake, in Sholinganallur, has shrunk from 152 acres to a mere 26 acres. The 2017 audit report of the Comptroller and Auditor General of India indicated that "*the built-up area in Chennai metropolitan has grown from 90.88 sq km in 1979 to 541.14 sq km in 2016. On the other hand, the water spread area of lakes and ponds has shrunk from*

100.98 sq km to 91.31 sq km in the past 40 years."[16] Such a heavy burden imposed on the ecosystem is completely unsustainable and as has been somewhat unemotionally stated, *"of all land-use changes affecting the hydrology of an area, urbanisation is by far the most forceful."*[17]

Moreover, extensive research indicates that the number of people living in the 'Low Elevation Coastal Zone (LECZ),[18] as also the number of people exposed to adverse '1-in-100 year' events related to climate change, such as flooding and storms surges is the highest in Asia. The coastal populations of India, China, Bangladesh, Indonesia and Vietnam are expected to have the highest exposure to such events. In fact, the result depicts that under a high-economic growth scenario, *"India could experience a three-fold increase of its LECZ population between the baseline year 2000 (64 million; 6.1% of its total population) and the year 2060 (216 million; 10.3% of its total population)."*[19] As has already been explained, the urban-poor and low-income groups dwell in low-lying areas that have a minimal capacity to respond-to or cope-with these impacts. However, it is also important to recognise that the continued rapid growth of megacities and informal settlements, and poorly-planned developmental activities along the coastline further not only threaten the coastal environment but also accelerate urban crime, and impose extra burdens upon policing and disaster-relief organisations.

Non-climatic factors such as population growth, too, are changing coastal landscape and impacting the coastal ecosystem.[20] Urbanisation in terms of continued development and redevelopment, leading to an ever increasing density in terms of land-use, as also a sharp increase in urban infrastructure such as roads, roofs, paving, etc., lead not only to greatly enhanced water run-off but also enhanced urban flooding. Therefore, coastal disaster-development managers need to invest in inclusive and compatible climate infrastructure development in coastal regions, and simply cannot afford to exclude some sections of people, especially not the already-vulnerable ones.

Conflict of Interests and Environmental Injustice

The diversity of resources and opportunities along the coastline are important drivers of demographic shifts on account of urbanisation. Once the acceleration in urbanisation overtakes existing socio-economic infrastructure to a point where the influx of people into overtakes the ability of the burgeoning town or city (i.e., the 'urban agglomeration') to develop additional physical infrastructure or to create societal safety-nets the socio-economic environment deteriorates very sharply and very swiftly. When this socio-economic deterioration occurs in coastal areas, the poor and economically disadvantaged tend to occupy dwellings located in areas that had already been rejected by the more affluent classes. These areas are often low-lying ones, which are the most prone to being adversely impacted by the effects of climate change in general and flooding in particular.

The problem of instituting climate-change adaptation measures for these disadvantaged segments of urban society are exacerbated by the fact that the stakeholders involved in the coastal development are required to meet often-incompatible demands such as facilitating economic development, meeting needs of the rapidly-expanding tourist industry, while simultaneously protecting vulnerable communities from the effects of erosion and flooding. The interests of business and local communities are frequently in conflict as their concerns are different. To the business community it appears that policies aimed at conservation of the natural ecosystem limit the prospect of economic growth.

On the other hand, the more enlightened segments of resource-dependent communities tend to recognise the severity of destruction of the environment due to unregulated development. Economic growth, modernisation and markets are still viewed as the core drivers of development and poverty alleviation. However, the Sustainable Development Goals (SDGs) to eradicate poverty are undermined by the economic aspect of development. Writing in the UN HRC report on extreme poverty, Australian academic Philip Alston warned that states and global organisations are *"completely off track"* to meet the goal of eradicating extreme poverty by 2030. Instead, more people are likely to become highly impoverished by existing challenges like the climate crisis, as well as by new shocks, including the Coronavirus. He stated that *"they are failing in relation to key goals such as poverty eradication, economic equality, and climate change."* Alston also suggests the framework they provide for poverty eradication appeared more tailored for *"colourful posters"* and *"bland reports"*.[21]

The Secretary General's "SDG Progress Report 2020" notes that "*the SDGs have had little impact in slowing global warming*." A deeply problematic fact is that each country's development tends to be focused solely upon a traditional model of economic growth without much consideration being given to its environmental impact or the extent to which it is tied to emissions and extraction. Hence it is important that the nexus between poverty, development, and climate change be holistically studied while formulating adaptation strategies and policy-measures related to climate change. There is a marked lack of equity in decision-making and even less in the actual action taken in terms of coastal adaptive measures, with the most vulnerable and disadvantaged section of the population often being completely overlooked. This is particularly problematic since the adaptive capacity of this section of urban society has already been significantly reduced by existing socio-economic and environmental inequalities. Therefore, it is vital to understand how India responds to its marginalised communities. Since 2015, India has committed itself to achieving the SDGs and their associated targets, including the social, economic and environmental dimension of development, with a sustained focus on ending poverty in all its forms and dimensions.[22]

Unequal Participation in the Decision-making Process

The responsibility for the conservation and regulation of coastal areas in tackling climate-change rests with a variety of stakeholders, local communities, state and central government agencies, etc. Consequently, the proactive and enthusiastic participation of different sectors and groups in the decision-making process is vital in order to formulate a holistic and integrated national climate approach. Ironically, however, the recent Environment Impact Assessment (EIA) 2020 amendment draft[23] has proposed the exclusion of local decision-makers and local communities in the decision-making process, thereby ignoring and marginalising their concerns and traditional knowledge of the environment. Indigenous and resource-dependent communities have a deep understanding and knowledge of natural disasters and how to cope with them. When their participation is excluded, we lose out on a wealth of knowledge about resources that have been an integral part of their lives.

In a broader sense, such short-sighted policies border on arrogance and, more importantly, create structural inequalities within the socio-environmental system.

Marginalised communities are the one who usually face environmental injustice in terms of exposure to environmental hazards. Consequently, access to natural resources, equitable protection from climate-change burdens, meaningful involvement in decision-making procedures, and fair access to the benefits of adaptive measures, collectively constitute a *sine qua non* for a successful climate-change policy.

The EIA 2020 draft amendment has also proposed that violations are to be reported either by a government authority or the developers themselves. Civil society has been left with little or no scope to raise public complaints. Incredibly, the onus is on the violators themselves to disclose, *suo motu*, that they broke the law. In the case of encroachment and illegal land use, a public complaint would not be considered as a proper channel to report any violations. This makes a mockery of the State's commitment in preserving the fragile ecosystem, especially in coastal cities, where land for development is limited, and the possibility of encroachment of protected areas for commercial purposes is high. Land-grabbing from local communities for ostensibly-developmental purposes, with little compensation to displaced segments of society (more often than not these are the already disadvantaged segments) is commonplace. For instance, the Kerala government has proposed to relocate some 18,000 households that dwell within 50-metres of the sea by offering to compensate the residents with Rs 10 lakh each. However, so unrealistically meagre is this compensation that 16,000 of the 18,000 flatly refused to accept the offer.[24] Such actions by the local and national governments put profits above people and are detrimental to the environment and equity for minorities.

Limiting public-engagement and giving inadequate time to public hearings are actions that have an acutely adverse impact on the environment and the cost of this sort of negligence will be very high. It is likely to result in climate refugees, poverty, unemployment, migration, amongst a host of other undesirable primary, secondary and tertiary effects. It is reiterated that the people most affected by this new draft-amendment of the EIA 2020 are those belonging to the most vulnerable sections of society. The more powerful and more affluent sections have the facilities and assets to insure and rebuild, whereas the poor are unable to do so. A case in point is the infection rates in the Covid-19 pandemic, where densely populated coastal cities like Mumbai, Kolkata and Chennai have become infection hot-spots. Within these overcrowded coastal cities, poor and marginalised communities are the ones who are hardest hit, largely due to their lack of access to resources and health-care facilities and a concomitant lack of basic opportunities. Climate-change impacts are placing them at an even higher risk of exposure to the pandemic. Climate-induced disasters such as devastating monsoon flooding that regularly hits both the east and west coasts of India [Cyclones *Amphan* and *Nisarga* are recent examples] has increased the vulnerability of the coastal communities even further. The harsh aftermath of such disasters is a reminder that climate adaptation and resilience measures and mechanisms are more urgent than ever.

The COVID-19 pandemic has also shown that individual resilience is essential to reduce community vulnerability. What this means, of course, is that livelihood and economic security are crucial if people are to have uninterrupted access to food, water, sanitation, shelter, and other services essential to the maintenance of health. This is true to withstand any disaster, whether it is a pandemic or a climate-related one. Ensuring sustainable and reliable access to resources and facilities will reduce the risk of exposure to hazards and provide the capability of individuals and communities to recover.

Social Equity in Climate Change Adaptation

Adaptation measures alone cannot provide a holistic approach to reduce climate change impacts in the context of the rapid rise in population and urbanisation. When developmental projects do not take into consideration the adaptive capacities of the poor, the mitigation measures, and climate change impact, they further denude the urban poor, and the gap between rich and poor widens, generating societal tensions that are too well known in India. In many cases, regional and national level developmental policies actually and actively undermine the resilience of the weaker section of the society. Therefore, identifying and addressing the root cause of the vulnerability of different societal segments to the impacts of climate change are of foremost importance. Similarly, development policies that address only certain aspects of poverty are likely to fail, resulting in detrimental impacts on the overall response-capacity and sustainable adaptation of the nation. Clearly, adaptation measures and development must be considered within a broader social and environmental context. Sadly, development plans that fail to include climate-change risk-assessment are all too common even in mega projects such as SAGARMALA, which seeks to promote port-led development of the country as a whole.

If the policies and measures for climate adaptation and mitigation are not adequately comprehensive or sufficiently inclusive, they may increase resilience on one level while increasing vulnerability on others. Therefore, socio-economic and environmental inequalities that often reduce adaptive capacity need to be properly and sincerely addressed. Local knowledge about adverse climate change impact and how it can be mitigated, and about adaptation and development must be valued and must be shared at the national level. A strong capacity to reduce risk and build resilience requires a firm local government policy that is pro-poor. Such a policy or policies must be especially aimed at ameliorating the vulnerabilities of those living in suburban slums, which are amongst the most hazardous locations. In the final analysis, only local government can provide better access to resources and assistance in improving the quality of housing, which can withstand hazards and reduce costs and susceptibility.

Towards Integrated Measures and Policy

The state and central governments cannot duck their own responsibilities either pinning the entire burden upon local government bodies. Clearly, climate-change adaptation and impact-reduction measures require to be integrated into larger socio-economic development programmes. Thus, the state and central governments need to ensure social sustainability and just and social equity to ensure equitable management of all institutions serving the public. While framing coastal management policies, policymakers must integrate regional and local perspectives, and recognise the dynamic nature of the coastal environment, as also the vulnerability of coastlines, instead of viewing each of these as distinct factors.

A strong integration of well directed adaptation efforts, with a sustained focus on the disadvantaged sections of the population, is required. Addressing and providing inclusive, equitable and environmental justice in the planning and policy-making procedures will strengthen and increase the adaptive capabilities and resilience of vulnerable groups. As Mr Ovais Sarmad, Deputy Executive-Secretary of UN Climate Change, said: "*we do not have time to lose, and urgent climate action is absolutely critical and necessary. What benefits the most vulnerable will benefit us all.*"[25] Therefore, equity simply has to play a very much more significant role in local, regional and national climate change adaptation strategies in Indian coastal cities than is currently the case. Equal participation needs to be considered a 'core' strategy for fostering sustainable development and socio-economic advancement that would support an improvement in the quality of life while maintaining natural resources.

The marginalised group must be prioritised in efforts to end social injustice and environmental inequality, and must be given enough political protection against environmental threats as well as the opportunity to participate in decision-making processes. The systemic change for effective management of the coastal zone requires resolution of conflicting demands on resources while ensuring that human activity does not significantly affect the coastal system or the ecosystems which they support. It further requires improved institutional capacity and effective urban governance, the involvement of non-government organisations and civil society at large into the urban governmental decision-making processes.

ENDNOTES

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Note

This chapter was first published as a two-part article series (on 29 November 2020 and 05 December 2020) on the Website of the National Maritime Foundation

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Rs. 550.00

ISBN 978-81-959079-7-7

9 788195 907977

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