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Steering Ahead – Leveraging Science, Technology and Innovation in Blue Economy"

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Working Paper

Acknowledgments

This the second working paper by TERI as part of the Quadrilateral dialogue series being jointly implemented by Konrad Adenauer Stiftung India office and National Maritime Foundation and FICCI. This paper focuses on the theme of "Steering ahead – Leveraging Science, Technology and Innovation in Blue Economy".

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INTRODUCTION -ROLE OF SCIENCE, TECHNOLOGY AND INNOVATION IN BLUE ECONOMY

As populations around the world expand, our coastal and marine environments are becoming a very significant means for global economic development, to the extent that the oceans have been labelled the 'economic frontier', which is still largely unexplored. The oceans have been utilized for traditional economic activities over several generations. However, since over three billion people depend on coastal and marine ecosystems for their livelihoods, either directly or indirectly, unregulated economic activities occur that cause notable damage to the oceanic environment. With the oceans being used more intensely now than ever before, it is only through the development of new technologies and innovations that resources from the oceans may be better and more sustainably utilized. Science and technology will lead in determining new sources for growth, while innovations will aid in gaining access to new resources and spaces for development. The vast resources of the world's oceans can only be harnessed if countries develop the technological means of doing so. Within the Indian Ocean, this still is a challenge for the countries of the region to achieve (Mostaque, 2020, OECD STI policy note 2019).

Studies indicate that those countries that are able to guide the processes of science, technology, and innovation (STI) in the direction of becoming knowledge-based economies, obtain higher economic

growth and success than those countries that do not. Furthermore, STI capacities are also seen by the World Bank as a tool for countries to achieve their foremost objectives for social and economic development (Schwachula et al, 2014). The policies of governments in terms of science and research greatly impact business development and marine preservation, and additionally, are critical in ocean stewardship, regulation, and management. For effective performance across these areas, it becomes necessary for the policies to be evidence-based and coherent, the supporting evidence for which could be obtained by advancing economic measurement and monitoring of the oceans. This may be achieved by standardizing the approaches utilized in measuring and valuing ocean industries and integrating them into the national accounting using satellite accounts; measurement and valuing of natural resources and ecosystem-derived services and exploring for the means by which they may be integrated into the national accounting frameworks; and improved identification and measurement of the benefits of public investment in long-term ocean observation systems (OECD 2019).

OVERALL CURRENT ROLE

The world's marine and freshwater ecosystems – the Blue World – provide essential ecosystem services, biodiversity, food and livelihoods for hundreds of millions of people. It is estimated that over three billion people either directly or in-directly depend on marine and coastal systems for their livelihoods (Senaratne, 2017). The importance of harnessing ocean economy is, therefore, cannot be stressed enough. But sustainable ocean economy has to be based on clean technologies that will ensure the economic and social needs of the people without damaging the planet. While traditional ocean industries tend to comprise the fisheries sector, tourism and maritime transport, often do not take into account environmental factor and within the blue economy new and emerging activities, such as offshore renewable energy, aquaculture, marine biotechnology and bioprospecting, and seabed extractive activities could also be included. It also incorporates services provided by water ecosystems for which markets do not exist, such as carbon sequestration, coastal protection, waste disposal and the existence of biodiversity. The role of science, technology and innovation in blue economy is to shift society from a scarcity to abundance based on existing resources. This includes the use of water resources that can be reused and contribute to the production of sustainable energies, reduction in energy costs for water, etc. Science and technology will have to search for new sources of growth, while innovative advances will make new resources and spaces accessible for development. The first requirement for successfully exploring the oceans and for a sustainable ocean economy is to know about it more thoroughly, for which there is need for data about the oceans. This calls for more ocean observation and scientific missions.

Another major role of science and technology, in regards to the ocean economy is using them to stimulate improvements in efficiency, productivity and cost structures in the ongoing oceanic activities. Whether it is shipping, port facilities, energy or tourism, scientific research is required to make them more cost-effective. Technologies such as imaging and physical sensors, satellite technologies, advanced information and communication technology (ICT), big data analytics, biotechnology, nanotechnology and subsea engineering etc. For example, some countries are using the Block chain and Big data analytics applications in their port facilities and maritime supply chains. This will help them to provide more integrated services for shipping companies, port operators and marine transport stakeholders while saving cost by deploying a more efficient system. The most popular area where science and technology are used in the ocean economy is in the area of blue biotechnology. It has an important role in the extraction of marine species, which are then applied to a number of sectors including biotechnologies, nanotechnology, bio-materials and the introduction of genetically modified fish that can yield high economic returns (Ninawe and Indulkar, 2019). The ocean environment is still a largely unexplored area where new compounds can be found with

potential to be used in novel drugs, health, nutraceuticals and personal care products. Some examples of the use of blue technology is the bioremediation of ocean pollutants and also developing cost effective and non-toxic antifouling technologies used in the shipping industry. In the renewable energy sector new technology and innovation is largely required in offshore wind industry, harnessing wave and tidal energy and capturing the ocean thermal and salinity gradient energy (Patil et al.,2018)

Evolution of S & T in India- From Past to Present

Over the past few decades India has sought to prioritise reducing dependence on foreign technology through indigenous innovation. Security concerns about neighbouring countries and protecting the coastline make development of dual-use technologies (such as nuclear technology, space and ocean exploration) a high priority. Developing capacities in health and agricultural technologies, information and communication technologies, biotechnology, and nanotechnology is also a priority. Instead of a multi-year, long-range S&T plan, India's planning commission had issued five-year plans since independence was achieved in 1947, each of which contains an important section on S&T. A review of previous five-year plans reveals the continuation of strategies in key technology areas, which indicates that there is a long-term strategy, even though it is not documented beyond five years. The five-year plans identifies detailed research foci and envisioned outcomes for 16 sectors with the greatest proposed national laboratory funding in the following areas, in descending order: aerospace, pharmaceuticals, materials, information technology, biology, earth systems and exploration (including on- and off-shore geophysical studies), and energy.

India is holding a distinctive Global Innovation Index ranking in 2019 (ranked 52).For India ocean economy initiatives have mostly consisted with port facilities and building partnership with many of its neighbours. So far, the country has blue economy cooperation initiatives with Seychelles, Mauritius, Sri Lanka and Bangladesh among other countries and ocean technology is one of the areas of cooperation among others (Islam and Mostaque, 2019). When it comes to ocean technologies, the country has generated significant revenue for marine biology and biotechnology. It has been projected that the country will generate USD 100 Million by 2025 through biological and bio-technology industrial growth. The Indian Department of Biotechnology has taken initiatives to explore the potential. The department is setting up an institute on ocean biology and bio-technology for research and development of oceanic resources. On the other hand, the Indian Ministry of Shipping is also becoming more tech-savvy. It has started using IT enabled services extensively for its port-led development programmes (Ninawe, and Indulkar, 2019). Additionally, the "Sagar-Mala" initiative, is assisting in increasing Africa's maritime capabilities, which includes development of maritime capacity building in, among other areas: coastal area development, port infrastructure buildings marine sciences, renewable energy and hydrography.

India's technology requirements are vast and imply great utility for a wide variety of scientific fields from nuclear energy to agricultural science. In order to understand India's current areas of focus, it is helpful to highlight achievements in the past five-year plans. The 10th Five-Year Plan, completed in 2007, was considered by many to be an enormous success. Its accomplishments include the commissioning of two 540 MW indigenously designed PHWR, the first light from the Indus-2 synchrotron, and the debut of a countrywide environmental radiation monitoring network with 37 monitoring stations across the country. Substantial progress has been made in satellite technologies, beginning with the operation of the Geosynchronous Satellite Launch Vehicle (GSLV), the development and qualification of an indigenous cryogenic rocket engine. Other scientific achievements include installing early tsunami and storm surge warning system, Strengthening the ocean observation network by deployment of state-of-the-art technology data buoys and Argo

floats, completing the maiden flight of SARAS, a multi-role civilian aircraft, beginning the Nano Science and Technology Initiative, forming a new Ministry of Earth Sciences for programs related to Earth and atmospheric sciences and qualification of an indigenous cryogenic rocket engine.

"Technology Vision 2020," a strategy document prepared by the Technology Information, Forecasting and Assessment Councils of Department of Science & Technology has identified key programs under the 11th five-year plan: Space (development of satellite launch capabilities and critical technologies required for manned missions), Biotechnology (stem-cell, animal and plant biotechnology), Ocean (coastal protection, ecosystem modelling and marine ecotoxicology), Atomic Energy (improve nuclear capacity, enhance competitiveness of nuclear energy), Pharma (drug discovery) and improvement of basic and rural infrastructure.

Dr Harsh Vardhan, Union Minister of Department of Science and Technology, has reiterated that technology is a strong priority area for the Government, and it aims to make people science centric. Modern India has had a strong focus on science and technology, realising that it is a key element for economic growth.

MAJOR POLICIES AND INITIATIVES IN BLUE ECONOMY

The Indian Ocean is projected to become a dominant global geopolitical and economic force in the 21st century. Indeed, the region's contribution to global GDP has significantly increased over the last century from an average six to seven percent in 1980 to 10 percent or USD 78 trillion in 2014. However, based on Gross National Income, only three Indian Ocean Rim Association countries (IORC)—i.e., Australia, Singapore and United Arab Emirates—feature among the top 20 nations with highest per capita gross national income. Owing to limited land resource base, many of the coastal and island IORCs are dependent on marine resources for economic opportunities. Therefore, pursuing the goals of blue economy would be critical to the region's prosperity and development.

India has a coastline of above 7,500 km, spanning into nine maritime states and two Union Territories (UTs) in the mainland, and two islands with 12 major and 187 non-major ports, which play crucial role in sustaining growth for trade and commerce. The largest coastline supports various enterprising activities in inland waterways and ports with the Indian Ocean Region presenting tremendous trade potential. The other countries in the Indian Ocean Rim Association (IORA) exhibited significant dynamism in the past few years as the trade in the region increased by over four times from US$ 302 billion in 2003 to US$ 1.2 trillion in 2012. It is necessary for India to tap the enormous potential of the ocean based Blue Economy, which will propel the nation into a higher growth trajectory. The development of Blue Economy can serve as a growth catalyst in realizing the vision to become a $10 trillion economy by 2032.

There is great potential for marine aquaculture, capture fisheries, fish processing, offshore wind, and port based activities to provide employment. Promising sectors include capture fishery and aquaculture, novel marine products of high value drugs, chemicals and bio-products, mineral resources for oil and gas, deep-sea mining and hydrocarbon, renewable energy resources for wave energy projects and offshore wind energy.

Marine biology and biotechnology is providing significant revenue generation to the Indian economy. India has projected revenue generation of USD 100 Million by 2025 through biological and bio-technology industrial growth and therefore there appears to be enormous potential from ocean based resources. The Department of Bio-technology has taken initiative to set up state of art institute on ocean biology and bio-technology to address various marine bio-technology issues and interventions by giving emphasis on research & development. This would address research,

education, knowledge exchange programmers including specialized trainings. The promotion of blue economy with ocean resources and conservation would create both challenges and opportunities for new India. Additionally, the Indian Ocean Region is of strategic importance to India's economic growth as the most of the country's oil, and gas is imported through the sea. The Sagarmala project, launched by the Ministry of Shipping, is the strategic initiative to maximize **economic and trade potential** for port-led development through the extensive use of IT enabled services for modernization of ports. It tackles the issue of underutilized ports by focusing on port modernization, efficient evacuation, and coastal economic development. The government has allocated over Rs. 3 lakh crore to fund 199 projects under the Sagarmala programme under "*port modernization, port connectivity, port-led industrialization and coastal community development*" themes to be implemented in the next three years. Of these identified programs, projects of more than Rs. 1 lakh crore are already under implementation. Moreover, the Union Budget of 2017-18 has increased the allocation to the project from Rs. 406 crore (RE 2016-17) to Rs. 600 crore (BE 2017-18), giving further impetus to the port-led development Under the Make in India program of the Government, shipbuilding industry can benefit from a major thrust. This industry has a high multiplier effect on investment and can accelerate industrial growth along with its large number of associated industries. In December 2014, India had a fleet strength of just over 1,200 ships, which is expected to reach over 1,600 by 2025. A strong push in India's commercial shipbuilding and ship repair sectors, complementing the Sagarmala project of port development have the potential to drive economic transformation. Further, this dependency is expected to rise by 2025 exponentially.

The Indian Ocean has always enjoyed a place of prominence in global strategy with many nations establishing a presence in the region to ensure their strategic interests. Increase in piracy issues and the growing importance to secure the oceanic ecosystem has put greater emphasis on **international relations and security**. India has become pro-active in engaging in cooperative arrangements with like-minded neighbouring countries. The "Trilateral Cooperative in Maritime Security between India, Sri Lanka, and Maldives" is one such example. The Indian Navy has also published *The India Maritime Security Strategy* articulating the country's policy in the Indian Ocean region. It states that in the Indian Ocean region India is committed to (i) ensuring a safe, secure and stable Indian Ocean Region; (ii) deepening security cooperation, through increased surveillance and monitoring with regional partners; (iii) forging a multilateral cooperative maritime security initiative in the Indian Ocean to combat terrorism and piracy; (iv) deepening cultural linkages with the people in region; and (v) building Indian Ocean Region as a frontier of sustainable economic development. Indian Ocean is essential to maritime trade connecting the Middle East and Africa to South- East Asia and East Asia. It is the gateway to major oil chokepoints of the world- Suez Canal, Strait of Hormuz and Strait of Malacca. Majority of Maritime trade between the West and the East passes through the Indian Ocean region. The increasing naval activity in the IOR region is an evidence of joint naval exercises with many of the IOR regional countries as well as with other Maritime powers. From QUAD, STIMEX and other naval exercises have become a regular feature and the TROPEX exercises also highlight India's increasing emphasis on ensuring readiness.

The increasing emphasis on naval readiness also highlights the increasing importance of the Indian Ocean and the rising focus on joint cooperation as the critical focal point for regional cohesiveness. In 2019, India was also asked by the USA to expand its reach in the Indo-pacific region especially from an energy perspective to counter China's growing presence beyond the South China Sea. The Joint clean energy Initiative launched between India and US in the Indo-pacific region is a clear indication on India's growing strategic interests beyond the IOR region. The Flexible Resources

Initiative (FRI)[1] launched in 2019 is the first ste p towards strengthening the Indo-US Joint initiative in the Indo-pacific region in the area of clean energy. The increasing strategic presence is coupled with increasing international collaborations in Science and technology domain. In the past decade, joint or bilateral scientific research collaborations have increased exponentially in India. Importantly, India requires a coordinated approach among stakeholders in the region in combating other plaguing issues like the rise in IUU, narco-terrorism, human trafficking, etc. These need to be tackled by strengthening transoceanic partnerships and developing a synchronized strategy for a way forward.

S&T INSTITUTIONS AND INTERNATIONAL COLLABORATION INITIATIVES IN INDIA

India has recently drafted the blue economy policy based on strenuous work carried out by seven working groups that were formulated to address various key issues within the framework. The draft policy is a step towards creating coherence and harmony amongst various blue economy sectors, yet each sector within the framework has unique characteristics, features, processes and requirements. With separate institutions governing and implementing policies and initiatives in each of these sectors, the need for understanding institutional structures and their role in enhancing collaboration both within sectors and between nations is important.

India has several ministries and allied agencies that oversee blue economy sectors including the Ministry of Agriculture and Farmers Welfare, Ministry of Earth Sciences, Ministry of Environment, Forests and Climate change, Ministry of Ports, Shipping and Waterways, Ministry of Tourism, Department of Science and Technology among others. Each of these ministries have several agencies that focus on specific aspects of science and innovation, additionally they also collaborate with their counterparts in other countries. The key to enhance innovation is to collaborate and exchange knowledge to create path breaking innovations- these innovations could be both to enhance economic development of oceans and to address the environmental and social challenges emanating from these economic activities. India has been steering partnerships at bilateral and multilateral level in the oceans' domain. India has been a consistent collaborator of the Antarctic research, is a part of the Argo platform and also engages in bilateral partnership on ocean such as the recent India-Norway partnership for Blue economy.

The International Ocean Discovery Program (IODP) steered by the National center for Polar and Ocean research is significant example of India's multilateral research cooperation. The IODP is an international marine research collaboration that explores Earth's history using ocean-going research platforms that aid in data recovery recorded in seafloor sediments and rocks and to monitor subsea floor environments. IODP depends on facilities funded by three platform providers with financial contributions from five additional partner agencies including USA, Japan, India, Brazil, Australia, China, Canada, Europe and Canada. Representing 23 countries, scientists work together for IODP across the globe. IODP science plan for 2013-2023 identifies 14 challenge questions in the areas of climate change, deep life, planetary dynamics, and geo-hazards. All of these areas are critical to understand Anthropocene activities and also provide relevant answers to address the rapidly changing environment.

Another instance of bilateral cooperation is , "The National Institute of Oceanography and the National Geophysical Research Institute have signed a memorandum of understanding with Russia's

[1] https://www.ndtv.com/india-news/amid-china-concern-india-us-to-launch-energy-initiative-in-indo-pacific-2110674

V.I. Il''Ichev Pacific Oceanological Institute for collaboration on the field of marine sciences and technology in January 2021. The collaboration will enable Indian and Russian scientists to enhance capacity and skill development in the field of marine sciences and technology, sharing knowledge and expertise in the field of sustainable development for national economic interests of both countries.

One of the key success stories of enhanced ocean science collaboration is Argo. With more 4000 active floats and for more than 20 years, the Argo platform has been collecting and assimilating data for Climate ocean observation system. The platform has more than 30 participating countries with several others aiding the deployment of floats. The platform has been continuously been able to gather and collate data on oceans that is for climate change assessments. India has been an active participant in this platform with the Indian National Centres for Ocean Information services taking a lead.

A recent partnership to enhance maritime surveillance was initiated and launched by India and France. Both countries have joined to develop the world's first space-based automatic identification system (AIS) to track merchant ships on a real-time basis. Both countries will be operating it jointly with the French space agency (Centre national d'études spatiales or the National Centre for Space Studies and Indian Space Research Organisation (ISRO), signing an agreement to begin the development and production of a constellation of satellites.

These partnerships highlight the increasing efforts to enhance coordinated action and implementation, yet these progresses are still emerging in few areas within each sector rather than at a broader level. The concept of blue economy requires transdisciplinary and multidisciplinary thinking and research. Increased collaborative innovation is required to intensify activities to enhance sustainability for long term economic development.

EXAMINING S&T ACROSS DIFFERENT SECTORS OF BLUE ECONOMY

The role of science and technology is imperative to all the sectors of blue economy. India's investment in science and technology has been increasing in the past few years and in the sectors related to ocean economy as well. Yet the gaps in financing and investment are evident and vast in comparison to other sectors and countries.

Fisheries and Aquaculture

The fisheries sector is a major sector of blue economy and India is the third largest fish producing country and the second largest aquaculture fish producer in the world. India contributes about 7 per cent to the global fish production. The country is also home to more than 10 per cent of the global fish biodiversity and is one of the 17-mega biodiversity rich countries (NFDB 2020a). Further with the advancement of the fishing technology, the demand for fishery is increasing due to its dependence on food and livelihood. Fisheries are also a major aspect of blue economy as they provide food security and nutrition. The marine fisheries potential is estimated at 5.31 million tons as against present production of 4.17 million tons during 2018-19 and its activities are spread along the country's vast coastline. Besides, India is also bestowed with varied inland fisheries potential resources in the form of rivers and canals (1.95 lakh km), floodplain lakes (8.12 lakh hectares), ponds and tanks (24.1 lakh hectares), reservoirs (31.5 lakh hectares), brackish water (12.4 lakh hectares), saline/alkaline affected areas (12 lakh hectares) etc., with current estimated fish production potential of about 17 million ton as against production of 9.58 million tons during 2018-19 (NFDB 2020).

There are different techniques used for fishing like in artisanal fishing, fishing gears are used that include boats, motors, nets and lines (Bhilave MP 2018). Among the traditional techniques of fishing, gears, gillnets, drift nets and bag nets of different mesh sizes, all of them are widely used across the coastal states of India. Bottom trawlers up to 13 m Over All Length (OAL) are operated along the entire coast, while the second-generation large trawlers 13-17 m are operated from selected harbours (Pillai and Katiha 2004). There are 1,332 fish landing centres in India, 6 major fishing harbours, 27 minor fishing harbours, 58,911 mechanised vessels, 75,591 motorised vessels and 104,270 non-motorised vessels (CMFRI 2012). The Indian fishing sector has shown a shift towards mechanisation in the recent past.

Table 1: Number and Growth of non-mechanised, motorised and mechanised fishing fleet in India

Year	Non-mechanised		Motorised		Mechanised	
	Number	Growth Rate (%)	Number	Growth Rate (%)	Number	Growth Rate (%)
1961-62	90424	-	-	-	-	-
1973-77	1064800	18	-	-	8086	-
1980	137000	29	0	0	19013	135
1998	160000	17	32000	0	47000	147
2003	76596	-52	50922	59	49070	4
2005	104270	36	75591	136	58911	25
2010	50618	-51	71313	-6	72559	23

Source: R. Sathiadas and Shyam S. Salim (2012)

There has been a decline in the number of non-mechanised boats from the last two decades and a sharp increase in the motorised and mechanised boats. This development of harbours and landing jetties, motorization of artisanal crafts and the rapid expansion of mechanized fishing have contributed towards a significant increase in fish production, employment generation and revenue earnings (NCAP 2003).

Aquaculture is also a fast-growing sector in the blue economy and has shown more than six-fold increase in the past two decades. Freshwater aquaculture with a share of 34per cent in inland fisheries in mid 1980s has increased to about 80per cent in recent years (DADF, 2017). The technologies of induced carp breeding and polyculture in static ponds and tanks have brought about remarkable upward trend in aquaculture productivity and turned the sector into a fast-growing industry. There have been technological developments both for fish seed development and production of aquaculture. The different technologies for seed production include eco or circular hatchery or collection of spawn from natural abode, raising the spawn to fry in nursery ponds; and rearing of fry to fingerlings in ponds. The major freshwater culture technologies may be classified as, polyculture of Indian carps, mono-and polyculture of air-breathing fishes, mono- and polyculture of freshwater prawns, integrated fish farming, cage culture, pen culture and pearl culture (NCAP 2003).

Marine Biotechnology

Marine biotechnology also has an important role in the extraction of marine species which are then applied to a number of sectors including biotechnologies, nanotechnology, biomaterials and the introduction of genetically modified fish, that can yield high economic returns (Ninawe and Indulkar, 2019). It has been projected that India will generate USD 100 million by 2025 from biological and bio-technology industrial growth. Though the 'Sagar Mala' programme focuses on development of maritime infrastructure, it will have significant spin off benefits for the marine biotechnology sector. The hope that the oceans are a treasure trove of bioactive compounds, elixirs and lifesaving drugs has been sustained ever since the days of 'Sagar Manthan' narrative.

Offshore energy sources

There is also an important role of science and technology in exploring offshore energy sources. Technologies related to harnessing wind, wave and even hybrid energy from oceans like Ocean Thermal Energy Conservation (OTEC) help reap benefits of the oceanic energy. The National Offshore Wind Energy Policy was also released in 2015 by the Government of India and some of its key objectives were to explore and promote offshore wind energy in EEZs of the country, promote investment in energy infrastructure, promote R&D in offshore wind energy sector and facilitate deployment of Project EPC (Engineering, Procurement, and Construction) and Operation & Maintenance concerning the offshore wind industry (Gulia and Jain 2019).

Shipping and Ports

The shipping and port industry is also incorporating more and more science-based technologies and IT enabled services (Lam-ya Mostaque 2020). The government has also signed several MoUs with countries such as Korea and Egypt for cooperation in the development of ports, sharing of technology, manpower training and stimulating the steady growth of maritime traffic (Dasgupta 2018). The digitisation of various processes in both the major and non-major ports have enabled seamless coordination in the logistics while ushering in the regulation of the activities at the various container freight stations (CFSs), inland container depots (ICDs) and port terminals. Technology has indeed induced transparency in the various processes while lowering their costs.

Harnessing technological solutions for Blue economy sectors

Other technological instruments like acoustics, optics and radars are also extensively used in extracting data and potential of various resources from oceans. Remotely Operated Underwater Vehicles, Satellite Oceanography, GIS, SONAR and Animal Telemetry, among others, also help in mapping varied ocean resource base. India has a status of Pioneer Investor and has been allotted a site in the Central Indian Ocean Basin (CIOB) by the International Sea Bed Authority (ISA) for exploration and technology development for polymetallic nodule mining. Development of reliable Deep-sea mining system for harnessing resources from ocean will help to meet the country's growing mineral requirements and increase the country's self-sufficiency, in the near future (MoES 2015).

S&T BUDGET AND INVESTMENTS IN BLUE ECONOMY

Investments in the marine technology and research is imperative and sustained and cost-effective investments in the blue economy is required. However, both the availability and allocation of budgets for ocean sciences and technology vary across countries wherein the developed countries have higher share of the budgets allocated to science and technology. The investments in marine science and technology are overall less compared to other major fields of research. Globally it has been estimated that only 1.7per cent of the national budgets are allocated to ocean sciences and technology. The survey of various countries estimating the ocean science budget by UNESCO indicated that out of the total 24 countries, 14 countries had increased their budget allocations for marine science and technology between 2013 and 2017. The Russian Federation had the highest annual growth being more than 10per cent, followed by UK and Bulgaria. However, 10 countries like Japan, USA, Brazil and Italy have decreased their ocean science and technology budgets drastically. Overall, the USA reports the highest institutional funding for ocean activities. In 2016, more than USD 12 billion were allocated to ocean activities which includes science and technology. Followed by USA, Japan allocated USD 600 million to ocean activities and Australia allocated USD 511 million in 2017 (UNESCO 2020). However, such assessments for India have not been done yet. The various

indicators under the SDG14 (Life Under Water) that represent any budget allocation to marine sciences and technology are currently under compilation by the authorised ministry for India.

Overall, ocean sustainability projects have received just USD 8.3 billion in grants from philanthropic donors and USD 5 billion in financing from development banks which is insufficient to manage the USD 3 trillion per year valued ocean-based economy globally. Public sector financing contributes around 70per cent of the total financing for ecosystems and biodiversity (UNCTAD 2019). Though private capital commitments have shown an increasing trend between 2004 and 2015, but many opportunities still remain untapped in the private sector investments. Therefore, the major sources of funding for blue economy have been Official Development Assistance (ODAs) and philanthropy grants till now. In the past 10 years, philanthropy has the maximum share in the funds, followed by ODA globally (WEF and FOA 2020). A total funding of USD 8 billion has been received from philanthropy and USD 5 billion from ODAs in the past one decade for blue economy but this funding is now not enough to fund even the conservation and sustainability activities of the sector (ibid.). Therefore, not just investment in sustainable oceans is required because of their increasing need but also because of the certain regulatory, market and physical risks associated with the current levels of unsustainable activities in the blue economy. This goes for investments in marine technology and innovations as well. However, in the past few years the role of private sector has increased in overall funding for ocean activities.

It has been estimated that from the USD 500 million allocated to ocean related activities and projects, around USD 150 million were spent on more than 1000 marine science projects globally. In the past few years, private sector has contributed around USD 668 million to marine science and technology through granting support to more than 6000 projects. Around USD 200 million have been invested in marine energy only globally in 2019. This was around USD 700 million in 2007 and around USD 400 million in 2014 (IRENA 2020).

Investments to science and technology have been significant in India and numerous efforts have been taken to deepen the knowledge base on ocean sciences. Around Rs. 5,500 crores were budgeted for science and technology in the Union Budget 2019-2020, which was increased to Rs. 6,300 crores in 2020-21 (MoST 2020). Since the scope of blue economy is spread across many sectors, the budget allocation varies across different ministries. Table 2 summaries the overall budget allocated to various blue economy sectors. This list is representative of public sectors funds at the centre only and does not include any intergovernmental, bilateral or multilateral agency funds or any private sector funding or any state level budgets for ocean related activities.

Table 2: Budget allocated to various blue economy sectors through the different ministries

Ministry	**Budget 2015-16 (in Rs. Crores)**	**Budget 2019-20 (in Rs. Crores)**	**Budget 2020-21 (in Rs. Crores)**
Agriculture and Allied Activities (Department of Fisheries)	410	805	825
Environment, Forests and Climate Change (National Coastal Management Programme)	100	95	103
Earth Sciences*	508	1700	2070
Shipping and Ports	1440	1900	1800
Tourism	1570	2190	2500
Total	**4,028**	**7,590**	**7,300**

Source: Compiled by Authors

*This includes Oceanographic survey, Marine Living Resources, Central Sector schemes like Ocean Services, Technology, Observations, Resources Modelling and Science (O-STORMS), Ocean services, Modelling, Application, Resources and Technology (O-SMART), and Oceanographic research and Other scientific research

Out of the budget allocated to the Department of Fisheries, particularly the Fisheries Institutes that handle post-harvest technology and training was allocated Rs. 140 crores in 2019-20 which was increased to Rs. 150 crores in 2020-21 (MoFAD 2020). The total budget allocation to Blue Revolution was Rs. 570 crores in 2020-21 which has increased from Rs. 455 crores in 2019-20. This budget allocation to Blue Revolution was only Rs. 410 crores in 2015-16 which included marine and inland fisheries and even assistance to Fisheries Institutes that only got Rs. 97 crores in 2015-16 against Rs. 150 crores in 2020-21.

The National Coastal Management Programme under the Ministry of Environment, Forests and Climate Change is responsible to ensure livelihood security of coastal communities including fisher folks, to conserve, protect the coastal stretches and to promote sustainable development based on scientific principles. The Shipping ministry includes the development of ports, shipping and ship building, inland water transport and investments in public enterprises as well.

Other than these funds that are a part of the budget allocated for ocean-based activities and research, budgets are also allocated at the state level as well. There are investments from the private sector as well that are in the form of CSR funds and in the form of other innovative financing tools. Though the role of private sector has been limited but their share in funding science-based programmes has been increasing in the past. Many private players that are a part of this space, have developed strong expertise, by partnering with researchers to improve their science-based decision-making, respect regulations and avoid negative environmental impacts on the ocean. The role of private foundations in funding ocean science projects is also increasing. A total sum of USD 150 million were allocated to ocean science projects globally in 2017. Further it has been estimated that private foundations and donors alone contributed around USD 668 million to various marine science and technology projects between 2013 and 2017 globally (UNESCO 2020).

SKILL AND CAPACITY DEVELOPMENT IN S&T

To advance in the era of technology, it is imperative to increase literacy among the youth and the workforce in science and engineering, redesigning the system of national investments hand-in-hand with a stronger pledge to scientific research, and take up incentives that encourage private companies to undertake research and development (Bordoff et al, 2006). In a system of innovation, both private and public actors are able to interrelate with the goal of producing technological innovations, in which learning plays the lead role. Innovation thus also becomes a social intervention, where several actors and institutions come together (Schwachula et al, 2014).

Innovation is the principal drive of growth performance, and its development is supported by 5 pillars (Schwachula et al, 2014):

- The development of appropriate capacity via training and education, imparting of entrepreneurial skills, as well as greater participation of users and consumers in the innovation processes that are thought to be pertinent in empowering people to innovate
- Countries should provide assurance of the conditions of finance and frameworks that are required for innovations to prosper
- Creation and usage of knowledge, principally scientific and technical knowledge, that can be diffused and applied to public sectors, and setting in place an efficient system for the protection of intellectual property rights.

- International cooperation for research, and application of innovations to address global challenges and the transfer of technology to developing countries
- Inclusion of innovation policies at every level of government, its measurement, and application of policy-making and evaluation that is based on evidence.

Human talent forms a nation's primary capital. Improved education and training, especially in science and mathematics, would develop a high quality labour force that can flourish in the knowledge-based, technology-driven international economy of the 21st century. To drive growth and improve the standards of living, access to advanced technologies should be provided, including broadband internet. Financial incentives would spur the number of students studying science and mathematics at the university level, in combination with advanced instruction with practical training, would broaden the scope of the degree programmes and improve retention (Bordoff et al, 2006).

Effective investments by the government in basic research, and the creation of suitable incentives to propel philanthropic and private sector investments in technological innovations that enhance growth are equally important for furthering development. This becomes necessary as the benefits of innovation build up for society by means that any individual company would be unable to capture (Bordoff et al, 2006). The World Bank indicates, as elaborated by Schwachula et al (2014), that an active governmental stance that supports innovation leads to the fostering of entrepreneurship by giving the necessary resources, removing barriers, and supporting research and education. UNESCO recommends that, in the global STI context, developing countries better their absorptive capacity and clear any barriers that hinder the flow of positive spillovers of technology from countries that are leading technologically (Schwachula et al, 2014).

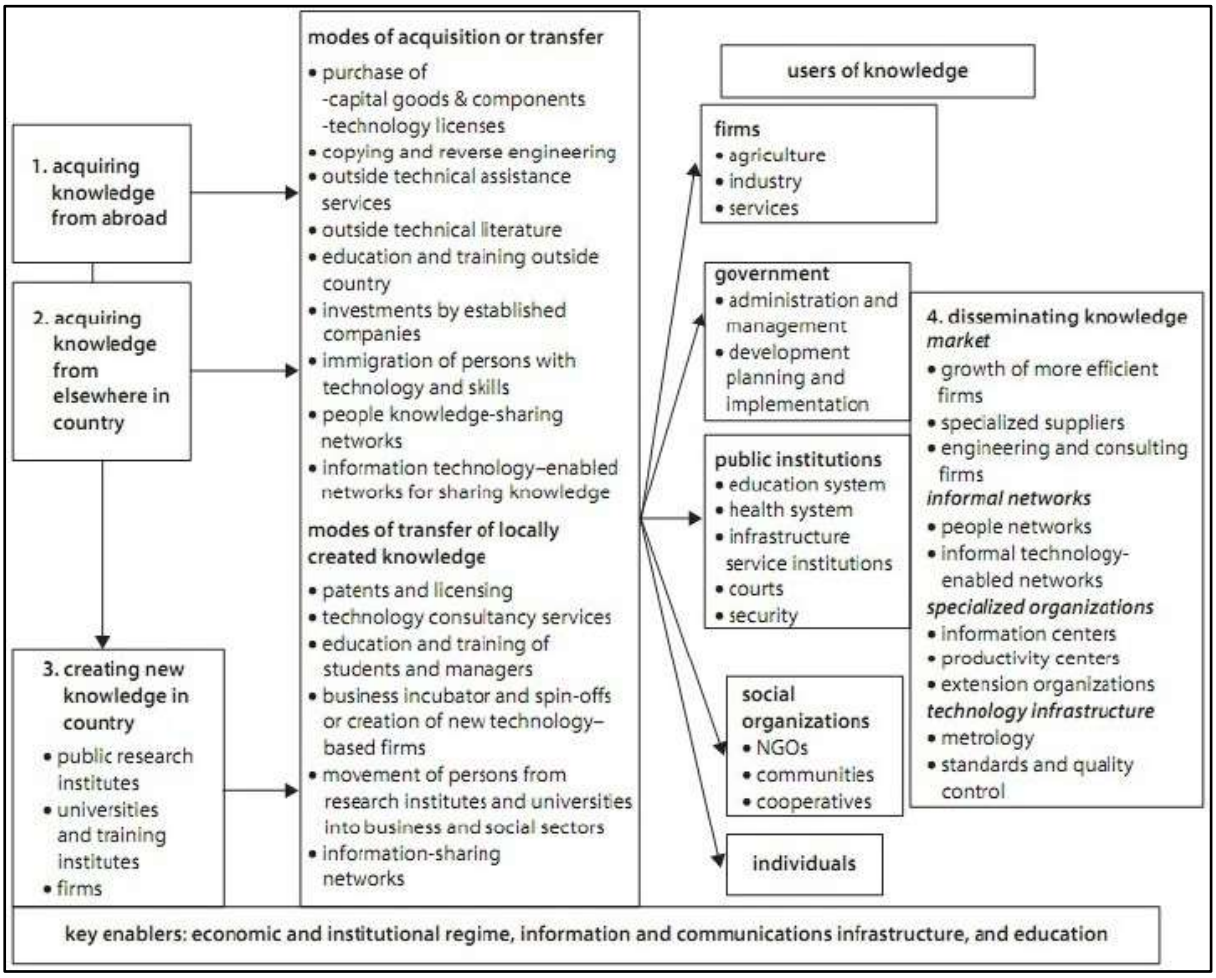

Figure 1: World Bank conceptualisation of innovation in developing countries

Source: Schwachula et al, 2014

Basic research in the form of ocean observation, and scientific missions and explorations can provide new data through which the understanding of the oceans and its resources may be enhanced, and the capacity for sustainably utilizing the oceans in an effective manner can be strengthened (Mostaque, 2020). National ecosystem assessments have an important role to play in communicating the benefits of ecosystem services, and monetary valuation can be a useful component of the national assessments (OECD, 2019). Scientific research can also be utilized to further streamline and integrate ongoing oceanic economic activities and improve their efficiency and productivity. Greater research in blue biotechnology, including nanotechnology, biomaterials, and genetic resources can yield high economic returns, and have potential for novel uses in health and personal care, environmental issues. Greater research into renewable energy, and development of dedicated marine economic innovation and development demonstration areas, and greater bilateral cooperation between countries and private-public partnerships would boost development in the ocean economy (Mostaque, 2020).

The country's laws on intellectual property must meet a suitable balance between the protection of intellectual property as a policy instrument to boost innovation and scientific openness in which future innovations can be developed upon past work (Bordoff et al, 2006).

The exchange of knowledge between economic sectors would provide opportunities for progress in ocean-related innovation which would be at hand if attention were given to only ocean-related activities. Such networks, which forge collaborations between distinctly different organisations, are important in keeping abreast with technology markets and assessing a larger number of potential avenues than any organization would be able to achieve single-handedly. The development of an innovation network centres aid in tracking technological developments, assessing possible applications to ocean activities, and communicating the advances to their partner organisations, which may occur through conferences and newsletters of a dedicated nature. Innovative developments may also flow from the ocean economy to other sectors. This encourages economic activity and opens new market avenues where no connections existed previously. These activities together thus contribute to the pool of resources available for the general progress of society. Innovation networks also provide a vital service by sharing the costs of outreach among various parties, which is of particular importance for small enterprises without the individual means of investing in greater exposure. (OECD, 2019).

Improving the knowledge of policymakers regarding the potential of the ocean economy to provide social benefits would permit better distinguishing between land-based and ocean-based economies. This is required as ocean-based industries often fall under the domain of policies that have a broad focus, and therefore become restrained and poorly regulated. Ocean-based applications require more attention in policymaking than is currently afforded to prevent underestimation by policymakers who are unaware of their potential. Innovation networks are also of note in this scenario as they provide a platform of various actors and pooled resources that have greater visibility than individual organisations, and represent a broad range of viewpoints. The multi-stakeholder approach in such networked collaboration creates the space and opportunity for consultation and communication that is more effective during the policymaking process, making the benefits to society more likely to be realized (OECD, 2019).

Pace and Drago (2020) elaborate on the utility of foresight in policy formation and implementation, as a tool that can be adapted to specific areas of innovation or fields of activity. Among the principal functions of foresight are raising awareness regarding emerging challenges, risks and opportunities, future orientations and policy options, as well as to create a common understanding of the issues at stake and building a shared picture of desirable futures among stakeholders, thus facilitating policy implementation. As indicated by OECD (2019), foresight in terms of technological developments and the volume of new science that would be enabled by them would permit countries to maintain researchers with appropriate skills who would be prepared to exploit fast-developing technologies. This may be achieved by incorporating opportunities for education in the innovation process, and furthered by strengthening the connections between the various types of stakeholders. Such increased awareness of innovative business activities among scientists and students, when combined by greater understanding of the ocean among the general population via enhanced emphasis on ocean literacy, the benefits obtained by society through improvements in ocean research are likely to continue apace (pg 126, OECD 2019).

The ocean economy is a system based on interaction between ocean-based industries and the marine ecosystems on which they are based, which implies that is necessary that economic activity be conducted in a manner that encourages the conservation and sustainable use of these ecosystems. In addition, innovation in networks, by building bridges between a diversity of organisations and overcoming the challenges that arise, also play a role in making a sustainable ocean economy a reality. Closing of the gap between academia and industry will aid in maintaining a flourishing pipeline of appropriately-skilled workers for a sustainable ocean economy. Optimising the

education system to create the right capacity is viewed as the most important factor in determining long term sustainability (OECD, 2019).

Initiatives and potential of skill and capacity development in S&T in India skill gaps

A MoU for skill development in Port and Maritime sector was signed between the Ministry of Shipping and the Ministry of Skill Development and Entrepreneurship (MSDE) aimed at skilling, re-skilling and up-skilling manpower for the growing maritime industry and development of coastal community. The MSDE will help develop course curriculum, National Occupational Standards, content, etc. for Cruise Tourism, Logistics, Fisheries, Ship building, Ship repair and ship breaking, Dredging, Offshore supply chain etc. It will also leverage its existing infrastructure such as ITIs, NSTIs and PMKK and PMKVY centres to train manpower required as per the skill gaps of the coastal districts. MSDE will also help in mobilizing private sector/CSR funding for skill development in the port and maritime sector and facilitate port and maritime sector in TVET agreements signed for skill development with international partners. To ensure technology based skill development, Ministry of Shipping have setup Centre of Excellence in Maritime & Shipbuilding (CEMS) with two campuses at Vizag and Mumbai that are operational since February 2019. The centres will provide for skilled manpower in Maritime and Ship building sector within its capacity of training and have trained around 10,500 trainees per annum. Ministry is also funding the fire safety training project for workers at Alang-Sosiya Shipyard. The Ministry further has ensured third party certification of this training programme to ensure quality of training. Indian Register of Shipping (IRS) is now conducting third party assessments. The course curriculum has been revised and updated to conform to the common norms for skill development schemes under National Skill Qualification Framework notified by the Ministry of Skill Development & Entrepreneurship.

The support in funding the implementation of various skilling initiatives wherever applicable and feasible under the Sagarmala Mission will be extended by the Ministry of Shipping (MoS). Also under the Sagarmala Programme, an integrated approach is being adopted for improvement in quality of life with focus on skill building and training, upgrading of technology in traditional professions, specific and time bound action plan for improving physical and social infrastructure in collaboration with the coastal states. Main features of Coastal Community Development plan consists of skill development, coastal tourism, development of fishing harbours, R&D in Port and Maritime Sector

The total fish production from the country during 2017-18 is 12.4 million tonnes with large share of aquaculture production (7.2 million tonnes). The coastal shrimp aquaculture has been a major driver to the country's seafood export of over Rs. 45000 crore during 2017-18. Even though the shrimp aquaculture and freshwater carp culture are growing, non-availability of quality seed remained as the major constraint for aquaculture diversification over these years, it is expected that the assured seed availability through commercial seed production. India's research capabilities in modern marine biology are vast and the focus is given on basic and applied research in marine biology, ecology and marine biotechnology. The multidisciplinary science can emphasize on the production of most needed novel bio-molecules and processes for therapeutics, enzymes, hormones, bio-plastics, metabolites etc. Therefore, from the Indian perspective, in the marine capture sector, improvement must be in the following major areas as a matter of priority:

- Ecosystem based fisheries management with co-management and knowledge management as a part of major reforms in sector governance is needed.
- Developing a detailed coastal zone management plan for sustainable coastal aquaculture development.

- Addressing waste accumulation in the coastal and inshore area threatening the marine ecosystem and affecting fisheries production.
- Introducing updated fish production technology as a large gap exists between the technology available and accessible to fish farmers.
- Cold chain development needs to be established in all major production centres.
- Domestic food safety standards should be implemented to ensure delivery of quality products to consumers.
- Fish processing centres and value added product processing units need to be promoted based on market demands.

Other capacity building programs could include

- Capacity building in SCUBA diving skill set for documentation of the seabed to understand the status the seabed, ghost net removal efforts and seabed studies to disseminate ocean literacy, skills for coastal communities to secure jobs in marine enforcement, coast guard and coastal police, navy, disaster management, rescue level operations etc.

CONCLUSIONS AND WAY FORWARD

With the world finally noticing the need to prioritise oceans from economic and environmental perspective, the need to converge existing scientific developments in blue economy sectors to map their impacts, trade-offs and advantages is necessary to understand the scope of the work in the future. Each innovation and scientific development in one sectors has domino effects on the other and yet its positive or negative impacts on related sectors is still hasn't been taken into consideration as a major factor.

For instance, the interlinkages and trade-offs that occur in the food-water-energy nexus are being discussed and studied only in the recent years. Many energy innovations have been considered to have posed significant challenges for water sector that are emerging in the post deployment phase of energy solutions. It would be beneficial for blue economy sectors to integrate ideas and innovations to understand the overlapping and underlying impacts on other sectors to reduce and eliminate negative consequences.

- Budgetary enhancements and promotion of investments for technological innovations and resources is necessary and critical to achieve a harmonised blue economy framework.
- Accelerating bilateral and multilateral relations in ocean sciences, research and sectoral innovations would be essential to drive economic development and sustainability initiatives.
- Investing in innovation has been the key for countries to achieve high rate of economic and social development while preserving the environment. This needs to be prioritised in India for higher gains and to strengthen global presence.
- Leveraging on existing technological solutions and information is essential to pave the roadmap for the future of ocean based research.
- Creating synchronised and harmonious platforms for blue economy sectors to share their knowledge, data and experiences is essential to achieve the blue growth that India is envisaging.
- Skill development, capacity building and training needs to be accelerated and enhanced in India to ensure a strong and skilled workforce is enabled for future ocean related sectors.

- India also needs to invest in creating more research institutions both in the public and private space to accelerate the innovation and ideation process in blue economy.
- Increased awareness generation on potential opportunities for employment in blue economy sectors would generate interest and aid in building a workforce.
- The proposed National Blue economy council should prioritise science and technological innovations in blue economy sector to guarantee India's long term future in the global oceans.

A strong blue economy framework thus requires an essential foundation of science and technological innovations to thrive. With ambitious plans, India has the opportunity to focus on innovation and technology that is the bedrock of blue economy. It is imperative for India to stay one step ahead in the oceans sector to counter increasing strategic presence, rising economic activity and address environment and climate change challenges simultaneously. Science and technology can provide the right solutions to steer ahead blue economy in India.

REFERENCES

CMFRI (Central Marine Fisheries Research Institute) (2012), Present and Future Scenario of Indian Marine Fisheries, CMFRI: Central Marine Fisheries Research Institute, Kochi, India

Dasgupta, Srinjoy (2018), "Indian Shipping Industry- an ocean of opportunities", presented at 55th National Maritime Day celebration Conference at IMU (Indian Maritime University – formerly DMET Kolkata) Campus in Kolkata

Gulia, Jyoti and Jain, Shipli (2019), Offshore Wind Energy in India: A territory to be explored, JMK Research and Analytics

IOC-UNESCO. 2020. Global Ocean Science Report 2020–Charting Capacity for Ocean Sustainability. K. Isensee (ed.), Paris, UNESCO Publishing.

IRENA (International Renewable Energy Agency) (2020), Investment trends in marine energy, IRENA: International Renewable Energy Agency, Abu Dhabi, United Arab Emirates

Islam, M. and Mostaque, L. (2018), "Blue Economy and Bangladesh: Lessons and Policy Implications", BIISS Journal, Vol. 39, No. 2, pp.135-162.

MoES (Ministry of Earth Sciences) (2015), "Development of Deep-Sea Mining Machine (Continuing)", MoES: Ministry of Earth Sciences, New Delhi, India

MoFAD (Ministry of Fisheries, Animal Husbandry and Dairying) (2020), Notes on Demands for Grants, 2020-21, Demand No. 39, Department of Fisheries, MoFAD: Ministry of Fisheries, Animal Husbandry and Dairying, New Delhi, India

MoST (Ministry of Science and Technology) (2020), Notes on Demands for Grants, 2020-21, Demand No. 87, Department of Science and Technology, MoST: Ministry of Science and Technology, New Delhi, India

Mostaque, Lam-ya. (2020). Science, Technology and Innovation for Sustainable Ocean Economy: A South Asian Perspective. 37. 23-29.

MP, Bhilave (2018), "Traditional Fishing methods of Kolhapur district", International Journal of Fisheries and Aquatic Studies 2018; 6(6): 368-371

NCAP (National Centre for Agricultural Economics and Policy Research) (2003), A Profile of People, Technologies and Policies in Fisheries Sector in India, Workshop Proceedings, Proceedings Series 10

Ninawe, A. and Indulkar, S.T.(2019), "Blue Economy Mission: India's Focus", Journal of Aquaculture & Fisheries, Vol. 3, No.017

Patil, P.G; Virdin, J.;Colgan, C. S;Hussain, M.G.;Failler,P. andVegh, T. (2018). Toward a Blue Economy: A Pathway for Sustainable Growth in Bangladesh. Washington, DC: The World Bank Group

Pillai, N.G.K and Pradeep K. Katiha (2004), Evolution of Fisheries and Aquaculture in India, p 240. Central Marine Fisheries Research Institute, Kochi, India

R. Sathiadas and Shyam S. Salim (2012), Marine Fisheries Management in India: Policy Initiatives, Central Marine Fisheries Research Institute, Kochi, India

Senaratne, A. (2017), "Oceans and Sri Lanka's future: Towards a blue economy", The Daily FT, availbleat http:// www.ft.lk/article/620407/Oceans-and- Sri-Lanka-s-future--Towards-a-blue-economy, accessed on December 27, 2019/

UNCTAD (United Nations Conference on Trade and Development) (2019), SDG Investment Trends Monitor, UNCTAD: United Nations Conference on Trade and Development, Geneva

WEF (World Economic Forum) and FOA (Friends of Ocean Action) (2020), The Ocean Finance Handbook: Increasing finance for a healthy ocean, WEF, Switzerland