Nature-Based Solutions (NbS) for Sustainable Development of the Resource Base and Ecosystem Services of Marine and Coastal Ecosystems of India

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Harini Santhanam and Sudip Kumar Kundu

Abstract

The imminent dangers due to increasing anthropogenic stress on the coastal seas, as well as marine pollution in the Anthropocene, have highlighted the need to devise and adopt novel eco-sustainable solutions through the use of technology for India. Special emphasis on the use of scientifically derived marine fishery advisories (MFAs) can have multiple co-benefits with the utilization of nature-based solutions (NbS) for monitoring and management of coastal and marine resource bases. Such co-management options can be effective to realize the targets for Sustainable Development Goals 14 (SDG 14) for 2030. At present, the Indian National Centre for Ocean Information Services (INCOIS) under the Ministry of Earth Sciences (MoES) provides the MFAs on a daily basis by using a combination of data from satellite imageries and ground-based datasets. However, sustainable use of marine and coastal ecosystems services needs to be informed by appropriate technological models of resources usage, including the incorporation of coastal zone management plans as per NbS frameworks for achieving long-term successes. The present study highlights the need to adopt NbS and MFAs as co-management approaches for adaptation and/or mitigation of the impacts of climatic and environmental factors as well as for fostering sustainable fishing initiatives for the Bay of Bengal. Such integrative methodologies are crucial for the development of model-based policy frameworks for sustainable marine resources management. Accordingly, an

H. Santhanam (✉)
National Institute of Advanced Studies, Bengaluru, Karnataka, India
e-mail: harini@nias.res.in

S. K. Kundu
National Institute of Advanced Studies, Bengaluru, Karnataka, India

Manipal Academy for Higher Education, Manipal, Karnataka, India

S. Dhyani et al. (eds.), *Blue-Green Infrastructure Across Asian Countries*,
https://doi.org/10.1007/978-981-16-7128-9_15

assessment of the NbS techniques for deriving a new adaptive framework is presented and discussed in the context of consideration of MFAs as NbS Assisting Technologies (NAT) to obtain significant co-benefits for sustainable development.

Keywords

Marine resources · Coastal zone · Ecosystem services · Nature-based solutions · Marine fishery advisories

15.1 Introduction

The Indian region is characterized by the various landforms forming the unique tapestry of diverse coastal and marine ecosystems along with its 8118 km of long coastline. From the perspective of ecosystem services for India, the coastal regions act as a buffer zone as it links land and ocean together and also creates a system of socio-ecological interactions typical to the Indian subcontinent. On the other hand, the marine ecosystems form the basis of the ecological heritage as well as the source for national, regional and local economies for India. The coastal region of India also plays a vital role in marine fish landings across its 1511 fish landings centres located in 9 maritime states and 2 union territories (UTs). In case of India, marine fishes have been treated as one of the best source of animal protein to remedy malnutrition (Hinds 1992). Further, the fishery sector creates large employment in India, and currently about 16 million fishers are directly dependent on this sector, while the number is double along the value chain (NFDB 2020). In 2019, India has harnessed about 3.56 million metric tons (Mt) of marine fishes with a 2.1% of annual growth rate where Tamil Nadu contributed the highest share among all maritime states and UTs (ICAR-CMFRI 2020). As per the latest statistics, fish capture from the mechanized sectors contributed about 83%, while the contribution is only 1% from the traditional fishing sector. India also exported nearly 1.40 Mt. of seafood worth INR 465.89 billion (USD 6.73 billion) during 2018–2019 (NFDB 2020). In this way, coastal and marine ecosystems have provided the vital basis to support lives and livelihoods by improving the economy of the country and henceforth improved the socio-economic conditions (Nayak 2017). In recent times, various anthropogenic activities along with global warming-derived climate change have been posing major threats for the conservation and sustainable development of the coastal and marine ecosystems in India (Nayak 2017).

Activity-based challenges in coastal and marine area management have enhanced the recognition of the imminent limits for exploitation of the marine resources base. However, the matching of the management approaches requires the expansion of the current technological solutions to meet not just the present but even presumptive challenges to sustainable development. For example, at present, the fishery sector in India faces a wide range of challenges associated with lack of infrastructure, overfishing, water pollution, habitat degradation, insufficient market information, post-harvest losses, weak organizations, a lack of access to financial services, etc. (FAO 2018). In the last two decades, small-scale fishers had also reported the forced displacement of fishes from their traditional fishing grounds as well as reduction in the stocks, as a direct consequence of the impacts of industrialization, pollution, etc. Despite the recognition of the environmental limits and the need for sustainable fishing, overfishing becomes a substantiated activity at local levels to enhance the sources of the incomes of fishers caught in the loop of poverty and indebtedness (Pramod 2010). Such activities in turn lead to the inevitable environmental degradation of unimaginable proportions. Matthew (2015) also reported that small-scale fishers in India suffer from water pollution, destruction of fish habitats, increasing competition and high prices of coastal land. Anthropogenic pollution in the marine environment is the most common threat in achieving sustainable marine resources, i.e. marine fish management (Bradley et al. 2019).

A large part of the management approaches undertaken at national and local levels in dealing with these challenges have been ably supported by several of India's flagship programmes at central and state levels for maritime conservation, supported through the use of spatio-temporal monitoring of the resources. For example, the use of geospatial technologies has contributed to a wealth of data on the coastal and marine environments from various remote sensing satellites such as INSAT, OCEANSAT, RESOURCESAT, CARTOSAT, RISAT, SCATSAT, SARAL-ALTIKA, IRNSS, etc. by enhancing the knowledge on physical structure and conditions, spatial pattern and extent along with its temporal changes of coastal and marine habitats (Nayak 2017, 2020). However, mainstreaming the use of data for managing the critical ecosystems requires three major perspectives:

1. Approaching marine and coastal conservation by adopting nature-inspired and nature-based management options which provide long-term benefits to the environment as well as the society.
2. Planning for infrastructural approaches which reduce and prevent human dependence on pollution-causing materials for achieving livelihood targets through use of sustainable technologies.
3. Use of assistive technologies to plan, establish, monitor and manage the resource base.

In this context, nature-based solutions (NbS) can be considered as effective measures to preserve the coastal and marine ecosystem services especially in the case of a maritime country as India facing the numerous challenges due to accelerated urbanization.

In general, NbS refers to the sustainable use as well as sustainable management of nature to remedy various socio-environmental challenges. The outcomes of NbS are also associated with human welfare and biodiversity enrichment through the sustainable resource management (IUCN 2021). The lives and the livelihoods of the coastal people including marine fishers are highly dependent on the coastal and marine ecosystem; however, they are also exposed to extreme weather events associated with cyclones, storm surges, coastal erosion, etc. (Gajjar 2020). In connection, NbS can play an important role in reducing the effect of weather extremeness through the use of natural resources which is also helpful in the conservation of natural resources. For instance, by increasing the mangroves forest and salt marshes in the coastal areas, it is possible to reduce the strength of wave height and velocity by 31% and 72% along with coastline stabilization by sediment aggregation. In this context, coral reefs, seagrass and sandy beaches are also useful to minimize the coastal erosion, storm surges, etc. (Cohen-Shacham et al. 2016; Kapos et al. 2019). Additionally, Kapos et al. (2019) also mentioned that NbS are beneficial for the improvement of marine fish stocks, marine biodiversity conservation and carbon sequestrations along with tourism and recreation associated with the sea. Table 15.1 shows the list of marine habitats, the ecosystem services rendered by them as well as scope for nature-based management approaches which need to be considered for appropriate blue-green infrastructure development.

In this context, the Sustainable Development Goal 14 ‘Life below water’ imposed by the United Nations places an emphasis on mainly three thematic areas: marine pollution, marine climate and sustainable usages of marine resources by balancing the environmental, social and economical dimensions of the sustainable development. The United Nations Economic and Social Council (2019) reported that marine environment is suffering from unsustainable depletion, environmental deterioration, saturation of carbon dioxide and henceforth oceanic acidification while oceans and marine fisheries are continued to global economic, social and environmental needs. Most significantly, the present efforts to protect the marine environment are yet not been so impressive globally. Further, the sustainability of the global marine fishery resources continues to decrease at a reduced rate, while the contribution of the sustainable marine fishery capture to the GDP remained stable at the global scale with a regional variation in Pacific Small Island developing countries and least developed countries where it largely contributes to the GDP with an average of 1.55 and 1.15, respectively, during 2011–2017. Hence, it is evident that an urgent assessment of the ecosystem services is required, which can support the planning of national policies on sustainable fishing.

15.2 Marine Ecosystem Services: Existing Approaches and Relevance to Resources Modelling

Although oceans, seas and coastal ecosystems support a large population of humans through their multiple ecosystem services, it is difficult to assess these services completely particularly because of the challenges in capturing the dynamics of the marine habitats and owing to the dynamicity of the oceanic processes such as winds, tides and currents (e.g. Townsend et al. 2018). Since the primary goal of planning the assessments is towards producing the desired observation on the socio-economic benefits, the models of resource usages are usually region- or location-specific and cannot be generalized, which make decision-making quite complex. Further, the technical, technological and the implementation capacity of a country can limit the use of decision support tools (Posner et al. 2016). Specifically, in the case of

Table 15.1 Marine and coastal habitats and scope for nature-based (NbS) green management

Marine/coastal habitat component	Ecosystem service rendered	Scope for nature-based (NbS) green management
Estuaries, tidal creeks, backwaters	Fisheries	Sustainable fishing practices using traditional crafts and gears
	Nutrient circulation	Maintenance of natural channels of recirculation; minimizing land-based solid waste and fertilizers run-off
	Navigability	Use of traditional, non-polluting modes of transport
Wetlands and marshlands	Nutrient sequestration	Controlling eutrophication using wetlands
	Water residence and recirculation	Balancing tidal and wind-driven recirculation by protective barriers
	Sediment enrichment	Waterlogging and marshland protection to increase organic content in sediments
Coastal sand dunes	Barriers and embayment	Protective barrier management using natural sluices and gates
Coastal lagoons and mangroves	Fisheries	Sustainable fishing practices using traditional crafts and gears
	Nutrient circulation	Maintenance of natural channels of recirculation; minimizing land-based solid waste and fertilizers run-off
	Bird and protected marine animals sanctuary	Protective areas approaches to preserve biodiversity
	Perpetuation of keystone species	
	Bioshields	Mangrove reforestation
Open sea ecosystems and marine protected areas	Climate regulation	Decrease in anthropogenic emissions of particulates along coast and offshore
	Fisheries	Sustainable fishing practices; using traditional crafts and gears and preventing overfishing
	Nutrient circulation	Maintenance of natural salinity and hydrological cycles, reducing desalination and improved bioavailability by providing regeneration periods

modelling the marine fisheries resource base, it is important to derive the potential reference points for ecosystem-based fisheries management which can characterize the ecosystem status practically (e.g. Link et al. 2002). Thus, the need for planning NbS-based green solutions for management hinges on the use of the ecosystem modelling approaches to optimize the resource usages.

Taking an example of ecosystem-based management (EBM) approaches defined in recent times, it emerges that there are several 'levels' of consideration of the datasets to model the overall efficiency of these approaches (Link and Browman 2014). For example, considering the case of fisheries as major ecosystem services

Table 15.2 Ecosystem services assessment and approaches in the context of marine resources management (adapted from Seppelt et al. 2011)

Marine ecosystem services parameter	Considerations to select appropriate NbS
Biophysical and environmental services	Realism of the ecosystem data and models
Off-site usages	Recognition of the off-site effects
Local resource usages	Accounting for local trade-offs
Stakeholder participation	Evaluate the critical involvement of stakeholders in assessments

component, the ecosystem approach to fisheries (EAF), an integration of the fish stocks with environmental and ecological components such as temperature, predator removals, multispecies interactions, etc., is necessary to select the appropriate NbS strategy. This system accounts not only the interactive elements but also the impacts of the fisheries stock changes on other components of the ecosystem. A typical blueprint for ecosystem services studies thus includes the consideration of four facets which need to be critically evaluated (Seppelt et al. 2011) as shown in the Table 15.2.

In each of the parameters critically considered to model the marine resource base, a degree of normalization needs to be incorporated to achieve the practical implementation of the goals and challenges. A recent approach of using the Multiscale Integrated Model of Ecosystem Services (MIMES) incorporates the integration of multiple ecological processes with human dynamics to simulate the interactions between coupled human and natural systems (Boumans et al. 2015). Such integrative framework often requires inputs of datasets from multiple platforms and sources including varied spatial and temporal databases, to match with the intangible and tangible benefits of the use of an appropriate NbS.

From the perspective of mainstreaming the NbS, it is also observed that the ecosystem services are not readily linked to market values and economic assessments, which put a huge pressure on deriving truthful representations of these services themselves. However, there exists huge scope to improve the supply chain assessments and their relationships with the demand side as inherent processes for sustainable development of marine resources. These require a higher level of involvement with computational regime that incorporates local- to regional-level considerations for regional development. Another perspective in the sustainable development of marine resource base includes accounting for the challenges to the achievement of the targets due to indirect drivers such as extreme weather events, sea level rise and invasive species. These multiple drivers and pressures need to be linked to the adaptive management plans and bring the experiences in dealing with these stressors into operationalizing the ecosystem-based management approaches. The computational challenges of integrating these datasets become huge considerations while deriving assessments of the impacts of the NbS-based policy frameworks.

Incorporating the NbS frameworks into marine resources management will hence require the integration of different pathways considering the ecological interactions including impacts, the services rendered as well as the administrative and governance challenges. The flow across these pathways is aligned with the use of the correct NbS strategies which will alleviate the impacts, improve the services and reduce the governance challenges across the long-term temporal scales. At the end of the process, it is important to integrate these experiences into the database to provide the blueprint for futuristic development. In order to do so, data transparency, as well as flow pathways, has to be logically and intuitively reorganized to present the inherent scenarios for futuristic development. The computational advantages can be interlinked to the decision support tools using inference-based modelling frameworks. These aspects are discussed in the role of technology in adopting NbS for coastal and marine systems.

15.3 Examples of Coastal and Marine NbS Options in Global and Indian Contexts

Globally, the NbS adopted for coastal and marine environments can be divided into four categories – fully natural solution, i.e. natural coral reefs, mangroves, etc.; managed natural solution, i.e. planted mangroves, artificial coral reefs and renourished sea beach; hybrid solution, i.e. combination of engineering structure and natural features like dune-dyke system, etc.; and environment-friendly engineering structure, i.e. bamboo sediment fences (Pontee et al. 2016; Fig. 15.1).

Pontee et al. (2016) also highlighted that the implementation of NbS also depends on some factors, e.g. types of habitat, water depth as well as habitat characteristics related to the effective coastal protection. In this connection, several examples of

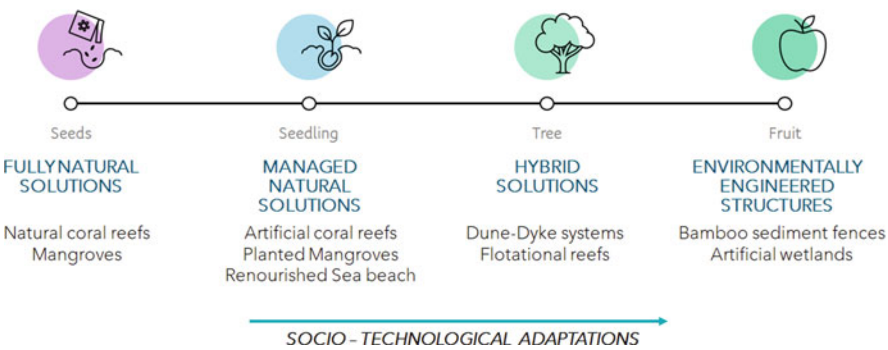

Fig. 15.1 Types of nature-based solutions (NbS) available and adopted for coastal and marine habitat management and development. The NbS can provide green alternatives for total habitat management (seed) or supportive (seedling). Ensemble solutions (tree) and naturally conceived products (fruit) can also be effective NbS options as illustrated

coastal and marine NbS options can be provided in the global as well as Indian context.

15.3.1 Global Case Studies

Global case studies provide a glimpse of the NbS efforts that may of three important interventional types as described in Eggermont et al. (2015):

1. No or minimal interventions in ecosystems: examples include mangrove conservation and/or preservation as core/buffer area protective solutions.
2. Partial interventions: implementation of innovative management approaches towards development of landscapes in order to improve the delivery of selected NbS options compared to conventional interventions. Examples for the coastal zone operations include evolutionary-oriented fisheries management which has a beneficial effect on restoration of native fishery stocks and thereby contribute to coastal resiliencies.
3. Management of the ecosystems on an intrusive level or creation of new ecosystems themselves. Examples include creation of artificial wetlands, reefs, seaweed farms, etc.

The entire scales of the operations described above from the perspectives of benefits and trade-offs are described here taking specific case studies as examples. To reduce the effect of coastal erosion and hurricane-induced strong wave in Puerto Morelos, Mexico, on the Mayan Riviera, artificial coral reefs were planted as a part of NbS (Acclimatise News 2019). It had been noticed after 5 years of completion in 2015 that artificial reefs helped to recover the beach along with the fish attraction in the reefs. In case of Mayakoba beach, also artificial coral reefs were planted to reduce the sand dune losses, which negatively impacted the nearby mangroves, turtles, birds, etc. owing to the effect of hurricane (Acclimatise News 2019). The establishment of Sand Motor, Netherlands, under an NbS was useful to set up natural sand dunes against beach erosion on the coast. The expansion of sea beach attracted tourist and has transitioned into good places for community recreation (Luijendijk and Oudenhoven 2019). The port city of Dar es Salaam in Tanzanian was suffering from deforestation, soil erosion and sedimentation owing to the rapid urbanization which resulted in the loss of fertile agricultural land as well as loss of lives and livelihoods due to the successive floods (Gajjar 2020). In such scenario, Tanzania Urban Resilience Programme has been prepared a draft under NbS through reforestation, dredging of the river, plantation of mangroves and solid waste management by 2030. Gajjar (2020) also studied that the Municipal Climate Protection Programme developed key components of community-based ecosystem, green economy and disaster management system under NbS programme to reduce several climate change-oriented impacts such as sea level rise, storm surges, water scarcity, etc. in Thekwini, South Africa. It was also useful in terms of co-beneficial effects of employment generation, community ownership, etc. for societal benefits. In connection, the 'Ecosystem-based Adaptation to Climate Change in Seychelles project (2014–2020)' has been adopted in Mahé and Praslin, Seychelles, to minimize the risk generated by cyclone and associated storm surges, sea level rise, etc. through the restoration of ecosystem functionality where local civil societies were deeply involved (Gajjar 2020). Moreover, Mueller and Bresch (2014) mentioned that annual damages worth USD20 can be avoided due to hurricanes through the protection of Folkestone Marine National Park, located in Barbados.

Duarte et al. (2017) studied the global NbS services of seaweed farms highlighting their significant carbon sequestration properties and roles as carbon dioxide (CO_2) sinks, contributing to total or partial biofuel production. Further, they highlighted the huge potentials of the seaweed farms as CO_2 mitigators to the tune of about 1500 tons CO_2 per km^2 per year of avoided emissions from: (1) fossil fuels and (2) facilitating further reduction of the emissions from agriculture, as well as, (3) lowering methane emissions attributed to cattle when included in cattle feed. Other ecosystem services of the seaweed aquaculture such as damping the wave energy in the sea, mechanical consolidation of shorelines, enhancing the pH and supplying dissolved oxygen to the surface waters by their presence contribute twofold to NbS: (1) mitigation and adaptation to climate change as biomass and (2) alleviating the effects of ocean acidification and anoxia as a constituent of the coastal and marine food web.

Kelly et al. (2012) described the use of human-nature partnerships as NbS methodologies to secure the conservation and preservation of marine resources, including living resources such as the dolphins, illustrating the uses and apparent trade-offs through three case studies from the Shannon Dolphin and Wildlife Foundation (SDWF, Ireland), the Dolphin Space Programme (DSP, Scotland) and the Pembrokeshire Marine Code Group (PMCG, Wales). The study highlighted the use of heuristic analyses of the indicators of sustainability of the NbS partnerships as well as the development of policy interventions supportive of the NbS measures adopted. Recently, Narayan et al. (2016) researched the multimodal ecosystem services of NbS in coastal and marine environments; these advancements in the knowledge of the use of NbS for coastal studies are illustrated in Fig. 15.2. The study highlighted the efficiency of two types of NbS hitherto mentioned (see Fig. 15.1) to support different anthropogenic uses, for example, the shoreline protection.

15.3.2 Indian Scenario

In case of India along with other South Asian countries, i.e. Indonesia, Sri Lanka, Thailand and Malaysia, community-based coastal habitat restoration has been initiated by Wetlands International, IUCN, under NbS approaches of ecological restoration. The government of India had notified Island Protection Zone (IPZ) in 2011 through the conservation of mangroves and renourishment of beaches and sand dunes with the objectives of promoting development in a sustainable manner along with supporting the livelihoods of the local community (University of Oxford 2021). India is also on the way to implement the Integrated Coastal Zone Management

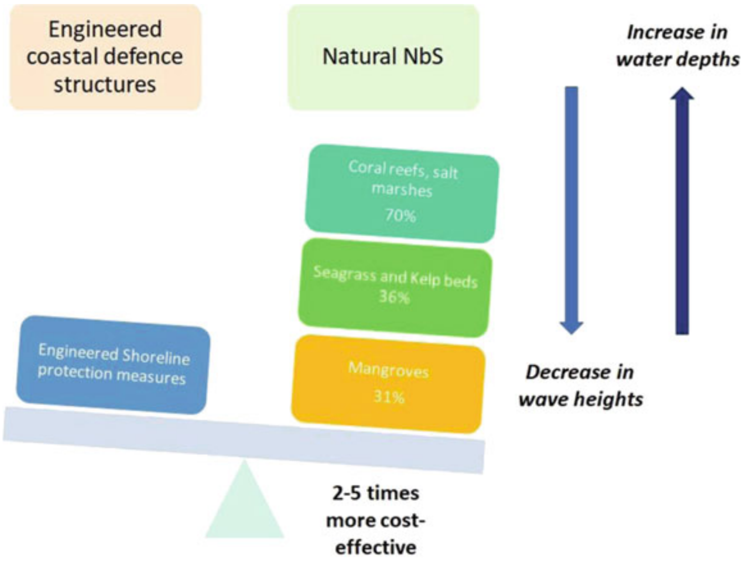

Fig. 15.2 Example of implementation of coastal NbS for shoreline defence and protection described in Narayan et al. (2016) illustrating the benefits of the use of natural NbS ecosystems for the coastal defence

(ICZM) to conserve and protect the critical coastal and marine habitats as well as coastal and marine geomorphology in association with ‘Mangroves for the Future (MFF)’ coordinated by IUCN with an initiative of coastal livelihood support. Under the latest ‘BG infrastructural policy scheme’, Atal Mission for Rejuvenation and Urban Transformation (AMRUT) is aiming to improve the governance and sustainability of Indian cities under NbS approaches, having eight components: water supply, sewerage, septage, storm water drainage, urban transport, green spaces and parks, administrative reforms and capacity-building (Gajjar 2020). Such studies are quite important to address challenges to coastal cities in India; for example, the coastal city of Panaji is impacted by coastal erosion, land degradation and loss of biodiversity owing to the sea level rises, urbanization and habitat alternation, respectively, where mainstreaming of NbS can offer both short-term and long-term benefits by technological interventions. Another example of the planning for NbS-based coastal protective measures is presented at the 6 km long St Inez Creek, connecting Mandovi River and the Arabian Sea, which is significant from the environmental as well as socio-cultural perspectives; however, its functionality has been reduced due to both anthropogenic activities and natural degradation. To restore the functionality of the creek, a floating bioremediation system was created as NbS in 2017 with the help of experts and local youths with varied effects. Apart from this, a mixed approach, i.e. water quality monitoring, natural remediation, solid waste filtering, sewage treatment and green space coverages along the creek, has been proposed under NbS approach for the restoration of the functionality of the creek (Gajjar 2020).

In 2007, IUCN and MSSRF jointly developed the Integrated Mangrove Fishery Farming System (IMFFS) in Tamil Nadu to sustain the livelihoods of the local fishing community and also to stop the unsustainable aquaculture practices that resulted in the collapse of shrimp farming since the 1990s (IUCN 2016). Further NbS at vulnerable locations along the coastal Bay of Bengal has been reported to benefit the lives and livelihoods of the fishing community at several marine fish landing centres by artificial coral reefs formation, dredging of the sedimented rivers, beach nourishment, etc.

15.4 NbS for Achieving Targets of the Sustainable Development Goals (SDG) for India

The Sustainable Development Goal (SDG) 14 ('Life below water') deals with the dependence of human beings on the ocean, especially with respect to the coastal and marine fisheries. About 40% of the total world population lives within 100 km of the coast and fully depend on the ocean for their livelihoods. Further, more than 15% of the total protein consumed by 4.3 billion people across the globe comes from seafood (Pisupati 2016). Apart from these, the offshore ocean provides 30% of the total global petroleum and natural gas production, while ocean currents, tides, waves and winds are used to generate non-conventional energy worldwide which is environment-friendly due to low CO_2 emissions (Cicin-Sain 2015). However, the conservation and sustainable usages of marine resources under SDG 14, imposed by the United Nations, are still limited (Pisupati 2016). The SDG 14 consisting of seven targets, i.e. 14.1, 14.2, etc., emphasize on three thematic areas: marine pollution, marine climate as well as marine resources.

With more than 25 marine protected areas consisting of 10,000 sq. km located in 106 peninsular islands, the marine biodiversity of India is a great asset, providing numerous ecosystem services; however, suitable and proper plans and approaches need to be implemented for achieving the target related to the SDG 14. In India, NITI Aayog has been empowered to oversee the overall progress associated with the SDGs and the capacity-building to achieve the same. Such efforts from the central government have been crucial to promote the use of NbS in the sustainable management practices across the country.

For example, it has been reported that 112 km^2 of mangrove forest had been increased in the coastal regions of India compared to the previous assessment while more than 15,000 ha were planted in the coastal Gujarat region. The Government of India has also been launched *National Fisheries Policy 2020* to provide momentum in *Blue Revolution* (NFDB 2020). Presently, various national- and state-level legislations are collaborating for the management as well as protection of the marine environment through the community participation under the scheme of Integrated Coastal Zone Management Project (Government of India 2017). Despite a long history of its marine resource management, however, India suffers from reliable datasets associated with the depth information on the marine resources, its status and trends at national as well as state level (Pisupati 2016). Under the circumstances, it is clear that NbS options if facilitated for the country through policy-driven changes can provide effective means to plan and execute the sustainable management practices. Further, the following are the major considerations that need to be addressed for dealing with the management of the coastal and marine resources:

1. The availability of knowledge to pursue NbS.
2. The policy-driven gaps in addressing the need for NbS-based planning for coastal and marine conservation.
3. The gap between the availability and use of technology to provide the impetus for capacity-building and training of all levels of stakeholders for coastal and marine governance under the perspective of NbS.
4. The complexity of the data and the need for multi-criteria decision analyses make a case for the need for coordinated computational efforts and technology-based approaches to realistically achieve the targets of the SDG 14.

Presently, it is very urgent to collate various information and data regarding different agreed targets and indicators of SDG 14 for achieving sustainable marine resource management. In this connection, the Ministry of Statistics and Programme Implementation, Government of India, has prepared National Indicator Framework (as shown in Table 15.3) related to the SDGs for identifying data and information gaps; probable indicators align with the global indicators and also create a strong network in between ministries, institutions and civil societies (Government of India 2020). The present investigation provides a unique compilation of the indicator-wise assessment of the NbS needs for India which are summarized in Table 15.3.

15.5 Scope for the Use of Technology for Adapting to NbS Frameworks as NbS Assisting Technologies (NAT)

A significant amount of research and development efforts in the area of marine resources monitoring in India is focussed on the generation of marine fishery advisories including potential fishing zone (PFZ) and ocean state forecast (OSF), introduced in the earlier subsection. ESSO-INCOIS-derived Marine Fishery Advisories, i.e. PFZ advisory, a reliable and short-term forecast of the fish aggregation zone in the open sea, using remotely sensed data would be helpful for the sustainable marine resource management in the Indian context (ESSO-INCOIS, 2020). PFZ not only contributes to an increase in the capture of fishes with shortening the time period but also is environment-friendly as it is helpful in declining the CO_2 emissions in the marine environment as a result of less fuel consumption due to minimization of search time (NCAER 2010, 2015). According to the study conducted by NCAER (2015), it has been revealed that saving one litre of diesel can reduce 2.63 kg of CO_2 which is equal to INR 36,200 crores per annum in a 25 years life. From a management perspective, the use of PFZ and OSF

Table 15.3 Present status of India in achieving Sustainable Development Goal 14 (SDG 14), associated indicators for each target under SDG 14 as well as selection of NbS methods for achieving the targets (source: Government of India 2020; modelling frameworks from Culhane et al. 2020)

Target	Descriptions of target	Indicators	Appropriate NbS models or systems
14.1	Prevention and reduction of marine pollution particularly from land-based activities by 2025. This includes marine debris and nutrient pollution	14.1.1 Coastal Water Quality Index	Flotational wetlands for sequestration of excess nutrients
		14.1.3 Percentage of use of nitrogenous fertilizer to total fertilizer (NPK)	
14.2	Sustainable management and protection of marine and coastal ecosystems, strengthening their resilience and restoration by 2020	14.2.1 Percentage change in area under mangroves (similar to 14.5.2)	Mangrove plantation
		14.2.3 Percentage change in marine protected areas (MPA)	Beach nourishment
14.3	Minimize and address the impacts of ocean acidification scientifically	14.3.1 Average marine acidity (pH) measured at the agreed site of representative sampling stations	Use of seaweed farms, etc.
14.4	Regulation of harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices by 2020, protect/conserve fish stocks	14.4.1 Maximum sustainable yield (MSY) in fishing, (in million metric ton (mt)/year	Artificial coral reef formation, riverine channel preservation through shore-based plantation management to allow fish stock diversification, etc.
14.5	Conservation of at least 10% of coastal and marine areas by 2020	14.5.1 Coverage of protected areas in relation to marine areas	Plantation of mangroves, seaweeds, seagrass, preservation of local eco-cultural ecosystem services preservation etc.
		14.5.2 Percentage change in area under mangroves (similar to 14.2.1)	Mangrove plantation
14.6	Prohibition of fisheries subsidies which contribute to overcapacity and overfishing planning by 2020	National indicator is still under development	Technology-aided scenario modelling, policies to encourage foot fishing in shallow seas and coastal lagoons to preserve fish stocks and prevent habitat fragmentation of economically important species
14.7	Achieving an increase in economic benefits to small island developing states	National indicator is still under development	NbS habitats attractive to native fish species

(continued)

Table 15.3 (continued)

Target	Descriptions of target	Indicators	Appropriate NbS models or systems
	and least developed countries through sustainable use of marine resources by 2030		
14.a	Scientific management of marine technology, as per the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology	14.a.1 Budgeting resources (budget estimates)	Use of marine fishery advisories such as Potential Fishing Zones, including species-specific advisories, Ocean State Forecasts, coral bleaching alert, multi-hazard vulnerability mapping, oil spill advisory for effective budgeting of resources managment protocols
14.b	Access for small-scale artisanal fishers to marine resources and markets	14.b.1 Assistance to the traditional/artisanal fishers	Integrated Mangrove Fishery Farming System, river channel widening by adopting on-shore NbS practices, improving markets for locally procured marine products through their promotion as food which is sustainably-procured, encouraging foot-fishing and non-motorised fishing in shallow water environments with provisions for direct, on-site markets for eco-tourists, etc.
14.c	Conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, as per the legal framework for the conservation and sustainable use of oceans	14.c.1 Compliance of international laws	NbS scenario-based computational models

advisories can contribute towards planning a technology-based NbS framework for sustainable fishing.

PFZ forecasts in India were initiated in 1989–1990 for the first time using NOAA AVHRR-derived sea surface temperature (SST; Mane and Mishra 2017) until the successful launching of the IRS-P4 satellite (Giri et al. 2016). However, SST-derived PFZ advisory was found to be not adequate in tropical and equatorial waters during summer owing to strong stratification which prevented the arrival of cool nutrient-rich waters to the sea surface from the deeper layer; surface wind might also affect the frontal structure (Wilson et al. 2008). Post the launch of the IRS-P4 (Oceansat) on May 26, 1999, Solanki et al. (2001) developed an integrated approach using OCM-derived chlorophyll-a (Chl-a) and AVHRR-derived SST to constrain PFZ in the Indian water. Hence, the PFZ algorithm matches the presence of Chl-a along with favourable SST which are very productive, to predict the highly favourable zones in the coastal sea for the fish aggregation (Giri et al. 2016).

At present, marine fishing in India has been concentrated within the narrow belt of 50 m depth in inshore water (Nammalwar et al. 2013), providing maximum contributions to the fishery-based economy. Remote sensing data can also provide better information regarding the planning and managing of the fishing-related activities nearer to the coastal region (Miguel and Santos 2000; Sreedhar 2002). The oceanographic conditions, such as SST, Chl-a and Ocean Fronts, influence the fish stocks (Klemas 2012, 2013), and satellite-derived SST and Chl-a have been found to be satisfactory in providing high receptivity and large spatial coverage for monitoring the same (Pillai and Nair 2010). The advisories provided by INCOIS for OSF services were initiated in 2009; include wave heights, wave direction, wind speed, wind direction, tides, currents, etc.; are also helpful to ensure the safety of the fishermen by making their appropriate decision for venturing into the deep ocean (e.g. Kundu and Santhanam 2021a); and are also helpful for the coastal community (Nayak et al. 2007; Nair and Pillai 2012; ESSO-INCOIS 2020). In the formulation of the PFZ advisory, the ocean colour (concentration of chlorophyll) indicates the area of high biological production 'fish accumulation zones' where the fishes accumulate for their feeding and spawning (Chandran et al. 2004; Solanki et al. 2005) in relation to ocean state factors: SST, front, topographic structure, upwelling, eddies, etc. The SST are indicative of the thermal environment for enhancing biological productivity (Solanki et al. 2003), and since the cooler waters contain the highest nutrient materials, SST inversely correlate with PFZ areas (Solanki et al. 2003, 2005). The temperature gradient in the ocean also attracts fishes; the ocean colour features coincide with the thermal fronts, related to the high primary productivity (Solanki et al. 2001; Kripa et al. 2014). An additional example is the restricting of a traditional model of PFZ, wherein the PFZ advisory systems consider real-time parameters and predict most favourable spots using multi-criteria analysis between the parameters (Kundu et al. 2020).

Studies conducted by the National Council of Applied Economic Research (NCAER) the net economic benefits from successful identification of PFZ can be of the order of INR 500 billion per annum. Such improved capabilities of the advisories can add to eco-sustainability by saving fuel consumption of motorized boats to reach the PFZ (NCAER 2010). Thus, while the PFZ advisories help the fishing community to locate large fish shoals by reducing the search time, thereby saving diesel consumption, the OSF advisories provide fishers and their family accurate and critical information on the status of the ocean-related weather conditions and hence provide a greater sense of security, avoiding the loss of lives and property (MSSRF 2014a, b; Kundu and Santhanam 2021b). Presently, marine fisheries add to the earnings by foreign exchange from the export of fishery products corresponding to 10% of overall export, while it accounts only for 0.91% of total GDP (NFDB 2020). From the above perspective, the effective use of geospatial technology in the form of national marine fishery advisories is proposed here as unique ‘NbS Assisting Technologies’ (NAT) since they are excellent tools for promoting and minimizing the sea-based anthropogenic effects on the ecosystem.

15.6 Conclusions

The present study highlights the fact that the use of NbS measures if inculcated into the marine and coastal resources planning can invariably lead to infrastructural and developmental benefits by meeting the SDG targets 14 for India. Strategies incorporating NbS would be helpful in preserving coastal and marine ecosystem properties and, at the same time, promoting sustainable fisheries as well as promoting equity among the fishers and capacity-building in fishery-based occupations. These directly correspond to the achievement of societal goals for development in India promoted by prestigious programmes of national interests such as SAMAVESH of NITI Aayog. Hence it becomes important to support the capacity-building in terms of technological advancements in improving the NbS for sustainable fishery practices.

NbS Assisting Technologies (NAT), such as the potential fishing zone (PFZ) and the ocean state forecast (OSF) advisories provided on a regular basis to maritime states in India, can help to achieve the maximum benefits of the installations that support NbS on the coast and at sea by three ways: (1) as scientific planning tools to optimize the activities of motorized and mechanized fishing boats made, (2) as tools to derive policy-based decisions on permissible fishing ranges of the motorized versus non-motorized boats operating in the Indian seas based on the carrying capacity of the sea and (3) to optimize the marine trophic status with the maximum sustainable yields by the conjunctive use of technology with coastal NbS strategies. Thus, the use of NAT can be crucial to advance the infrastructural benefits of the use of NbS for coastal and marine ecosystems.

Further, such NAT approaches can support causality-linkage frameworks, by linking geospatial modelling tools with a combination of stakeholder-driven decisions support systems which provide the outputs for management of the ecosystems. Further, simulation and virtual testing of the green solutions in the place of conventional solutions in computational environments such as deep learning environments can save considerable time and effort to test the applicability in real time. Thus, the use of inference-based approaches in ecosystem assessments can be beneficial to achieve the targets of SDG 14 by automating the monitoring efforts and the use of evolutionary learning approaches of NAT for active and dynamic management of India’s coastal and marine resources. The above-mentioned points require consideration from a policy perspective and need to be formalized to achieve

NbS goals and a green solutions-backed economy to improve socio-ecological relationships between the humans and the seas.

Acknowledgements The authors wish to thank Prof. Shailesh Nayak, Director, NIAS Bengaluru, and Prof. S. Ayyappan, Chancellor, Central Agricultural University, Imphal, and Chairman, Karnataka Science and Technology Academy, Bengaluru, for inspiration to study the current gaps in policy-based research for coastal and marine environments in India. The authors are grateful to Prof. R. Srikanth, NIAS Bangalore, for his encouragement to do socially relevant research. The authors are also grateful to two anonymous reviewers for reviewing the manuscript and for providing suggestions to improve the same. SKK acknowledges the PhD Fellowship provided by the Ministry of Earth Sciences (MoES), Government of India, vide Grant No. MoES/16/15/11-RDEAS (NIAS) awarded to the National Institute of Advanced Studies, Bengaluru, Karnataka. HS acknowledges the use of Turnitin Software provided by NIAS Bangalore for similarity checking for the present paper.

Conflict of Interest Statement The authors report no conflict of interest for this publication.

References

Boumans R, RomanJ AI, Kaufman L (2015) The Multiscale Integrated Model of Ecosystem Services (MIMES): simulating the interactions of coupled human and natural systems. Ecosyst Serv 12:30–41. https://doi.org/10.1016/j.ecoser.2015.01.004

Bradley D, Merrifield M, Miller KM, Lomonico S, Wilson JR, Gleason MG (2019) Opportunities to improve fisheries management through innovative technology and advanced data systems. Fish Fish 20(3):564–583. https://doi.org/10.1111/faf.12361

Chandran RV, Solanki HU, Dwivedi RM, Nayak S, Jeyaram A, Adiga S (2004) Studies on the drift of ocean colour features using satellite-derived sea surface wind for updating potential fishing zone. Indian J Mar Sci 33(2):122–128

Cicin-Sain B (2015) Goal 14—conserve and sustainably use oceans, seas and marine resources for sustainable development. UN Chronicle LI(4) Retrieved from https://www.un.org/en/chronicle/article/goal-14-conserve-and-sustainably-use-oceans-seas-and-marine-resources-sustainable-development

Cohen-Shacham E, Walters G, Janzen C (eds) (2016) Nature-based Solutions to address global societal challenges. IUCN, Switzerland. https://doi.org/10.2305/IUCN.CH.2016.13.en

Culhane FE, Robinson LA, Lillebø AI (2020) Approaches for estimating the supply of ecosystem services: Concepts for ecosystem-based management in coastal and marine environments. In: Ecosystem-based management, ecosystem services and aquatic biodiversity. Springer, Cham. https://doi.org/10.1007/978-3-030-45843-0_6

Duarte CM, Wu J, Xiao X, Bruhn A, Krause-Jensen D (2017) Can Seaweed Farming Play a Role in Climate Change Mitigation and Adaptation? Frontier Marine Science 4:100. https://doi.org/10.3389/fmars.2017.00100

Eggermont H, Balian E, Azevedo JM, Beumer V, Brodin T, Claudet J, Fady B, Grube M, Keune H, Lamarque P, Reuter K (2015) Nature-based solutions: new influence for environmental management and research in Europe. GAIA-Ecol Perspect Sci Soc 24(4):243–248. https://doi.org/10.14512/gaia.24.4.9

ESSO-INCOIS (2020) Potential Fishing Zone (PFZ) advisory. Earth System Science Organization—Indian National Centre for Ocean Information Services. Retrieved from https://incois.gov.in/MarineFisheries/PfzAdvisory

FAO (2018) Exploring SDG 14.b and its proposed indicator 14.b.1. In: Franz N (ed) FAO Fisheries and aquaculture proceedings, vol 59, pp 1–39. Retrieved from http://www.fao.org/3/ca0140en/CA0140EN.pdf

Gajjar S (2020) Nature-based solutions to climate change in coastal cities. Afr Perspect Global Insights 308:1–17. Retrieved from https://media.africaportal.org/documents/Occasional-Paper-308-gajjar.pdf

Giri S, Manna S, Chanda A, Chowdhury A, Mukhopadhyay A, Chakraborty S, Hazra S (2016) Implementing a spatial model to derive potential fishing zones in the Northern Bay of Bengal lying adjacent to West Bengal Coast, India. J Indian Soc Remote Sensing 44(1):59–66. https://doi.org/10.1007/s12524-015-0472-2

Government of India (2017) Voluntary national review report on implementation of sustainable development goals. Retrieved from https://sustainabledevelopment.un.org/content/documents/15836India.pdf

Government of India (2020) Sustainable development goals—national indicator framework (Version 2.1). Retrieved from https://www.mospi.gov.in/documents/213904/0/Annex-III.pdf/d4679e60-071e-0652-b147-582dd520b3f9?t=1596972547966

Hinds L (1992) World marine fisheries: Management and development problems. Mar Policy 16(5):394–403. https://doi.org/10.1016/0308-597X(92)90007-C

ICAR-CMFRI (2020) Marine fish landings in India 2019. Retrieved from http://eprints.cmfri.org.in/14325/1/MarineFishLandingsinIndia_2020_CMFRI.pdf

IUCN (2016, October 1) Farmed fishing: a nature based solution to increased resilience. Retrieved April 07, 2021, from International Union for Conservation of Nature: https://www.iucn.org/news/india/201610/farmed-fishing-nature-based-solution-increased-resilience

IUCN (2021) Commission on ecosystem management. Retrieved from Nature-based Solutions: https://www.iucn.org/commissions/commission-ecosystem-management/our-work/nature-based-solutions

Kapos V, Wicander S, Salvaterra T, Dawkins K, Hicks C (2019) The role of the natural environment in adaptation. Background Paper for the Global Commission on Adaptation, Rotterdam and Washington DC. Retrieved fromhttps://www.ecoshape.org/app/uploads/sites/2/2017/08/3324-19_WP_GCA_Paper_WEB-002.pdf

Kelly C, Essex S, Glegg G (2012) Reflective practice for marine planning: a case study of marine nature-based tourism partnerships. Marine Policy 36(3):769–781. https://doi.org/10.1016/j.marpol.2011.10.023

Klemas V (2012) Remote sensing of environmental indicators of potential fish aggregation: an overview. Baltica 25(2):99–112. https://doi.org/10.5200/baltica.2012.25.10

Klemas V (2013) Fisheries applications of remote sensing: an overview. Fish Res 148:124–136. https://doi.org/10.1016/j.fishres.2012.02.027

Kripa V, Mohamed KS, Prema D, Mohan A, Abhilash KS (2014) On the persistent occurrence of potential fishing zones in the southeastern Arabian Sea. Indian J Geo-Mar Sci 43(5):737–745

Kundu SK, Santhanam H (2021a) All pain and no gain: factors impacting local and regional sustainability due to COVID-19 pandemic with respect to the Indian marine fisheries. Curr Res Environ Sustain 3. https://doi.org/10.1016/j.crsust.2021.100086

Kundu SK, Santhanam H (2021b) A report on the impacts of cyclone Yaas over a fish landing centre vulnerable to cyclonic storms and natural hazards – Talsari, Northern Odisha. Local Environ 26(9):1043–1050. https://doi.org/10.1080/13549839.2021.1964457

Kundu SK, Santhanam H, Srikanth R (2020) A technical assessment of the use of current geospatial technologies to derive marine fishery advisories in India and the Way Forward, Asian Conference on Remote Sensing 2020 Full paper available at: https://a-a-r-s.org/proceeding/ACRS2020/ifomqo.p

Link JS, Browman HI (2014) Integrating what? Levels of marine ecosystem-based assessment and management. ICES J Mar Sci 71(5):1170–1173

Link JS, BrodziakJ K, Edwards SF, Overholtz WJ, Mountain D, Jossi JW, Fogarty MJ (2002) Marine ecosystem assessment in a fisheries management context. Can J Fish Aquat Sci 59(9):1429–1440

Luijendijk A, Oudenhoven VA (2019) The sand motor: a nature-based response to climate change: findings and reflections of the interdisciplinary research program nature coast. Delft University

Publishers, Retrieved from. http://pure.tudelft.nl/ws/portalfiles/portal/53666598/2019_Luijendijk_van_OUdenhoven_eds_The_Sand_Motor_A_Nature_Based_Response_to_Climate_Change_NATURECOAST.pdf

Mane SU, Mishra AD (2017) Application of remote sensing with R tool in validation of PFZ along Coast of Ratnagiri: a survey. IOSR J Electron Commun Eng (IOSR-JECE) 12(3):104–109. https://doi.org/10.9790/2834-120302104109

Matthew A (2015) Small-Scale Fisheries (SSF) in India. Retrieved from https://www.un.org/Depts/los/nippon/unnff_programme_home/unnff_programme_sg_report/AnsyMatthew_Small-scale_fisheries.pdf

Miguel A, Santos P (2000) Fisheries oceanography using satellite and airborne remote sensing methods: a review. Fish Res 49(1):1–20. https://doi.org/10.1016/S0165-7836(00)00201-0

MSSRF (2014a) Impact of INCOIS scientific forecast services towards improving the lives and livelihoods of fishing communities across Tamil Nadu and Puducherry. Retrieved from https://incois.gov.in/documents/scientificForecastServices.pdf

MSSRF (2014b) Potential fishing zone advisories and conversion from partnership in Gilakaladindi Village in Krishna District, Andhra Pradesh-a preliminary study. Retrieved from https://incois.gov.in/documents/Gilakaladindi_Study.pdf

Mueller L, Bresch D (2014) Economics of climate adaptation in Barbados – facts for decision making. In: Murti R, Buyck C (eds) Safe Havens: protected areas for disaster risk reduction and climate change adaptation. IUCN, Switzerland. Retrieved from https://portals.iucn.org/library/sites/library/files/documents/2014-038.pdf

Nair PG, Pillai VN (2012) Satellite based potential fishing zone (PFZ) advisories – acceptance levels and benefits derived by the user community along the Kerala coast. Indian J Fish 59(2):69–74

Nammalwar P, Satheesh S, Ramesh R (2013) Applications of remote sensing in the validations of Potential Fishing Zones (PFZ) along the coast of North Tamil Nadu, India. Indian J Mar Sci 42(3):283–292

Narayan S, Beck MW, Reguero BG, Losada IJ, Van Wesenbeeck B, Pontee N, Sanchirico JN, Ingram JC, Lange GM, Burks-Copes KA (2016) The effectiveness, costs and coastal protection benefits of natural and nature-based defences. PLoS One 11(5):e0154735

Nayak S (2017) Coastal zone management in India - present status and future needs. Geo-Spatial Inform Sci 20(2):174–183. https://doi.org/10.1080/10095020.2017.1333715

Nayak S (2020) Remote sensing for national development: the Legacy of Dr. Vikram Sarabhai. J Indian Soc Remote Sensing 48(8):P1101–P1120. https://doi.org/10.1007/s12524-020-01156-x

Nayak S, Srinivaskumar T, Nagarajakumar M (2007) Satellite-based fishery service in India. In: GEO Secretariat (ed) The full picture. Tudor Rose, Geneva, Switzerland, pp 256–257

NCAER (2010)impact assessment and economic benefits of weather and marine services. https://moes.gov.in/writereaddata/files/ImpactAssessment-MOES.pdf

NCAER (2015) Economic benefits of dynamic weather and ocean information and advisory services in India and cost and pricing of customized products and services of ESSO NCMRWF & ESSO-INCOIS. https://incois.gov.in/documents/ImpactAssessment-NCAER2015.pdf

Acclimatise News (2019) Life's a beach: nature-based solutions for coastal protection. Nottinghamshire: climate change impact, defence Retrieved from https://www.acclimatise.uk.com/2019/06/06/lifes-a-beach-nature-based-solutions-for-coastal-protection/

NFDB Report, National Fisheries Policy, National Fisheries Development Board (2020). Retrieved from: http://nfdb.gov.in/PDF/National_Fisheries_Policy_2020.pdf

Pillai VN, Nair PG (2010) Potential fishing zone (PFZ) advisories-are they beneficial to the coastal fisherfolk? A case study along Kerala coast, South India. Biol Forum – Int J 2(2):46–55

Pisupati B (2016) Marine resources and the challenges to sustainability. In India and sustainable development goals: the way forward. pp. 173–179. Retrieved from http://ris.org.in/pdf/SDGs_Report_Chapter_14.pdf

Pontee N, Narayan S, Beck WM, Hosking A (2016) Nature-based solutions: lessons from around the world. Maritime Eng 69(1):29–36. https://doi.org/10.1680/jmaen.15.00027

Posner S, VerutesG KI, Denu D, Ricketts T (2016) Global use of ecosystem service models. Ecosyst Serv 17:131–141. https://doi.org/10.1016/j.ecoser.2015.12.003

Pramod G (2010) Illegal, unreported and unregulated marine fish catches in the Indian exclusive economic zone. https://www.researchgate.net/publication/238790315

Seppelt R, Dormann CF, Eppink FV, Lautenbach S, Schmidt S (2011) A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. J Appl Ecol 48(3):630–636

Solanki HU, Dwivedi RM, Nayak SR (2001) Synergistic analysis of SeaWifs chlorophyll concentration and NOAA-AVHRR SST features for exploring marine living resources. Int J Remote Sensing 22(18):3877–3882. https://doi.org/10.1080/01431160110069845

Solanki HU, Dwivedi RM, Nayak S, Gulati DK, John ME, Somvanshi VS (2003) Potential Fishing Zones (PFZ) forecast using satellite data derived biological and physical processes. J Indian Soc Remote Sensing 31(2):67–69. https://doi.org/10.1007/BF03030773

Solanki HU, Mankodi PC, Nayak SR, Somvanshi VS (2005) Evaluation of remote-sensing based potential fishing zones (PFZs) forecast methodology. Continent Shelf Res 25(18):2163–2173. https://doi.org/10.1016/j.csr.2005.08.025

Sreedhar U (2002) Remote sensing and fisheries. In: Handbook of fishing technology. Retrieved from http://210.212.228.207/bitstream/handle/123456789/1332/Remote%20sensing%20and%20fisheries.pdf?sequence=1

Townsend M, Davies K, Hanley N, Hewitt JE, Lundquist CJ, Lohrer AM (2018) The challenge of implementing the marine ecosystem service concept. Front Mar Sci 5:359

UN Economic and Social Council (2019) UN Special edition: progress towards the Sustainable Development Goals. https://www.un.org/ga/search/view_doc.asp?symbol=E/2019/68

University of Oxford (2021, April 7). Nature-based solutions policy platform. Retrieved from Your Nation: https://www.nbspolicyplatform.org/your-nation/?country=116

Wilson C, Morales J, Nayak S, Asanuma I, Feldman G (2008) Ocean-colour radiometry and fisheries. In: Platt T, Hoepffner N, Stuart V, Brown N (eds) Why ocean colour? The societal benefits of ocean-colour technology. Reports of the International Ocean-Colour Coordinating Group, No. 7. IOCCG, Dartmouth, Canada, pp 47–58

Harini Santhanam is an environmental scientist working as an Assistant Professor with the School of Natural Sciences and Engineering at the National Institute of Advanced Studies (NIAS), Bengaluru, India.

Sudip Kumar Kundu is a doctoral student with the National Institute of Advanced Studies (NIAS), Bengaluru, India.