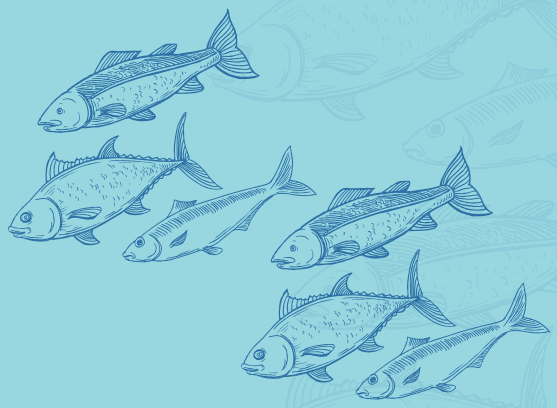
Compendium of Fish Stock Assessment Practices in South Asia



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Inter-Governmental Organization
91, St. Mary's Road, Abhirampuram, Chennai - 600 018. INDIA

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About the compendium

This compendium outlines data collection practices, methodologies, approaches for fish stock assessment employed by the South Asian countries, providing a comprehensive resource for enhancing collaborative efforts and promoting best practices in the region. The information used in this compendium are provided by Bay of Bengal Stock Assessment Network (BOB-SAN) Experts nominated by the respective governments.

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Foreword

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In the dynamic field of fish stock assessment, the **Compendium of Fish Stock Assessment Practices in South Asia** stands as a baseline for the collective efforts and evolving strategies employed by practitioners and experts in the region. This compendium encompasses insights, experiences, and practical approaches focused on understanding the intricacies of fish stock assessment - an essential element in achieving sustainable and responsible fisheries management.

I am happy to know that the genesis of BOB-SAN (Bay of Bengal Stock Assessment Network) can be traced back to the FAO Regional Workshop for a Network of Practitioners on Fishery Stock Assessment held in Bangkok, Thailand, from January 23-25, 2023. The Bay of Bengal Programme Inter-Governmental Organization (BOBP-IGO) took the initiative to call for a transparent stock assessment framework and increased coordination among Bay of Bengal Rim Countries. The subsequent establishment of BOB-SAN underscores the necessity for collaboration and regional cooperation, addressing the challenges faced by South Asian countries in managing shared stocks.

The establishment of BOB-SAN (Bay of Bengal Stock Assessment Network) emerges as a crucial initiative, embodying the spirit of collective wisdom and coordinated efforts. The network's commitment to periodic gatherings, knowledge sharing, and envisioning specialised working groups reflects a proactive approach to addressing the intricacies of fisheries management in the Bay of Bengal.

As South Asia witnesses a growing interest in stock assessment studies, this compendium serves as a baseline for practitioners, policymakers, and researchers. It is not merely a collection of practices; rather, it is a repository of insights that contribute to the broader narrative of sustainable fisheries management in the region. The compendium's role extends beyond documentation, it serves as an instrument for fostering understanding, collaboration, and continuous improvement in the field of stock assessment practices in South Asia.

I appreciate the lead taken by the BOBP-IGO to take forward FAO's call; their efforts are an excellent example of effective regional cooperation. I hope others will be inspired and build upon this type of effort in the years to come.

Vera Agostini

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1. Introduction

1.1. Stock Assessment and Fisheries Management

Stock Assessment is an integral part of fisheries management, which, according to the modern definition, "stock assessment involves the use of various statistical and mathematical calculations to make quantitative predictions about the reactions of fish populations to alternate management choices" (Hilborn and Walters, 1992). Stock assessment involves analysing the data on the life history of fish species, monitoring fishing activities i.e. landings and length compositions, and conducting resource surveys to estimate the size of a stock and its harvest rate in comparison to sustainable reference points; it also helps in forecasting the response of the population to the different management scenarios. The scientific aim of the stock assessment is to estimate the sustainable long-term catch through a theoretical mathematical model. An effective stock assessment will not offer a correct "answer" but should instead present a range of options, revealing predicted outcomes and any associated tradeoffs (Hoggarth et al., 2006).

The outcomes of stock assessments form the foundation for making both long-term and short-term decisions in fisheries management. Stock assessment helps in evaluating whether underfishing or overfishing is taking place and identifying the optimal level of fishing that would yield the maximum sustainable yield (harvest). It also provides predictions for anticipated future catches and estimates of stock abundance related to proposed harvest policies. In the last century, the techniques used for stock assessment have evolved from basic descriptive models to sophisticated statistical models. Many fishery management systems in various regions now depend on regularly conducted stock assessments to ascertain the status of stocks and receive management recommendations aimed at achieving fishery and conservation goals (Cadrin et al., 2015). It's crucial to recognise that stock assessment is not the ultimate goal of management; rather, it constitutes one phase within a broader process designed to attain management objectives in the face of uncertainty.

1.2. Need for BOBSAN

Approximately 50% of South Asia's catch is derived from shared stocks, indicating a reliance on collaborative management strategies (Fig.1). Tunas and small pelagics, key components of the catch, are harvested by multiple countries in the region, emphasizing the transboundary nature of these fisheries. However, the management of shared stocks remains unaddressed, posing a challenge to sustainable catches over the region. The prevalence of miscellaneous and unidentified fisheries in the region is largely attributed to the vibrant trawl and gillnet fishery. Furthermore, the lack of comprehensive catch reporting contributes to poor data resolution, hindering effective fisheries management and sustainability efforts. Addressing these issues is crucial for fostering responsible and sustainable practices in South Asia's diverse and interconnected fisheries sector.

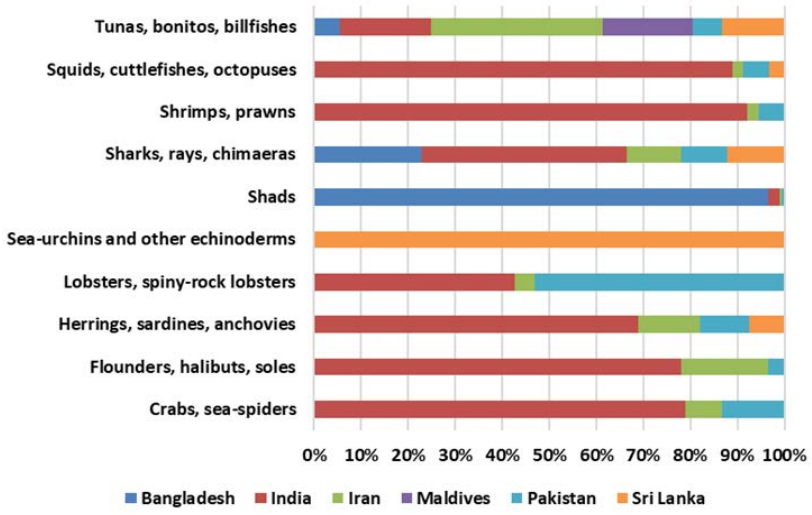


Figure 1: Shared Fisheries in the South Asian Region (Source: FAO)

A recent analysis of stock assessment studies in South Asia reveals a notable increasing trend in publications on this subject. This suggests a growing interest and recognition of the importance of understanding and managing fish stocks in the region. However, despite this rising trend, there appears to be a lack of regional cooperation to collectively address the various issues and complexities associated with stock assessment. The absence of regional cooperation is evident in the network map among the countries in South Asia, In this context, it is notable that the predominant pattern is

characterized by north-south cooperation rather than south-south cooperation. (Fig.2). The lack of substantial collaborative efforts indicates a fragmented approach to addressing common challenges related to fisheries and stock assessment. Several factors could contribute to this lack of regional cooperation. These may include differing national priorities, limited resources for collaborative initiatives, or lack of coordinated efforts to share data and expertise. The absence of a unified approach hinders the ability to develop effective and sustainable fisheries management strategies that could benefit the entire region. Addressing these challenges and fostering regional cooperation is crucial for several reasons. Fish stocks often migrate across national boundaries, making it essential for neighbouring countries to collaborate on management strategies to ensure the sustainability of shared resources. Additionally, a coordinated effort can lead to the development of standardized methodologies, data-sharing mechanisms, and best practices, which can enhance the accuracy and reliability of stock assessments.

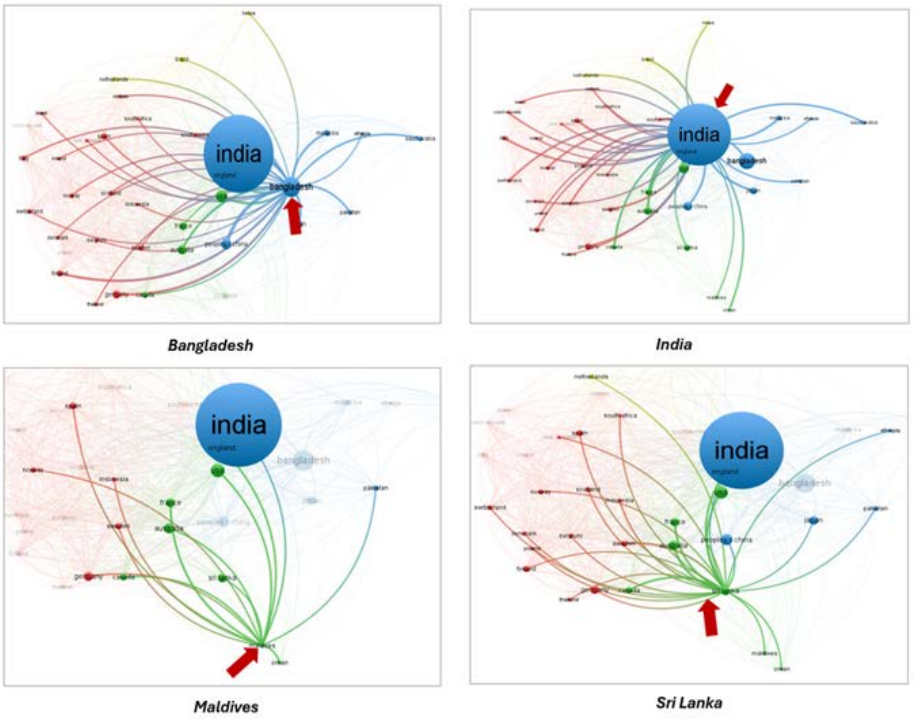


Figure 2: Network map of collaboration among Countries in the field of Stock Assessment (Created using data from Web of Science)

1.3. BOB-SAN: A Brief

The genesis of BOB-SAN (Bay of Bengal Stock Assessment Network) can be traced back to the FAO Regional Workshop for a Network of Practitioners on Fishery Stock Assessment held in Bangkok, Thailand during January 23-25, 2023. During this event, the Bay of Bengal Programme Inter-Governmental Organization (BOBP-IGO) called for a transparent stock assessment framework and heightened coordination among the Bay of Bengal Rim Countries. Recently, BOBP-IGO, in collaboration with CMFRI and FAO, validated a new stock assessment method to assess the status of stock in FAO Fishing Area 57.

BOB-SAN, functioning as an informal virtual network with BOBP-IGO as its nodal point, aims to leverage the collective wisdom and experiences of its members to enhance stock assessment methodologies and contribute to coordinated regional fisheries management. Understanding the intricacies of fish stock assessment in the Bay of Bengal region, BOB-SAN has committed to meeting periodically, convening once every six months. These gatherings serve as forums for sharing knowledge and best practices in fish stock assessment, discussing advanced methodologies, and collectively advancing the frontiers of stock assessment based on cumulative experiences and collaboration. The network operates on the premise that addressing the complexities of fisheries management in the Bay of Bengal requires a unified effort, with each member contributing to the shared goal of sustainable and effective stock assessment in the region.

In the future, BOB-SAN envisions a dynamic and collaborative structure with specialized working groups dedicated to crucial thematic areas, including data collection, modelling techniques, technology integration, and policy recommendations. These groups will serve as think tanks, fostering in-depth research and development within their respective domains. Additionally, BOB-SAN will encourage its members to propose collaborative projects, providing a platform for addressing specific challenges in stock assessment collectively. The establishment of a secure online platform will be pivotal, offering members a centralized space to access valuable resources, share information seamlessly, and engage in meaningful discussions. Committed to capacity building, BOB-SAN plans to organize workshops, webinars, and training sessions to enhance the skills of researchers and administrators involved in stock assessment methodologies. As part of its commitment to continuous improvement, BOB-SAN will develop key performance indicators to systematically evaluate the impact and effectiveness of its activities, ensuring a strategic and impactful approach toward sustainable fisheries management in the Bay of Bengal region.

2. Marine Fisheries Sector in South Asia

The BOB region encompasses lower to middle-income countries characterized by multiple fishing points and diverse fisheries (FAO, 2021). Approximately 44% of the BOB Large Marine Ecosystem area is covered within the EEZ of four countries in the Bay of Bengal (Fig. 3). Within this region, a substantial number of fishing vessels operate, reflecting the significance of fisheries as a livelihood activity. The focus is on increasing production to meet the demands of the population. The fisheries sector in the BOB region operates within a framework of co-existing formal and informal governance mechanisms, although there is a recognized inadequacy in bridging the gap between these two systems. According to the FAO Fisheries & Aquaculture Yearbook 2019, the BOB region alone accounts for over 1 million fishing vessels out of the global total of approximately 2.6 million, underscoring its substantial presence in the worldwide fishing industry. Further, the region is characterised by predominant presence of small-scale fisheries (SSF) susceptible to the impacts of climate change, including rising sea levels, changing ocean temperatures, and extreme weather events. These factors can significantly influence fish migration patterns and the availability of certain species that poses challenges to the SSF. Additionally cyclones can cause damageto fishing fleets and communities, as evidenced by events such as cyclone Nargis in 2008.

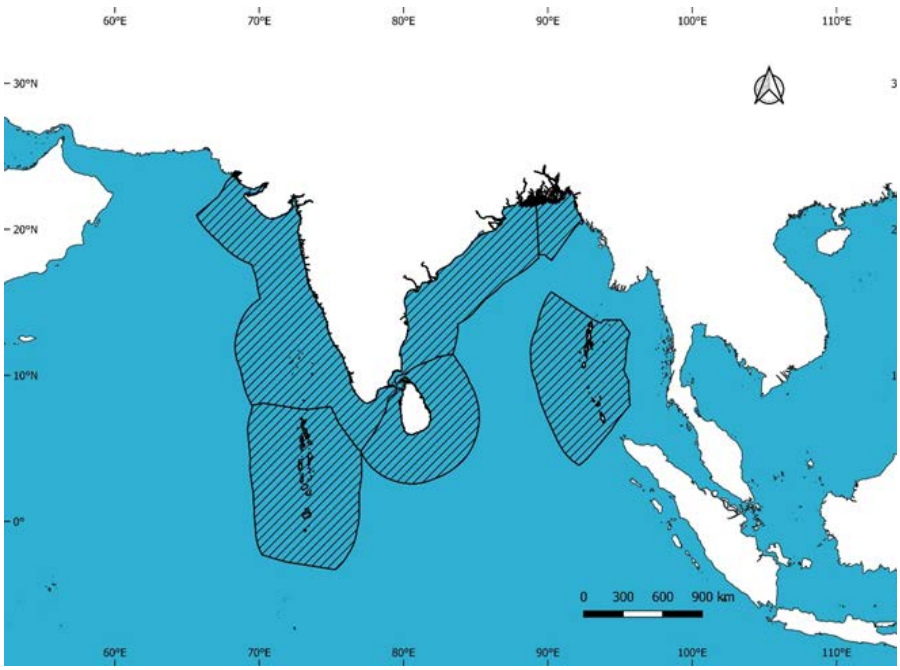


Figure 3: EEZ of BOBP Member Countries

The fish catch data from 2000 to 2021 in Bangladesh, India, Maldives, and Sri Lanka reveals distinct trends (Fig. 4). Bangladesh maintained a gradual increase from 0.33 million tonnes in 2000 to 0.68 million tonnes in 2021. India, as the leading contributor, demonstrated overall growth despite fluctuations, with the catch increasing from 2.82 million tonnes in 2000 to 3.17 million tonnes in 2021, marking a rise of about 13%. The Maldives showcased a modest and consistent catch, fluctuating between 0.11 million tonnes in 2009 and 0.18 million tonnes in 2005. Sri Lanka's fish catch displayed moderate fluctuations, reaching a peak of 0.45 million tonnes in 2014 and decreasing to 0.31 million tonnes in 2021. These changes underscore the dynamic nature of fish catch across the years and countries in the South Asian region.

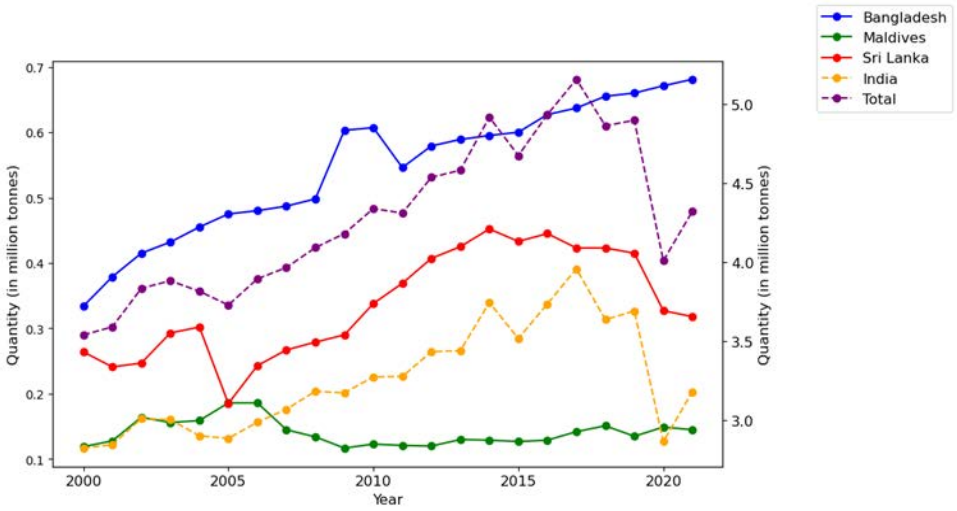


Figure 4: Marine Capture Production in BOBP-IGO Member Countries (Source: FAO)

2.1. Bangladesh

The country has a coastal area of 2.30 million ha and a coastline of 714 km along the Bay of Bengal, which supports a large artisanal and coastal fishery. In addition to this, there is a total of 166,000 sq. km. water area including Exclusive Economic Zone (EEZ). The fisheries sector of Bangladesh is highly diverse in recourse types and species. In Bangladesh, traditional fisheries exist side by side with commercial fisheries. The overall marine fishing potential of the country is 9.83 Lakh tonnes. About 231 industrial trawlers are active in fishing, and 67,669 mechanised and artisanal boats are engaged in traditional fishing in the Bay of Bengal. These traditional mechanised and artisanal fishing boats are involved in the use of relatively simpler gears such as gillnets, set bag nets, and trammel nets. Marine fisheries production is only 15% of the national fish production (DoF, 2021). Marine fishing operations are demarcated for up to 40 m depth for artisanal and mechanised boats to operate; (2) from 40 m to 200 m depth for industrial trawlers; and (3) from 200 m depth to the end of the EEZ and ABNJ for long-liners and purse-seiners (Fig.5). Commercially important groups include Hilsa, Mackerel, Mullets, Croakers, Ribbonfishes, Penaeid Shrimps, etc. Offshore fishery operations primarily involve the utilisation of trawl nets, encompassing both demersal and bottom trawl methods, as well as gillnets and purse-seine nets. Artisanal fishermen carry out inshore fishing in small open non-mechanized boats ranging from 5 to 12 m in length with a variety of fishing gears (Hoq et al., 2013).

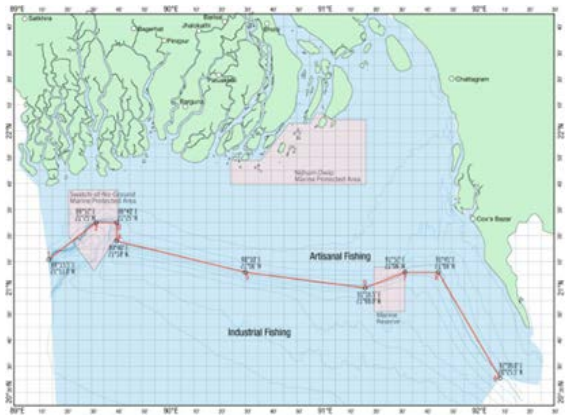


Figure 5: Administrative boundaries for the marine fishing sector in Bangladesh

2.2. India

India, is blessed with a highly diverse nature of marine fishery resources in its 2.02 million km2 EEZ with an estimated annual harvestable potential of 5.31 million metric tonnes. The marine fisheries sector provides livelihood to nearly 4 million people and meets the food and nutritional requirements of a significant proportion of the population. Periodic advancements in fish-catching techniques through the development of efficient craft and gear to capture fish occurring horizontally on the ocean surface as well as in different depth contours. The marine fishing fleet in India is highly heterogeneous, with trawlers, gillnetters, seiners and liners and includes a limited number of longliners, some of which are involved in offshore tuna fishing in the outer reaches of the EEZ. The number of mechanised boats has increased by more than ten times in 50 years, together with an increase in capacity, jointly increasing fishing efficiency by many folds. For fisheries management

purposes, fisheries in territorial waters are a subject of coastal states, while those of other zones are a Union subject. For the estimation of fisheries potential and for assessing the status of stock, Indian EEZ is differentiated into several regions (Fig.6). A total of 1,66,333 fishing crafts exists in the marine fishery of India, out of which 25.8% are mechanized (boats with inboard engine and wheelhouse), 58.7% are motorized (boats with outboard motor), and 5.4% are nonmotorized (CMFRI-FSI-DOF, 2021). Commercially important species include Oil sardine, Mackerel, Threadfin breams, Lesser sardines, and Penaeid and Non-Penaeid shrimp.

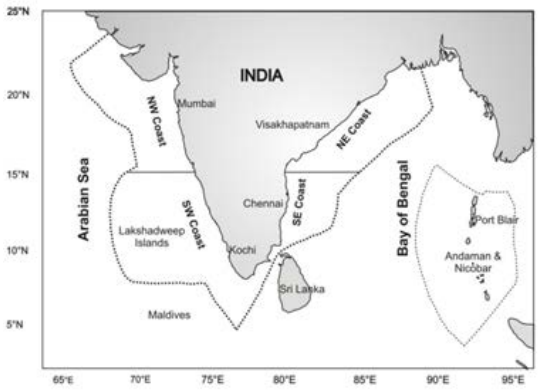


Figure 6: Regions for estimating fishing potential and assessing the status of stock

2.3. Maldives

The Maldives, with an Exclusive Economic Zone (EEZ) spanning 900,000 square kilometres, boasts a significant fishing industry, ranking as the island's second main economic driver after tourism. Fishing within the EEZ by other countries is permitted by license. However, a 75-mile exclusion zone exists around all atolls (the Coastal Fishery Zone) solely for Maldivian fishers (Fig. 7). A notable 2.86% of the world's coral reefs are found in these waters. Notably, more than half of the working population is engaged in the fishing industry (Faiz, 1997). The traditional Maldivian fishing fleet consists of three main vessel types, varying in size, range, and utilization: Masdhnoi, Vadhu Dhoni, and Bokkora. Fishing activity has intensified from subsistence to artisanal levels to supply the increasing demand. Traditionally, the tuna fishery has been the cornerstone of the Maldives' fishing, enduring for centuries as the primary fishery. The most important tuna species is the skipjack tuna and yellowfin tuna. The tuna is caught by pole and line, handline, and longline. The traditional use of the pole and line method in the Maldivian tuna industry has contributed to the sustainability of the tuna resources. The increasing fishing effort and catches of the pole-and-line fleet have increased the demand for live bait in the Maldives. Live-bait catches were dominated by fusiliers (Caesionidae) and silver-stripe round herring (Spratelloides gracilis), which

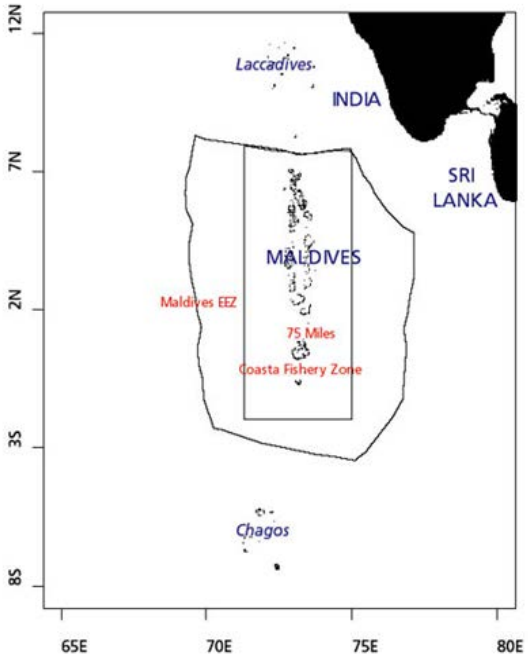


Figure 7: Map showing the 200 nautical miles EEZ and the Coastal Fisheries Zone - the area between the atoll boundary and the 7aile zone.

contributed over 70% to the catch (Hemmings et al., 2014). Handline and longline fishing are commonly employed in the reef fishing industry, targeting popular species such as grouper, snapper, emperor and reef-associated jack.

2.4. Sri Lanka

Sri Lanka has an extensive stock of fishing resources in its 5.17 Lakhs square kilometres of EEZ. The fisheries sector plays a crucial role in ensuring food security, supplying more than 60% of the country's animal protein requirements. The fisheries sector in Sri Lanka is a vital component of the national economy, providing direct and indirect employment opportunities for approximately 583,000 people. It serves as a source of livelihood for around 2.7 million coastal communities, contributing significantly to the socio-economic fabric of the country. The marine fisheries accounts for nearly 71% to the total fish production and of which coastal landings makes up 53% while the rest (47%) from offshore catches (NARA, 2022). The fisheries sector is supported by a considerable fleet of fishing boats, with a total of 26,600 vessels contributing to various fishing activities, which include 1700 multi-day boats (32-52 ft) (EDB, 2022). Gillnet, purse-seine and line fishing methods are the major fishing gears contributing 70% to the total fish catch. Commercially important fish categories are Tuna, Swordfish, Prawns and Shrimps, Mud and blue swimming crabs, lobsters, Sea cucumber and Sea bass. Seven fisheries management areas had been declared under the Fisheries and Aquatic Resources Act, No. 2 of 1996 for the management of fisheries resources through community participation (Fig.8).

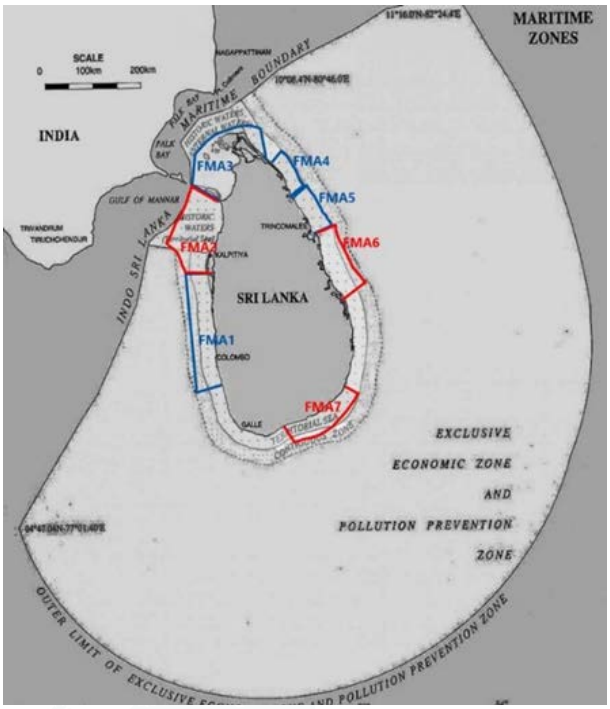
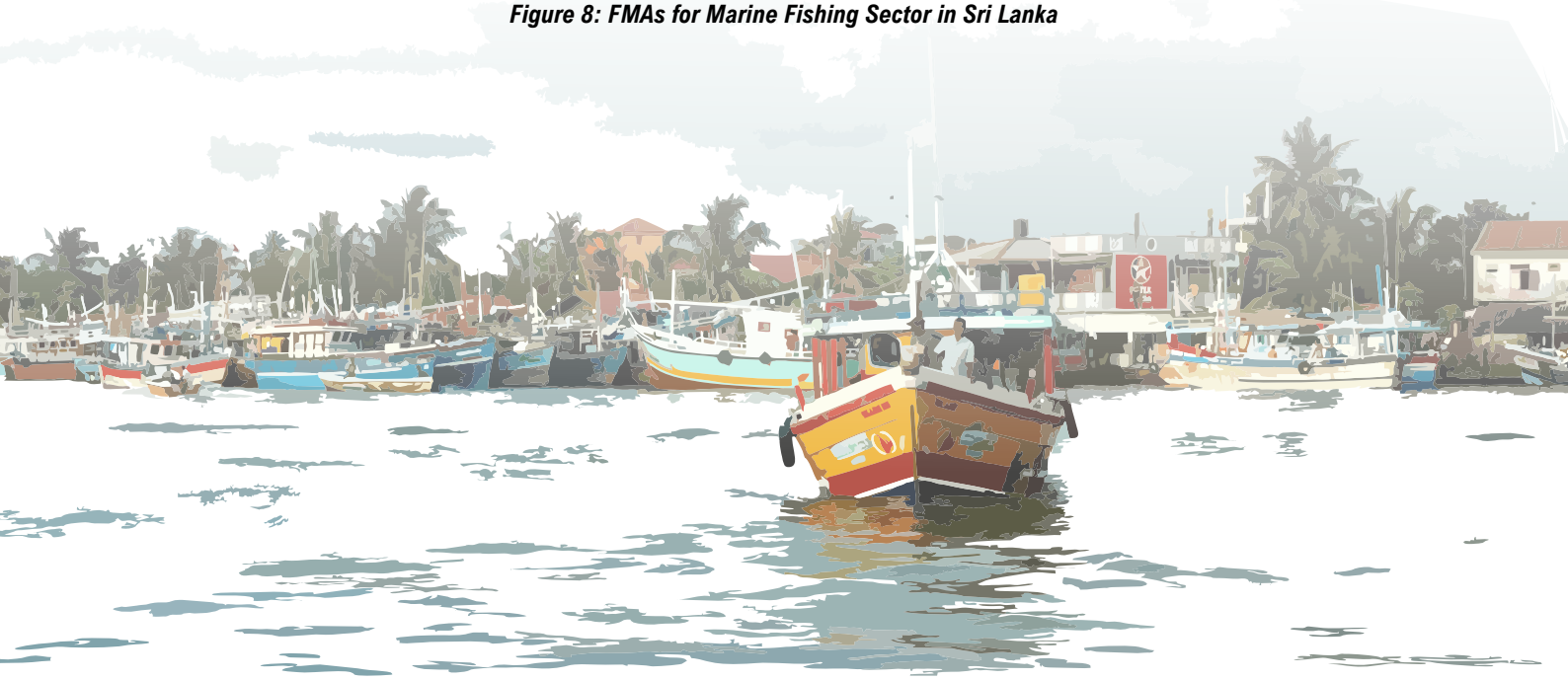


Figure 8: FMAs for Marine Fishing Sector in Sri Lanka



3. Overview of Fish Stock Assessment in South Asia

3.1. Bangladesh

3.1.1. Agency

In Bangladesh, the government has designated the Marine Fisheries Survey Management Unit under the Department of Fisheries, as the nodal agency responsible for fish stock assessment. This unit operates within the Ministry of Fisheries Department and plays a pivotal role in evaluating the status of fish populations in the country's marine waters. Additionally, the Department of Fisheries itself serves as the nodal agency for the estimation of marine fish landings. Collaborating closely with these government bodies is the Bangladesh Fisheries Research Institute, a key Research Institute involved in the comprehensive assessment of fish stocks. Furthermore, there is collaboration on an ad-hoc basis with regional and international institutions such as the Food and Agriculture Organization (FAO) and the Bay of Bengal Programme (BOBP-IGO). Notably, the budget allocated for these endeavours last year amounted to 6 lakhs BDT. Further, the estimation of marine fish landings for industrial fisheries involves logbook record-keeping. Land-based data collection is a key methodology employed for artisanal fisheries.

3.1.2. Status of Stock Assessment

In Bangladesh, there are institutionalized procedures in place for the regular evaluation of fish stocks, with an average frequency of assessment occurring every three years. The assessments encompass both multi-species and single-species evaluations. Fisheries-dependent data include species such as Hilsa Shad, Bombay Duck, Silver Pomfret, Savalai Hairtail, and Coromandel Ilisha, as well as groups like Croakers, Pomfret, Finfish, and Shrimp. Fisheries independent data are sourced from Research Vessel Survey Data, providing comprehensive data from Stock Assessment.

For multi-species assessments, various types of fishing gear, such as gill nets, set bag nets, and trawl nets, are employed to analyse species groups, including croakers, pomfret, finfish, and shrimp, across all regions. In the case of single-species fish stock assessments, key species like Hilsa shad, Bombay Duck, Silver Pomfret, and Savala Hairtail, accounting for 70% of the fishery, are meticulously studied. The methodologies employed for these assessments include the State Space Production (JABBA) model, focusing on biomass and catch, and the length-based catch curve (fishblicc) model, considering length frequency and life history parameters. These models utilize data collected from the nodal agency (DoF, BD) and fisheries dependent/independent surveys.

3.1.3. Actions post stock-assessment

The stock assessment reports play a vital role in informing and guiding fisheries management decisions at various levels. The Bangladesh Fisheries Research Institute, operating at the national level, receives these reports every three years, facilitating the dissemination of crucial information for informed decision-making. Additionally, the Food and Agriculture Organization (FAO) and National Universities also receive the stock assessment reports at a triennial frequency. To further enhance accessibility and understanding among policymakers, the results are communicated through multiple channels. Policy briefs, exclusively prepared for policymakers, serve as concise summaries of the assessment findings. Advisory meetings and consultations are conducted to facilitate in-depth discussions and insights into the stock assessment results. Furthermore, a comprehensive Stock Assessment Report is compiled and released every three years by the designated nodal agency.

3.1.4. Fisheries Management

The current fisheries management strategy in Bangladesh encompasses a range of technical measures. Under input control, fishing capacity is regulated through licensing mechanisms, ensuring that only authorised vessels are allowed to fish. Spatial and seasonal moratoriums are in place to manage fishing activities in specific areas and during critical times, contributing to the conservation of sensitive ecosystems. Fishing effort controls are implemented through measures such as sailing permissions, and a proposed Total Allowable Effort (TAE) system is being considered to further regulate and optimise fishing efforts.

In terms of output control, Commercial minimum size regulations are enforced to ensure that only mature individuals are harvested. Mesh size controls and the prohibition of the juvenile catches of Hilsa contribute to species-specific conservation efforts. Additionally, regulations governing the maximum length of nets are in place to prevent overfishing and minimise environmental impacts.

Bangladesh has faced challenges in implementing absolute evidence-based management due to a data-poor situation. However, specific regulatory initiatives have been established based on previous stock assessments. The stock assessment report of 2019 indicated an overall status of demersal finfish and shrimp as overfished and depleted. In response to this information, a strategic plan has been devised. Within the next five years, all bottom trawlers will be converted to mid-water trawlers. Furthermore, in adherence to the Marine Fisheries Rules of 2023, the licenses of all shrimp trawlers will be cancelled within ten years.

3.2. India

3.2.1. Agency

In India, the government has designated the Fishery Survey of India (FSI) under the Ministry/Fisheries Department as the nodal agency for collating marine fish landings and related information. Additionally, the responsibility for the estimation of marine fish landings lies with the State fisheries departments of each maritime state and the Central Marine Fisheries Research Institute (ICAR-CMFRI), a prominent research institute in South Asia. BOBP-IGO plays a coordinating role in facilitating stakeholder discussions and providing expert advice. In the domain of fish stock assessment, ICAR-CMFRI contributes significantly by supplying the basic requirement of landing data and related surveyed based estimates life history parameters of major demersal and pelagic resources up to a depth of 200 meters. Both for the estimation of Marine fish landings and the size-based sample driven life history trait parameter estimation a scientifically proven and statistically robust evolutionary method, the Multi-Stage Stratified Random Sampling method developed by ICAR-CMFRI is being followed.

In the case of assessing marine fishing potential, which is being carried out at regular intervals, a multitude of agencies, such as FSI, ICAR-CMFRI, National Institute of Oceanography (NIO), National Institute of Ocean Technology (NIOT), Centre for Marine Living Resources and Ecology (CMLRE), Zoological Survey of India (ZSI), and the Bay of Bengal Programme Inter-Governmental Organization (BoBP-IGO), participate. The current estimated Marine Fishing potential of India is 5.31 million Metric Tonnes of conventional fishery resources.

3.2.2. Status of Stock Assessment

Length-frequency data for various fish species were collected from landings obtained through different fishing gears in four distinct regions of the Indian coast—northwest, southwest, northeast, southeast—as well as in the island regions of Andaman & Nicobar Islands and Lakshadweep.

For oceanic resources, assessments are usually done for the entire Indian EEZ as a whole, keeping in view the migratory nature of the species. The basic data for assessing the oceanic resources is rooted on experimental fishing as well as catch rates of concerned vessels. Such estimates for the time series of reference data leading to target yield of select oceanic resources in the Indian EEZ monitored and recommended by RFMOs like IOTC in the Indian Ocean region. Mostly the catch rates obtained from fishery independent experimental fishing is used to assess the resource deep water and oceanic resources using swept area method.

ICAR-CMFRI conducted stock assessments for the Indian region utilizing the length-based analytical models. The multigear nature of the fishery situation was solved by introducing a gear standardization parameter into the biomass dynamics model. The relative positions of the fish stocks were depicted through Kobe plots generated for the 10 maritime states/ union territory and the fish stocks were categorised into sustainable, overfished, recovering and overfishing based on the status.

Besides, ICAR-CMFRI recently developed a well-balanced, quickly calculated, and routinely implementable metric that assesses the stock health of all or key fisheries-related resources to arrive at Fish Stock Status (FSS) by keeping an informed base prepared by periodically carried out elaborate stock assessment exercises and the landings trends in tandem, weighted further by the vulnerability ranking of the stock concerned viz., Environmental Performance Index-Fish Stock Status (EPI-FSS) and Fortified FSS. EPI-FSS index was developed which is based on the landings of a resource and optimal biological removal of the resource. A Weighted Tropic Level Index (WTLI) was also developed based on landings of a resource and its mean trophic level. Values of EPI-FSS of 4 and above indicate an early phase, between 3 and 4 indicate developing phase, between 2 and 3 sustainable phase and below 2 an overfished phase (Jayasankar et al., 2021).

3.2.3. Actions post stock-assessment

The Department of Fisheries, operating under the Ministry of Fisheries, Animal Husbandry & Dairying, within the Government of India, receives stock assessment based harvestable potential of commercially exploited resources at intervals of ten years. In addition to these routine reports, policymakers benefit from the delivery of concise and focused Policy Briefs. The Nodal Agency responsible for fish stock assessment provides periodical reports, either annually or half-yearly. Furthermore, the detailed insights obtained from the stock assessments are shared with the wider scientific communities through the publication of research papers

3.2.4. Fisheries Management

Input control measures are in place for fishing boats operating along the Indian coast, requiring them to possess both boat registration certificates under the Merchant Shipping Act and Fishing License certificates under the MFR Act. Its objective is to serve as a one-stop for all Indian fishing boats, to regulate the movements of fishing boats, to strengthen coastal security, etc. While MFRAs and related instruments and promulgations have a comprehensive framework for regulating fishery in the Territorial Waters, homogenized regulatory measures are spelt out from time to time by the Federal Ministry, which has the EEZ under its purview, which are again adpted by the states. A uniform ban on fishing by all fishing vessels

in the Indian Exclusive Economic Zone (EEZ) beyond the territorial water on the East Coast, including the Andaman and Nicobar Island (15th April – 14th June) and West Coast including Lakshadweep Island (1st June – 31st July) exist for 61 days. In tune with tune with these coastal bans, respective state governments also issue fishing regulations. Spatial zoning across states designates coastal water zones with restrictions or prohibitions on certain types of fishing vessels, gear, or practices. Maritime states have prohibited the use of mechanised fishing activities based upon engine power/tonnage within a distance of 5-10 km, which is reserved for artisanal fishermen. Also, fishing in some regions declared as Marine Protected Areas is not allowed.

On the output control side, some Indian states have regulations to prohibit the catching of fish below the minimum legal size. In India, Kerala is the first state to prohibit catching 44 fish species less than the minimum legal size under the Kerala Marine Fishing Regulation Act, 1980. Also, the state government of Karnataka banned fishermen from catching 19 fish species below a certain length. The order was passed under the Karnataka Marine Fishing (Regulation) Act, 1986. A minimum legal size for 20 species is declared to avoid juvenile fishing in the states of Goa. Further, In West Bengal, catching of Hilsa below 23cm is prohibited. Furthermore, under the Indian Wildlife Protection Act, 1972, certain fish and other marine fauna mainly mammals are safeguarded, and any attempt to capture or kill these protected species is deemed an offence.

3.3. Maldives

3.3.1. Agency

The Maldives Marine Research Institute holds a crucial role as the government-designated nodal agency for fish stock assessment, actively engaged in evaluating the health and status of marine fisheries in the region. Simultaneously, the Ministry of Fisheries, Marine Resources, and Agriculture serves as another nodal agency with a specific responsibility for estimating marine fish landings. The mandate of the nodal agency includes assessing the status of fish stocks, contributing to sustainable fisheries management. Furthermore, funding support from international agencies, notably the World Bank, is instrumental in facilitating comprehensive stock assessment initiatives.

3.3.2. Status of Stock Assessment

In the Maldives, the primary data source for stock assessment is fisheries-dependent data, which involves information gathered through activities directly related to fishing. Unfortunately, the country currently lacks institutionalized procedures for the regular evaluation of fish stocks. However, single-species fish stock assessments are undertaken, focusing on key species that collectively account for a substantial portion of the fishery, with a specific emphasis on Katsuwonus pelamis, Thunnus albacares, Plectropomus laevis, Plectropomus aerolatus, Plectropomus pessuliferus, Epinephelus fuscoguttatus, and Epinephelus polyphekadion. These assessments utilise the Hook and Line fishing gear and cover the entire country. The frequency of assessment varies, with details yet to be specified.

Methodologies employed for the single-species stock assessment include the use of Other (Length Catch Curve) methods, which involve Length Frequency, Lm, and Length-weight relationship. The data is obtained through fishery-dependent length sampling conducted by the Maldives Marine Research Institute (MMRI), utilising the fishblicc platform. These comprehensive assessments and methodologies aim to provide valuable insights into the status of these significant fish stocks, contributing to informed fisheries management decisions and sustainable practices in the Maldives.

3.3.3. Actions post stock-assessment

The stock assessment reports from the Maldives are primarily directed to the Fisheries Management Section of the Ministry of Fisheries, Marine Resources, and Agriculture. These reports are submitted as soon as the assessments are completed, indicating that the frequency of submission is contingent upon the timing of the assessments.

3.3.4. Fisheries Management

The Grouper Fishery Management Plan of 2020 in the Maldives establishes stringent regulations to protect and sustain the grouper population. According to the plan, it is explicitly prohibited to catch 20 grouper species below their specified size limits. Further, ecologically important species such as marine turtles, sharks, and parrotfish are prohibited from fishing.

3.4. Sri Lanka

3.4.1. Agency

In the realm of fish stock assessment in the country, the National Aquatic Resources Research and Development Agency (NARA) has been designated as the nodal agency by the government. Specifically, for the estimation of marine fish landings, the Ministry of Fisheries (MoF) has been identified as the responsible nodal agency. Beyond these primary agencies, Pelagikos Pvt Ltd is also involved in the stock assessment of fish in the country. Furthermore, in the pursuit of comprehensive and collaborative efforts, several regional and international institutions play a crucial role. The World Bank contributes by providing guidance through international SA experts to facilitate the assessment process. Additionally,

collaboration with regional entities such as the Indian Ocean Tuna Commission (IOTC) and Bay of Bengal Large Marine Ecosystem Project Implementation Group (BOB IGO) involves capacity-building initiatives. The Food and Agriculture Organization (FAO) is also engaged in collaborative efforts, focusing on enhancing capacity in the assessment of fish stocks.

3.4.2. Status of Stock Assessment

Acoustic surveys done by Dr. Fridtjoff Nansen's survey vessel between 1978 and 1980 targeted coastal fish resources and estimated a potential yield of 250,000 metric tons. Further, he fisheries-dependent data utilized for stock assessment encompass various species, including Spotted sardinella, Goldstriped sardinella, Scalloped spiny lobster, Blue swimming crab, Amber fish (Sea cucumber), and Brown sandfish (Sea cucumber).

Despite the absence of institutionalized procedures for regular evaluations of fish stocks in the country, fish stock assessment in Sri Lanka encompasses both multi-species and single-species approaches. The multi-species assessment employs small meshed gillnets and other gear in coastal fisheries, focusing on coastal species such as small pelagic, demersal fish, and coastal tunas. This assessment covers the West, South, and East coasts of Sri Lanka and has been conducted Utilizing Ecopath with Ecosim On the other hand, single-species fish stock assessments are conducted for species mentioned above. The methodologies employed for single-species stock assessment include the surplus production model and LB SPR and Leslie DeLury depletion method.

3.4.3. Actions post stock-assessment

Stock assessment reports from Sri Lanka are disseminated to various stakeholders at different levels, including national, regional, and international agencies. The Department of Fisheries and Aquatic Resources (DFAR) within the country receives these crucial reports annually. To ensure effective utilization of the stock assessment results in policymaking, the nodal agency, which is the National Aquatic Resources Research and Development Agency (NARA), publishes periodic reports, typically on an annual or half-yearly basis. Additionally, the dissemination process includes advisory meetings and consultations, fostering direct engagement between scientists, policymakers, and others.

3.4.4. Fisheries Management

Sri Lanka employs input controls include fishing capacity restrictions such as limitations on scuba divers and oxygen tanks brought onboard, as well as size restrictions on gillnets (less than 2.5 km). Vessel usage controls involve the prohibition of night fishing for scuba divers and the deregistration of selected fishing boats engaged in tuna fishing. Fishing effort is managed through area closures and temporal closures, particularly in fisheries like sea cucumber and lobster. Additionally, mechanised bottom trawling is strictly prohibited in Sri Lankan waters. Output controls involve quotas and catch limits, exemplified by catch limits on Yellowfin tuna, commercial minimum size limitations in lobster and blue swimming crab fisheries, and the prohibition of catching, processing, and transporting certain species, including five shark species and Cephalopholis sonnerati.

Moreover, evidence-based management measures have been implemented based on stock assessments. For instance, a 2020 stock assessment conducted by NARA focused on the sea cucumber fishery in Mullaitivu district. The assessment revealed indicators of resource depletion, such as the absence of high-valued species in the catch and longer travel distances for sea cucumber fishing. Using the depletion method, the initial stock size of Bohadschia vitiensis was estimated at 432,549 individuals, with over 90% of the stock depleted by the end of the season. Following NARA's recommendations, the fishing ground was entirely closed for sea cucumber fishing to allow for the recovery of the depleted resource.

The overall management of fisheries in the country involves uniform rules and regulations throughout the Exclusive Economic Zone (EEZ) for many species. Additionally, area-specific management is applied to certain fisheries, such as the Southern lobster fishery, while a few fisheries, like the sea cucumber fishery in the Mullaitivu district, have stock-specific management measures in place.

Table 1: Brief overview of stock assessment practices in South Asia

	Bangladesh	India	Maldives	Sri Lanka
Nodal Agency for Estimation of Marine Fish Landings	Department of Fisheries, Bangladesh	FSI through state fisheries departments of each maritime state ICAR-Central Marine Fisheries Research Institute	Ministry of Fisheries, Marine Resources and Agriculture	Ministry of Fisheries
Nodal Agency for Stock Assessment	Marine Fisheries Survey Management Unit, Department of Fisheries, Bangladesh	ICAR-Central Marine Fisheries Research Institute Fishery Survey of India	Maldives Marine Research Institute	National Aquatic Resources Research and Development Agency (NARA)
Other Agencies for stock assessment	Bangladesh Fisheries Research Institute	ICAR-Central Marine Fisheries Research Institute	-	Pelagikos Pvt Ltd
Fishery Units for Stock Assessment	Two	Six	One	Seven
Marine Fishing potential	9.83 Lakh tonnes	5.31 million Metric Tonnes	-	2.50 Lakh tonnes
Frequency of Stock assessment	Every 3 years	According to stock assessment calendar	-	Annually
Process of Estimation of Marine Fish Landings	Log Book record keeping for Industrial Fisheries Land-based data collection for Artisanal Fisheries	Multi-Stage Stratified Random Sampling	-	Data collection from Field enumerators
Model used for Single Species Stock Assessment	JABBA, fishblicc	Length-based analytical models Length Based Indicators (LBI) Length Based Spawning Potential Ratio (LBSPR) CMSY/BSM approach Stock Status Plots Surplus production model-based approaches Environmental Performance Index	fishblicc	Surplus production model LB SPR Leslie DeLury depletion method
The model used for Multi-Species Stock Assessment	-	Multispecies virtual population analysis Multispecies Biomass Dynamic Model Multispecies Biomass Dynamic Model Size spectrum model Ecopath with Ecosim Models Model for Intermediate Complexity Ecosystem (MICE)		Ecopath with Ecosim
Reference Point used to assess the state of the fishery	B/BMSY, F/FMSY & SPR	B/BMSY, F/FMSY & SPR/ F-Ratio	SPR	B/BMSY, F/FMSY & SPR

4. Gaps and Challenges in Conducting Stock Assessments

4.1. Impediments in Implementing Stock Assessment Results

The assessment of fisheries stocks and the subsequent implementation of management measures are crucial components of sustainable marine resource management. Examining the responses from BOB-SAN experts from Bangladesh, India, Maldives, and Sri Lanka on the major reasons for the potential failure to implement stock assessment results reveals common challenges across these South Asian nations (Fig. 8). In all cases, there is a unanimous acknowledgement (rating of 5) that incomplete assessments or a lack of a comprehensive understanding of the status of fish stocks hinder effective implementation. Additionally, conflicting priorities between managers and policymakers, as well as a lack of monitoring and implementation mechanisms, are identified as significant barriers to successful execution in each country. Economic considerations, particularly the challenge of aligning economic interests with conservation goals, are recognised as a hindrance to implementation in Bangladesh and India.

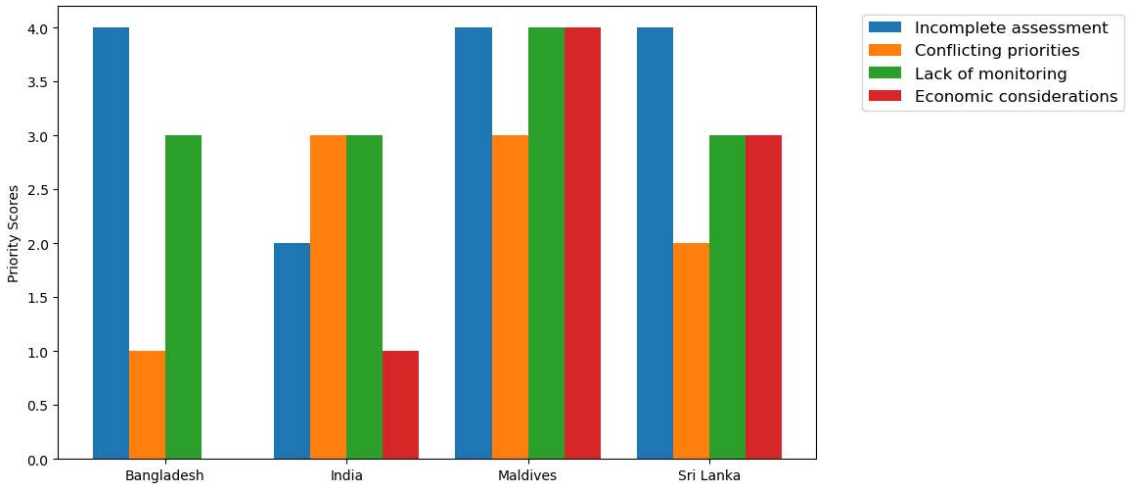


Figure 8: Constraints faced by South Asian Countries

4.2. Challenges Faced in Fish Stock Assessment

Across Bangladesh, India, Maldives, and Sri Lanka, a comparative analysis of input provided by BOB-SAN experts on the specific challenges faced during stock assessment reveals both shared concerns and unique nuances. In most of the countries, lack of manpower poses a significant challenge in conducting stock assessment (Fig. 9). This underscores a regional issue in terms of human resources dedicated to fisheries management and highlights the need for strategic investments in building capacity. Inadequate data availability is another universally recognized hurdle, emphasizing the necessity for improved data collection and management infrastructure across South Asian nations.

While all four countries express agreement on challenges related to manpower and data, variations emerge in the degree of consensus regarding other issues. For instance, robust data collection mechanisms receive varied ratings, suggesting differences in the effectiveness of existing systems or the prioritisation of this aspect in each country. Similarly, limited funding is recognised as a substantial challenge in Bangladesh and Maldives, underscoring the financial constraints that may impede comprehensive stock assessments. The lack of standardised methodology is identified as a challenge in Bangladesh and Sri Lanka, highlighting the importance of establishing uniform protocols to ensure consistency and comparability in assessment processes. Furthermore, delays in assessment and communication issues with policymakers are acknowledged as challenges in all countries, emphasising the critical need for timely and transparent information flow within the fisheries management framework.

4.3. Priority Areas in Fish Stock Assessment / Management

The assessment of priority areas for future stock assessment and fishery management efforts across Bangladesh, India, Maldives, and Sri Lanka reveals striking similarities in the perceived importance of key aspects. Real-time data collection mechanisms, incorporating ecosystem-based approaches, and considering climate change in stock assessments are universally recognised as extremely important, with all countries rating these aspects with a scale of 5 (Fig.10). This consensus underscores a shared recognition of the significance of adaptive and holistic approaches in fisheries management.

Another common priority area among the countries is the emphasis on precautionary measures, long-term monitoring and evaluation, and the implementation of a quota system, all of which receive high-importance ratings across the board.

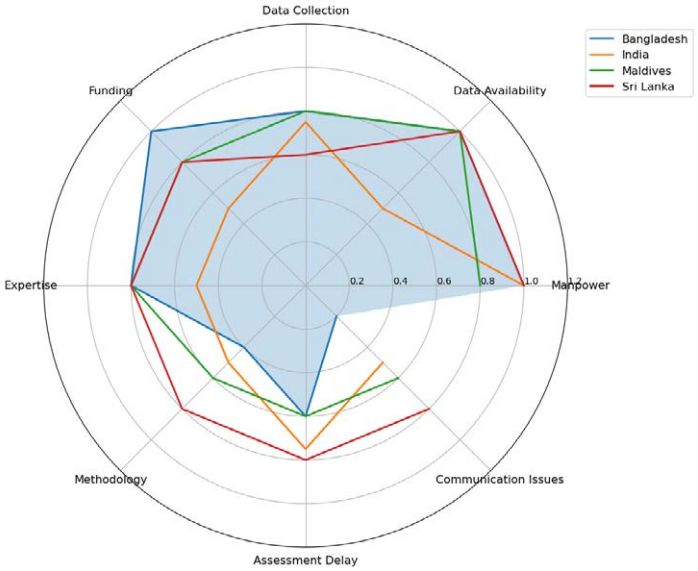


Figure 9: Challenges faced in Fish stock assessment

The recognition of the need for sustainable practices, coupled with effective monitoring and precautionary approaches, reflects a shared commitment to preserving and managing marine resources responsibly. Additionally, aspects such as eco-labelling/certification of fish stocks, improved capacity building, and international cooperation are deemed crucial, indicating a collective understanding of the importance of global collaboration and responsible practices in the fisheries sector.

While the overall priorities are consistent, subtle variations exist in the emphasis placed on specific areas. For instance, Bangladesh highlights the importance of improved capacity building, possibly indicating a specific need for skill enhancement in the local context. In contrast, Maldives places a particularly strong emphasis on implementing a quota system, reflecting a specific focus on regulated harvesting. These variations may stem from unique challenges or priorities within each country's fisheries sector. Overall, the alignment in priority areas suggests potential for collaborative efforts and knowledge-sharing among these South Asian nations to strengthen their collective approach towards sustainable fishery management.

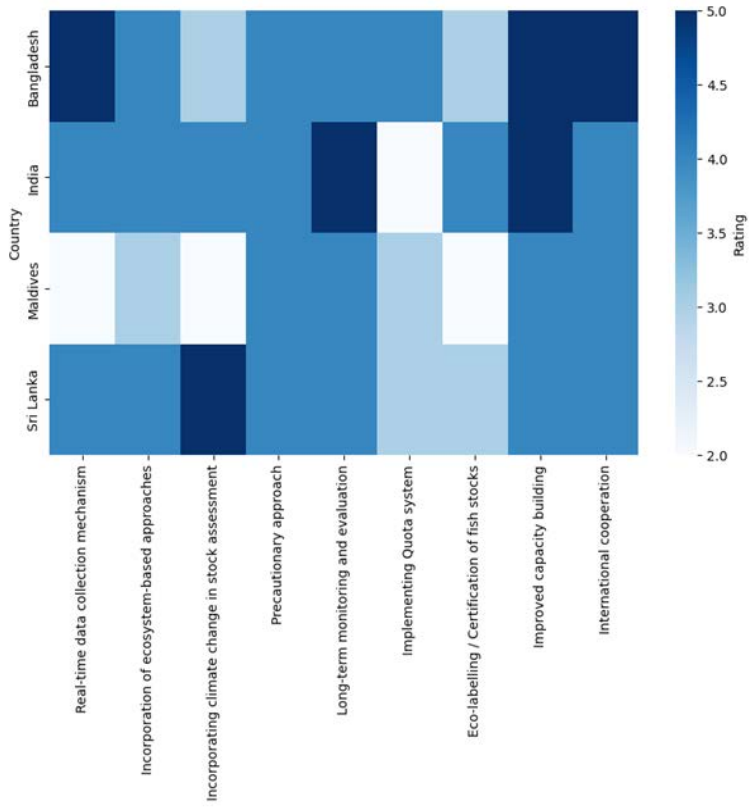


Figure 10: Priority Areas in Fish stock assessment

5. Good Practices for Stock assessment in South Asia

5.1. Data collection and Methodology

In many countries around the globe, use of logbooks by the fishers has emerged as a crucial aspect in the context of fisheries data collection, analysis and management. This practice involves the systematic recording of essential information, including precise details about fishing locations, types of gear employed, composition of the catch, amount of discard, and biological data of fish species caught etc. Encouraging use of logbooks, South Asian countries can establish a robust foundation for accurate data, stock assessments and well-informed decision-making in fisheries management. The adoption of logbooks enables comprehensive documentation that proves invaluable in understanding the dynamics of marine resources. Electronic logbooks, or e-logs, are like digital versions of traditional paper logbooks used in fisheries. Instead of recording fishing activities on paper, fishermen use computer programs or software on fishing vessels to enter and submit daily logs electronically. This modern approach streamlines the data collection process, making it more efficient and reducing the chances of errors. In South Asia, adopting electronic logbooks can be a game-changer for fisheries management.

India has a well-established data collection and estimation system for generating information on species-wise and fishing gear-wise marine fishery resources landings and fishing effort for different maritime states every month using skilled observers in fish landing ports. The method was developed by ICAR-Central Marine Fisheries Research Institute jointly with ICAR-Indian Agricultural Statistics Research Institute following a scientific sampling scheme named “Stratified Multistage Random Sampling Design (SMRSD)” (Sukhatme et al., 1958; Srinath et al., 2005), where stratification is done over space and time. This system of data collection and estimation has been in use since 1960. The sampling frame was created by gathering information on marine fishing villages, landing centres, crafts, and gears, among other things, and it is updated on a regular basis to reflect changes in the sector through all India frame surveys. Species-wise catch, fishing effort, details of fishing crafts and gears and other related information are collected through this sampling scheme.

Central Marine Fisheries Research Institute took the lead in developing an online system for the collection and retrieval of data on the marine fish landings and other related parameters named Fish Catch Survey and Analysis (FCSA) and the system is operational since 2018. FCSA was proved to be an excellent system for the data collection and estimation of marine fishery resources. The changes that were brought by the introduction of the new system were huge in comparison to the traditional paper-based system, which was less efficient in terms of cost-effectiveness, manpower requirement, difficulty in manual scrutiny, the time requirement for data processing, more chances of errors, etc. It facilitates the fetching of the monthly work programmes for each of the field staff (harbour-based observers), which are configured in the server maintained at headquarters and permits the observers to store the information in the data recording devices (tablets).

A noteworthy suggestion for improvement involves integrating the electronic logbook (e-log) mechanism with the existing multi-stage stratified random sampling method. By combining these two approaches and devising a methodology for the combined estimation of landings, India and other South Asian countries can significantly enhance their data collection practices. The e-logbook system, with its digital efficiency, can complement the traditional multi-stage stratified random

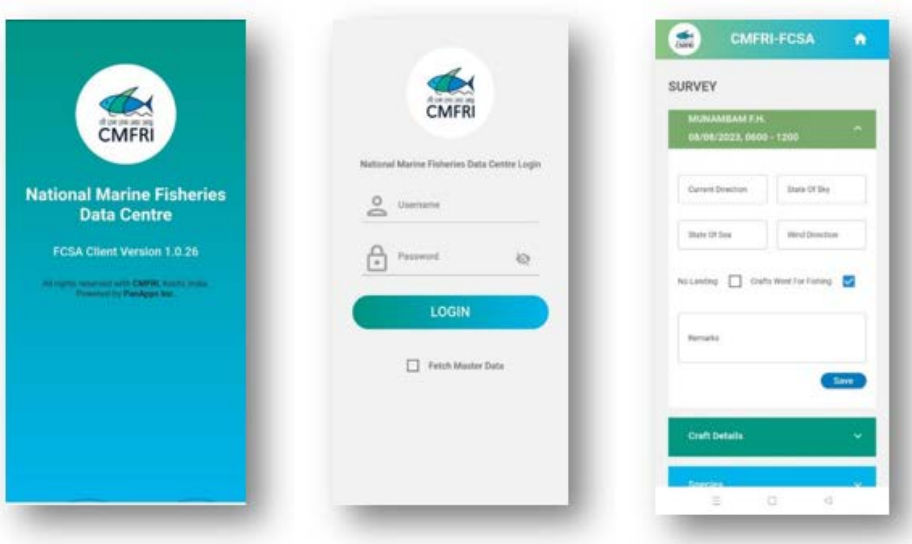


Figure 11: Fish Catch Survey and Analysis (FCSA) Software

sampling method. Fishermen using e-logs can efficiently record real-time information about fishing activities, providing accurate data.

Fishery management can benefit greatly from the use of geographic information system tools for habitat mapping, georeferencing fish catch and fishing effort data, and linking catch to oceanographic and biogeochemical parameters. As exploratory fishery resource surveys are time-consuming and expensive, landing centre-based surveys are frequently used in India to estimate the marine fishery resources. But it is challenging to map the habitat of the resources in such surveys as the resources seen at the landing centre are not geo-tagged. Passive georeferencing refers to the process of determining the geographical location of an object or entity using external information without actively transmitting any signals and is useful in situations where active transmission may not be desirable or feasible, and it allows for effective tracking and positioning without relying on active participation from the object being located. In India, the landings records have information about bearing and the distance covered by the craft surveyed which can aid in finding the destination coordinates based on the start point coordinates, which will end up in zeroing in on probable latitude and longitude of the fishing grounds.(Varghese et al., 2023). This can further help to arrive at the resource abundance on a spatially gridded scale. Further, Sri Lanka successfully implementated VMS for monitoring 4200 multi-day fishing vessels (MFV).

5.2. Consideration of Spatial Structure in Stock Assessment

Effectively addressing spatial and stock structure is crucial in conducting a comprehensive stock assessment. Fish populations typically exhibit spatial structure, leading to variations in demographic parameters and fishing mortality (Berger et al., 2017; Cadrin et al., 2020). Misidentifying stocks can result in biased estimates of management-related quantities, posing challenges in achieving management goals. To identify stocks, valuable information can be obtained by leveraging age/length-frequency data from common gear types and tagging information. These data help pinpoint areas with spatial variations in population structure or biological characteristics. Establishing ecological boundaries among spatial areas is preferable.

However, in cases of a single panmictic population, boundaries based on management jurisdictions (e.g., state/province boundaries) may be the only feasible option due to data limitations. Methodology for incorporating spatial structure into fisheries management programs can be implemented, as shown in Figure 12. This approach can be justified, as these jurisdictional boundaries often dictate the implementation of management regulations (Punt et al., 2023).

It is crucial to define clear units for “population” and “subpopulation,” taking into account factors such as movement, dispersal, and demographic linkages. In a multi-species, multi-fleet fishery, many fish populations span multiple jurisdictions. A collaborative approach among countries can offer a more comprehensive understanding of the stock structure of commercially important species in the region. For instance, in the case of a shared stock between two countries like India and Bangladesh, employing spatial data along with a consistent stock assessment methodology can yield clear insights into the status of the stocks. This collaborative effort enhances the accuracy and reliability of stock assessments for effective fisheries management.

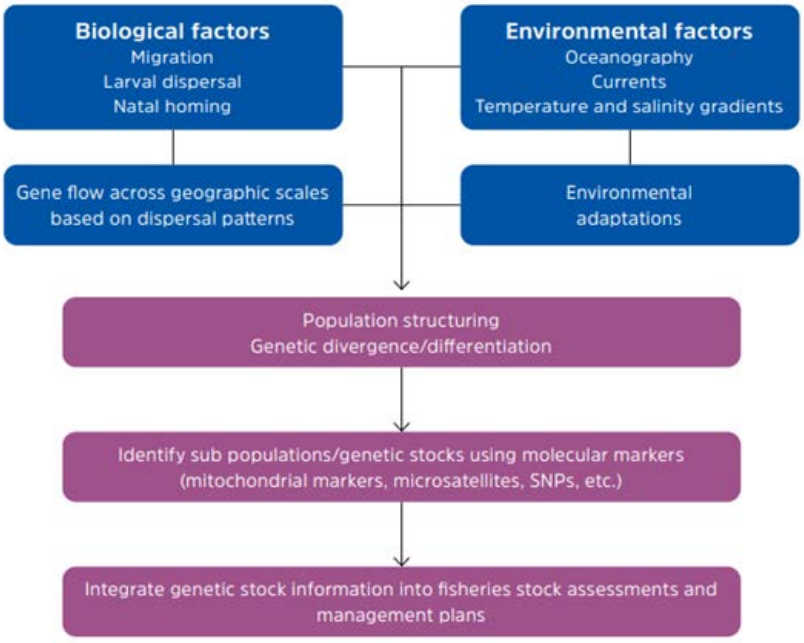


Figure 12. Concept of incorporating Genetic stock structure in Fisheries Management (Source: CMFRI)

5.3. Selection of Stock Assessment Model

The availability and quality of fisheries data in South Asian countries play a crucial role in shaping the selection of appropriate stock assessment models. In order to conduct effective assessments, it is imperative to have sufficient data on catch, effort, and biological parameters. Countries equipped with comprehensive datasets may opt for sophisticated models (Stock Synthesis, CASAL, MULTIFAN-CL) that offer detailed insights into the dynamics of fish stocks. Conversely, nations facing data limitations should consider simpler, data-efficient approaches to ensure practical applicability. Striking a balance between model complexity and available data is paramount for South Asian countries. While complex models can provide in-depth insights, they demand more extensive data and resources.

Among the widely employed models are Biomass Dynamic Models, which estimate changes in fish biomass over time using catch and effort / survey indices of abundance. In data-limited situations, length-based models prove invaluable, considering size composition data (FAO, 2023). Software tools like Fishblicc and size-based catch curve models can be applied to estimate growth, mortality, and recruitment. A relatively recent approach for analyzing length-based data is the Length-Based Spawning Potential Ratio (LBSPR). This method calculates the Spawning Potential Ratio (SPR) by using the length composition data of a harvested stock (Prince et al., 2015). Additionally, Bayesian approaches offer a flexible framework that incorporates uncertainties and facilitates the updating of models with new information.

To accurately depict trends in stock abundance, it is often essential to standardize effort and Catch Per Unit Effort (CPUE). This process should account for advancements in fishing gear technology and other alterations in fishing practices. For multi-species fisheries, considering interspecific interactions within the assemblage, aggregate-species models often outperform models that focus on higher taxonomic resolutions. Aggregate production models provide one potentially effective approach to coping with the issues that emerge with increasing model complexity. Ecopath with Ecosim can be also be used for multi-species modelling than other techniques.

5.4. Incorporating Stock Assessment result into Management

- *Transparent Communication:* Clear and transparent communication is very important when conveying stock assessment results to diverse stakeholders including policymakers, fishers, scientists, and public. Use of local language and incorporating visual aids (Dashboards) are essential strategies to enhance the understanding of assessment findings. By adopting a transparent approach, countries can ensure that all stakeholders are well-informed, fostering trust and cooperation in the management of fisheries resources.
- *Stakeholder Engagement:* Engaging with all relevant parties is crucial for successfully managing fisheries with the use of citizen science approach. It involves actively involving fishing communities, industry representatives, and environmental organizations in the stock assessment process. Seeking input from stakeholders during the development of management plans is crucial for obtaining a more comprehensive understanding of the local context. This inclusive approach not only improves the decision-making process but also increases the likelihood of successful implementation of management measures by considering diverse perspectives and interests.
- *Adaptive Management:* To effectively deal with the ever-changing conditions of marine ecosystems and fisheries, it's crucial to use an adaptive management framework. This approach enables timely adjustments to management strategies based on new information from ongoing stock assessments or shifts in the ecosystem. Shifting towards adaptability ensures that management strategies remain effective and responsive to evolving conditions, ultimately promoting the long-term sustainability of fisheries resources.
- *Flexible Management Measures:* Recognizing the inherent uncertainties in stock assessments and the variability of environmental conditions, it is essential to implement flexible management measures. These measures should be designed to be adjustable based on the results of ongoing stock assessments and changing environmental circumstances. This flexibility enables a responsive and proactive approach to fisheries management, ensuring that interventions are well-suited to the current state of the ecosystem and the specific needs of stakeholders.

6. CMFRI Methodology for Estimation of Marine Fish Landings: Lessons for the Region

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Background

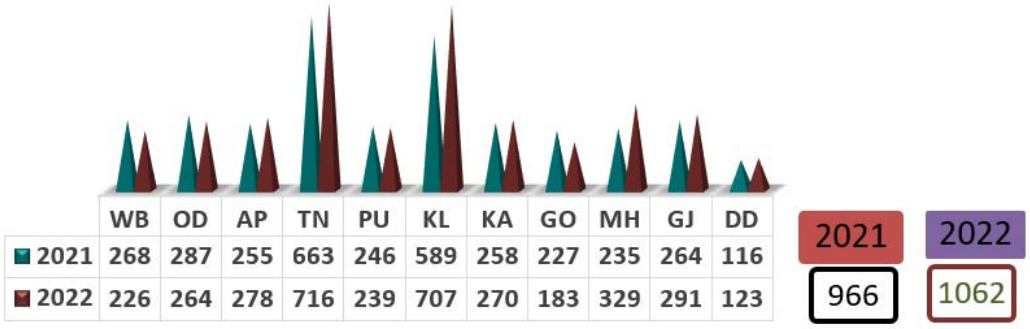
The fisheries sector and its scientific underpinnings have the unique distinction of being the most promising in terms of opportunities and livelihoods as well as the most fertile for those pursuing research towards achieving any welfare goal in most of the coastal nations. In South Asia, this sector has witnessed an intense race between potential, development and adoption of innovation to tap the same. The fishing potentials have been regularly facing contour shifts and the methods adopted for fishing complement with major "gear shifts". Though the marine and inland domains have been seemingly separated in most of these countries, they often have their threshold manned by common factors like market and resource dynamics. With the reinvigorated thrust on culture activities, both aquaculture and mariculture, spilling through the last few decades straddling the two centuries, the set of technologies which were once conceived as a supplement to the fish production of coastal countries have brought the various aquaculture and mariculture propelled blue economy to the fore.

The Indian marine fisheries sector supports the livelihood of a significant portion of the population in different ways. It is one such hybrid type of sectors wherein subsistence and commercial, bordering industrial scale, exploit the common shared resources of Indian territorial waters and EEZ. With diversity at the operator level itself being a major driver the State has drawn up mechanisms to register various categories of vessels and issue licenses periodically apart from enforcing regulations that deem fit. Indian waters also have protected areas and a couple of bioreserves apart from terrain-limited vessel limitations. There are overarching regulations leading to the cessation of fishing activities during selected periods to ease the pressure off the spawners of critical marine fishery resources. Needless to add, these kinds of management measures have been borne out of an informed regime that supervises the entire gamut of activities falling under the marine sector. Thus data on the quantity of fish harvested each year and the effort expended by various gears is critical for developing management plans for the sustainable exploitation of marine fisheries resources. Tropical fisheries are characterised by great diversity and multiplicity of gear, many of which are not so selective in their targets and mode of operation and collect a variety of species in a single haul (CMFRI-Kochi and BOBP-IGO, 2017). This makes the systematic collection of generically verified data on three major dimensions viz spatial, temporal and fishery level all the more crucial. While the practical solution for such a sampling methodology may be quite challenging, the basic tenets that could lead to information on the vital inputs to managerial and assessment perspectives are inevitable. Hence India has been one of the pioneering countries in this part of the globe which took this task at the right earnest some six decades ago and has created a strong foundation for any such data assimilation with so much inbuilt heterogeneity armed with robust ingenuity.

Having a quantitative measure of the scale and contrast of the fisheries that are being pursued in a stretch starting in the near temperate northern part of the peninsular region to the tropical southern tip, is a precursor to all that one needs to appreciate the enormity and charm of the challenge thrown up by this sector. Currently, 42,985 mechanised, 97,659 motorised, and 25,689 non-mechanized fishing vessels operate in India, with catches being landed in 1269 landing centres, including fishing harbours (CMFRI-FSI-DoF, 2020). Trawlers, gillnetters, liners, purse seines, ring seines, and dolnets are the most common types of fishing craft-gear combinations in the mechanized sector. In the fishery, more than 30 boat and gear combinations (fleets) are used. The liners and about 45% of the trawlers make multi-day voyage fishing of 40 to 60 trips of varying duration per annum and all other mechanized fishing crafts make around 240 single-day trips per annum. The motorized and non-mechanized fishing crafts undertake up to 300 single-day trips per annum. In a year, fishing vessels make almost 44.7 million trips and land catches at 1269 landing centres. (Sathianandan et al., 2021). As a result, comprehensive enumeration and recording of catch data would necessitate a large number of people, limiting its feasibility. Due to the wide diversity of the species, using log sheets for capturing data collection is wrought with challenges, especially by multi-day trawlers. To ensure the easy and comprehensive transcendence between commercial exploitation and an indicator of biomass dynamics, a scientific sampling plan is the most viable fishery data-gathering approach in tropical nations with a high diversity of marine fishery resources. Although there are apparent seemingly advantageous alternatives like onboard observation and mandatory reporting for multiple reasons, the best option next to experimental fishing would always be an unbiased recording of data by skilled hands as per a solid survey methodology founded on a sound sampling design that suits the challenges of the field and is diachrony enshrined in its formulation.
The diachronic self continually evolving methodology is even more crucial as the diversity of the fishery along the

Indian coast as reflected in the number of species documented in the fished taxa in recent years (FRAD-CMFRI, 2021; FRAD-CMFRI, 2022), is quite significant (Figure 13). Additionally, the variety of gears in operation, as observed even on the southwest coast of India (Varghese et al., 2021), serves as an indicator of the intricate nature of the fishery. The combination of high species diversity and the utilization of multiple types of fishing gear contributes to the complexity of fisheries management in tropical countries like India.

Figure 13. Species distribution in landings along the coastal states



(Adapted from Varghese et al., 2021; WB: West Bengal; OD: Odisha; AP: Andhra Pradesh; TN: Tamil Nadu; PU: Puducherry; KL: Kerala; KA: Karnataka; GO: Goa; MH: Maharashtra; GJ: Gujrat; DD: Daman& Diu)

Methodology for Marine Fishery Data Assimilation and Estimation

As outlined earlier India has a well-established data collection and estimation system for generating information on species-wise and fishing gear-wise marine fishery resource landings and fishing efforts for different maritime states every month using skilled observers in fish landing ports. The method was developed by ICAR-Central Marine Fisheries Research Institute (CMFRI) jointly with ICAR-Indian Agricultural Statistics Research Institute (IASRI) following a scientific sampling scheme named "Stratified Multistage Random Sampling Design (SMRSD)" (Sukhatme et al., 1958; Srinath et al., 2005), where stratification is done over space and time. This system of data collection and estimation has been in vogue since 1960. The sampling frame was created by gathering information on marine fishing villages, landing centres, crafts, and gears, among other things, and it is updated regularly to reflect changes in the sector through all India frame surveys. Species-wise catch, fishing effort, details of fishing crafts and gears and other related information are collected through this sampling scheme. This sampling design has been successfully performing while evolving ever since and has been accredited by international institutions like FAO.

The population that is being attempted to be assessed through the samples is two-dimensional and is zone-month in this case. The zones are sub-civic spatially contiguous divisions that may be equated to districts within the administrative provinces, and states, in India. The parameters like total catch, effort and catch rates of these zone-month populations are estimated through a two-stage sampling procedure, with the first one having strata and pseudo-strata of time intervals within a month. The sampling units are accordingly the fishing vessel or unit selected at the second level after the selection of a landing centre/ fishing harbour on a particular day referred to as landing centre day (lcd) of the zone- month.

In spatial stratification, based on the fishing intensity, geographical boundaries and number of landing centres, each maritime state is divided into suitable non-overlapping regions called fishing zones. These zones have been further stratified into substrata, depending on the intensity of fishing. The number of centres may vary from zone to zone (Figure 14).

The landing centres are classified into High-Intensity Landing Centres (number of vessels in operation 300 or more), Major Landings Centres (number of vessels in operation between 100-299) and Minor Landing Centres (number of vessels in operation less than 100). The sampling coverage is more for High-Intensity Landing Centres than that for Major Landings Centres and it is still less for Minor Landing Centres. Among the fish landing centres, the major fisheries harbours/centres are classified as single-centre zones for which there is exclusive and extensive coverage.

The temporal stratification (Figure 15) is more conventional than statistical, wherein the landing centre days to represent the population are spread evenly throughout the month, which is a major component defining the population. This gives enough support to take into account all the periodic oscillations noticed in resource availability within a month.

To have a better understanding of this procedure the following sample situation can be considered. Suppose there are 10 landing centres in a zone, there will be 300 landing centre days (10 centres x 30 days) in a month. A month is divided

Figure 14. Spatial stratification

Figure 15. Temporal stratification

into three groups, each with ten days. A day is selected at random from the first five days of a month, and the next five consecutive days are chosen automatically and form cluster groups of two consecutive days. In the remaining ten-day groups, the clusters are systematically selected with an interval of ten days. Normally, in a month, there will be nine clusters of two days each. Among the total number of landing centres in the given zone, nine centres are selected with replacement and allotted to the nine cluster days described earlier. Thus, nine landing centre days are observed in a month. The observations are made as per Table 2.

Table 2. Data collection during a landing centre day

24 hrs landings (One landing centre day)	Data collection method
1200 hrs to 1800 hrs of 1st day	By observation on the first day
0600 hrs to 1200 hrs of 2nd day	By observation on the second day
1800 hrs of the 1st day to 0600 hrs of the 2nd day (night landing)	By enquiry on the second day

During an observation period, when the number of boats/craft landings is high, it may not be practically possible to record the catches of all boats landed. With randomness enshrined within the sampling strategy at each level, the solution to this is obtained by having a random start followed by systematic selection. Hence, the following procedure given in Table 3 is adopted (Alagaraja, 1984):

Table 3. Number of boats/crafts to be observed

Number of boats/crafts landed	Fraction to be observed
≤ 15	100 %
Between 16 and 19	The first 10 and 50 % of the remaining
Between 20 and 29	1 in 2
Between 30 and 39	1 in 3 etc.

In the case of single centre zones, sixteen to eighteen days are selected randomly in a month and the units (fleets) landed on a selected day (either as a cluster of 2 days or a single day itself) are enumerated.

In the data collection system, dedicated technicians (harbour-based observers) with species identification skills visit the landing centres according to work schedules generated under SMRSD and record different aspects of the fishery from sampled boats. These observers are being provided with regular taxonomic training with support from scientific staff in the other resource divisions of ICAR-CMFRI to enhance their species identification skills in the field.

Based on observed landings and fishing efforts, an estimate of fish landings and fishing effort for all fleets for a landing centre in a day is made. Monthly zonal landings are estimated using these data. Furthermore, estimates at the District, State, and National levels are obtained on a Monthly, Quarterly, and Yearly time scale. Detailed estimation methodology is provided in (Srinath et al., 2005).

The unique traits of this methodology are summarised in the infographics presented in Figure 16. The best part of the whole design is its statistical rigour coupled with ease of adoption. Added to these is the dynamic nature of this methodology, which paves the way for self-evolution.

- The core method is advocating sampling at two strategic stages viz. landing centre -day (first stage) and vessels (second stage). The same can be easily extended to more stages depending upon the ground exigencies.
- The coverage and sampling variances are quite straight forward to calculate at each stage and in combination.
- The fisheries defining gears or resources, or both can be seamlessly introducing at the population level. If the zones have clear-cut demarcations based on unique fisheries, they can be taken as the base while defining the population alongside spatial and temporal blocking and this plan can be executed.
- The major benefit of this sampling plan is the inherent provisions for creating additional strata within zones depending upon sudden palpable enhanced fishery returns during specific season and also to drop the landing centres out, wherein due to seasonality the activities have ceased. The constituent units of strata can be re-stratified, updated and dropped at any stage of the sampling exercise.
- Unexpected spikes in landings for a short duration or even for a particular kind of craft-gear combination in a given zone can still be estimated in isolation. The basic randomness at first and second stages ensure their additivity to the figures estimated through other landing centre days.
- The methodology is also capable of yielding basic statistics like average yield per vessel or daily average catch rate or even resource-wise means at the finest granularity with aggregation possible at each higher level.
- This methodology offers flexibility to include all kinds of craft-gear combinations and all possible innovations that uniquely define fisheries as they exist on a given day and thus had proven to be conceptually robust.

Figure 16. Methodological flexibility of CMFRI sampling design

Data Collection in the New Regime

With the introduction of computers and information technologies, the access and dissemination of information have become easier. Central Marine Fisheries Research Institute took the lead in developing an online system for the collection and retrieval of data on marine fish landings and other related parameters named Fish Catch Survey and Analysis (FCSA) and the system has been operational since 2018 (Figure 17 and 18). FCSA proved to be an excellent system for the data collection and estimation of marine fishery resources (Mini et al., 2023). The changes that were brought by the introduction of the new system were huge in comparison to the traditional paper-based system, which was less efficient in terms of cost-effectiveness, manpower requirement, difficulty in manual scrutiny, the time requirement for data processing, more chances of errors, etc. It facilitates the fetching of the monthly work programmes for each of the field staff (harbour-based observers), which are configured in the server maintained at headquarters and permits the observers to store the information in the data recording devices (tablets). Once the data entry is completed in the designed format, it can be synchronised with the server. Therefore, data collection through the system can be done even in remote areas where network connectivity is poor, and the stored information can be sent to the server when the network connection is restored. This, in a way, enhances the efficiency of the data collection and estimation mechanism in terms of coverage, accuracy and resolution.

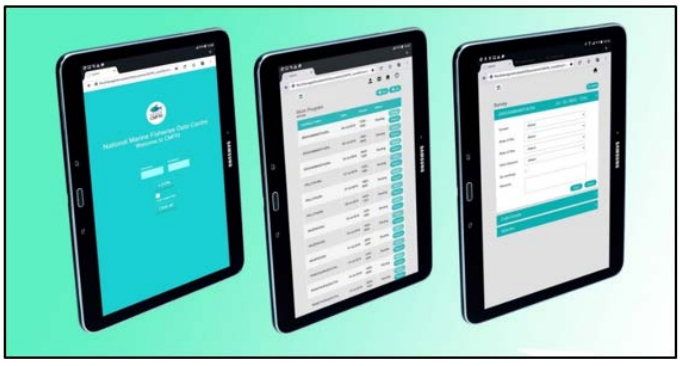


Figure 17. Fish Catch Survey & Analysis (FCSA) Software

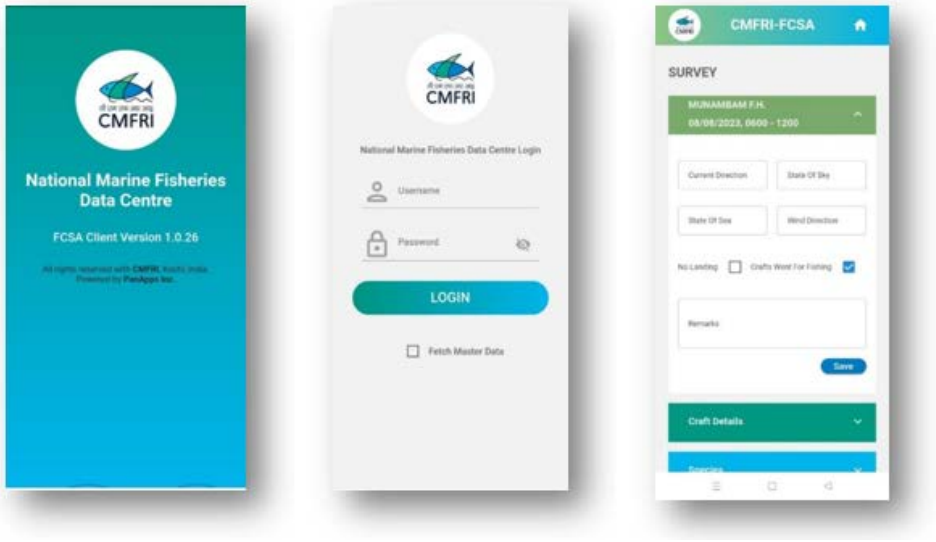


Figure 18. FCSA: Some snapshots

National Marine Fishery Resources Data Centre (NMFDC)

The information on the landings of marine fish by numerous fishing crafts that take place at various landing centres situated along the coastline of the mainland in India in all seasons during day and night so generated is processed at the server battery located at the Central office with sufficient redundancy ensured and stored in the National Marine Fishery Resources Data Centre (NMFDC) of ICAR-CMFRI which holds historic Indian marine fishery data at different granulations. This database is unique on two counts, the first being its long period starting from the 1960s and it is based on a core consistent self-evolving sampling methodology that has been catering to high-quality research activities like quantitative assessment of the stock status of marine fishery resources, that have been economically important and formed fishery, at various stages of the past six decades (Srinath and Jayasankar, 2007).

Information at the spatial level

The database consists of the estimated landings from the entire coast of the mainland (excluding Lakshadweep; but Andaman & Nicobar Islands were recently added to this list from November 2022 onwards), which is divided into four regions viz., North-East, South-East, South-West and North-West consisting of nine coastal states viz., West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat and two union territories viz., Puducherry and Daman & Diu apart from the east island extension of South-East of the Union Territory of Andaman and Nicobar Islands.

Sector-wise landings

The fishery is divided into three sectors, namely, Mechanized, Motorized and Non-motorized. There are more than 30 craft-gear combinations. Some of the major gears are Mechanized Trawlnets, Mechanized Gillnets, Mechanized Hooks & lines, etc., under the mechanized sector and Outboard Gillnets, Outboard Ring seines, Outboard Hooks & lines under the motorized sector. Besides, several gears are being operated in the non-motorized sector/ artisanal sector.

Species taxonomic resolution

Based on the assemblage, the species recorded have been divided into four groups: pelagic, demersal, crustacean, and molluscs. The digital repository consists of information available at various scales that were reflective of the eras that defined extant fishery, viz., 1950-1968: all species aggregated into 15 groups; 1969-1981: all species aggregated into 43 groups; 1982-1985: all species aggregated into 63 groups; 1985-2006: all species aggregated into 83 groups and from 2007 onwards, individual species level landings are available. These data form the basis for the regular marine fish stock assessments for promoting the sustainable use of marine resources, balancing economic interests with ecological conservation, and supporting the long-term health of marine ecosystems.

Marine fish landing trends and fish stock assessment have been inseparable with the advent of the information-based study of fisheries be it arriving at management options or status appraisal. These two areas form the core of two overlapping processes. However, due to simplicity and ease of handling, landing or catch trends of various marine resources have hogged the limelight as compared to the more intrinsically relationship-woven stock assessment research. Although the approaches to quantitative fish stock assessment could vary from bivariate studies like surplus production models to life history incorporated assessments like stock synthesis, the inference had always been straightforward, pointing out whether the stock is overfished or optimally exploited.

Conclusion and the Way Forward

NMFDC is built on a sturdy, redundant and scalable platform powered by one of the best-of-the-class processors and database solutions available at the time of its inception. The snapshot of the hardware and application specifications is given in the following Figure 19.

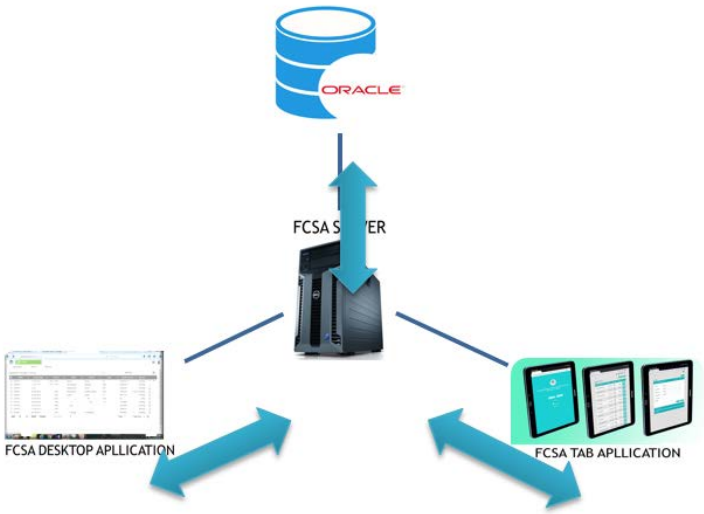


Figure 19. Conceptual FCSA architecture

Added to this data server is a High-Performance Cluster, Facility for integrated modelling, Simulation and High-end analytics (FISH@ICAR-CMFRI), which has been installed for any kind of high-end analytics emerging out of the data stored. A brief infographic on FISH@ICAR-CMFRI is given in Figure 20.

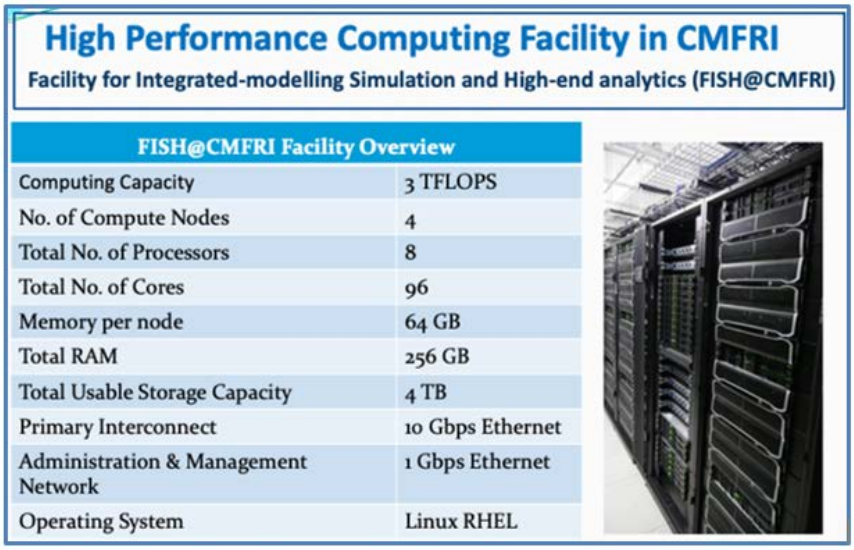


Figure 20. HPC facility integrated with ICAR-CMFRI database

It would be interesting to record here that the simplest possible time series data of fish catch and effort can be analysed and inferred in a whole lot of generic methods, ranging from fitting production functions to Bayesian procedures with the incorporation of prior information and also multiple stochastic simulations based exercises to GIS-based spatiotemporal analyses using Generalized Additive Model (GAM) approach. The basic trigger would be a plain query made to the data server and the HPC gives ways and means for uncompromised and unrestrained exploratory and confirmatory investigations.

The power of seamless integration of this NMFDC-FISH@CMFRI HPC model has been a success story worth taking note of. Especially with the demand for heuristic as well as conformational analytics being the order of the day, such integrations will always serve the State well. If only we could expand this operational paradigm both vertically and horizontally, the blue economy-related queries would get near real-time studied answers. The stock assessment models, both of classical mould as well as the more holistic integration of dynamic factors of various ilk getting amalgamated using computationally rigorous algorithms are almost automatically coupled with these kinds of databases that the management strategies evolve and get evaluated instantaneously. Such horizontal scalability, which may include databases ranging from marine resource genetic records to traceability tagged value addition of products can be powerfully portrayed in one frame using a dashboard.

The utilization of geographic information system tools can significantly enhance fishery management by facilitating habitat mapping, georeferencing fish catch and fishing effort data, and establishing connections between catch and oceanographic and biochemical parameters. As exploratory fishery resource surveys are time-consuming and expensive, landing centre-based surveys are frequently used in India to estimate marine fishery resources. However, it is challenging to map the habitat of the resources in such surveys as the resources seen at the landing centre are not geo-tagged. “Passive georeferencing” refers to the process of determining the geographical location of an object or entity using external information without actively transmitting any signals and is useful in situations where active transmission may not be desirable or feasible, and it allows for effective tracking and positioning without relying on active participation from the object being located. In India, the landings records have information about bearing and the distance covered by the craft surveyed which can aid in finding the destination coordinates given distance and bearing from start point coordinates, probable latitude and longitude of the fishing grounds can be obtained (Varghese et al., 2023). This can further help to arrive at the resource abundance on a spatially gridded scale.

The operation of a large number of boats in most landing centres and the diversity of the species make it difficult to gather information on all the resources in the entire boats landed in a particular landing centre. As of now, more than 120 trained field observers have been deployed all along the Indian coast (in 1269 landing centres) exclusively for this job to ensure a good coverage. But, limited manpower in all sectors also necessitated the use of some automated techniques to gather such information. It would always be helpful, time-saving and more accurate if such assessments could be made using some photographs taken using cameras mounted either on the boat or at the landing centres. Under this background, deep learning algorithms coupled with computer vision in marine resource identification could play an important role in future in extracting information about marine resources from images taken.

7. Way Forward

7.1. Shared Priorities and Contribution to Regional Fish Stock Assessment

In comparing the responses from Bangladesh, India, Maldives, and Sri Lanka regarding potential assistance from experts affiliated with BOB-SAN notable similarities and differences underscore a collective recognition of the need for collaborative efforts in stock assessment and fisheries management in the Bay of Bengal region.

All four countries emphasise the high importance of various aspects related to stock assessment and fisheries management. Specifically, there is alignment in seeking assistance from BOB-SAN experts in real-time data collection mechanisms, incorporating ecosystem-based approaches, and addressing climate change in stock assessments. This shared vision suggests a regional consensus on adopting advanced methodologies and considering environmental factors for effective fisheries management. Experts from Bangladesh, India, Maldives, and Sri Lanka collectively highlight their capacity in areas such as data collection for stock assessment, demarcation of boundaries, and the use of biological data.

Despite these commonalities, subtle variations exist in the priorities and perceived strengths of each country. Bangladesh places a high emphasis on the appropriate use of fish stock assessment models, indicating a specific interest in refining modelling techniques for accurate predictions. In contrast, Maldives prioritises the estimation of marine fishing potential and demarcation of boundaries, reflecting a focus on understanding the regional context and boundaries for sustainable resource management.

Table 4: Area for Regional Contribution

Area of Contribution	Bangladesh	India	Maldives	Sri Lanka
Estimation of marine fishing potential	High	High	Moderate	Low
Estimation of marine fish landings	Moderate	High	Low	Low
Data collection for fish stock assessment	High	High	High	High
Demarcation of boundaries for stock assessment	Moderate	High	Moderate	Low
Use of biological data in fish stock assessment	High	High	Moderate	Low
Appropriate use of fish stock assessment models	High	High	Low	Low
Reporting / Communication / Publications	High	High	Low	Moderate
Management decisions based on stock assessment results	High	High	Moderate	Low
Implementation and monitoring	High	High	Moderate	Low

Note: The levels of contribution are subjective ratings based on the perceived strengths and priorities of each country.

7.2. Advancing Fish Stock Assessment in the Bay of Bengal

7.2.1. Establishment of Working groups on different aspects of stock assessment

Acknowledging the multitude of stock assessment, the formation of specialised working groups within the framework of BOB-SAN is the need of hour. These dedicated groups will consist of experts, scientists, and practitioners possessing specialised knowledge spanning various facets, ranging from the intricacies of data collection mechanisms to the nuanced processes of analysis and the practical implementation of assessment results.

7.2.2. Harmonization of Data Collection Protocols & Mechanisms

Considering the transboundary nature of fish stocks, developing standardised data collection protocols is crucial to ensure consistency and comparability of fisheries data across South Asia. Additionally, facilitating training programs will enhance the capacity of fisheries personnel, enabling them to effectively implement these protocols and contribute to the generation of high-quality, reliable data. Modern technologies such as satellite monitoring and electronic reporting systems will enable real-time data collection. Establishing a regional platform for sharing this data fosters prompt and informed decision-making, enhancing the overall efficiency and effectiveness of fisheries management efforts.

7.2.3. Collaborative Stock Assessment Projects

Fostering joint research initiatives will deepen the understanding of regional dynamics, fish migrations, and ecological interactions in the Bay of Bengal. Cross-border research projects can be initiated which will contribute to a comprehensive understanding of the ecosystem.

7.2.4. Capacity Building and Training Programs

Prioritizing capacity building through regional training programs on advanced stock assessment methodologies is key to developing a skilled workforce. Establishing a collaborative network for scientists and researchers will facilitate the sharing of expertise and the building of a collective knowledge base, strengthening the region's capacity for sustainable fisheries management.

7.2.5. Development of a Regional Stock Assessment Model

Collaborating on the development of a comprehensive regional stock assessment model that considers the unique characteristics of the Bay of Bengal is crucial. Regularly updating the model based on new data and emerging research findings ensures its relevance and accuracy in guiding fisheries management decisions.

7.2.6. Implementation of a Regional Quota System

Collaboratively designing and implementing a regional quota system based on scientific assessments and conservation goals will contribute to responsible fisheries management. Sharing experiences and lessons learned among member countries will optimize the effectiveness of quota management, promoting sustainable fishery practices.

7.2.7. Transparency and Reporting Mechanisms

Establishing transparent reporting mechanisms for fish stock assessment results is vital to fostering open communication among member countries. Encouraging timely sharing of assessment outcomes will enhance transparency and collaboration, ultimately contributing to effective and collectively informed fisheries management.

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Annex I

AGENDA

Date: 17 August 2023 ***Time in IST: 10.00 - 1300 hrs***

10.00 - 10.10	**Setting the Context**	**Dr. P. Krishnan,** *Director, BOBP-IGO*
1010 - 1020	**BOBSAN: Emerging Opportunities**	**Dr. Rishi Sharma** *Senior Fisheries Officer, FAO, Rome*
1020 - 1040	**Remarks from the Member Countries** **Bangladesh** : **Dr. Ashraful Alam,** *Senior Scientist, BFRI, Mymensingh* **India** : **Dr. Sijo Varghese,** *Zonal Director, FSI, Kochi* **Maldives** : **Mr. Hassan Shakeel,** *Senior Marine Biologist, MMRI, Male'* **Sri lanka** : **Ms. Irangani Swarnalatha,** *Deputy Director, Min of Fisheries, Colombo*	
1040 - 1200	**Country Presentations** **Chair: Dr. E. Vivekanandan,** *Principal Scientist (Rtd), ICAR-Central Marine Fisheries Research Institute (CMFRI), Cochin; Ex-FAO Consultant; & Hon. Adviser, BOBP-IGO.* **Stock Assessment Methods & Opportunities for Knowledge Sharing**	

Each country shall make a coordinated presentation as per the following DRAFT outline.

- Status of Marine Fisheries Resources
- Overview of Stock Assessment - *Organizational structure for stock assessment; Methodology used; Data source; Status of Commercially important fish species;*
- Current Challenges in Stock Assessment
- Way Forward / Future Plans for Stock Assessment in the Country
- Expectations from BOB-SAN

1040 – 1105	**Bangladesh**	**Dr. Mohammed Shariful Azam** **Mr. Al Mamun** *Dept. of Fisheries, Dhaka.*
1105 - 1130	**India**	**Dr. John Chembian** **Dr. GVA Prasad** *Fishery Survey of India (FSI), Mumbai*
1130 – 1155	**Maldives**	**Dr. Mohamed Ahusan** **Dr. Mohamed Shimal** *Maldives Marine Research Institute, Male'*
1155 - 1220	**Sri Lanka**	**Dr. Sujeewa Haputhantrige,** *NARA, Colombio* **Dr. Sinesha Karunarathne,** *DoFAR, Colombio*
1220 – 1250	**Interactions & Feedback; Way Forward**	**Moderation & Summary Presentation** **Dr. E. Vivekanandan**
1250 – 1300	**Closing Remarks**	**Dr. P. Krishnan,** *Director, BOBP-IGO*

Annex II

Bay of Bengal Stock Assessment Network (BOB-SAN)

What is BOB-SAN?

The Bay of Bengal Stock Assessment Network (BOB-SAN) is an informal virtual network of fish stock assessment practitioners and experts from the BOB region. With BOBP-IGO as its coordinating entity, the Network would serve as a platform for collaboration among the members and facilitate experience and knowledge-sharing.

- The need for the establishment of the BOB-SAN stems from the realization that effective management and conservation of fish stocks in the Bay of Bengal require a collaborative and knowledge-sharing approach. With fish stock assessment experts scattered across the region, it becomes crucial to create a platform that fosters communication and cooperation.
- BOB-SAN aims to harness the collective wisdom and experiences of its members to improve stock assessment methodologies and contribute to coordinated regional fisheries management.
- BOB-SAN is driven by the understanding that no single entity or individual can tackle the complexities of fish stock assessment in the Bay of Bengal region alone. Through this network, practitioners can leverage their combined expertise to enhance the understanding of fish stocks and contribute to their sustainable management in the Bay of Bengal region.
- Under the aegis of BOB-SAN, BOBP-IGO shall organize periodic meetings/interactions and provide opportunities for sharing knowledge and best practices in fish stock assessment, advanced methodologies.

Launch Meeting	: 17 August 2023
Draft Agenda	: Familiarization; National Status Reports Presentations.
	Review Practices
Expected Outcome	: Knowledge Sharing & Lessons for the Region
Deliverable	: Compendium of Approaches and Best Practices

Questionnaire for Review of Fishery Stock Assessment Practices in South Asia

- The Survey schedule aims at collating information about the methodologies, approaches, and data collection practices employed by stock assessment practitioners in the region.
- The survey results will be analyzed and compared against the global best practices and compiled as a Compendium, which will allow for a comparative analysis of various aspects related to stock assessment practices by the South Asian countries.
- The survey results will aid in identifying best practices, challenges and bottlenecks in stock assessment processes. The Network will discuss strategies to address these challenges and devise action points for enhancing the effectiveness of the stock assessments process in the respective countries. This in turn will aid in mapping the competencies and capacity needs for addressing under the BOBLME Phase II project.

Questionnaire

A. Organizations and Agencies Involved in Stock Assessment

1. Name and type the organization notified by the government as a nodal agency for the fish stock assessment.

   ☐ Ministry / Fisheries Department
   Provide the name of the nodal agency

   ☐ Research Institute
   Provide the name of the nodal agency

   ☐ Academic Institute
   Provide the name of the nodal agency

   ☐ Others
   Provide the name of the nodal agency

2. Name and type the organization notified by the government as a nodal agency for the estimation of marine fish landings.

   ☐ Ministry / Fisheries Department
   Provide the name of the nodal agency

   ☐ Research Institute
   Provide the name of the nodal agency

   ☐ Academic Institute
   Provide the name of the nodal agency

   ☐ Others
   Provide the name of the nodal agency

3. Are there any other agencies involved in the stock assessment of fish in the country?

   ☐ Ministry / Fisheries Department
   Provide the name of the nodal agency

   ☐ Research Institute
   Provide the name of the nodal agency

   ☐ Academic Institute
   Provide the name of the nodal agency

   ☐ Others
   Provide the name of the nodal agency

4. Does the nodal agency for fish stock assessment collaborate with other nodal agencies in conducting stock assessments?

   ☐ Yes
   Please provide the capacity in which the collaborating institute is being used.

   ☐ No
   Please provide a reason for the response

5. What are the regional and international institutions that assist in the stock assessment and what is the extent of collaboration in the assessment of fish stock?

Organization	Institutionalized	Ad-hoc basis	Not considered

6. What are the main funding sources for nodal agency stock assessment activities? Please use tick (✓), wherever necessary

☐	Mandate of the nodal agency to assess the status of the fish stocks	
☐	Funding from other national agencies	Provide the names of the funding agency and the frequency
☐	Funding from International agencies	Provide the names of the funding agency and the frequency
☐	Others	Provide the names of the funding agency and the frequency

7. What is the total estimated budget utilized by the nodal agency for conducting the fish stock assessment last year? (Indicate if data is not available)

USD:

What is the estimated annual budget requirement for conducting fish stock assessments effectively – only if the current allocation is insufficient?

USD:

B. Overview of Fish Stock Assessment

1. Is the country divided into management units/regions for conducting fish stock assessments? Please use tick (✓), wherever necessary

☐ Yes ☐ No

1.1. If YES, the demarcation is based upon (if available provide a map indicating the boundaries)

Tick	Characteristics	Name of the units	Number of units in the country
☐	Administrative boundaries		
☐	Biological considerations		
☐	Economic Considerations of Fishers		
☐	Others		

1.2. If NO, please provide how the stock assessment is being carried out.

2. Name the fishing gears that cumulatively contribute to about 70% of the total catch in the country?

☐	Demersal trawl fishery
☐	Pelagic trawl fishery
☐	Gill net fishery
☐	Purse seine fishery
☐	Line fishery (long line/pole & line/troll line)
☐	Trap fishery
☐	Others (Please mention)

3. Whether the overall marine fishing potential of the country (within EEZ) is estimated?

☐ Yes (…….. Tonnes) ☐ No

4. What is the methodology/process used for the estimation of marine fish landings?
(Please provide a reference/link, if available)

5. What is the data source for stock assessment?

Data type	Species for which it is used
Fisheries dependent data	
Fisheries independent data	
Biological data	

6. Are there any institutionalized procedures in place for regular evaluation of the fish stocks in the country?

☐ Yes ☐ No

6.1. If yes, what is the average frequency: _____

7. What type of fish stock assessment is undertaken in your country?

☐ Multi-species assessment ☐ Single species assessment

8. Please provide details about the status of the multi-species fish stock assessment in the country.

Type of Gear	Species groups analysed	Region of assessment (Refer Question: B.1)	Frequency of assessment (years)

8.1. Methodologies used for multi-species stock assessment

Method	Data inputs1 (tick)	Data source[2]	Software[3]	Region of assessment[4]
Multispecies Surplus production model	Biomass: _____ Catch: _____			
Others (Specify): _____				
Multispecies virtual population analysis	Catch at Age: _____ Maturity: _____			
Weight at Age: _____ Fishing Mortality: _____				
Stomach Content data: _____				
Residual Mortality:_____				
Predation Mortality: _____				
Stock Synthesis	CPUE:_____ Effort:_____ Discards:_____			
Length Composition: _____ Age composition:_____				
Environmental data (Specify): _____ Tag-recapture data:				
Stock composition:_____				
OSMOSE	Life history parameters (Specify):_____			
Ecopath with Ecosim	Catch: _____ Biomass:_____ Morality:_____			
Diet: _____ Production / Biomass:_____				
Consumption / Biomass: _____				
Others (Specify): _____				
Others				

1 Mention the various input parameters for the particular model
2 Mention the data source i.e., data collected from the nodal agency, fisheries dependent/independent surveys etc.
3 Mention the software used to perform the analysis
4 If a particular method is used throughout the country mention "ALL" and if a particular method is used especially for a particular region, mention the "Region" and the reason for using it.

9. Please provide details about the status of single-species fish stock assessment in the country. (List the species which collectively account for 70% of the fishery)

Species analysed	Type of Gear	Region of assessment (Refer Question: B.1)	Frequency of assessment (years)

9.1. Methodologies used for single-species stock assessment

Method	Data inputs 1	Data source 2	Software 3	Region of assessment 4
Surplus production model				
Virtual population analysis				
Yield Per recruit models				
Catch-MSY				
Others				

1 Mention the various input parameters for the particular model.
2 Mention the data source i.e., data collected from the nodal agency, fisheries dependent/independent surveys etc.
3 Mention the software used to perform the analysis.
4 If a particular method is used throughout the country mention "ALL" and if a particular method is used especially for a particular region, mention the "Region" and the reason for using it.

10. What is the status of the commercially important fish species which cumulatively contribute to 75% of the total annual marine fish landings in the country?

Species 1	Assessment Year (Latest)	Reference point2	Catch (In tonnes) during the assessment year	Status 3

1 Mention the status of the species which contributes to 75% of the total marine catch of the country
2 Mention the reference points like MSY, MEY, FMSY, BMSY, F0.1 etc used in the country for identifying the status of the fish stocks
3 Based upon the reference point classify the status of the stocks into Overfished, sustainably fished, or Underfished

C. Action Post-Fish Stock Assessment

1. Which National, regional and international agencies receive the stock assessment reports from the country, and how frequently are they submitted?

Agencies	Frequency (In years)

2. How the stock assessment results are made available to the policymakers for taking management decisions?

☐ Periodical report (Annual / Half-yearly) by Nodal Agency

☐ Policy Briefs exclusively prepared for policymakers

☐ Advisory meetings and consultations

☐ Research papers accessible to the policymakers

☐ Online databases/dashboards

☐Others (please mention)

2.1. What can be the best way to represent the status of stocks to the policymakers
On a 5-point scale; (1 – Strongly Disagree, 2 – Disagree, 3 – Neither agree/disagree, 4 – Agree, 5 – Strongly Agree)

Ways to represent the stock status	1	2	3	4	5
Periodical report (Annual / Half-yearly) by Nodal Agency					
Policy Briefs exclusively prepared for policymakers					
Advisory meetings and consultations					
Research papers accessible to the policymakers					
Online databases/dashboards					

3. Rate the performance of the country in the following processes of stock assessment.
On a 5-point scale; (1- Poor; 2- Fair, 3 – Good, 4 – Very good, 5 – Excellent

Processes of stock assessment and fisheries management	1	2	3	4	5
Estimation of marine fishing potential					
Estimation of marine fish landings					
Data collection for fish stock assessment					
Demarcation of boundaries for stock assessment					
Use of biological data in fish stock assessment					
Appropriate use of fish stock assessment models					
Reporting / Communication / Publications					
Management decisions based on stock assessment results					
Implementation and monitoring					
Collaborating with other agencies within the country					
Collaborating with other agencies outside the country					

4. What are the current technical measures for fisheries management in the country?

Technical measures	Types of controls	Details & Weblink
Input	Fishing capacity controls	
	Vessel usage controls	
	Fishing effort controls	
	Others	
Output	Quotas and catch limits	
	Commercial minimum sizes	
	Prohibited species	
	Others	

5. Are there any evidence-based specific management measures or regulations that have been implemented/adopted based on the results of stock assessments?

5.1. If Yes, Provide a case study with an example and weblink (if available)

5.2. If No, Rate the major reasons why stock assessment results cannot be implemented in the country
On a 5-point scale; (1–Strongly Disagree, 2–Disagree, 3–Undecided; 4- Agree, 5- Strongly Agree)

Reasons	1	2	3	4	5
Incomplete assessment / Lack of complete picture of the status of stocks in the country					
Conflicting priorities between managers and policymakers					
Lack of monitoring and implementation mechanism					
Economic considerations (Economic interests not aligning with conservation goals)					

6. How the fishery is currently being managed in the country?

	Rules and Regulations	Details and Weblinks
☐	Rules and Regulations throughout EEZ of the country are same	
☐	State / District / Area-specific Management	
☐	Stock–Specific Management	
☐	Other	

D. Gaps and Way Forward

1. Rate the specific challenges faced in the country while conducting the stock assessment.

   On a 5-point scale; (1–Strongly Disagree, 2–Disagree, 3–Undecided; 4- Agree, 5- Strongly Agree)

Challenges	1	2	3	4	5
Lack of Manpower					
Inadequate data availability					
Robust data collection mechanism					
Limited funding					
Lack of expertise					
Lack of standardized methodology					
Delay in assessment					
Communication and transparency issues with policymakers					
Others: …….					

2. What are the priority areas or aspects that should be considered in future stock assessment/fishery management efforts of the country?

   On a scale of 5-point scale; (1 – Not at all important, 2 – Slightly important, 3 – Moderately important, 4 – Very important, 5 – Extremely important)

Priority Areas	1	2	3	4	5
Real-time data collection mechanism					
Incorporation of ecosystem-based approaches					
Incorporating climate change in stock assessment					
Precautionary approach					
Long-term monitoring and evaluation					
Implementing Quota system					
Eco-labelling / Certification of fish stocks					
Improved capacity building					
International cooperation					
Others: …….					

3. In which of the following areas, the assistance from the experts from BOB-SAN would aid in improving fisheries management in the country?

   On a 5-point scale; (1 – Low, 2 – Limited, 3 – Moderate, 4 – High, 5 – Very High)

Areas of stock assessment/fisheries management	1	2	3	4	5
Estimation of marine fishing potential					
Estimation of marine fish landings					
Data collection for fish stock assessment					
Demarcation of boundaries for stock assessment					
Use of biological data in fish stock assessment					
Appropriate use of fish stock assessment models					
Reporting / Communication / Publications					
Management decisions based on stock assessment results					
Implementation and monitoring					
Others: ……..					

4. In which of the following areas, experts from the country can contribute to the regional fisheries management/stock assessment?

   On a 5-point scale; (1 – Low, 2 – Limited, 3 – Moderate, 4 – High, 5 – Very High)

Areas of stock assessment/fisheries management	1	2	3	4	5
Estimation of marine fishing potential					
Estimation of marine fish landings					
Data collection for fish stock assessment					
Demarcation of boundaries for stock assessment					
Use of biological data in fish stock assessment					
Appropriate use of fish stock assessment models					
Reporting / Communication / Publications					
Management decisions based on stock assessment results					
Implementation and monitoring					
Others: ……..					

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