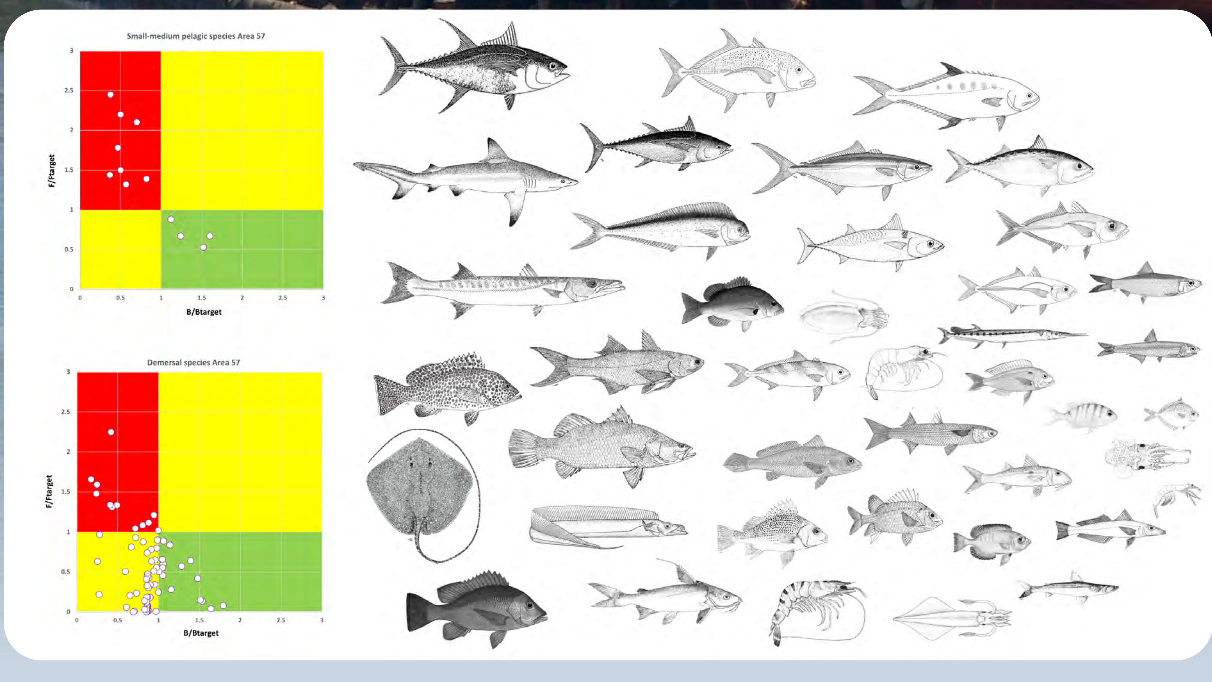
Food and Agriculture
Organization of the
United Nations

The status of marine fishery stock assessments in the Asian region and the potential for a network of practitioners



The status of marine fishery stock assessments in the Asian region and the potential for a network of practitioners

Food and Agriculture Organization of the United Nations

Bangkok, 2023

Required citation:

FAO. 2023. *The status of marine fishery stock assessments in the Asian region and the potential for a network of practitioners*. Bangkok. https://doi.org/10.4060/cc9002en

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO in preference to others of a similar nature that are not mentioned.

ISBN 978-92-5-138437-4

© FAO, 2023

Some rights reserved. This work is made available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; https://creativecommons.org/licenses/by-nc-sa/3.0/igo/legalcode).

Under the terms of this licence, this work may be copied, redistributed and adapted for non-commercial purposes, provided that the work is appropriately cited. In any use of this work, there should be no suggestion that FAO endorses any specific organization, products or services. The use of the FAO logo is not permitted. If the work is adapted, then it must be licensed under the same or equivalent Creative Commons licence. If a translation of this work is created, it must include the following disclaimer along with the required citation: “This translation was not created by the Food and Agriculture Organization of the United Nations (FAO). FAO is not responsible for the content or accuracy of this translation. The original [Language] edition shall be the authoritative edition.”

Disputes arising under the licence that cannot be settled amicably will be resolved by mediation and arbitration as described in Article 8 of the licence except as otherwise provided herein. The applicable mediation rules will be the mediation rules of the World Intellectual Property Organization http://www.wipo.int/amc/en/mediation/rules and any arbitration will be conducted in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL).

Third-party materials. Users wishing to reuse material from this work that is attributed to a third party, such as tables, figures or images, are responsible for determining whether permission is needed for that reuse and for obtaining permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

Sales, rights and licensing. FAO information products are available on the FAO website (www.fao.org/publications) and can be purchased through publications-sales@fao.org. Requests for commercial use should be submitted via: www.fao.org/contact-us/licence-request. Queries regarding rights and licensing should be submitted to: copyright@fao.org.

Cover page: Fishing boats, India © Derek Staples
Images © FAO

PREPARATION OF THIS DOCUMENT

This document is based on the outcomes of FAO's Regional Workshop for a Network of Practitioners on Fishery Stock Assessment (the FAO Regional Assessment Workshop) convened from 23 to 25 January 2023 in Bangkok, Thailand. The workshop was organized by the FAO Regional Office for Asia and the Pacific (FAO RAP) with technical support from the FAO Fishery and Aquaculture Division (NFI) in Rome, Italy and a workshop scientific advisory group, convened and coordinated by Murdoch University, Australia. This workshop built on two FAO and SEAFDEC co-organized regional training workshops on stock assessment, which developed the first understanding of the current status and regional capacity on stock assessment and examined available datasets. It also drew on other complementary work under parallel initiatives funded by other donors and FAO.

Technical editing of the contents was provided by Neil Loneragan, Derek Staples, Wilfredo Campos, Budy Wiryawan, Simon Funge-Smith and Rishi Sharma.

Robin Leslie was the copyeditor.

ABSTRACT

The global fisheries sector in 2023 is now appreciably different compared to that of the 1970s, as are the dominant fish stocks that comprise most of the current global landings, their location and modes of their exploitation. The fisheries of South and Southeast Asia have also changed over this period and alongside their changing nature, there has been the continuous evolution of the tools and the requirements for calculating and presenting global sustainability information. This has transformed our ability to assess fish stocks, use data-poor methodologies, assess multispecies fisheries and also take into account some of the complex interactions between target and non-target species and related ecosystem effects. The adoption of the Sustainable Development Goals (SDGs) has led to greater recognition of the importance of the world's oceans and their living resources and now means there is much closer attention to fisheries sustainability. The SDG indicator 14.4.1 (fish stocks sustainability) has also created a requirement for countries to report on their marine fish stocks every few years to evaluate progress on this indicator. This has been accompanied by increasing expectations and requirements for transparency on how stocks are assessed and recognition of the need to incorporate local knowledge. This review of South and Southeast Asian fish stocks and their status is based on the outcomes of FAO's Regional Workshop for a Network of Practitioners on Fishery Stock Assessment convened from 23 to 25 January 2023 in Bangkok, Thailand. It aims to provide a broad background on the status of stock assessments in Asia and as well as an overview of the status of stocks in the region and the approaches being used to make these assessments.

The country analysis describes the data sources and assessment methods currently being applied in national fishery management areas and in smaller regions. Information presented in country overviews indicated that marine fish stock assessment has been undergoing a quiet revolution in Asia and there is a wide variety of stock assessments being conducted in the region. There are indications from the reported stock assessments that very few fisheries in the region appear to be underfished and these preliminary results are in line with FAO's assessments. Importantly, assessments were, in general, not well connected to management decision-making and action; linking stock assessment results into a harvest strategy process is an important strategy to create a stronger relationship between science, the fishing industry, policymaking and management. Thematic reviews of assessment approaches conclude that single species assessment and single species management, in isolation from the other species in the fishery, are rarely applicable in the tropical and or Asian context.

The discussions of the working groups identified approaches that are best suited to different fisheries (i.e. coastal inshore fisheries including reef, demersal and small to medium pelagics) within the region, given the current resources available for assessments and levels of data collection. Historically, fishery data systems have been developed and designed for the purpose of a particular type of assessment and this may limit the application of other assessment models. In particular, it is concluded that assessment results may need to be interpreted with caution, especially in light of the underlying model and data assumptions. The review also identifies human capacity-building needs to enhance stock assessments in the region and examined the potential and value of forming a network of people for assessing Asian fish stocks and building a community of practice in stock assessment. There is a strong need to improve awareness of the value of stock assessments and for effective communication to different stakeholders. The review concludes with recommendations on the needs for capacity building and how improved regional networking can provide support to the greater understanding and application of new or improved methods of stock assessment in the region.

CONTENTS

	Preparation of this document	iii
	Abstract	iv
	Abbreviations	vii
1	**Background to stock assessment in the Asian region**	**1**
	References:	4
2	**Summary findings of the review**	**5**
	2.1 Identified needs and recommendations for strengthening stock assessment for fishery management	7
3	**Fish stock status assessment of the FAO major fishing Area 57 (East Indian ocean)**	**10**
	3.1 Background	10
	3.2 Fish stock classification approach	12
	3.3 Improvements in coverage of Tier 1 stocks	13
	3.4 Improvements in Tier 2 stock assessments	14
	3.5 Summary of the analysis	16
	References	18
	Appendices	19
4	**Single species stock assessments for a range of data in Asia**	**30**
	4.1 Introduction	30
	4.2 Stock assessment and fisheries management	30
	4.3 Data needs for stock assessments	32
	4.4 Data limitations	33
	4.5 Assessment options	33
	4.6 Conclusions	39
	References	40
5	**Assessing stocks for multispecies fisheries: a multispecies approach relevant to the Asian region**	**41**
	5.1 Background	41
	5.2 Assessing total catch based on ecosystem productivity	43
	5.3 Multispecies and ecosystem modelling	45
	5.4 Conclusions	50
	References	51

6	**Trawl surveys in Southeast Asia**	**52**
	6.1 Introduction	52
	6.2 Standardized catch per unit effort	52
	6.3 The first 15 years of industrial fishing, the example of the Gulf of Thailand	55
	6.4 Conclusions	57
	References	57
7	**Interpreting single species stock assessment results in a multispecies fishery**	**58**
	7.1 Introduction	58
	7.2 Case study stocks	58
	7.3 The sum of the MSY of individual stocks is greater than the aggregate MMSY	59
	7.4 In a multispecies fishery fished at MMSY, there will be stocks at their MSY and others that are above or below their MSY	60
	7.5 Focusing assessments on a small number of commonly fished stocks will result in a biased understanding of the status of a multispecies fishery	62
	7.6 The way forward	63
	7.7 Conclusions	67
	References	68
	Appendices	69
8	**Country stock assessment overviews**	**72**
9	**Individual fishery assessments**	**79**
10	**Thematic review of the submitted assessment information**	**84**
	10.1 Coastal inshore fisheries, including reef fisheries	84
	10.2 Demersal multispecies fisheries	90
	10.3 Small to medium pelagic (non-tuna) species	93
11	**Regional and international fishery research, networking and capacity building**	**99**
Appendix 1. list of presentations at the FAO regional assessment workshop		**101**
Appendix 2. list of participants at the FAO regional assessment workshop		**102**

ABBREVIATIONS

AFS	Asian Fishery Society
ASPIC	a stock production model incorporating covariates
BFAR	Bureau of Fisheries and Aquatic Resources (Philippines)
BLIM	biomass limit
BOBP-IGO	Bay of Bengal Programme Inter-Governmental Organisation
Bmsy	biomass at MSY
BRIN	National Research and Innovation Agency (Indonesia)
CIFRF	coastal inshore fisheries, including reef fisheries
CMFRI	Central Marine Fisheries Research Institute (India)
CMSY	CMSY method for data-limited stock assessment
CPA	catch per area
CPUE	catch per unit effort
DFAR	Department of Fisheries and Aquatic Resources (Sri Lanka)
DOF	Department of Fisheries (Thailand)
EwE	Ecopath with Ecosim
FAO RAP	FAO Regional Office for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FiA	Fisheries Administration (Cambodia)
FiSAT	FAO-ICLARM Fish Stock Assessment Tools
FMA	fishery management area
FMP	fisheries management plan
Fmsy	Fishing mortality needed to achieve MSY
FRI	Fisheries Research Institute (Malaysia)
GLM	generalized linear modelling
HP	horsepower
ICAR	Indian Council of Agricultural Research
ICLARM	International Center for Living Aquatic Resources Management
IPB	Institut Pertanian Bogor (Indonesia)
IUU	illegal, unreported and unregulated
JABBA	Just Another Bayesian Biomass Assessment
LBB	length-based Bayesian biomass estimation
LBSPR	length-based spawning potential ratio
LOA	length overall
MAF	Ministry of Agriculture and Fisheries (Malaysia)
MaFReDI	Marine Fisheries Research and Development Institute (Cambodia)
MEY	maximum economic yield
MIMRA	Ministry of Fisheries, Marine Resources and Agriculture (Maldives)
MMAF	Ministry for Maritime Affairs and Fisheries (Indonesia)
MMRI	Maldives Marine Research Institute
MMSY	multispecies maximum sustainable yield
NFRDI	National Fisheries Research & Development Institute (Philippines)
NGO	non-government organization
PRI	point of recruitment impairment
PSA	productivity/susceptibility analysis
R	R software environment for statistical computing and graphics
RFMO	Regional fisheries management organization
SEAFDEC	Southeast Asian Fisheries Development Center
SPM	surplus production model
SPR	spawning potential ratio
SRA	stock reduction analysis
TAC	total allowable catch
TAE	total allowable effort
WoE	weight of evidence
WTO	World Trade Organization

1 BACKGROUND TO STOCK ASSESSMENT IN THE ASIAN REGION

The fisheries of Asia are a critical component in terms of food security and the broader Asian economies. Asian marine fishery landings reported to FAO (wild capture, not including aquaculture) have averaged 38 million tonnes per year since the mid-1990s, accounting for nearly 49 percent of the world's marine capture fishery production, which directly involves over 50 million people and a regional population of billions. Over the past 30 years, the reported catches from capture fisheries have declined in the Northwest Pacific, nearly doubled but eventually became stable in the Western Central Pacific and are now stable with a slower rise in the Eastern Indian Ocean.

Despite the importance of fisheries to the Asian economy, scientific monitoring and management are modest, with most stocks lacking modern scientific stock assessments, although from 1980 to 2000, stock assessment programmes were carried out in most countries in the region assisted by regional and international scientists (Silvestre *et al.,* 2003). National stock assessment programmes still operate in the region and there is a regional cadre of stock assessment scientists, however very few stock assessment reports have been published in recent years. Part of the reason may be attributable to confidentiality issues, but also because this work is not being made publicly available in English.

One of the global effects of having limited information on recent stock assessments is that there is an apparent lack of assessments from the Asian region to contribute to FAO's global analyses of the status of world fish stocks. These analyses are, in turn, used to give feedback on global progress towards achieving SDG 14 – "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" – particularly targets addressing:

- Natural resources and people with a focus on sustainable fishing; conserving coastal and marine areas; and increasing the economic benefits from sustainable use of marine resources.

- How these outcomes can be achieved through increasing scientific knowledge, research and technology for ocean health and supporting small-scale fishers.

Another issue is that different teams of scientists rely on the same public databases of catch data. They use different methods (that make different assumptions and aggregate data in different ways) and arrive at different overall assessment of the status of global fish stocks, ranging from around one-third (FAO, 2022) to two-thirds of global stocks being overfished (Worm *et al.,* 2009). These conclusions are not universally accepted and have been criticized for their reliance on a global stock assessment database (the RAM Legacy) in which fisheries from developing countries are seriously under-represented (Ricard *et al.,* 2012).

Although the RAM Legacy database has been greatly expanded over the past decade and now includes stocks representing more than half of global fishery landings, FAO's world assessment continues to primarily rely on "traditional" full statistical stock assessments, as well as some data-limited assessments or expert elicitation methods where full stock assessments are not available. It is possible that the FAO selection bias in favour of larger stocks with formal assessments is behind its relatively optimistic outlook compared to Worm's global assessment in 2009. FAO's methodology also tends to aggregate stocks into larger units versus the Worm approach which could be another factor for explaining the differences.

This uncertainty highlights the fact that databases, and analyses based on them, remain constrained by the lack of publicly available and reliable fisheries data and stock assessments in Asian countries such as China, India, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Viet Nam. These countries represent some of the largest global producers of capture fish with five countries ranked in the top ten capture fisheries producers globally by FAO (2022) – China (1), Indonesia (2), India (3), Viet Nam (7) and Bangladesh (10). Fisheries in these countries range from large-scale industrialized fisheries for demersal fish such as grouper, threadfin bream and pony fish as well as pelagic fish like oil sardine, herring and tuna to small-scale fisheries, including artisanal fisheries, for nearshore and estuarine species such as blue swimming crab and shellfish. Asian countries have tried to improve their respective fisheries management policies and regulations towards better sustainability and meeting international commitments such as the SDGs as well as commitment to relevant conventions for food security and the health of the oceans. For example, the ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 is a regional policy framework that highlights (1) priority actions to establish reference points and (2) calculation of estimated biomass or capacity level to determine the maximum sustainable yield (MSY), allowable biological catch or allowable effort for marine fisheries in support of achieving sustainability. However progress has been slow.

At the national level in the Asian region, fishery yields have largely plateaued over the past decade, while the Asian population has continued to increase, and thus the need for sustainable protein sources has also increased. Does the current plateau in fishery yields represent the MSY or is greater harvest possible? If higher yields are possible, will they be achieved by fishing harder or by rebuilding overfished stocks? These are questions that can be addressed only if we assess our stocks.

International trade-related issues have increased the urgency for better stock assessments. The World Trade Organization (WTO) has been working with WTO members for over two decades to negotiate an international commitment toward achieving SDGs, covering the scope of fishery subsidies and ways to regulate them. During the WTO Ministerial Conference in Buenos Aires in 2017, the WTO was mandated to continue the discussion to meet Target 6 of SDG 14, i.e. “by 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, and eliminate subsidies that contribute to IUU fishing, and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the WTO fisheries subsidies negotiation”. The WTO Agreement on Fisheries Subsidies, adopted at the 12th Ministerial Conference (MC12) on 17 June 2022, marked a major step forward for marine sustainability by prohibiting harmful fisheries subsidies, which are a key factor in the widespread depletion of the world’s fish stock. The Agreement emphasizes the need for better information on the status of stocks.

Despite the apparent lack of information from Asian countries, most countries in the region have several stock assessment scientists. The FAO Regional Office for Asia and the Pacific (FAO RAP) and the FAO Fisheries Division (NFI), in partnership with the Southeast Asian Fisheries Development Center (SEAFDEC), Murdoch University and Institut Pertanian Bogor (IPB) University, and other regional and national institutions have been delivering capacity-building workshops in the Asian region (Loneragan *et al.,* 2021). FAO and SEAFDEC have also been providing training in stock assessment for Southeast Asian scientists that encourages sharing among the participants.

These capacity-building activities have highlighted the need to better harmonize stock assessment activities, to gain greater benefits from shared learning and exchange understanding of techniques and experiences on how to assess the diverse and complex fisheries of the region under different levels of data availability and resourcing that typify the regional developmental context. As a first step, this review brings together the results of recent stock assessments in the region on which to base a long-term goal. FAO RAP, with the support of the FAO Fishery and Aquaculture Division (NFI) are promoting the establishment of an organized network of stock assessment practitioners that will regularly communicate and cooperate in capacity building and sharing knowledge on applying appropriate methods for assessing the status of stocks in the Asian region.

The strategic value of this initiative to FAO is that the network members will contribute to improving the assessment of fishery resources in the Asian region and assist with sharing this information with FAO. This will support FAO's global process of collating stock assessment information and reporting on the state of global fisheries. The network will also contribute to regional capacity building using tools and methods to contribute to improved national stock assessments for fishery management and national reporting requirements for the SDG 14 fisheries indicator.

The needs for capacity building and improved cooperation in stock assessment have been identified as priorities for action by:

- The 36th Session of the Asia-Pacific Fishery Commission (APFIC) which *… emphasized the importance of fishery management grounded on science for sustainable marine and inland fisheries.* It acknowledged the challenges related to lack of adequate capacity for conducting stock assessment and analyses.

- The 37th FAO Asia-Pacific Regional Conference (APRC) which recommended to *…build capacity for development and implementation of sustainable fisheries management plans, fisheries stock assessment and sustainable aquaculture systems, in cooperation with relevant regional fishery bodies*.

- The 34th Session of the FAO Committee on Fisheries (COFI) which *…requested FAO to consider, in future SOFIA reports, additional information and methodological improvements to better reflect the regional status of fish stocks*.

- The ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030 which recommended to *…foster cooperation with other countries for the conduct of stock assessment on straddling, transboundary, highly migratory, and shared fishery resources, as appropriate, to serve as inputs for formulating science-based fishery management plans*; and *…enhance the participation of local communities, fisheries-related organizations, and other stakeholders in fisheries management and in fisheries and stock assessment*.

References:

FAO. 2022. *The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation*. Rome, FAO. https://doi.org/10.4060/cc0461en

Loneragan, N.R., Wiryawan, B., Hordyk, A.R., Halim, A., Proctor, C., Satria, F. & Yulianto, I., eds. 2021. *Proceedings from Workshops on Management Strategy Evaluation of Data-Limited Fisheries: Towards Sustainability – Applying the Method Evaluation and Risk Assessment Tool to Seven Indonesian Fisheries*. Western Australia, Murdoch University and Indonesia, IPB University. 185 pp. ISBN 978-0-646-82951-7.

Ricard, D., Minto, C., Jensen, O.P. & Baum, J.K. 2012. Examining the knowledge base and status of commercially exploited marine species with the RAM Legacy Stock Assessment Database. *Fish and Fisheries*, 13(4): 380–398

Silvestre, G., Garces, L., Stobutzki, I., Ahmed, M., Valmonte-Santos, R.A., Luna, C., Lachica-Aliño, L., Munro, P., Christensen, V. & Pauly, D., eds. 2003. *Assessment, management and future directions for coastal fisheries in Asian countries*. WorldFish Center Conference Proceedings, No. 67. https://hdl.handle.net/20.500.12348/2157

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S. et al. 2009. Rebuilding global fisheries. *Science*, 325: 578–585.

2 SUMMARY FINDINGS OF THE REVIEW

Marine fishery stock assessment has been undergoing a quiet revolution in Asia: Marine fishery stock assessment has for some time been perceived as being given ever decreasing priority in the Asian region. This has been driven by a several factors such as increased attention and resourcing being directed towards aquaculture development and a false assumption that effective management of marine capture fisheries does not result in production increases. Part of this is related to frustration in national fishery agencies that existing single stock assessment approaches are unsuited to assessing (tropical/low latitude) complex, multispecies, multigear fisheries and are not able to provide useful advice for the management of such fisheries.

The review reveals that there are ongoing stock assessment programmes and that there has been a quiet revolution and revitalization in marine fishery stock assessments and their application to fishery management. The reasons for this are primarily related to:

- increased accessibility to modelling methodologies due to much greater computing power and ability to manipulate data using freely available, documented resources (e.g. through the increased use of the programming language and environment for statistical computing and graphics ‘R’ and the code hosting platform ‘GitHub’);

- new multispecies and ecosystem models that allow greater understanding of fishing effects within mixed stocks and the identification of indicator species for evaluating change in multispecies fisheries;

- the recent, rapid development of data-poor assessment methods, capable of using the types of data that are most commonly available for fisheries in South and Southeast Asia, or data that are easier to collect at low cost; and

- greater access to other forms of data and information that can inform assessments or management decision-making (e.g. remote sensing, vessel and other electronic data; fisher interviews).

There is a wide variety of stock assessments being conducted in the region: Country overviews indicated that assessments are being completed on a wide range of fisheries, a wide range of species and use a range of metrics to assess stock status. These include those coming from surplus production models (SPMs) when a time series of catch and effort data is available and those from length-based methods when time series data are limited or not available. These assessments are completed in the larger geographic areas of the country, such as declared fishery management areas (FMAs).

Very few fisheries in the region appear to be underfished and preliminary results are in line with the FAO assessments: The preliminary results from the data and assessments provided for this review indicate that the stock assessments correspond, more-or-less, to the FAO assessments regarding the proportion of fisheries that are overfished or sustainably fished, with some fisheries rebuilding. Very few, if any, stocks were identified as being underfished.

Country overviews indicated that the findings from stock assessments were, in general, not well connected to management decision-making and action: This is due to various reasons relating to institutional disconnections, poor communication from scientists to policy decision-makers and the failure to link assessment results to real world outcomes. It was noted that the results of stock assessments may be poorly communicated to fishery managers, policy decision-makers and fishers. This communication often does not provide sufficient options for management action or evaluating the likely impact of different management decisions, partly because there is typically limited linkage between stock assessment and the economic and social implications of management actions. This is important, as management agencies and government ministries often also take social and economic considerations into account when establishing management measures. These considerations are not necessarily clearly specified as objectives so that indicators and performance measures are not clearly defined for the social and economic performance of fisheries.

An important strategy to increase impact is to link stock assessment results to the harvest strategy process to create a stronger relationship between science, the fishing industry sector, policymakers and management: The linking of stock assessments to harvest strategies provides a focus for developing effective management actions that can be adopted as subsequent assessment information is generated and reviewed. Some notable examples, where assessments were linked to effective management action, were identified, primarily in smaller geographic areas (e.g. Blue swimming crab in the Northwest of Sri Lanka and grouper fisheries in Saleh Bay, Indonesia). Harvest strategies have been, or are being, developed that involve information sharing, collaborations and partnerships among researchers, governments, fishers, the fishing industry and non-government organizations (NGOs).

Single species assessment and single species management in isolation from other species in the fishery are rarely applicable in the tropical and/or Asian context: Single species models may not provide meaningful results for multispecies fishery management and they create questions about the sustainability of a fishery when some species may be underfished, but others are overfished. The FAO Regional Assessment Workshop identified the need for increased use of multispecies assessments, bioeconomic modelling and ecosystem modelling approaches to inform fisheries management, particularly the multispecies, multimethod fisheries that are common throughout the region. New exciting models have been developed and are available for addressing multispecies, multigear fisheries. These include multispecies maximum sustainable yield (MMSY), evaluating groups of species with similar trophic levels (the species hub concept), application of the publicly available Ecopath with Ecosim software and indicator species approaches. When lengthy time series data are available, such as the fishery-independent trawl data collected by several countries in the region, simple, model-free indicators may be used as performance indicators for the fishery, e.g. changes in catch composition of the dominant species/taxa in the fishery or changes in the mean size of the dominant species/taxa in the fishery.

Fishery data systems have been historically developed and designed for purposes other than stock assessment and this may limit the application of other assessment models: The suite of assessment models that is being used in the region falls into two major groupings: those based on catch and effort indicators, with biomass indicators and a times series of catch and effort available (e.g. SPMs; and those using length distributions (such as the length-based spawning potential ratio [SPR]) and determine an estimate of SPR and the ratio of fishing to natural mortality (F/M) as indicators and reference points. The information that is generated is not always fit for purpose, or may lack essential additional variables, when used in models for which it was not designed. There is a need to evaluate data collection systems and their suitability for the stock assessment models (e.g. the length data collected as part of a catch/effort data collection system may not represent the whole population).

Fishery independent surveys are currently underutilized and underappreciated: The FAO Regional Assessment Workshop noted that fishery independent surveys are an invaluable source of information to understand baselines for fisheries, ecosystem change and provide an indicator of stock changes to evaluate in conjunction with catch/effort statistics. Currently, these are underutilized and underappreciated.

Assessment results may need to be interpreted with caution, especially in the light of the underlying assumptions: Generally, the stock assessment results presented were not accompanied by necessary warnings and caveats for the models to indicate the degree of confidence in the results and whether the information returned by the models presented an overly optimistic or pessimistic result of the stock status and fishing intensity. The application of (*prior*) assumptions about the distribution on the parameter values used in the models may introduce significant biases in the outputs generated by the models. This requires more evaluation of prior and model assumptions and model sensitivities when designing data collection systems and selecting models for assessment. It also requires the use of sensitivity analyses to identify those parameters that have the greatest influence on the model predictions and hence data collection that is likely to reduce uncertainty in the assessment results.

There is a strong need for improved awareness of the value of stock assessments and effective communication to different stakeholders: There is a need to raise awareness about the central importance of stock assessment to fishery management and governance actors. Effective communication of stock assessment information is the key to success. As the audiences are different (ranging from fishers and fishery managers, fishery biologists, coastal communities to policymakers), this needs to be tailored to suit their needs, as well as their capacity to understand complex technical messages. Non-government organizations often have considerable expertise in communication to diverse audiences. Part of improving understanding of the relevance of stock assessment to management is linking stock assessment to economic information, to underscore the economic implications of effective management. This is an important factor as part of communicating messages to those involved in policymaking and decision-making, as well as improving the understanding of the implications for fishers and the livelihoods of coastal communities.

2.1 Identified needs and recommendations for strengthening stock assessment for fishery management

The review identified a number of key areas where stock assessment in the region could be improved and made some recommendations as to how this might be supported.

(i) Evaluate current data collection systems and their suitability for the stock assessment models:

a. for example, catch and effort time series data and length data collected as part of a commercial fishery data collection system that may not be suitable for length-based assessment methods;

b. increase understanding of model assumptions and the uncertainty in model predictions, particularly the influence of selecting parameter values and the distribution of these values (*priors*) for the models; and

c. incorporate sensitivity analyses into modelling and presentation of the results from stock assessments.

(ii) Link stock assessment results into harvest strategy processes to promote greater understanding of the stock status, fishing intensity and alternative management options and the perspectives of fishers and the fishing industry on these management options:

a. improve communication of the stock assessment results to managers, fishers, the fishing industry and the coastal communities whose livelihoods are supported by fishing;

b. develop better communication strategies and mechanisms to convey understanding of the findings from stock assessments and implications for managing fisheries;

c. incorporate information on the social and economic importance of fisheries in the assessment process for presentation to managers; and

d. surveys of fishers and the fishing industry should be carried out routinely to understand their perspectives on stock status, issues in the fisheries and different management options. These can help gain insights into the social and economic considerations related to management objectives, as well as provide a source of local fisher/ecological knowledge to inform the interpretation of assessments.

(iii) New exciting models have been developed and are available for addressing multispecies, multigear fisheries:

a. these include MMSY, evaluating groups of species with similar trophic levels (the species hub concept), the application of Ecopath with Ecosim software and indicator species approaches; and

b. there is a need to increase the use of bioeconomic modelling and ecosystem modelling approaches to inform the management of fisheries, particularly the multispecies, multimethod fisheries that are common throughout the region.

(iv) Single species assessment and single species management, in isolation from the other species in the fishery, are rarely applicable in the multispecies tropical and/or Asian context.

a. they are likely to lead to overestimates of the total productivity of these fisheries in South and Southeast Asia and should be used with caution; and

b. single species approaches are appropriate when a single species is clearly targeted (e.g. Blue swimming crab fisheries).

(v) Enhanced networking across the region will assist capacity-building initiatives and can promote understanding of:

a. how to use the right approach for stock assessment in a particular fishery and the appropriate methods and data sources which should be applied, to meet management objectives;

b. how to choose appropriate models for different circumstances and design data collection systems to meet the assumptions and requirements of the models; and

c. the influence of model assumptions on the results of the assessments and how the distribution of data and design of data collection systems may impact on the assessment results.

(vi) Develop training programmes for stock assessment groups working in South and Southeast Asian fisheries, that cover:

a. stock assessments, model assumptions, interpreting outputs and uncertainties;

b. survey design, data exploration and analysis requirements for different assessment methods;

c. management strategy evaluation for fisheries;

d. survey design, analysis and interpretation for gaining social understanding and local ecological knowledge of fisheries from fishers and fisher communities;

e. incorporation of social and economic performance indicators and reference points in fisheries; and

f. communication training to audiences with different levels of knowledge and different backgrounds.

3 FISH STOCK STATUS ASSESSMENT OF THE FAO MAJOR FISHING AREA 57 (EAST INDIAN OCEAN)

K. Sunil Mohamed, T.V. Sathianandan and Rishi Sharma

3.1 Background

FAO started publishing its regular analysis of the state of global fish stocks in 1971 (Gulland, 1971) and has included an updated summary analysis in its biennial FAO flagship publication *The State of World Fisheries and Aquaculture* (SOFIA) since then (FAO, 2022). In order to promote consistency and comparability across time, these analyses have used a fixed list of stocks (which account for over 70 percent of global fish landings) and a clear process and methodology, which has undergone only minor adjustments since the start of the time series (FAO, 2011).

The global fisheries sector in 2023 is now appreciably different compared to that of the 1970s, as are the dominant fish stocks that comprise most of the current global landings, their location and modes of their exploitation. For example, the region's tuna fisheries changed dramatically with the introduction of industrial purse seiners, and the fisheries of South and Southeast Asia have increasingly targeted small pelagic fisheries, as catches from demersal trawl fishery stocks have declined.

Alongside the changing nature of global fisheries has been the continuous evolution of the tools and the requirements for calculating and presenting global sustainability information. This has transformed our ability to assess fish stocks, use data poor methodologies, assess multispecies fisheries and also take into account some of the complex interactions between target and non-target species and related ecosystem effects. Greater recognition of the importance of the world's oceans and their living resources now means there is much closer attention to the sustainability of fisheries. This has been accompanied by an increasing expectation and requirement for transparency on how stocks are assessed and recognition of the need to incorporate local knowledge. The adoption of the Sustainable Development Goals (SDGs) and SDG Indicator 14.4.1 (proportion of marine fish stocks within biologically sustainable levels) has also created a requirement for countries to report on their marine fish stocks every few years to evaluate progress on this indicator.

Against this backdrop, it has become increasingly evident that not only is there a need to update the list of stocks that form the global assessment, but also the manner in which they are assessed. FAO considers that the time is right to conduct a methodological update to compute and report on the state of world fish stocks that is better aligned with national SDG reporting initiatives, has broader expert participation and transparency, but which crucially, maintains the integrity of the time series. This new methodology will continue to generate stock status indices at the FAO fishing regions level and is designed to narrow current gaps in assessment over time through a process of continuous improvement stages.

The process by which this will be implemented comprises four parallel, but linked activities:

1) a comprehensive review of the Reference List of Stocks used to compute the indicator, with inclusion of additional stocks to increase its coverage and representation of global fisheries;
2) improvements in the process for collation of data and information;
3) improvement in the process for classification of the stocks covered using a tiered approach that reflects the quality of available information; and
4) improvements in the process for FAO's reporting on the results of the analysis at regional and global levels.

This process will result in the following key outcomes and outputs:

1) an updated, transparent and fully documented methodology for the FAO regular reporting of the state of the global fishery resources;
2) a dedicated section on the methodology and a revised section on the *State of World Fishery Resources* using the new methodology included in the 2024 edition of *The State of Fisheries and Aquaculture* (SOFIA);
3) a new edition of the FAO fisheries technical paper on "The State of the World Fishery Resources", applying the updated methodology, available for launching by 2025;
4) a coordinated and sustainable framework for collecting and processing information for the FAO State of Resources report and for SDG 14.4.1 monitoring;
5) a capacity-building programme that reinforces the capacity of fisheries institutions of Member Nations for collecting, managing and processing data and information for assessing and reporting on the state of fisheries and fish stocks; and
6) a clear and transparent system documenting all data and information used, as well as the justifications for the classifications obtained, that will facilitate peer review and auditing.

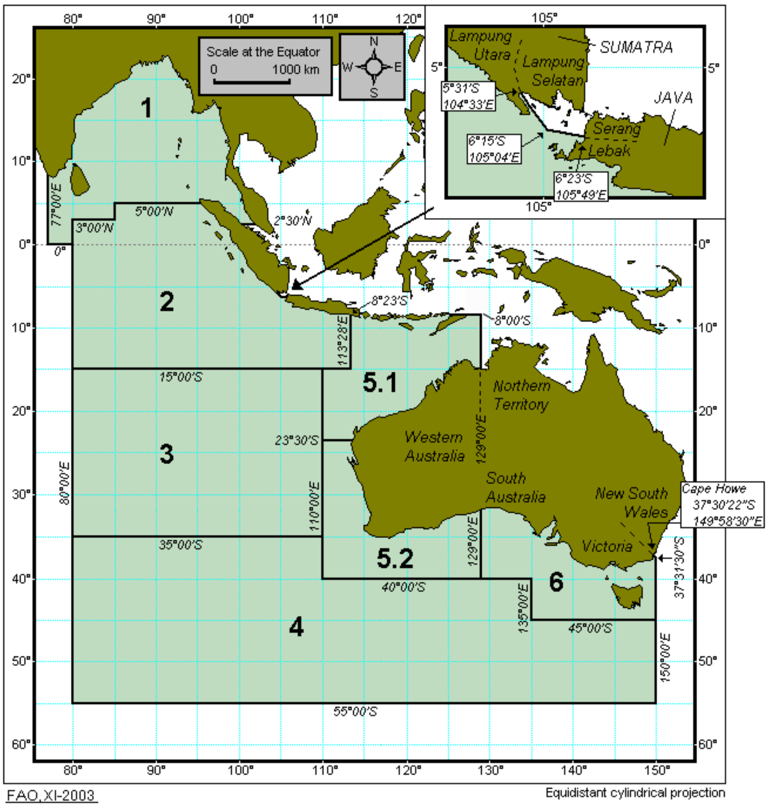
As part of the piloting activities FAO has developed "proof of concept" reports for the updated analysis that has been completed in two Major Fishing Areas (Area 37 and Area 31). FAO has also developed the new index generated from Major Fishing Area 57 in the Eastern Indian Ocean (Table 3.1, Figure 3.1).

Table 3.1. The six subareas of FAO Fishing Area 57, with two additional divisions in Western Australia

Subarea		Description
Bay of Bengal	Subarea 57.1	Includes eastern waters of Bangladesh, India, Malaysia (west coast of western peninsular), Myanmar, Sri Lanka, Thailand (west coast)
Northern	Subarea 57.2	Includes waters of western and southern Indonesia
Central	Subarea 57.3	Open ocean area without coasts
Oceanic	Subarea 57.4	Open ocean area without coasts
Western Australia	Subarea 57.5	Northwest Australia (Division 57.5.1) Southwest Australia (Division 57.5.2)
Southern Australia	Subarea 57.6	

Source: FAO. 2023. INDIAN OCEAN, EASTERN (Major Fishing Area 57). Fisheries and Aquaculture Division [online]. Rome.

Figure 3.1. Area 57 and its subareas covered for the new SOFIA state of stocks in the region



Source: FAO. 2023. INDIAN OCEAN, EASTERN (Major Fishing Area 57). Fisheries and Aquaculture Division [online]. Rome.

3.2 Fish stock classification approach

A standardized approach for the classification of stocks into the alternative categories of State of Exploitation will be defined and clearly communicated. Three tiers that define the level of quality and availability of data and information will be used to make decisions on the methodology used to derive stock status (Table 3.2).

Tier 1: "Traditional" stock assessments are available and deemed reliable. The status for stocks in this tier will be derived directly from the national or regional assessments.

Tier 2: No formal and reliable stock assessments are available, but catch data, accompanied by good quality and adequate supplementary information that can be used to infer stock status, are available. The status for stocks in this tier will be inferred by surplus production-type models.

Tier 3: Amount, detail and/or quality of data are insufficient for either Tier 1 or Tier 2 approaches. The status for stocks in this tier will be categorized by applying a "weight-of-evidence approach" (WoE)[1] coupled with a rigorous peer-review process. No stocks in Area 57 used this approach.

1 The WoE approach is a high level approach to support evidence-based decision-making. For a proposal of a simple use in fisheries assessment, see Stobutzki *et al.* (2015).

The stocks will be classified into one of the tiers using a clear decision matrix, and the process will be carried out in a well-documented transparent framework, allowing for full transparency of choices and assumptions, peer review and future revisions.

Table 3.2. Description of the stock assessment tiers according to the assessment method used and its related level of confidence.

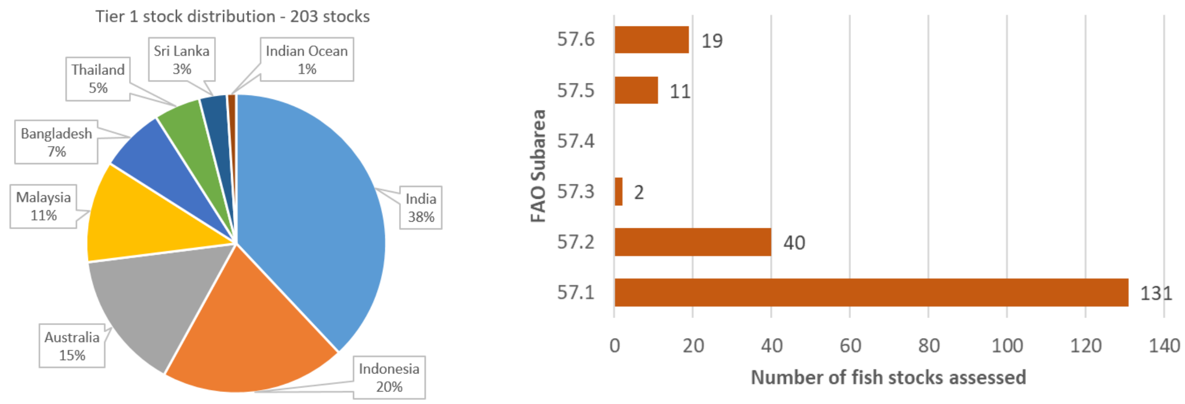
Stock tier	Description	Confidence level of assessment
Tier 1	Formal country-based stock assessments using analytical models published in peer-reviewed journals or country reports.	High – medium
Tier 2	Stock assessments based on catch with effort data using the surplus production model "sraplus".	Medium – low
Tier 3	Qualitative assessments based on the WoE. **Note:** this was not done in Area 57, however, 11 stocks using the catch at maximum sustainable yield (CMSY) package were put in this category as they had very few years of data.	Medium to low based on the fit of the data

Source: Authors' own elaborations.

3.3 Improvements in coverage of Tier 1 stocks

In late 2021, recent formal assessments of 134 Tier 1 stocks were collated from Area 57 and this was expanded by the outputs of the work by Jaya *et al.* (2022) from Indonesian waters. Based on assessments made for 9 aggregate species/groups and reported separately for 4 fishery management areas (FMAs) which are part of Area 57, 36 additional stocks were assessed by the authors. Besides, 33 fish stocks from Sri Lanka (5), Malaysia (west coast – 23) and Thailand (11) were added after the FAO Regional Assessment Workshop in January 2023 making a total of 203 fish stocks in Tier 1[2] (Figure 3.2).

Figure 3.2. Distribution of assessed stocks by country and numbers of stocks assessed by subareas of Area 57 (South and Southeast Asia and Western Australia)



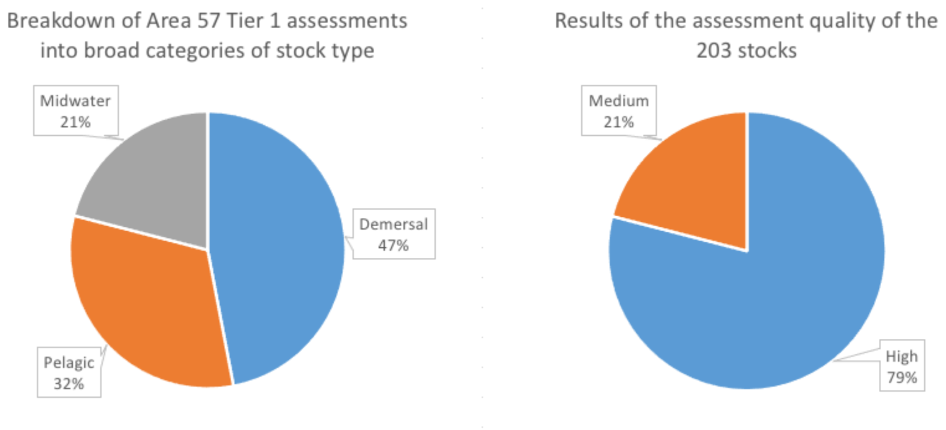
Source: Authors' own elaborations.

2 A complete listing of Tier 1 stocks and reference points is given in Appendix A3.2.

The number of stocks assessed in subarea 57.1 was high in Bangladesh, India, Malaysia and Thailand and moderate in Australia (subarea 57.5 and subarea 57.6) and Indonesia (subarea 57.2). The open ocean subarea 57.3 reported two Indian Ocean stock assessments and subarea 57.4 did not report any stock assessments. Reports of stock assessments from Myanmar were not available.

The quality of the assessments was judged by the method used and the available detailed information reported by the authors. The assessment quality was high for 79 percent of the 203 fish stocks and medium for 21 percent of the stocks. There were no low quality assessments. Demersal fish stocks accounted for 47 percent of the assessments, while pelagic and midwater fish stocks accounted for 32 percent and 21 percent respectively (Figure 3.3).

Figure 3.3. Percentage breakdown of the 203 Tier 1 assessments into broad categories of stock type and the quality of those assessments. Tier 1 assessment comprised formal country-based stock assessments using analytical models published in peer-reviewed journals or country reports



Source: Authors' own elaborations.

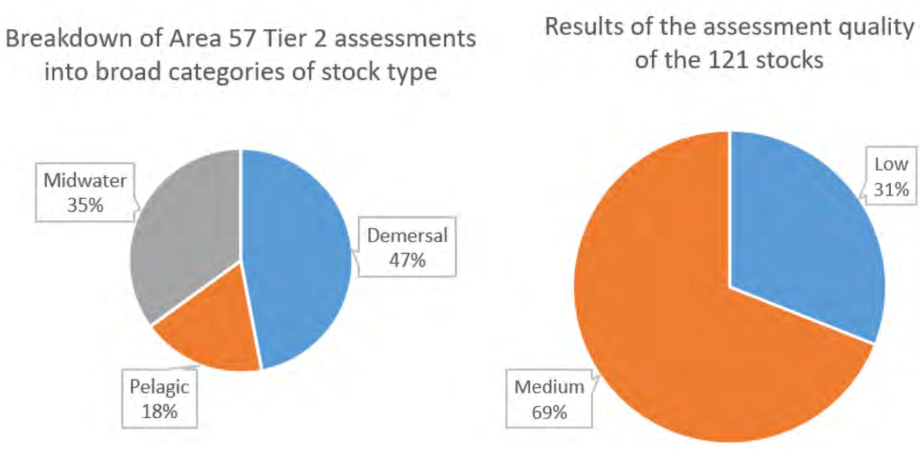
3.4 Improvements in Tier 2 stock assessments

Kimura and Tagart (1982) and Kimura, Balsiger and Ito (1984) used a surplus production approach, combining a biomass dynamics model with various data sources (e.g. priors on recent stock status or an index of abundance or effort) in order to produce estimates of the state of a fishery over time.

The Tier 2 fish stocks are those that have been assessed using the stock reduction analysis (SRA) approach in the R package "sraplus"[3] (Ovando *et al.,* 2021; Sharma *et al.,* 2021), which allows users to extend the traditional catch only models. These Tier 2 stocks are the 121 stocks which were earlier placed in Tier 3, based on the FAO catch-rule method (Figure 3.4). This group also included 33 stocks which have been historically monitored by FAO.

3 A complete listing of Tier 2 assessments is given in Appendix A3.3.

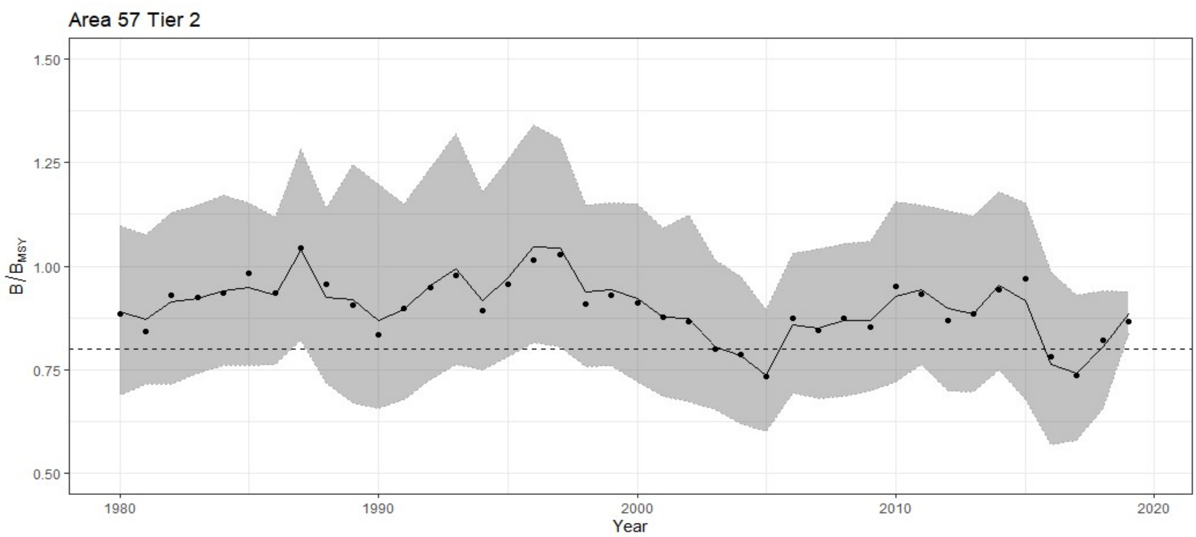
Figure 3.4. Percentage breakdown of the 121 Tier 2 assessments into broad categories of stock type and evaluation of the assessment quality of the 121 stocks



Source: Authors' own elaborations.

As part of piloting activities, FAO has developed proof of concept reports for the updated analysis that has been completed in two fishing areas (Area 37 and Area 31). FAO has also demonstrated the new index generated from Area 57. The results for the new analysis for each group of stocks are shown for the Tier 2 analysis in Figure 3.5.

Figure 3.5 Stock Status of all Tier 2 stocks examined (smoothed with uncertainty bands showing upper and lower confidence intervals) using FAO's updated approach. The status is expressed as the ratio of the biomass in any year to the biomass that achieves MSY (B/Bmsy) for selected stocks since 1980. This dashed line is 0.8Bmsy, the threshold that FAO uses as a reference point for overfishing.



Source: FAO FishStatJ (2020)

This analysis has added 88 new stocks from FishStatJ (Figure 3.5) to the existing 33 stocks which were previously used to inform the Area 57 assessment. The new index is shown in Table 3.3, showing how the coverage of stocks has increased from 39 aggregated stocks (previous analysis) to 203 finer resolution stocks (Tier 1), together with 121 aggregated stocks (Tier 2) and 11 stocks assessed with CMSY (Tier 3)[4] giving a total of 335 stocks.[5]

Table 3.3. The number of stocks used in the new index in Area 57 and their classification versus the SOFIA of 2022 index

Final categorization for Area 57	Underfished	Fully/ sustainably fished	Overfished	Total number of stocks
		Previous SOFIA		
2022 status (total number of stocks monitored in the current SOFIA)	**5.1%**	**64.1%**	**30.8%**	**39**
		Updated approach		
Tier 1 (stocks now assessed at a higher level of disaggregation)	39%	28%	33%	203
Tier 2 (aggregated stocks previously monitored)	0%	91%	9%	33
Tier 2 (additional aggregated stocks)	1%	91%	8%	88
Tier 3 (CMSY) Andaman Islands	82%	18%	0%	11
Total number of stocks assessed	**89**	**169**	**77**	**335**

Source: Authors' own elaborations.

3.5 Summary of the analysis

The overall analysis that gives individual stocks more weight than the aggregate stocks, suggests that the new overfished component for Area 57 is around 28 percent, as opposed to 31 percent in the SOFIA of 2022 (Table 3.4).

The overall index based on the new SOFIA analysis compared to the index previously used in the current SOFIA 2022 is shown in Figure 3.6. The analysis concluded that as more stocks were included, the proportions of overfishing did not change significantly. However, the distribution of underfished and maximally sustainably fished stocks changed significantly from 5 percent and 64 percent to 32 percent and 40 percent, respectively. This was because the additional disaggregated stocks that were added were previously assessed as underfished in the region, but represented relatively small proportions of the total catch.

It should be noted that the biases which are produced by adding these underfished components to the overall index need to be examined further. The overall message however is that aggregation of the stocks into "sustainably and unsustainably fished" results in a similar overall outcome for Area 57, compared with the previous SOFIA analysis based on the 39 aggregated stocks.

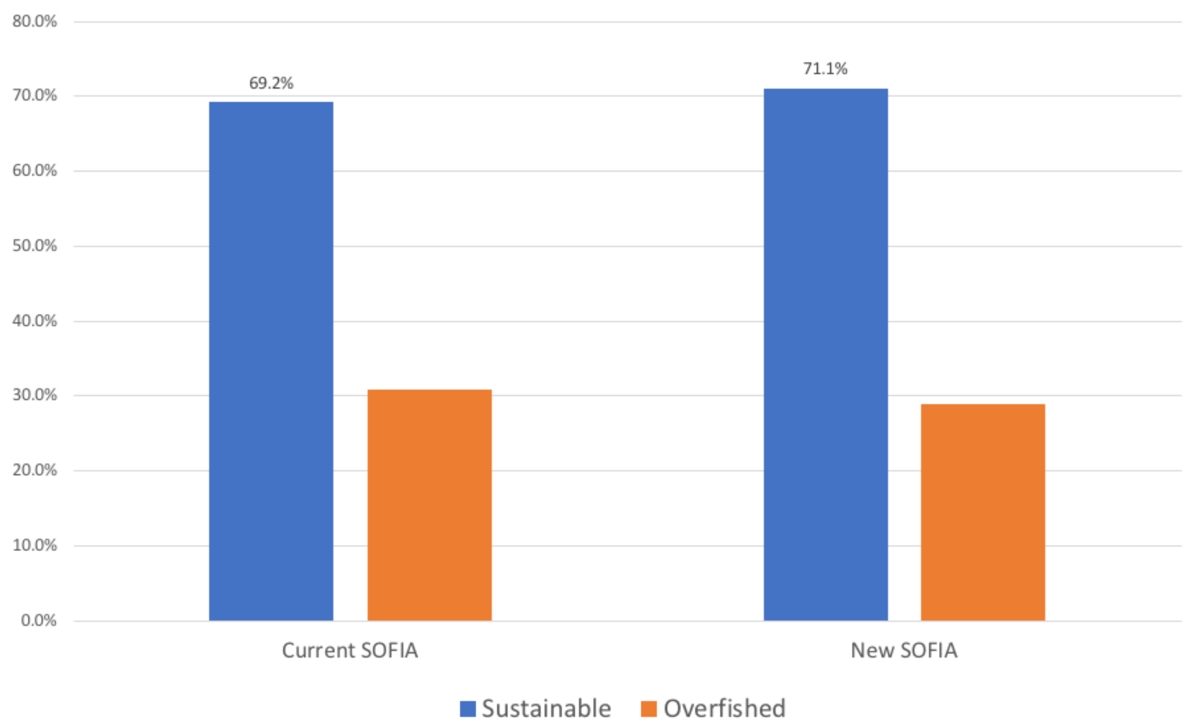
4 A complete listing of Tier 3 assessments is given in Appendix A3.4.
5 The results of the Tier 1, Tier 2 and Tier 3 analyses are provided in Appendix A3.1.

Table 3.4. Comparison of status of stocks in Area 57 summarized in the SOFIA of 2022 assessment and the new assessment, with increased number of stocks and higher resolution. The new assessment of Area 57 shows assessments from unweighted analyses and analyses weighted by biomass of the stocks

Original Area 57 assessment	**Number of stocks**	**Sustainably fished (%)**	**Overfished (%)**
2022 status (SOFIA)	39	69.2	30.8
New assessment of Area 57	**Number of stocks**	**Sustainably fished (%)**	**Overfished (%)**
Unweighted	335	77.0	23.0
Weighted	335	71.1	28.9

Source: Authors' own elaborations.

Figure 3.6. Comparison of the classification of fished stocks (sustainable or overfished) used in the current SOFIA method (FAO, 2022), with the new approach (New SOFIA).



Source: Authors' own elaborations.

References

FAO. 2011. *Review of the state of world marine fishery resources.* Fisheries and Aquaculture Technical Paper No. 569. Rome, FAO. https://www.fao.org/3/i2389e/i2389e00.htm

Gulland, J.A. 1971. *The fish resources of the ocean.* West Byfleet, UK, Fishing News Books. 255 pp.

Jaya, I., Satria, F., Wudianto *et al.* 2022. Are the working principles of fisheries management at work in Indonesia? *Marine Policy,* 140. https://doi.org/10.1016/j.marpol.2022.105047

Kimura, D.K. & Tagart, J.V. 1982. Stock reduction analysis, another solution to the catch equations. *Canadian Journal of Fisheries and Aquatic Sciences,* 39: 1467–1472.

Kimura, D.K., Balsiger, J.W. & Ito, D.H. 1984. Generalized stock reduction analysis. *Canadian Journal of Fisheries and Aquatic Sciences,* 41: 1325–1333.

Mohamed, K. S., Sathianandan, T. V. and Padua, S. 2018. Integrated spatial management of marine fisheries of India for more robust stock assessments and moving towards a quota system. Marine Fisheries Information Service; Technical and Extension Series (236). pp. 7-15. ISSN 0254-380 X. http://eprints.cmfri.org.in/13929/

Ovando, D., Hilborn, R., Monnahan, C., Rudd, M., Sharma, R., Thorson, J.T., Rousseau, Y. & Ye, Y. 2021. Improving estimates of the state of global fisheries depends on better data. *Fish and Fisheries*, 22(6): 1377–1391.

Sathianandan, T.V., Mohamed, K.S., Jayasankar, J., Kuriakose, S., Mini, K.G., Varghese, E., Zacharia, P.U., Kaladharan, P., Najmudeen, T.M., Koya, M.K. and Sasikumar, G., 2021. Status of Indian marine fish stocks: modelling stock biomass dynamics in multigear fisheries. *ICES Journal of Marine Science*, *78*(5), pp.1744-1757.

Sharma, R., Winker, H., Levontin, P., Kell, L., Ovando, D., Palomares, M.L.D., Pinto, C. & Ye, Y. 2021. Assessing the potential of catch-only models to inform on the state of global fisheries and the UN's SDGs. *Sustainability*, 13: 6101. https://doi.org/10.3390/su13116101

Stobutzki, I., Larcombe, J., Woodhams, J. & Patterson, H. 2015. *Stock status determination: weight- of-evidence decision-making framework.* Reducing Uncertainty in Stock Taking (RUSS) project. Canberra, Australia, Australian Bureau of Agricultural and Resource Economics. https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1027248/12

Appendices

Appendix A3.1. The number of Tier 1, Tier 2 and Tier 3 stocks classified by their status using the new approach and the influence of weighting on the assessment

Final categorization of Area 57	Number of stocks				Unweighted		Weighted		
	Underfished	Fully fished	Over fished	Total	Sustainably fished	Unsustainably fished	Weight applied	Sustainably fished	Unsustainably fished
Tier 1 stocks	80	56	67	203	136	67	2	272	134
Tier 2 Monitored FAO sraplus with priors	0	30	3	33	30	3	1	30	3
Tier 2 >70 years FAO data sraplus with priors	0	29	3	32	29	3	0.5	14.5	1.5
Tier 2 >50–69 years FAO data sraplus with priors	0	23	3	26	23	3	0.5	11.5	1.5
Tier 2 >25–49 years FAO data sraplus with priors	1	28	1	30	29	1	0.5	14.5	0.5
Tier 3 CMSY Andamans	9	2	0	11	11	0	0.25	3.75	0
Total	90	168	77	**335**	258	77		335.25	140.5
Percentage	**26.9**	**50.2**	**23.0**	**100**	**77.0**	**23.0**		**71.1**	**28.9**

Appendix A3.2. Tier 1 fish stock status for Area 57 in 2022

Tier 1 Stocks Area 57				Formal Country Assessments		Latest value Ref Point		Reference
No	**Sp. group**	**Sub-Area**	**Country**	**Name**	**Reference Point**	**B/BMSY Other**	**Stock status**	
1	76	57.1	Sri Lanka	Sea cucumber	Pop numbers	25% fished/yr	Overfished	Dalpathadu, 2021
2	35	57.1	Sri Lanka	Spotted sardinella	Bmsy Fmsy	0.150	Overfished	Haputhantri & Sharma, 2021
3	35	57.1	Sri Lanka	Gold striped sardinella	Bmsy Fmsy	0.840	Recovering	Haputhantri & Sharma, 2022
4	45	57.1	Sri Lanka	Spiny lobster	SPR%	0.200	Overfished	Liyanage & Sharma, 2021
5	45	57.1	Sri Lanka	Blue swimming crab	SPR%	0.370	Sustainable	Prince *et al*., 2020
6	35	57.1	India	Anchovies	Bmsy Fmsy	0.702	Recovering	Sathianandan *et al*., 2021
7	37	57.1	India	Barracudas	Bmsy Fmsy	1.542	Sustainable	Sathianandan *et al*., 2021
8	37	57.1	India	Sawtooth barracuda	Exp Ratio	0.180	Sustainable	Ghosh *et al*., 2021
9	37	57.1	India	Black pomfret	Bmsy Fmsy	1.394	Sustainable	Sathianandan *et al*., 2021
10	33	57.1	India	Bombay duck	Bmsy Fmsy	0.348	Overfished	Sathianandan *et al*., 2021
11	33	57.1	Bangladesh	Catfishes	F-ratio	2.100	Overfished	Fanning *et al*., 2019
12	33	57.1	India	Catfishes	Bmsy Fmsy	0.367	Overfished	Sathianandan *et al*., 2021
13	33	57.1	Bangladesh	Bombay duck	F-ratio	3.500	Overfished	Fanning *et al*., 2019
14	57	57.1	India	Cephalopods aggregate	Bmsy Fmsy	0.646	Overfished	Sathianandan *et al*., 2021
15	57	57.1	India	Indian Squid	Exp Ratio	0.623	Overfished	Chhandaprajnadarsini *et al*., 2021
16	42	57.1	India	Crabs aggregate	Bmsy Fmsy	0.431	Overfished	Sathianandan *et al*., 2021
17	42	57.1	India	Blue swimming crab	Bmsy Fmsy	0.790	Recovering	Josileen *et al*., 2019
18	33	57.1	India	Croakers	Bmsy Fmsy	1.054	Sustainable	Sathianandan *et al*., 2021
19	33	57.1	India	Croakers	Bmsy Fmsy	0.276	Recovering	Sathianandan *et al*., 2021
20	33	57.1	India	Croakers	Bmsy Fmsy	1.139	Sustainable	Sathianandan *et al*., 2021
21	33	57.1	Bangladesh	Indian threadfin	F-ratio	8.500	Overfished	Fanning *et al*., 2019
22	33	57.1	Bangladesh	Lesser tiger tooth croaker	F-ratio	6.000	Overfished	Fanning *et al*., 2019
23	33	57.1	Bangladesh	Donkey croaker	F-ratio	0.800	Recovering	Fanning *et al*., 2019
24	36	57.1	India	Frigate & Bullet tuna	Bmsy Fmsy	0.266	Overfished	Sathianandan *et al*., 2021
25	33	57.1	India	Goatfishes	Bmsy Fmsy	0.731	Recovering	Sathianandan *et al*., 2021
26	33	57.1	India	Goatfishes	Bmsy Fmsy	0.805	Overfished	Sathianandan *et al*., 2021
27	33	57.1	India	Goatfishes	Bmsy Fmsy	0.186	Overfished	Sathianandan *et al*., 2021
28	35	57.1	India	Grenadier anchovy	Bmsy Fmsy	1.542	Sustainable	Sathianandan *et al*., 2021
29	35	57.1	India	Grenadier anchovy	Bmsy Fmsy	1.172	Sustainable	Sathianandan *et al*., 2021
30	35	57.1	India	Hairfin anchovy	Bmsy Fmsy	1.382	Sustainable	Sathianandan *et al*., 2021
31	24	57.1	India	Hilsa shad	Bmsy Fmsy	0.210	Overfished	Das *et al*., 2019; Sathianandan *et al*., 2021; Dutta *et al*., 2021
32	24	57.1	Bangladesh	Hilsa shad	B/Bmsy	0.961	Overfishing	Alam *et al*., 2021; Dutta *et al*., 2021; Rahaman *et al*., 2018
33	37	57.1	India	Horse mackerel	Bmsy Fmsy	0.376	Overfished	Sathianandan *et al*., 2021
34	37	57.1	India	Horse mackerel	Bmsy Fmsy	0.056	Overfished	Sathianandan *et al*., 2021

Tier 1 Stocks Area 57				Formal Country Assessments		Latest value Ref Point		Reference
No	Sp. group	Sub-Area	Country	Name	Reference Point	B/BMSY Other	Stock status	
35	37	57.1	India	Indian mackerel	Bmsy Fmsy	0.524	Overfished	Sathianandan *et al*., 2021
36	37	57.1	India	Indian mackerel	Bmsy Fmsy	0.859	Overfishing	Sathianandan *et al*., 2021
37	33	57.1	India	Leatherjacket filefish	Bmsy Fmsy	0.953	Recovering	Sathianandan *et al*., 2021
38	36	57.1	India	Little tunny	Bmsy Fmsy	0.353	Recovering	Sathianandan *et al*., 2021
39	36	57.1	India	Little tunny	Bmsy Fmsy	0.570	Recovering	Sathianandan *et al*., 2021
40	33	57.1	India	Lizardfishes	Bmsy Fmsy	0.607	Recovering	Sathianandan *et al*., 2021
41	33	57.1	India	Lizardfishes	Bmsy Fmsy	0.246	Overfished	Sathianandan *et al*., 2021
42	45	57.1	India	Non-penaeid prawns	Bmsy Fmsy	0.273	Overfished	Sathianandan *et al*., 2021
43	45	57.1	India	Non-penaeid prawns	Bmsy Fmsy	0.866	Recovering	Sathianandan *et al*., 2021
44	45	57.1	India	Non-penaeid prawns	Bmsy Fmsy	1.061	Sustainable	Sathianandan *et al*., 2021
45	35	57.1	India	Oil sardine	Bmsy Fmsy	0.748	Recovering	Sathianandan *et al*., 2021
46	37	57.1	India	Carangids	Bmsy Fmsy	1.111	Sustainable	Sathianandan *et al*., 2021
47	37	57.1	India	Carangids	Bmsy Fmsy	1.092	Sustainable	Sathianandan *et al*., 2021
48	35	57.1	India	Clupeids	Bmsy Fmsy	0.169	Overfished	Sathianandan *et al*., 2021
49	35	57.1	India	Clupeids	Bmsy Fmsy	1.091	Sustainable	Sathianandan *et al*., 2021
50	35	57.1	Bangladesh	Clupeids	F-ratio	1.500	Overfished	Fanning *et al*., 2019
51	35	57.1	Bangladesh	Clupeids	Bmsy Fmsy	0.700	Overfished	Barman *et al*., 2021
52	35	57.1	Bangladesh	Rainbow sardine	F-ratio/ Bmsy Fmsy	1.600	Sustainable	Fanning *et al*., 2019; Barman *et al*., 2021
53	35	57.1	Bangladesh	Slender Rainbow sardine	Bmsy Fmsy	1.700	Sustainable	Barman *et al*., 2021
54	33	57.1	India	Perches	Bmsy Fmsy	0.985	Sustainable	Sathianandan *et al*., 2021
55	33	57.1	India	Perches	Bmsy Fmsy	0.492	Overfished	Sathianandan *et al*., 2021
56	33	57.1	India	Perches	Bmsy Fmsy	0.717	Recovering	Sathianandan *et al*., 2021
57	35	57.1	India	Sardines	Bmsy Fmsy	0.623	Recovering	Sathianandan *et al*., 2021
58	35	57.1	India	Sardines	Bmsy Fmsy	0.624	Overfished	Sathianandan *et al*., 2021
59	45	57.1	India	Penaeid prawns	Bmsy Fmsy	0.239	Overfished	Sathianandan *et al*., 2021
60	45	57.1	India	Penaeid prawns	Bmsy Fmsy	0.252	Recovering	Sathianandan *et al*., 2021
61	45	57.1	India	Penaeid prawns	Bmsy Fmsy	0.222	Overfished	Sathianandan *et al*., 2021
62	45	57.1	India	Penaeid prawns	Bmsy Fmsy	1.056	Sustainable	Sathianandan *et al*., 2021
63	45	57.1	India	Penaeid prawns	Bmsy Fmsy	0.157	Overfished	Sathianandan *et al*., 2021
64	45	57.1	Bangladesh	Brown shrimp	F-ratio	1.200	Overfished	Fanning *et al*., 2019
65	45	57.1	Bangladesh	Tiger shrimp	Bmsy Fmsy	0.530	Recovering	Barua *et al*., 2020
66	33	57.1	India	Pig-face breams	Bmsy Fmsy	0.667	Recovering	Sathianandan *et al*., 2021
67	38	57.1	India	Rays	Bmsy Fmsy	1.003	Sustainable	Sathianandan *et al*., 2021
68	38	57.1	India	Rays	Bmsy Fmsy	1.154	Recovering	Sathianandan *et al*., 2021
69	38	57.1	India	Rays	Bmsy Fmsy	1.281	Sustainable	Sathianandan *et al*., 2021
70	38	57.1	India	Rays	Bmsy Fmsy	0.407	Overfished	Sathianandan *et al*., 2021
71	37	57.1	India	Ribbonfishes	Bmsy Fmsy	0.527	Recovering	Sathianandan *et al*., 2021
72	37	57.1	India	Ribbonfishes	Bmsy Fmsy	1.137	Sustainable	Sathianandan *et al*., 2021
73	33	57.1	India	Rock cod	Bmsy Fmsy	0.812	Recovering	Sathianandan *et al*., 2021
74	37	57.1	India	Scads	Bmsy Fmsy	1.559	Sustainable	Sathianandan *et al*., 2021
75	37	57.1	India	Scads	Bmsy Fmsy	0.143	Recovering	Sathianandan *et al*., 2021
76	36	57.1	India	Spanish mackerel	Bmsy Fmsy	0.916	Sustainable	Sathianandan *et al*., 2021

Tier 1 Stocks Area 57				Formal Country Assessments		Latest value Ref Point		Reference
No	**Sp. group**	**Sub-Area**	**Country**	**Name**	**Reference Point**	**B/BMSY Other**	**Stock status**	
77	36	57.1	India	Spanish mackerel	Bmsy Fmsy	1.562	Sustainable	Sathianandan *et al*., 2021
78	36	57.1	Indian Ocean	Spanish mackerel	Bmsy Fmsy	0.960	Overfishing	IOTC, 2015
79	38	57.1	India	Sharks	Bmsy Fmsy	0.722	Recovering	Sathianandan *et al*., 2021
80	38	57.1	India	Sharks	Bmsy Fmsy	1.792	Sustainable	Sathianandan *et al*., 2021
81	38	57.1	India	Sharks	Bmsy Fmsy	1.535	Sustainable	Sathianandan *et al*., 2021
82	38	57.1	India	Sharks	Bmsy Fmsy	1.513	Sustainable	Sathianandan *et al*., 2021
83	37	57.1	India	Silver pomfrets	Bmsy Fmsy	0.611	Recovering	Sathianandan *et al*., 2021
84	37	57.1	India	Silver pomfrets	Bmsy Fmsy	0.597	Recovering	Sathianandan *et al*., 2021
85	37	57.1	Bangladesh	Silver pomfrets	F-ratio	1.300	Overfished	Fanning *et al*., 2019
86	37	57.1	Bangladesh	Chinese pomfrets	F-ratio	0.450	Sustainable	Fanning *et al*., 2019
87	33	57.1	India	Silverbellies	Bmsy Fmsy	0.594	Recovering	Sathianandan *et al*., 2021
88	36	57.1	India	Skipjack tuna	Bmsy Fmsy	0.211	Overfished	Sathianandan *et al*., 2021
89	36	57.1	Indian Ocean	Yellowfin tuna	Bmsy Fmsy	0.830	Overfished	IOTC, 2020
90	31	57.1	India	Soles	Bmsy Fmsy	0.172	Overfished	Sathianandan *et al*., 2021
91	31	57.1	India	Soles	Bmsy Fmsy	0.650	Recovering	Sathianandan *et al*., 2021
92	31	57.1	India	Soles	Bmsy Fmsy	0.910	Recovering	Sathianandan *et al*., 2021
93	36	57.1	India	Spotted seerfish	Bmsy Fmsy	0.822	Sustainable	Sathianandan *et al*., 2021
94	36	57.1	India	Spotted seerfish	Bmsy Fmsy	0.460	Overfished	Sathianandan *et al*., 2021
95	33	57.1	India	Threadfin breams	Bmsy Fmsy	0.418	Overfished	Sathianandan *et al*., 2021
96	33	57.1	India	Threadfins	Bmsy Fmsy	1.480	Sustainable	Sathianandan *et al*., 2021
97	35	57.1	India	Other anchovies	Bmsy Fmsy	0.458	Overfished	Sathianandan *et al*., 2021
98	35	57.1	India	Other anchovies	Bmsy Fmsy	1.013	Sustainable	Sathianandan *et al*., 2021
99	35	57.1	India	Wolf herring	Bmsy Fmsy	1.213	Sustainable	Sathianandan *et al*., 2021
100	33	57.1	Thailand	Purple-Spotted Bigeye	F-factor	1.500	Not fully exploited	Nootmorn, 2021
101	33	57.1	Thailand	Delagoa Threadfin Bream	F-factor	0.900	Fully exploited	Nootmorn, 2021
102	33	57.1	Thailand	Slender Lizardfish	F-factor	1.400	Not fully exploited	Nootmorn, 2021
103	33	57.1	Thailand	Brushtooth Lizardfish	F-factor	0.900	Fully exploited	Nootmorn, 2021
104	45	57.1	Thailand	Banana Prawn	F-factor	1.200	Fully exploited	Nootmorn, 2021
105	45	57.1	Thailand	Blue Swimming Crab	F-factor	2.500	Not fully exploited	Nootmorn, 2021
106	57	57.1	Thailand	Indian Squid	F-factor	0.800	Fully exploited	Nootmorn, 2021
107	35	57.1	Thailand	Anchovy	F-factor	1.300	Not fully exploited	Nootmorn, 2021
108	37	57.1	Thailand	Short Mackerel	F-factor	2.000	Not fully exploited	Nootmorn, 2021
109	37	57.1	Thailand	Indian Mackerel	F-factor	0.600	Overfished	Nootmorn, 2021
110	35	57.1	Thailand	Goldstripe Sardinella	F-factor	1.700	Not fully exploited	Nootmorn, 2021
111	35	57.1	Peninsular Malaysia	Anchovies	Bmsy Fmsy	1.776	Not fully exploited	Jamon *et al*., 2022
112	33	57.1	Peninsular Malaysia	Lizard fish	Bmsy Fmsy	0.331	Overfished	Jamon *et al*., 2022

Tier 1 Stocks Area 57				Formal Country Assessments		Latest value Ref Point		Reference
No	Sp. group	Sub-Area	Country	Name	Reference Point	B/BMSY Other	Stock status	
113	37	57.1	Peninsular Malaysia	Indian mackerel	Bmsy Fmsy	1.692	Not fully exploited	Jamon *et al*., 2022
114	33	57.1	Peninsular Malaysia	Threadfin bream	Bmsy Fmsy	0.918	Overfished	Jamon *et al*., 2022
115	37	57.1	Peninsular Malaysia	Oxeye scad	Bmsy Fmsy	0.575	Overfished	Jamon *et al*., 2022
116	37	57.1	Peninsular Malaysia	Short mackerel	Bmsy Fmsy	1.573	Not fully exploited	Jamon *et al*., 2022
117	33	57.1	Peninsular Malaysia	Fourfinger threadfin	Bmsy Fmsy	0.932	Overfished	Jamon *et al*., 2022
118	35	57.1	Peninsular Malaysia	Sardine	Bmsy Fmsy	1.026	Overfishing	Jamon *et al*., 2022
119	36	57.1	Peninsular Malaysia	Narrow barred Spanish mackerel	Bmsy Fmsy	0.263	Overfished	Jamon *et al*., 2022
120	36	57.1	Peninsular Malaysia	Indo-Pacific King mackerel	Bmsy Fmsy	0.835	Overfished	Jamon *et al*., 2022
121	33	57.1	Peninsular Malaysia	Gray eel catfish	Bmsy Fmsy	1.472	Not fully exploited	Jamon *et al*., 2022
122	45	57.1	Peninsular Malaysia	Paste shrimp	Bmsy Fmsy	0.998	Overfished	Jamon *et al*., 2022
123	36	57.1	Peninsular Malaysia	Kawakawa	Bmsy Fmsy	0.980	Recovering	Jamon *et al*., 2022
124	37	57.1	Peninsular Malaysia	Torpedo scad	Bmsy Fmsy	0.804	Overfished	Jamon *et al*., 2022
125	33	57.1	Peninsular Malaysia	Croaker	Bmsy Fmsy	0.684	Overfished	Jamon *et al*., 2022
126	33	57.1	Peninsular Malaysia	Soldier catfish	Bmsy Fmsy	0.418	Overfished	Jamon *et al*., 2022
127	33	57.1	Peninsular Malaysia	Groupers	Bmsy Fmsy	0.300	Overfished	Jamon *et al*., 2022
128	33	57.1	Peninsular Malaysia	Goatfish	Bmsy Fmsy	1.708	Not fully exploited	Jamon *et al*., 2022
129	57	57.1	Peninsular Malaysia	Squid	Bmsy Fmsy	1.583	Not fully exploited	Jamon *et al*., 2022
130	33	57.1	Peninsular Malaysia	Red snapper	Bmsy Fmsy	1.312	Not fully exploited	Jamon *et al*., 2022
131	45	57.1	Peninsular Malaysia	Crabs	Bmsy Fmsy	0.221	Overfished	Jamon *et al*., 2022
132	45	57.1	Peninsular Malaysia	Prawns	Bmsy Fmsy	1.474	Not fully exploited	Jamon *et al*., 2022
133	33	57.1	Peninsular Malaysia	Brackishwater fish	Bmsy Fmsy	0.533	Overfished	Jamon *et al*., 2022
134	36	57.2	Indonesia	Spanish mackerel	*C/Cmsy*	0.900	Recovering	Fauziyah *et al*., 2020
135	36	57.2	Indonesia	Bullet/Frigate tuna	*C/Cmsy*	0.800	Overfishing	Fauziyah *et al*., 2020
136	37	57.2	Indonesia	Queen fish	*C/Cmsy*	1.120	Overfished	Fauziyah *et al*., 2020
137	37	57.2	Indonesia	Mackerel	*C/Cmsy*	1.200	Overfished	Fauziyah *et al*., 2020
138	35	57.1	Indonesia	Small pelagics	Exp Rate	0.830	Fully exploited	Jaya *et al*., 2021
139	36	57.1	Indonesia	Large pelagics	Exp Rate	0.520	Sustainable	Jaya *et al*., 2021
140	33	57.1	Indonesia	Demersal fish	Exp Rate	0.330	Sustainable	Jaya *et al*., 2021
141	33	57.1	Indonesia	Coral fishes	Exp Rate	0.340	Sustainable	Jaya *et al*., 2021
142	45	57.1	Indonesia	Penaeid shrimps	Exp Rate	1.590	Overfished	Jaya *et al*., 2021

Tier 1 Stocks Area 57				Formal Country Assessments		Latest value Ref Point		Reference
No	Sp. group	Sub-Area	Country	Name	Reference Point	B/BMSY Other	Stock status	
143	45	57.1	Indonesia	Lobster	Exp Rate	1.300	Overfished	Jaya *et al*., 2021
144	42	57.1	Indonesia	Crab	Exp Rate	1.000	Fully exploited	Jaya *et al*., 2021
145	42	57.1	Indonesia	Blue swimming crab	Exp Rate	0.930	Fully exploited	Jaya *et al*., 2021
146	57	57.1	Indonesia	Squids	Exp Rate	0.620	Fully exploited	Jaya *et al*., 2021
147	35	57.2	Indonesia	Small pelagics	Exp Rate	0.500	Sustainable	Jaya *et al*., 2021
148	36	57.2	Indonesia	Large pelagics	Exp Rate	0.950	Fully exploited	Jaya *et al*., 2021
149	33	57.2	Indonesia	Demersal fish	Exp Rate	0.570	Fully exploited	Jaya *et al*., 2021
150	33	57.2	Indonesia	Coral fishes	Exp Rate	0.330	Not fully exploited	Jaya *et al*., 2021
151	45	57.2	Indonesia	Penaeid shrimps	Exp Rate	1.530	Overfished	Jaya *et al*., 2021
152	45	57.2	Indonesia	Lobster	Exp Rate	0.930	Fully exploited	Jaya *et al*., 2021
153	42	57.2	Indonesia	Crab	Exp Rate	0.180	Not fully exploited	Jaya *et al*., 2021
154	42	57.2	Indonesia	Blue swimming crab	Exp Rate	0.490	Not fully exploited	Jaya *et al*., 2021
155	57	57.2	Indonesia	Squids	Exp Rate	0.390	Not fully exploited	Jaya *et al*., 2021
156	35	57.2	Indonesia	Small pelagics	Exp Rate	1.500	Overfished	Jaya *et al*., 2021
157	36	57.2	Indonesia	Large pelagics	Exp Rate	1.060	Overfished	Jaya *et al*., 2021
158	33	57.2	Indonesia	Demersal fish	Exp Rate	0.390	Not fully exploited	Jaya *et al*., 2021
159	33	57.2	Indonesia	Coral fishes	Exp Rate	1.090	Overfished	Jaya *et al*., 2021
160	45	57.2	Indonesia	Penaeid shrimps	Exp Rate	1.700	Overfished	Jaya *et al*., 2021
161	45	57.2	Indonesia	Lobster	Exp Rate	0.610	Fully exploited	Jaya *et al*., 2021
162	42	57.2	Indonesia	Crab	Exp Rate	0.280	Not fully exploited	Jaya *et al*., 2021
163	42	57.2	Indonesia	Blue swimming crab	Exp Rate	0.980	Fully exploited	Jaya *et al*., 2021
164	57	57.2	Indonesia	Squids	Exp Rate	1.110	Overfished	Jaya *et al*., 2021
165	35	57.5.1	Indonesia	Small pelagics	Exp Rate	0.510	Fully exploited	Jaya *et al*., 2021
166	36	57.5.1	Indonesia	Large pelagics	Exp Rate	0.990	Fully exploited	Jaya *et al*., 2021
167	33	57.5.1	Indonesia	Demersal fish	Exp Rate	0.670	Fully exploited	Jaya *et al*., 2021
168	33	57.5.1	Indonesia	Coral fishes	Exp Rate	1.070	Overfished	Jaya *et al*., 2021
169	45	57.5.1	Indonesia	Penaeid shrimps	Exp Rate	0.860	Fully exploited	Jaya *et al*., 2021
170	45	57.5.1	Indonesia	Lobster	Exp Rate	0.970	Fully exploited	Jaya *et al*., 2021
171	42	57.5.1	Indonesia	Crab	Exp Rate	0.850	Fully exploited	Jaya *et al*., 2021
172	42	57.5.1	Indonesia	Blue swimming crab	Exp Rate	0.770	Fully exploited	Jaya *et al*., 2021
173	57	57.5.1	Indonesia	Squids	Exp Rate	1.280	Overfished	Jaya *et al*., 2021

Tier 1 Stocks Area 57				Formal Country Assessments		Latest value Ref Point		Reference
No	Sp. group	Sub-Area	Country	Name	Reference Point	B/BMSY Other	Stock status	
174	43	57.5	Australia	Western Rock Lobster	Harvest rate %	30.000	Sustainable	de Lestang *et al*., 2016
175	43	57.5	Australia	Australian Scampi	Bmsy Fmsy	NA	Sustainable	Pattersen *et al*., 2021
176	37	57.5	Australia	Blue mackerel	LRP/TAC	NA	Sustainable	Pattersen *et al*., 2021
177	34	57.5	Australia	Bight redfish	*SSB2020/SSB0*	0.640	Sustainable	Sporcic *et al*., 2019
178	33	57.5	Australia	Deepwater flathead	*SSB2020/SSB0*	0.450	Sustainable	Tuck *et al*., 2019
179	33	57.5	Australia	Ocean jacket	Bmsy CPUE	NA	Sustainable	Pattersen *et al*., 2021
180	36	57.5	Australia	Striped marlin	SSB	NA	Overfished	Pattersen *et al*., 2021
181	36	57.5	Australia	Swordfish	Bmsy Fmsy	1.163	Sustainable	Parker 2020; Pattersen *et al*., 2021
182	36	57.5	Australia	Albacore	*F/ Fmsy*	1.346	Overfishing	IOTC, Pattersen *et al*., 2021, Marin Trust 2022
183	36	57.5	Australia	Bigeye tuna	*SB/SBmsy*	1.290	Sustainable	IOTC, Pattersen *et al*., 2021
184	36	57.5	Australia	Yellowfin tuna	SSB	0.830	Overfishing	IOTC, Pattersen *et al*., 2021
185	35	57.6	Australia	Australian Sardine	*SSBcurr/ SSBtarg*	2.030	Sustainable	Ward *et al*., 2017
186	37	57.6	Australia	Garfish	CPUE Biomass	NA	Recovering	McGarvey *et al*., 2007; Steer *et al*., 2016
187	33	57.6	Australia	King George Whiting	Age composition	NA	Sustainable	Steer *et al*., 2020
188	56	57.6	Australia	Pipi	CPUE Biomass	NA	Sustainable	Smith *et al*., 2021; Ferguson & Hooper, 2017
189	33	57.6	Australia	Snapper	Egg density	NA	Overfished	McGarvey *et al*., 2018; Steer *et al*., 2020
190	33	57.6	Australia	Snapper	Egg density	NA	Overfished	McGarvey *et al*., 2018; Steer *et al*., 2020
191	57	57.6	Australia	Southern Calamari	CPUE Biomass	NA	Sustainable	Steer *et al*., 2020
192	43	57.6	Australia	Southern Rock Lobster	CPUE Biomass	NA	Sustainable	McGarvey *et al*., 2016; Linnane *et al*., 2017
193	35	57.6	Australia	Australian Sardine	Egg density	NA	Sustainable	Ward *et al*., 2015
194	33	57.6	Australia	Banded Morwong	Age composition	>30% initSSB	Sustainable	Moore *et al*., 2018
195	55	57.6	Australia	Commercial Scallop	LRP/TAC	High biomass	Sustainable	Pattersen *et al*., 2021
196	37	57.6	Australia	Blue mackerel	LRP/TAC	NA	Sustainable	Pattersen *et al*., 2021
197	38	57.6	Australia	Elephantfish	CPUE Biomass	NA	Sustainable	Pattersen *et al*., 2021
198	38	57.6	Australia	Gummy shark	Pup production	NA	Sustainable	Pattersen *et al*., 2021
199	38	57.6	Australia	Sawshark	CPUE Biomass	>TRP	Sustainable	Pattersen *et al*., 2021
200	38	57.6	Australia	School shark	Bmsy	<0.2B0 LRP	Overfished	Pattersen *et al*., 2021
201	57	57.6	Australia	Gould's squid	CPUE Biomass	NA	Sustainable	Pattersen *et al*., 2021
202	36	57.6	Australia	Skipjack tuna	*B/Bmsy*	1.590	Sustainable	IOTC, Pattersen *et al*., 2021
203	36	57.6	Australia	Southern bluefin tuna	*F/Fmsy*	0.520	Sustainable	Pattersen *et al*., 2021

Notes: Sathianandan *et al.* (2021) assess stocks based on maritime states, which are the administrative management units in India. For demersal stocks, these may be discrete stocks due to limited movement. For pelagic stocks, the stock classification has been integrated regionally (based on Mohamed et al, 2018) and the more adverse stock status was taken as a measure of precaution.

Appendix A3.3. Tier 2 fish stock status for Area 57 in 2022

No	stock	Ref Point	year	Mean value	Status	FAO Stock Type	Quality
1	Acanthocybium solandri	*B/Bmsy*	2019	1.082	Fully fished	70+ Non Monitored	Medium
2	Alopias spp	*B/Bmsy*	2019	1.006	Fully fished	70+ Non Monitored	Medium
3	Arripis trutta	*B/Bmsy*	2019	0.611	Overfished	70+ Non Monitored	Medium
4	Auxis rochei	*B/Bmsy*	2019	0.861	Fully fished	70+ Non Monitored	Medium
5	Auxis thazard / A. rochei	*B/Bmsy*	2019	1.068	Fully fished	70+ Non Monitored	Medium
6	Chirocentrus spp	*B/Bmsy*	2019	1.114	Fully fished	70+ Non Monitored	Medium
7	Crustacea	*B/Bmsy*	2019	0.975	Fully fished	70+ Non Monitored	Medium
8	Epinephelinae	*B/Bmsy*	2019	0.909	Fully fished	70+ Non Monitored	Medium
9	Gymnocephalus cernua	*B/Bmsy*	2019	0.580	Overfished	70+ Non Monitored	Medium
10	Istiompax indica	*B/Bmsy*	2019	0.922	Fully fished	70+ Non Monitored	Medium
11	Istiophorus platypterus	*B/Bmsy*	2019	0.993	Fully fished	70+ Non Monitored	Medium
12	Lates calcarifer	*B/Bmsy*	2019	0.996	Fully fished	70+ Non Monitored	Medium
13	Leiognathus spp	*B/Bmsy*	2019	0.901	Fully fished	70+ Non Monitored	Medium
14	Lutjanidae	*B/Bmsy*	2019	1.020	Fully fished	70+ Non Monitored	Medium
15	Mollusca	*B/Bmsy*	2019	0.899	Fully fished	70+ Non Monitored	Medium
16	Muraenesox spp	*B/Bmsy*	2019	0.863	Fully fished	70+ Non Monitored	Medium
17	Pagrus auratus	*B/Bmsy*	2019	0.767	Overfished	70+ Non Monitored	Medium
18	Pectinidae	*B/Bmsy*	2019	0.853	Fully fished	70+ Non Monitored	Medium
19	Perciformes	*B/Bmsy*	2019	0.854	Fully fished	70+ Non Monitored	Medium
20	Platycephalus	*B/Bmsy*	2019	0.967	Fully fished	70+ Non Monitored	Medium
21	Pleuronectiformes	*B/Bmsy*	2019	1.029	Fully fished	70+ Non Monitored	Medium
22	Prionace glauca	*B/Bmsy*	2019	1.094	Fully fished	70+ Non Monitored	Medium
23	Rastrelliger brachysoma	*B/Bmsy*	2019	1.010	Fully fished	70+ Non Monitored	Medium
24	Sarda orientalis	*B/Bmsy*	2019	1.186	Fully fished	70+ Non Monitored	Medium
25	Sardinella gibbosa	*B/Bmsy*	2019	0.994	Fully fished	70+ Non Monitored	Medium
26	Scomberoides spp	*B/Bmsy*	2019	0.973	Fully fished	70+ Non Monitored	Medium
27	Selaroides leptolepis	*B/Bmsy*	2019	1.029	Fully fished	70+ Non Monitored	Medium
28	Sillago sihama	*B/Bmsy*	2019	0.990	Fully fished	70+ Non Monitored	Medium
29	Tetrapturus audax	*B/Bmsy*	2019	0.895	Fully fished	70+ Non Monitored	Medium
30	Thunnus obesus	*B/Bmsy*	2019	0.917	Fully fished	70+ Non Monitored	Medium
31	Thunnus tonggol	*B/Bmsy*	2019	0.926	Fully fished	70+ Non Monitored	Medium
32	Xiphia gladius	*B/Bmsy*	2019	0.909	Fully fished	70+ Non Monitored	Medium
33	Anodontostoma chacunda	*B/Bmsy*	2019	0.850	Fully fished	Current FAO Monitored	Medium
34	Ariidae	*B/Bmsy*	2019	1.083	Fully fished	Current FAO Monitored	Medium
35	Caranx spp	*B/Bmsy*	2019	0.901	Fully fished	Current FAO Monitored	Medium
36	Carcharhinus falciformis	*B/Bmsy*	2019	0.848	Fully fished	Current FAO Monitored	Medium
37	Cephalopoda	*B/Bmsy*	2019	0.860	Fully fished	Current FAO Monitored	Low
38	Clupeoidei	*B/Bmsy*	2019	1.122	Fully fished	Current FAO Monitored	Low
39	Decapterus russelli	*B/Bmsy*	2019	0.997	Fully fished	Current FAO Monitored	Medium
40	Decapterus spp	*B/Bmsy*	2019	0.952	Fully fished	Current FAO Monitored	Medium

No	stock	Ref Point	year	Mean value	Status	FAO Stock Type	Quality
41	Leiognathidae	*B/Bmsy*	2019	0.996	Fully fished	Current FAO Monitored	Medium
42	Loliginidae Ommastrephidae	*B/Bmsy*	2019	0.871	Fully fished	Current FAO Monitored	Low
43	Loligo spp	*B/Bmsy*	2019	0.936	Fully fished	Current FAO Monitored	Medium
44	Megalaspis cordyla	*B/Bmsy*	2019	1.003	Fully fished	Current FAO Monitored	Medium
45	Mugilidae	*B/Bmsy*	2019	1.050	Fully fished	Current FAO Monitored	Medium
46	Natantia	*B/Bmsy*	2019	0.879	Fully fished	Current FAO Monitored	Medium
47	Nemipterus spp	*B/Bmsy*	2019	0.958	Fully fished	Current FAO Monitored	Medium
48	Octopodidae	*B/Bmsy*	2019	0.854	Fully fished	Current FAO Monitored	Medium
49	Pellona ditchela	*B/Bmsy*	2019	0.607	Overfished	Current FAO Monitored	Low
50	Penaeus merguiensis	*B/Bmsy*	2019	1.051	Fully fished	Current FAO Monitored	Medium
51	Penaeus spp	*B/Bmsy*	2019	0.897	Fully fished	Current FAO Monitored	Medium
52	Percoidei	*B/Bmsy*	2019	0.690	Overfished	Current FAO Monitored	Medium
53	Rajiformes	*B/Bmsy*	2019	0.876	Fully fished	Current FAO Monitored	Medium
54	Rastrelliger spp	*B/Bmsy*	2019	1.178	Fully fished	Current FAO Monitored	Medium
55	Sardinella spp	*B/Bmsy*	2019	0.856	Fully fished	Current FAO Monitored	Low
56	Scomberomorus spp	*B/Bmsy*	2019	0.845	Fully fished	Current FAO Monitored	Low
57	Scombroidei	*B/Bmsy*	2019	0.865	Fully fished	Current FAO Monitored	Low
58	Sepiidae Sepiolidae	*B/Bmsy*	2019	0.979	Fully fished	Current FAO Monitored	Medium
59	Sergestidae	*B/Bmsy*	2019	0.862	Fully fished	Current FAO Monitored	Low
60	Stolephorus spp	*B/Bmsy*	2019	0.941	Fully fished	Current FAO Monitored	Medium
61	Stromateidae	*B/Bmsy*	2019	0.943	Fully fished	Current FAO Monitored	Medium
62	Tenualosa toli	*B/Bmsy*	2019	0.872	Fully fished	Current FAO Monitored	Low
63	Thyrsites atun	*B/Bmsy*	2019	0.691	Overfished	Current FAO Monitored	Medium
64	Trichiuridae	*B/Bmsy*	2019	0.842	Fully fished	Current FAO Monitored	Medium
65	Trichiurus lepturus	*B/Bmsy*	2019	0.984	Fully fished	Current FAO Monitored	Medium
66	Anadara granosa	*B/Bmsy*	2019	0.860	Fully fished	25-49 Non Monitored	Low
67	Bregmaceros mcclellandi	*B/Bmsy*	2019	0.862	Fully fished	25-49 Non Monitored	Low
68	Carcharhinus longimanus	*B/Bmsy*	2019	0.854	Fully fished	25-49 Non Monitored	Medium
69	Chelidonichthys kumu	*B/Bmsy*	2019	0.827	Fully fished	25-49 Non Monitored	Low
70	Crassostrea spp	*B/Bmsy*	2019	0.852	Fully fished	25-49 Non Monitored	Low
71	Ex Mollusca	*B/Bmsy*	2019	0.858	Fully fished	25-49 Non Monitored	Low
72	Genypterus blacodes	*B/Bmsy*	2019	0.868	Fully fished	25-49 Non Monitored	Medium
73	Hoplostethus atlanticus	*B/Bmsy*	2019	0.852	Fully fished	25-49 Non Monitored	Medium
74	Istiophoridae	*B/Bmsy*	2019	0.866	Fully fished	25-49 Non Monitored	Low
75	Isurus oxyrinchus	*B/Bmsy*	2019	0.859	Fully fished	25-49 Non Monitored	Medium
76	Macruronus novaezelandiae	*B/Bmsy*	2019	0.854	Fully fished	25-49 Non Monitored	Medium
77	Megalops cyprinoides	*B/Bmsy*	2019	0.854	Fully fished	25-49 Non Monitored	Medium
78	Meretrix spp	*B/Bmsy*	2019	0.855	Fully fished	25-49 Non Monitored	Low
79	Monacanthidae	*B/Bmsy*	2019	0.703	Overfished	25-49 Non Monitored	Low
80	Mustelus antarcticus	*B/Bmsy*	2019	0.856	Fully fished	25-49 Non Monitored	Medium
81	Paphies australis	*B/Bmsy*	2019	0.864	Fully fished	25-49 Non Monitored	Medium

No	stock	Ref Point	year	Mean value	Status	FAO Stock Type	Quality
82	Pterygotrigla polyommata	*B/Bmsy*	2019	0.898	Fully fished	25-49 Non Monitored	Medium
83	Rachycentron canadum	*B/Bmsy*	2019	0.859	Fully fished	25-49 Non Monitored	Low
84	Rexea solandri	*B/Bmsy*	2019	0.854	Fully fished	25-49 Non Monitored	Medium
85	Rhodophyta	*B/Bmsy*	2019	0.861	Fully fished	25-49 Non Monitored	Low
86	Scolopsis spp	*B/Bmsy*	2019	0.882	Fully fished	25-49 Non Monitored	Low
87	Scylla serrata	*B/Bmsy*	2019	1.047	Fully fished	25-49 Non Monitored	Low
88	Scyllaridae	*B/Bmsy*	2019	0.967	Fully fished	25-49 Non Monitored	Low
89	Seriolina nigrofasciata	*B/Bmsy*	2019	0.864	Fully fished	25-49 Non Monitored	Medium
90	Serranidae	*B/Bmsy*	2019	0.859	Fully fished	25-49 Non Monitored	Medium
91	Siganus spp	*B/Bmsy*	2019	0.861	Fully fished	25-49 Non Monitored	Medium
92	Testudinata	*B/Bmsy*	2019	0.848	Fully fished	25-49 Non Monitored	Medium
93	Thenus orientalis	*B/Bmsy*	2019	0.856	Fully fished	25-49 Non Monitored	Medium
94	Zenopsis nebulosus	*B/Bmsy*	2019	1.642	Underfished	25-49 Non Monitored	Low
95	Zeus faber	*B/Bmsy*	2019	0.879	Fully fished	25-49 Non Monitored	Medium
96	Anguilla australis	*B/Bmsy*	2019	0.863	Fully fished	50-69 Non Monitored	Medium
97	Balistidae	*B/Bmsy*	2019	0.854	Fully fished	50-69 Non Monitored	Medium
98	Bivalvia	*B/Bmsy*	2019	0.860	Fully fished	50-69 Non Monitored	Low
99	Brachyura	*B/Bmsy*	2019	0.852	Fully fished	50-69 Non Monitored	Low
100	Caesionidae	*B/Bmsy*	2019	0.975	Fully fished	50-69 Non Monitored	Medium
101	Drepane punctata	*B/Bmsy*	2019	0.741	Overfished	50-69 Non Monitored	Low
102	Exocoetidae	*B/Bmsy*	2019	0.867	Fully fished	50-69 Non Monitored	Medium
103	Gymnosarda unicolor	*B/Bmsy*	2019	0.926	Fully fished	50-69 Non Monitored	Medium
104	Haemulidae (=Pomadasyidae)	*B/Bmsy*	2019	0.997	Fully fished	50-69 Non Monitored	Medium
105	Invertebrata	*B/Bmsy*	2019	0.861	Fully fished	50-69 Non Monitored	Low
106	Penaeus semisulcatus	*B/Bmsy*	2019	0.858	Fully fished	50-69 Non Monitored	Low
107	Phaeophyceae	*B/Bmsy*	2019	0.859	Fully fished	50-69 Non Monitored	Low
108	Plotosus spp	*B/Bmsy*	2019	0.865	Fully fished	50-69 Non Monitored	Low
109	Pomatomus saltatrix	*B/Bmsy*	2019	0.673	Overfished	50-69 Non Monitored	Low
110	Psettodes erumei	*B/Bmsy*	2019	0.974	Fully fished	50-69 Non Monitored	Medium
111	Rhopilema spp	*B/Bmsy*	2019	0.856	Fully fished	50-69 Non Monitored	Low
112	Sardinella lemuru	*B/Bmsy*	2019	0.902	Fully fished	50-69 Non Monitored	Medium
113	Scomberomorus lineolatus	*B/Bmsy*	2019	0.837	Fully fished	50-69 Non Monitored	Low
114	Scombridae	*B/Bmsy*	2019	0.866	Fully fished	50-69 Non Monitored	Low
115	Seriola spp	*B/Bmsy*	2019	0.774	Overfished	50-69 Non Monitored	Medium
116	Sparidae	*B/Bmsy*	2019	0.830	Fully fished	50-69 Non Monitored	Medium
117	Sphyraena spp	*B/Bmsy*	2019	0.853	Fully fished	50-69 Non Monitored	Low
118	Sphyrnidae	*B/Bmsy*	2019	0.915	Fully fished	50-69 Non Monitored	Medium
119	Synodontidae	*B/Bmsy*	2019	0.864	Fully fished	50-69 Non Monitored	Low
120	Thunnus maccoyii	*B/Bmsy*	2019	0.843	Fully fished	50-69 Non Monitored	Low
121	Upeneus spp	*B/Bmsy*	2019	0.942	Fully fished	50-69 Non Monitored	Medium

Notes: Stock types from the FAO catch database.

Monitored (for FAO SOFIA) and non-monitored:

1. 70+ non-monitored – having more than 70 years catch time series.
2. 50–69 non-monitored – having 50–69 years catch time series.
3. 25–49 non-monitored – having 25–49 years catch time series.
4. Current FAO monitored – stocks that are being monitored for stock status by FAO (45 stocks less those that are included in Tier 1 – 33 stocks).

Appendix A3.4. Tier 3 fish stock status (CMSY/OCOM – or catch only method) for Area 57 in 2022

No	Sp.group	Sub-Area	Country	Name	Ref Point	Stock status	Reference
1	35	57.1	India A&NI	Barracuda	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
2	37	57.1	India A&NI	Anchovies	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
3	37	57.1	India A&NI	Crabs	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
4	37	57.1	India A&NI	Elasmobranchs	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
5	38	57.1	India A&NI	Mackerel	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
6	33	57.1	India A&NI	Mullets	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
7	35	57.1	India A&NI	Sardines	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
8	33	57.1	India A&NI	Silver bellies	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
9	36	57.1	India A&NI	Tunas	*Bmsy/Fmsy*	Sustainable	Eldho *et al*., 2019
10	33	57.1	India A&NI	Perches	*Bmsy/Fmsy*	Overfishing	Eldho *et al*., 2019
11	57	57.1	India	Needle cuttlefish	Catch ratio	Fully exploited	Jasmin *et al*., 2018

Note: India A&NI = India Andaman & Nicobar Islands

4 SINGLE SPECIES STOCK ASSESSMENTS FOR A RANGE OF DATA IN ASIA

Ricardo Amoroso and Derek Staples[6]

4.1 Introduction

This paper provides an overview of single species stock assessment methods that could be used to assess stocks in South and Southeast Asia. It considers:

- stock assessment and fisheries management;
- data limitations;
- assessment options; and
- where things can go wrong.

4.2 Stock assessment and fisheries management

The central theorem of fisheries management is that there is relationship between fish abundance and the long-term sustainable catch (Figure 4.1) of any stock in a given fishery.

Figure 4.1. Relationship between fish abundance and the long-term sustainable catch. Blue shading shows the region where catch and/or effort management measures are used to control abundance

Source: Authors' own elaborations.

6 This paper was prepared by Derek Staples based on the presentation by Ricardo Amoroso to the workshop.

This relationship is often shown as a bell-shaped curve that shows for any stock size of which there is a surplus production that can be harvested without reducing the stock abundance. The long-term sustainable catch is at the maximum sustainable yield (MSY).

One of the goals of effective management is to keep stocks within a specific range of abundance by either controlling the catch, e.g. a total allowable catch (TAC) or controlling the fishing effort (total allowable effort (TAE) (see arrows in Figure 4.1). The desired level of catch depends on the trade-offs of multiple objectives – maintaining high catches, preserving ecological integrity, maintaining livelihoods or maintaining healthy and profitable fisheries.

To be able to control the abundance of the fishery resources, we need to know the current status of the resources by conducting a stock assessment as part of a management strategy (Figure 4.2) via:

- data collection;
- stock assessment; and
- management actions/measures.

Figure 4.2. The fisheries management cycle showing the link between data collection, stock assessment and management actions

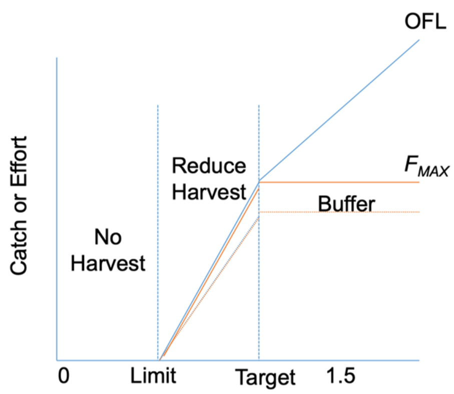
Source: Authors' own elaborations.

Stock assessments need to be translated into management actions/measures through:

- a long-term monitoring programme;
- regular stock assessments for estimating values for various indicators of the fishery's status (including the level of fishing, fish abundance, economic return and livelihoods) and population health;
- setting of targets and limits on harvesting – usually target and/or limit reference points for fishing mortality rates or biomasses; and
- agreeing on harvest control rules: What to do when the indicators do not align with the reference points.

The harvest control rule determines how much fishing can take place based on the stock status. The strategy can be very simple or very complicated (ranging from constant catch to multistep rules) (Figure 4.3).

Figure 4.3. Representation of a harvest control rule



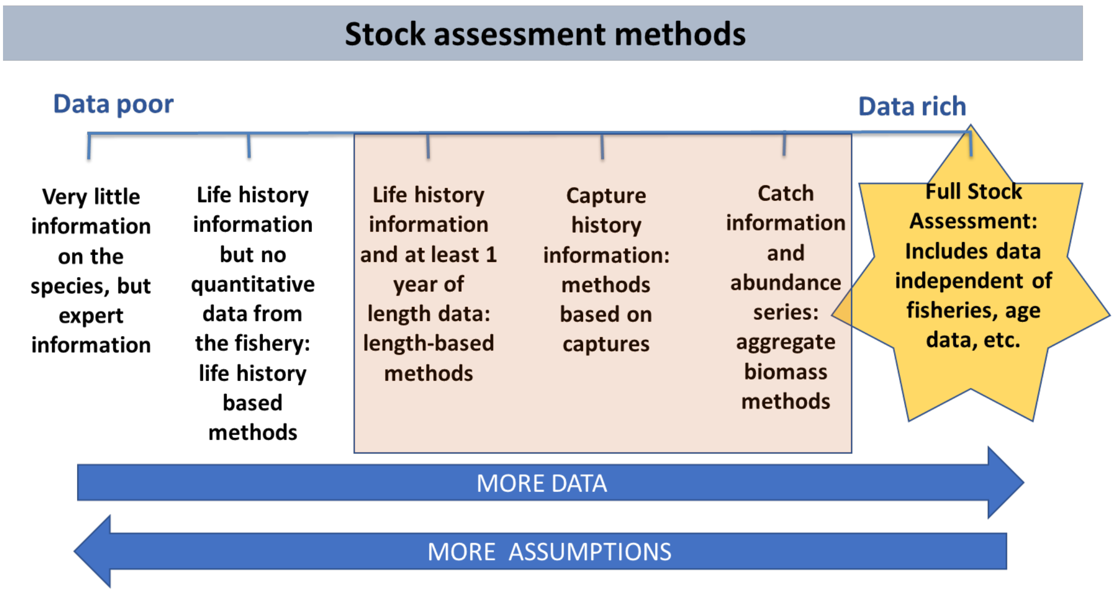
Notes: FMAX = maximum fishing effort and OFL = overfishing level

Source: Authors' own elaborations.

4.3 Data needs for stock assessments

A wide range of stock assessment methods have been developed over time. To a large extent, the method that is used for a particular fishery depends on what data are available. Depending on how extensive the data collection is in a given fishery, data can range from data poor (very little information) to data rich (e.g. fisheries with age-structured data and data that are independent of the fishery) – the gold star of data and stock assessment (Figure 4.4).

Figure 4.4. The range of data needed for different stock assessment methods spanning data poor to data rich fisheries



Source: Authors' own elaborations.

4.4 Data limitations

In the past, only a limited number of stock assessments were carried out in South and Southeast Asia because it was thought that the region did not have enough data. However, there are increasingly more methods being developed for data-limited situations and a greater ability to conduct meaningful assessments. When we look in detail, there are also more data than originally thought, and for most fisheries in South and Southeast Asia, there are usually some data that lie somewhere in the pink box in Figure 4.4 (data-limited to data-medium fisheries). Data limitation is not an excuse to avoid management.

Although data poor methods are becoming increasingly available, the model assumptions and uncertainty in the model predictions in these types of assessments are greater than in data rich situations (Figure 4.4). Thus, more care is needed in testing the assumptions and examining the uncertainty in data poor stock assessments.

Data limitations often go hand in hand with structural features that present a challenge for centralized management. The most important challenges in these cases are not only in the evaluation of the resource but also in broader governance issues. Berkes *et al.* (2001) made a plea to incorporate stock assessment into the broader management framework, especially in small-scale fisheries in developing countries.

4.5 Assessment options

The main methods that can be used in the case of "data medium" situations typical of South and Southeast Asia include:

- surplus production/biomass dynamic models;
- catch-only methods; and
- length-based methods.

4.5.1 Surplus production/biomass dynamic models

Model structure

The underlying logic of a biomass dynamic model is:

[New biomass] = [Old biomass] + [Production] – [Catch]

i.e :

$$B_{t+1} = B_t + P_t - C_t$$

Production = somatic growth + recruitment - natural mortality, which can be calculated as:

$$P_t = rB_t\left(1 - \frac{B_t}{K}\right)$$

Where r = intrinsic rate of population growth and K = carrying capacity and C_t = the catch at time t, resulting in:

$$B_{t+1} = B_t + rB_t\left(1 - \frac{B_t}{K}\right) - C_t$$

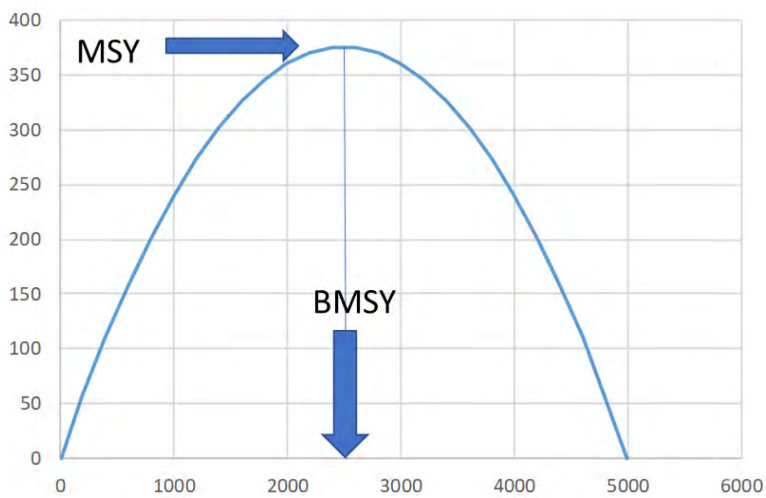
The model is shown graphically in Figure 4.5 and Figure 4.6.

Figure 4.5. Basis for the biomass dynamic model for assessing fish stocks

Source: Authors' own elaborations.

If we know the value of the parameters r and K, the different reference points can be easily calculated:

Figure 4.6. Estimating the MSY and the biomass at MSY (Bmsy) in a biomass dynamic model

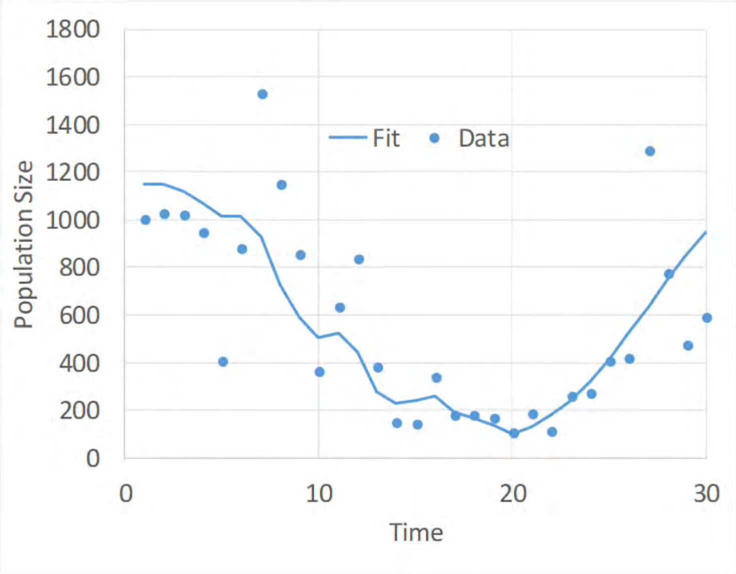


Note: B_0 = virgin biomass; K = carrying capacity; r = intrinsic rate of increase.

Source: Authors' own elaborations.

Fitted to time-series data (Figure 4.7), the model can provide estimates of total abundance, fishing pressure, status of the fish stock and reference points.

Figure 4.7. Fitting of the biomass dynamic model to time-series data



Source: Authors' own elaborations.

Where things can go wrong

- ***The index of abundance is not proportional to the true abundance*:** The model assumes that the index of abundance used to fit the model is proportional to the true population abundance. For example, if we use the catch per unit effort (CPUE) calculated from commercial catch and effort data, the CPUE index could reflect hyperdepletion – where the CPUE declines faster than abundance (using these data in an assessment can produce pessimistic results), or could reflect hyperstability – where the CPUE stays stable while the actual fish population declines drastically (resulting in an overoptimistic results).

- ***Biased catch data:*** Another cause of error is biased catch data resulting from under-reporting, over-reporting or increasing/decreasing rates of reporting during the history of the fishery.

- ***Changes in productivity:*** The model assumes that the productivity of the stock does not change over time. However, changes in productivity are known to occur in some fish stocks, e.g. Atlantic cod (*Gadus morhua*) in the Iceland fishing grounds (Vert-pre, Jensen & Hilborn 2013).

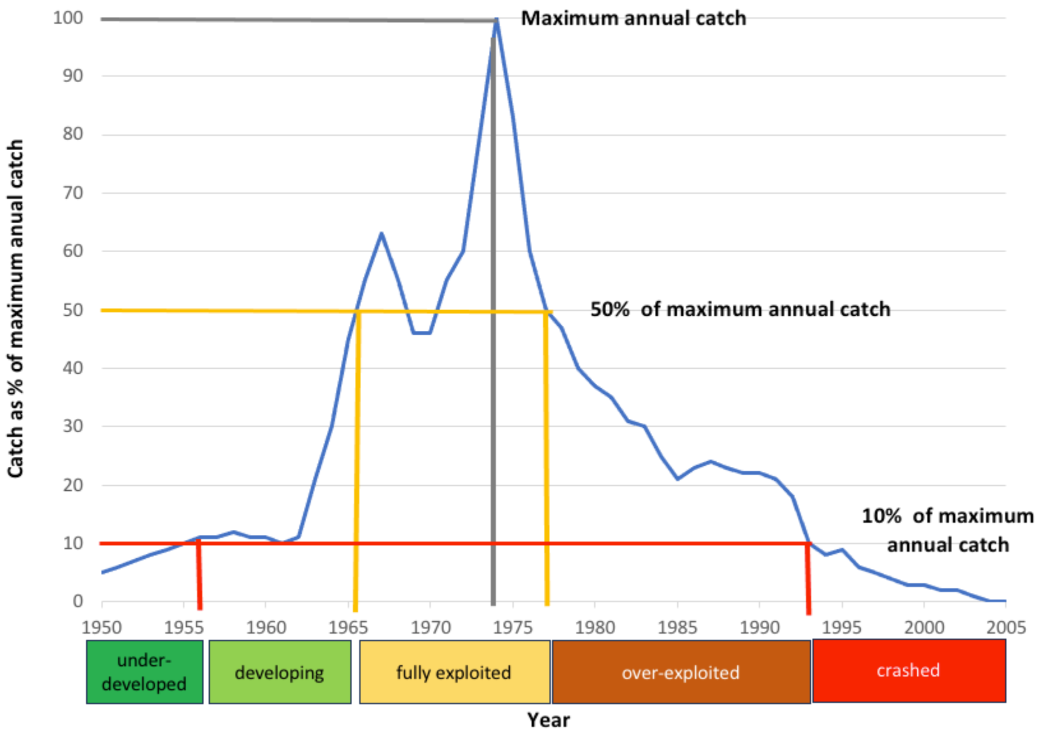
- ***Lack of contrast:*** A reliable fit of the model relies on having contrast in the data, with both increases and decreases in catch and abundance. The most common type of time series is increasing fishing effort and declining CPUE. This "one-way-trip" cannot provide enough contrast to reliably estimate the parameters of *r* and *K* in the model.

4.5.2 Catch-only methods

The past history of catches contains some information of stock status. Pauly *et al.* (2008) developed the following criteria based on the trend in catches (Figure 4.8):

- ***developing:*** (catches ≤% of peak and year is pre-peak, or the year of the peak is the final year of the time series);
- ***exploited:*** (catches ≥50% of peak catches);
- ***overexploited:*** (catches between 50% and 10% of the peak and the year is postpeak);
- ***collapsed:*** (catches <10% of the peak and the year is postpeak); and
- ***rebuilding:*** (catches between 10% and 50% of the peak and year is after the postpeak minimum).

Figure 4.8. Classification of status of stocks based on catch trends from fishery data



Source: Redrawn and adapted from Pauly, D., Alder, J., Booth, S., Cheung, W.W.L., Christensen, V., Close, C., Sumaila, U.R. *et al.* 2008. Fisheries in large marine ecosystems: descriptions and diagnoses. In: *The UNEP Large Marine Ecosystem Report: A perspective on changing conditions in LMEs of the world's regional seas,* pp. 23–40. UNEP Regional Seas Reports and Studies No. 182. Nairobi, UNEP.

Using a biomass dynamic model, the parameters that can explain the catch history without collapsing the populations can add more information to the assessment. This generates a distribution of *r* and *K* as well as reference points such as the MSY.

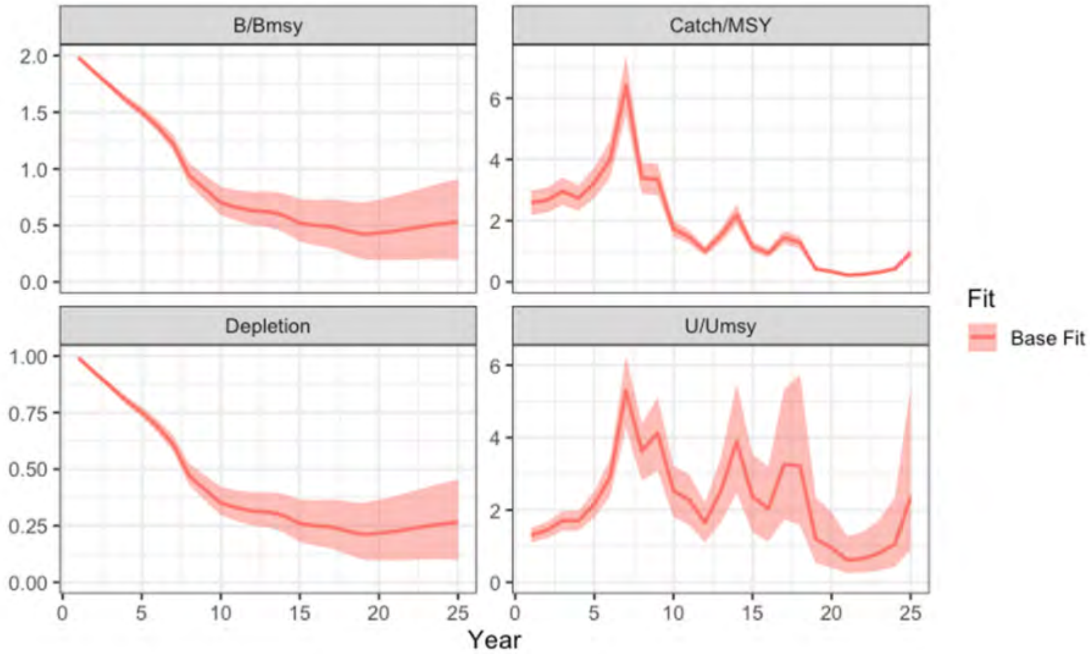
It is then possible to add previous knowledge of *r*, *K* and current status as priors to refine the assessment (Martell and Froese, 2023) based on expert opinion and/or previous studies.

Example statements of this would be:

- "Based on studies of similar species, the intrinsic growth rate *r* of this species is probably between 0.1 and 0.5"; or
- "Fishermen report that there are far fewer fish today than there were 30 years ago, so we believe that the current depletion is between 0.1 and 0.25".

Keeping the combination of parameters that align with our prior information on depletion produces a distribution of reference points and stock status that satisfy the assumptions of the model (Figure 4.9).

Figure 4.9. Stock status based on catch-only data informed by expert opinion and results from previous studies



Source: Authors' own elaborations.

Where things can go wrong

As with biomass dynamic models, there are various assumptions and uncertainties that need to be considered.

- *Sensitivity to the priors:* Changes in the prior *r* and *K* affects the conclusions about stock status changes with different selection of *r* and *K*. For example:
  - o a higher *r* prior results in a decrease in the depletion of the stock biomass and an increase in the ratio of the biomass to the biomass at MSY (B/Bmsy) in later years, as well as a decrease in the fishing mortality (U/Umsy);
  - o a higher *K* prior results in an even lower rate of depletion, higher B/Bmsy and a lower prediction for exploitation F/Fmsy (i.e. a more optimistic result for the stock status).
- *Biased catch data:* Changes in the time-series data (e.g. under-reporting or over-reporting) results in a different pattern of depletion, B/Bmsy and U/Umsy.

4.5.3 Length-based methods

Fishing decreases the number of fish that survive to old age, an effect that can also be seen in the size structure (e.g. length) of the fish population (Figure 4.10). These age and size distributions contain information about natural mortality and recruitment.

Figure 4.10. Examples of changes in the age and size distribution of an exploited and unexploited stock

Source: Authors' own elaborations.

Length-based spawning potential ratio

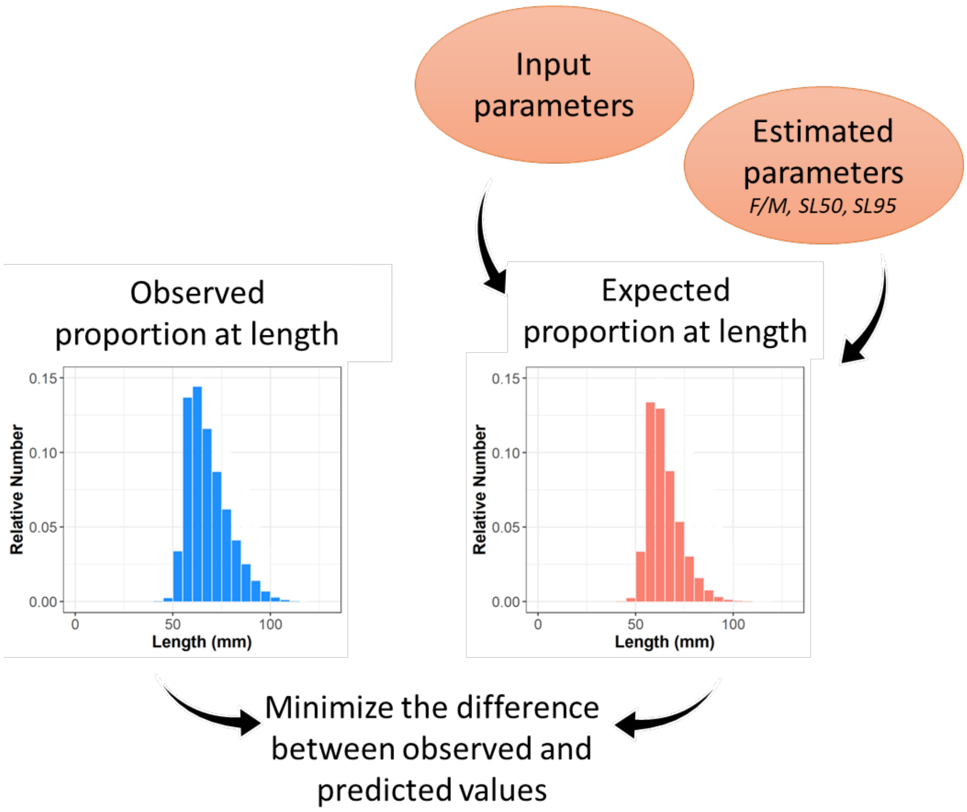
One of the more recent methods of analysing length-based data is the length-based spawning potential ratio (LBSPR), which estimates spawning potential ratio (SPR) from the length composition data of an exploited stock (Hordyk *et al.,* 2015; Prince *et al.,* 2015). The LBSPR is an equilibrium-based model, where the length composition must be a representative sample of the exploited population at a steady state (constant *F* and no recruitment variability). It assumes that somatic growth follows the von Bertalanffy growth equation and that the selectivity of the fishing gear can be represented by a logistic function in the model fitting. It also assumes constant natural mortality-at-length.

The method requires the following minimum parameter inputs:

- L_∞ is L infinity of the von Bertalanffy growth equation;
- M/K is natural mortality (*M*) / the instantaneous growth rate of the von Bertalanffy growth equation (*K*); and
- maturity at length:
  - o L_{50} *length at 50% maturity*
  - o L_{95} *length at 95% maturity*

The model then minimizes the difference between the observed and the expected length distribution based on the input parameters (Figure 4.11).

Figure 4.11. The process of fitting the LBSPR model to length-based data



Source: Authors' own elaborations.

Where things can go wrong

- *bias in M/K:* Bias in *M/K* produces biased estimates of *F/M* and SPR;
- *bias in* L_∞*:* A bias in L_∞ produces biased estimates of *F/M* and SPR; and
- *incorrect assumptions of the shape of the selectivity curve:* Incorrect assumptions of the selectivity curve also produce biased estimates of *F/M* and SPR.

4.6 Conclusions

- Rising computing power and readily available model codes allow several stock assessment methods to be easily performed in data poor contexts.
- These methods are very sensitive to the underlying data and model assumptions.
- Usually, the influence of the data collection, priors and model assumptions are not fully explored.
- Model-free management procedures may still be the most effective and best option for a given situation.

References

Berkes, F., Mahon, R., McConney, P., Pollnac, R. & Pomeroy, R. 2001. *Managing small-scale fisheries: alternative directions and methods.* Ottawa, Canada, International Development Research Center. https://www.researchgate.net/publication/272791687_Managing_Small-Scale_Fisheries_Alternative_Directions_and_Methods

Hordyk, A., Ono, K., Valencia, S.R., Loneragan, N. & Prince, J. 2015. A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for small-scale, data-poor fisheries. *ICES Journal of Marine Science*, 72: 217–231.

Martel, S. & Froese, R. 2013. A simple method for estimating MSY from catch and resilience. *Fish and Fisheries,* 14: 504–514.

Prince, J.D., Hordyk, A., Valencia, S.R., Loneragan, N.R. & Sainsbury, K.J. 2015. Extending the principle of Beverton-Holt Life History Invariants to develop a new framework for borrowing information for data-poor fisheries from the data-rich. *ICES Journal of Marine Science,* 72: 194–203.

Vert-pre, K.A., Jensen, O.P. & Hilborn, R. 2013. Frequency and intensity of productivity regime shifts in marine fish stocks. *PNAS,* 110(5): 1779–1784.

5 ASSESSING STOCKS FOR MULTISPECIES FISHERIES: A MULTISPECIES APPROACH RELEVANT TO THE ASIAN REGION

Elizabeth Fulton

5.1 Background

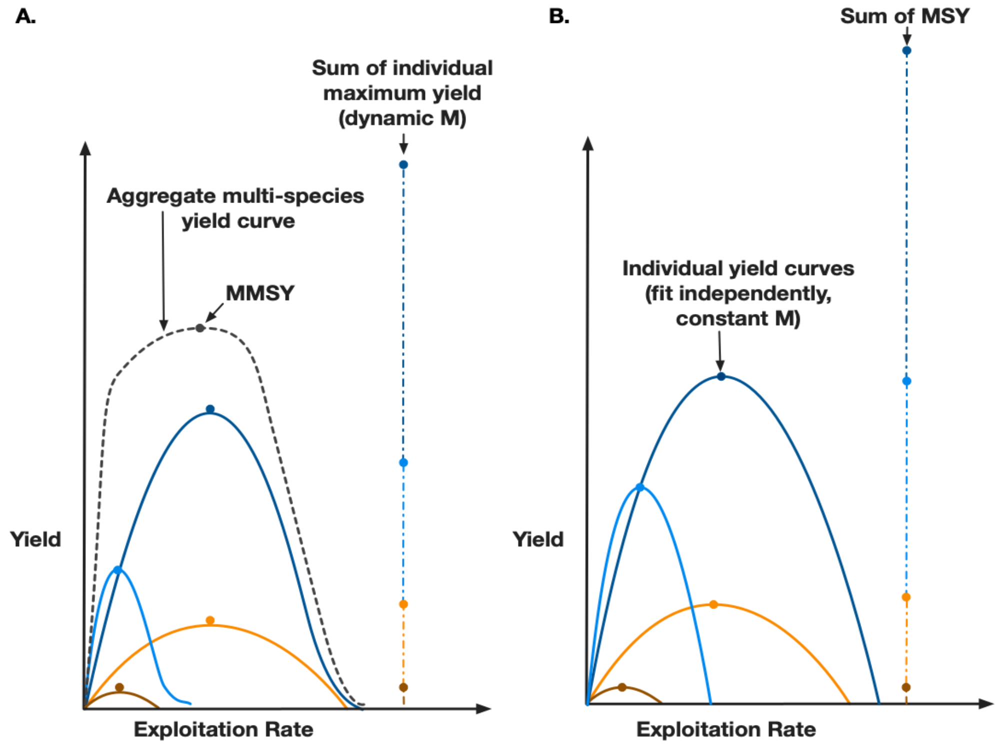
The vision of most national and international fisheries legislation is to guarantee the conservation of ecosystem structure and function, but in practice, operational fisheries management and fishery policy has focused on maximum sustainable yield (MSY) and the status of individual fish stocks.

Such an approach is appropriate for single species fisheries, whether operating in isolation or in parallel with no interactions. However, most of the world's fisheries are mixed species fisheries, where there are technological interactions, with many species caught in a fishery, or multispecies, multifleet fisheries, where there are both technological and food web interactions between species. These circumstances characterize many of the fisheries in the Asian region.

In these types of fisheries, the use of MSY and single species management can be challenging to deliver given the tens to hundreds, or more, species involved. There is also the risk that providing target reference points for all these species would be unachievable and would lead to overfishing.

This situation is demonstrated in Figure 5.1 by comparing the "sum of MSY" or "sum of individual maximum yield" and the "multispecies MSY" (MMSY) point. The MMSY is typically much lower than would be anticipated from following single species management advice (sum of MSY) alone for the component species in a fishery.

Figure 5.1. Example plot showing why summing individual maximum yields on the right (whether with or without constant natural mortality) does not match the MMSY point on the left. The coloured lines are the individual species curves (A) with interacting species (so there are dynamic natural mortalities) and (B) independent species curves



Source: Fulton, E.A., Sainsbury, K., Noranarttragoon, P., Leadbitter, D., Staples, D.J., Porobic, J., Ye, Y., Phoonsawat, R. & Kulanujaree, N. 2022. Shifting baselines and deciding on the desirable form of multispecies maximum sustainable yield. *ICES Journal of Marine Science*, 79: 2138–2154. Creative Commons CC.

Managing mixed species or multispecies-multifleet fisheries using an ecosystem approach is more appropriate as it is capable of addressing the effects of interactions. Effective management under these circumstances requires broad system understanding, so it is clear what is influencing the ecosystem and the different catches that are taken from it. This then informs management interventions so that they can be impactful and address the management objective.

Useful information to inform an ecosystem approach for multispecies, multifleet fisheries includes:

- system description: trophic and habitat connections;
- environmental drivers: such as productivity drivers, climate, seasonal cycles, river contributions and so forth;
- human pressures: both fishing and non-fishing;
- catch composition: of the different fisheries (who catches what?);
- what affects management: this is best explained by looking for the most important system connections, such as fisheries interactions, or connections between predators-prey-habitat and so on;
- time series: what has changed over time in the fishery dynamics, management and catch composition?; and
- trade-offs: what are the different objectives for different fisheries?

Although this appears to be a long and daunting list with huge data requirements, there is now a short list of approaches that can help track the status of the system and possible management approaches, that does not require large datasets.

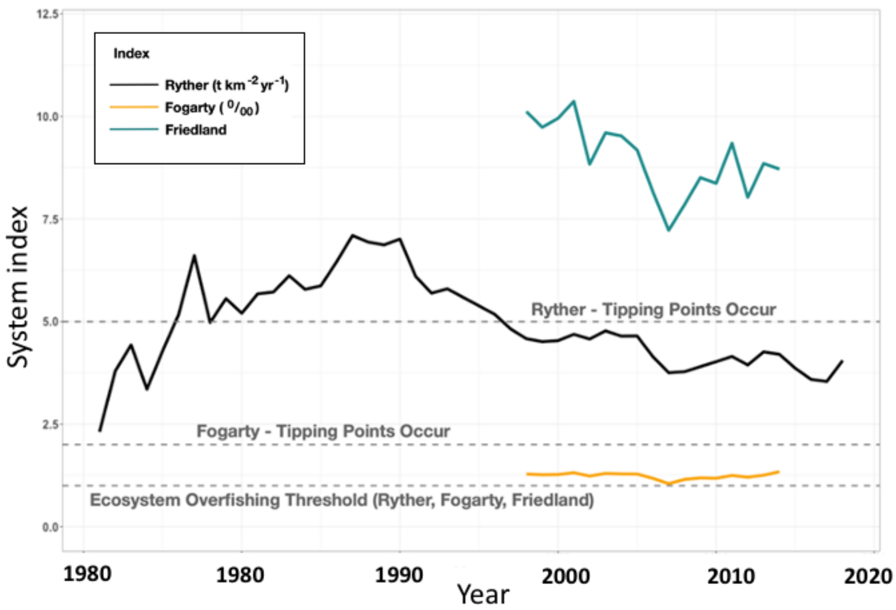
5.2 Assessing total catch based on ecosystem productivity

At the simplest level, the volume of total catch taken from a system can be compared with the system bounds identified from meta-analyses of global datasets. For example, CPUE (expressed as catch per unit area, tonne/km^2) or catch in comparison with primary production levels, as documented in Link and Watson (2019). Global datasets can provide useful regional or national proxies if no local information is available.

Index	Metric	Acceptable level
Ryther index	Catch per area	<1 tonne/km^2/year
Fogarty index	Catch/primary production	Catch/total primary production $<1^{0}/_{00}$
Friedland index	Catch/chlorophyll	Catch/total chlorophyll $<1^{0}/_{00}$

These methods provide an acceptable total catch level based on various broad ecosystem indicators (Figure 5.2).

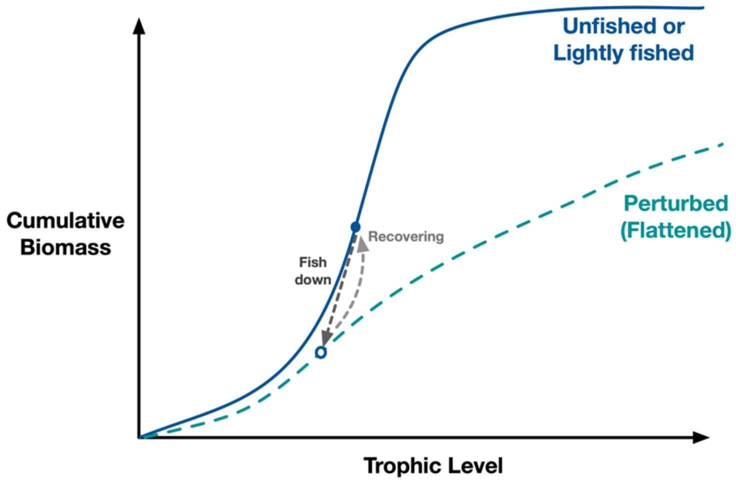
Figure 5.2. Broad ecosystem level indicators calculated for Thai waters of the Gulf of Thailand



Source: Leadbitter *et al*. (forthcoming).

Similarly, Libralato *et al.* (2019) show that the shape of a "cumulative biomass – cumulative trophic level" curve for a system can quickly indicate whether an ecosystem is lightly fished, being perturbed or recovering (the flatter the curve, the more perturbed the system). Where survey or local trophic information is hard to access, generating these curves can be done using catch in place of biomass and the species trophic levels can be drawn from FishBase (https://fishbase.se/). Tracking the curve with catch or survey biomass information through time can rapidly convey any ecosystem level responses to extraction or other pressures. The curve highlights the loss of ecosystem integrity – when the curve is sigmoidal, this indicates that the system is unfished or lightly fished, When the curve is flattened, this indicates overfishing (Figure 5.3).

Figure 5.3. System structure indicator – species versus trophic level



Source: Redrawn and adapted by the author based on Libralato, S., Pranovi, F., Zucchetta, M., Monti, M.A. & Link, J.S. 2019. Global thresholds in properties emerging from cumulative curves of marine ecosystems. *Ecological Indicators*, 103: 554–562.

5.2.1 Aggregate production models

Over the past few decades, but especially over the past ten years, a wide assortment of multispecies and ecosystem modelling frameworks has been developed and made available for use in fisheries.

At the simplest level, aggregate production models (which are applied to aggregate pools – such as "demersals, "pelagics", "overall") provide a useful means of simply identifying system-level allowable catches. These models combine all species within a fishery and treat the result as a "super species". A production model is then fitted to the aggregate time series of catch and CPUE, or survey index. This method is suitable for use in a system, no matter how diverse, but can be sensitive to the length of the time series; it is used especially when there has been significant system turnover (i.e. major changes in the structure of the stocks due to fishing, modified interactions or environmental changes).

For example, when applying this approach to the time series from the Gulf of Thailand, using only the most recent decades, when the system had lost many of its largest and longest-lived species, produced MMSY estimates much higher than for time series spanning earlier years when those large species still remained (Fulton *et al.*, 2022). Each different period considered produced a different MMSY, but also had different levels of biodiversity, employment and profitability per unit of effort (Figure 5.4). This is because they represented different system states as the system changed over time.

Figure 5.4. Aggregate production curves fit to various catch time series for the Gulf of Thailand. The different curves come from fitting to different time periods (and ecosystem states). The associated characteristics of those systems are summarized using indicators for biodiversity (and ecosystem resilience), total yield, jobs (employment) and profits per unit effort. The number of stars on the right of the plot shows the relative size of the various indicators for system properties that people often care about or hold as objectives

Production curves using data from different periods

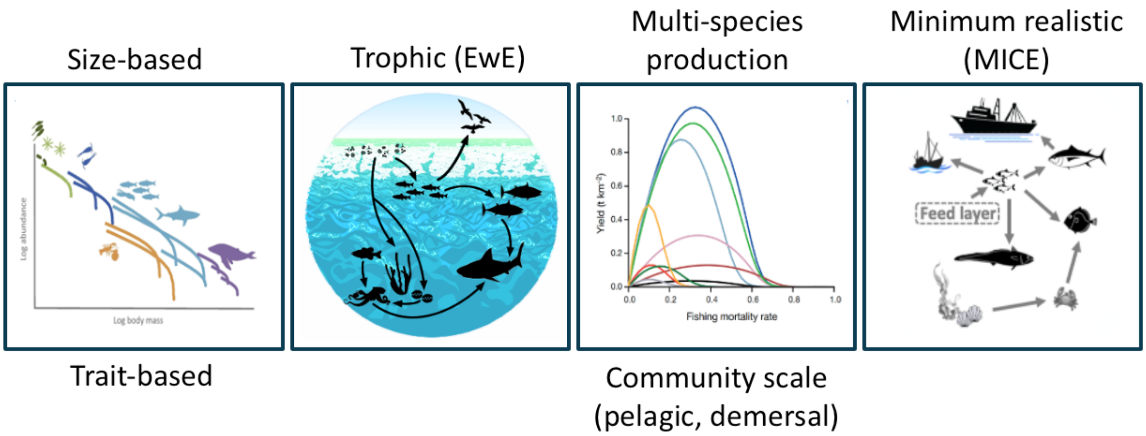
Source: Redrawn and adapted by the author based on Fulton *et al.* (2022).

An important conclusion of this analysis is that fishery management and policies using this approach require a decision by fishery managers and the fishing communities on selecting which system state is desirable in order to use the appropriate time series and reference points. The system state associated with the lowest (dark blue) production curve (1950–1964) supported a low total yield and few jobs (as there were few fisheries exploiting the system) but was very biodiverse, resilient and fishing was highly profitable (Figure 5.2). In contrast, the system state associated with the upper most (brown) production curve (1989–2017) had the highest total yield and supported many fishers (jobs) but was much less biodiverse and resilient and had low profits per unit effort. The states supporting the other curves sit between these two extremes.

5.3 Multispecies and ecosystem modelling

Other available multispecies assessment models tend to resolve species or functional groups in more detail using traits (such as maximum size and habitat use as in the Mizer software (Scott, Blanchard and Andersen, 2004); trophic feeding relationships, e.g. Ecopath with Ecosim (EwE) (Christensen, Walters and Pauly, 2005); multispecies production models, e.g. Gaichas *et al.* (2017) or "minimum realistic" or "models of intermediate complexity", as described in Plagányi *et al.* (2012) (Figure 5.5).

Figure 5.5. Different types of available multispecies assessment models



Source: Author's own elaboration, based on information in Plagányi, É., Punt, A., Hillary, R., Morello, E., Thébaud, O., Hutton, T., Pillans, R., Thorson, J., Fulton, E.A., Smith, A.D.M., Smith, F., Bayliss, P., Haywood, M., Lyne, V. & Rothlisberg, P. 2014. Multi-species fisheries management and conservation: tactical applications using models of intermediate complexity. *Fish and Fisheries*, 15: 1–22.

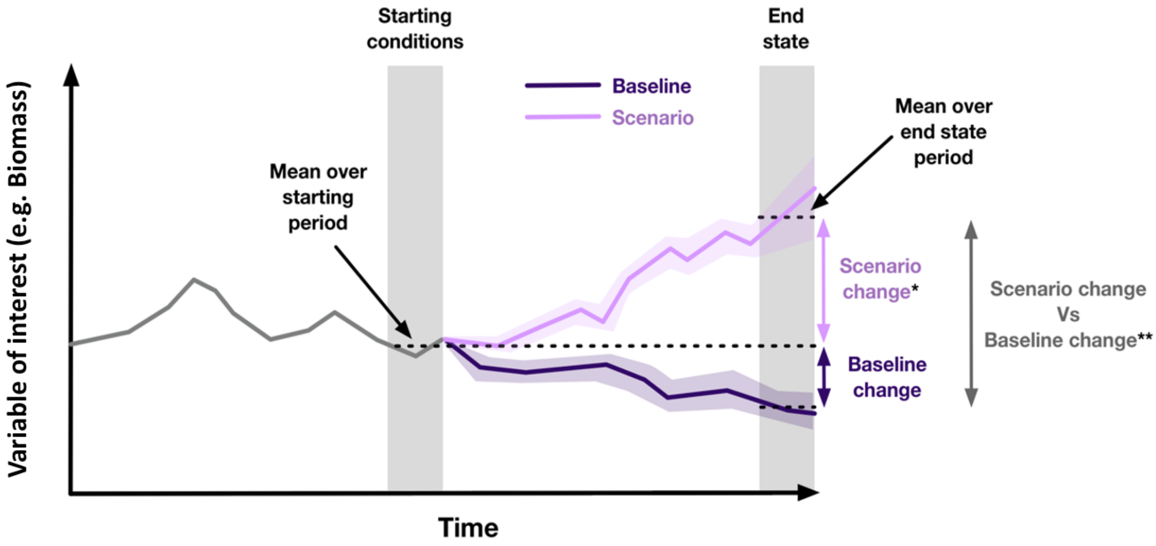
The value of these models is that the system can be broken up somewhat so that trajectories for species or groups of interest can be more easily tracked. These models can be used to evaluate historical or current status but can also be used to consider the outcome of alternative management scenarios and what trade-offs might exist between different species or fisheries. These models can also provide trajectories for ecosystem indicators, which inform on ecosystem state – such as the system maturity, the status of keystone or other species of management concern and the ratio of biomass of pelagic: demersal fish or piscivorous: planktivorous species, both of which are known to change in response to perturbation and indicate the dominant pathways operating in an ecosystem.

EwE is the probably the best known of all marine ecosystem modelling approaches and has been applied to many marine ecosystems across the world. The software includes three model components:

- Ecopath: A static mass-balance model for considering a snapshot of biomass or energy flow through a foodweb;
- Ecosim: Which takes the Ecopath state and projects it forward through time under scenarios of fishing pressure and primary production forcing; and
- Ecospace: A grid-based implementation of Ecosim, which can include movement and differential availability of habitat and spatially resolved fishing pressure.

After the model has been fitted, there are many useful ways to use the output. One common approach is to look at predictions of the future status of the fishery resource under different management intervention scenarios (Figure 5.6).

Figure 5.6. Using a multispecies model to predict future fishery status based on different future scenarios.



Notes: * This change is either calculated as: End state/Starting state or (End state/Starting state)/Starting state.
** This is usually presented as: Scenario change/Baseline change.

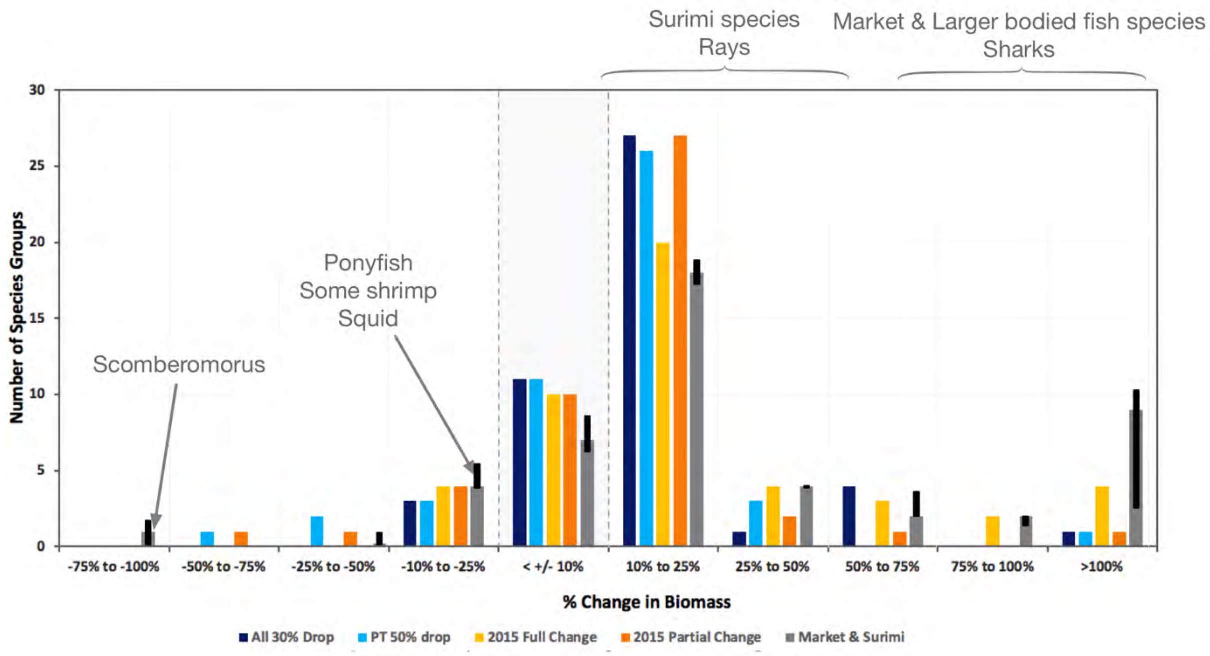
Source: Leadbitter *et al.* (forthcoming).

As an example, the multispecies production model was used to examine likely response changes in fishing effort in Thai waters of the Gulf of Thailand. The scenarios were:

- reducing the effort of all fishing gears by 20 percent;
- reducing the fishing pressure of all fishing gears by 30 percent;
- reducing the effort of pair trawlers by 50 percent; and
- increasing the effort of pair trawlers x2.

Most scenarios resulted in an increase in the production of the main surimi (fish paste)/market species (Figure 5.7), in particular, anchovies and threadfin bream.

Figure 5.7. Proportional changes in production biomass under different scenarios of fishing effort in Thai waters of the Gulf of Thailand



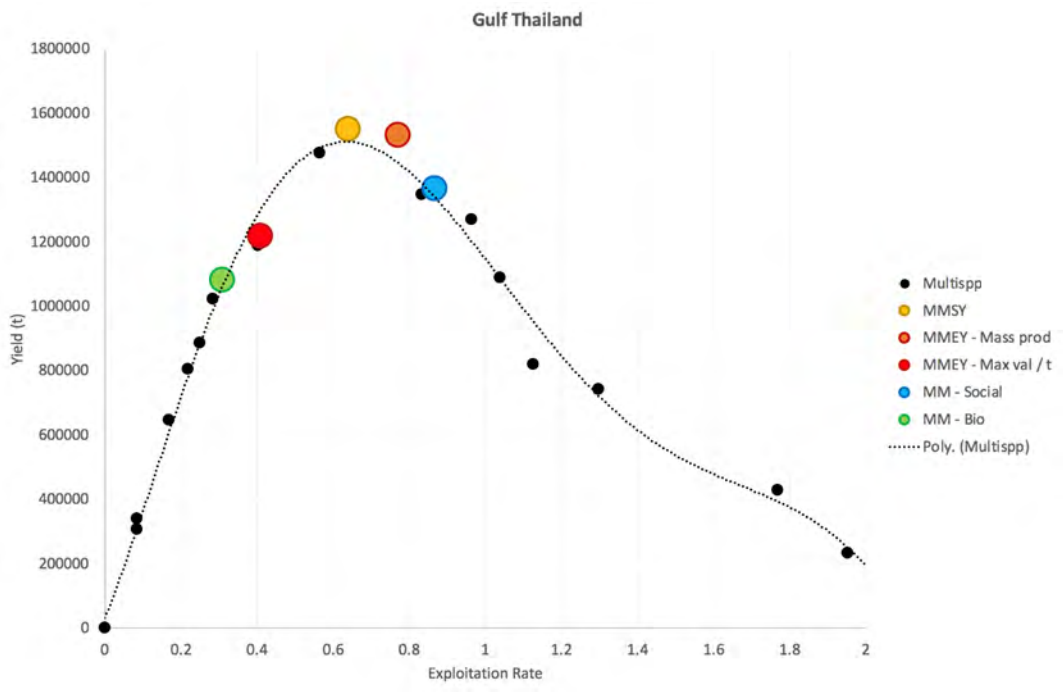
Source: Leadbitter *et al.* (forthcoming).

A particularly useful Ecosim tool is the "Fishing policy search" which runs an optimization to find what mix of relative effort across the different gears maximizes a set of user-defined objectives. An example for the Gulf of Thailand model is shown in Figure 5.8. This shows the differences in achieving the MMSY (1.5 million tonnes [yellow dot]) that occurred around 70 percent of the fishing effort in 2015.

The yields providing maximum economic return and robust ecosystem structure differ significantly from this point (1.2 million tonnes [red dot] and 1.1 million tonnes [green dot], respectively). The maximum social objective of maximum employment occurs around 1.4 million tonnes (blue dot), but this higher yield is based on an ecosystem that has ecosystem structures that are degraded, with many extirpated species, which is not robust enough in the event of environmental shocks and can show quite large interannual variation.

These features are undesirable for achieving ecosystem states that are reliably sustainable in the long term. The lower yield levels (red and green dots) are much more robust, but will not support as much short-term employment.

Figure 5.8. A yield curve generated by running the EwE policy search for the Gulf of Thailand under different objective weightings. The coloured dots mark particular optimization outcomes: MMSY is maximum multispecies yield (maximal food security); MMEY - Max value/tonne (val/t) is maximum multispecies economic yield that is equivalent to the classical definition of MEY for the classical single species theory; MM - Social is the point where maximal employment of fishers and their immediate supply chain contacts exists; MM - Bio is the point where environmental objectives of rebuilding and maintenance of a robust ecosystem structure is met



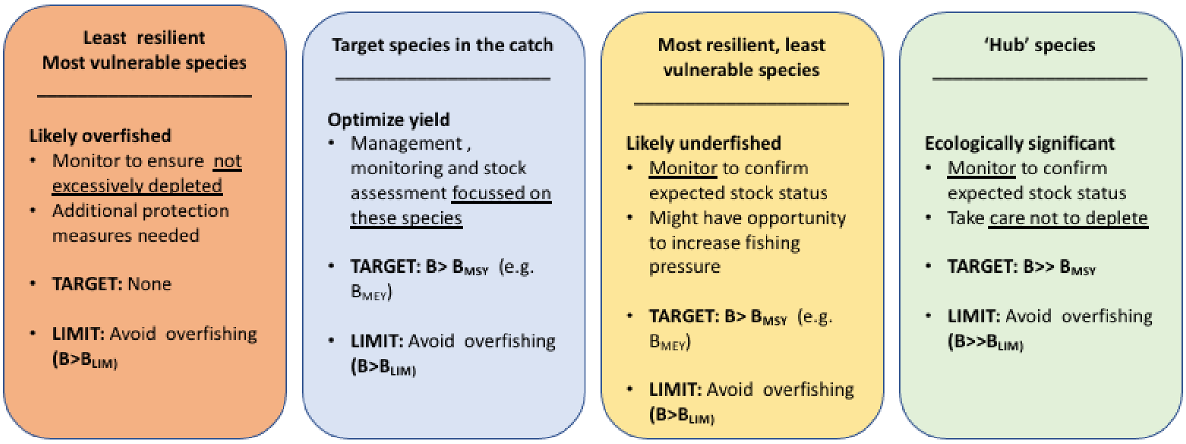
Source: Leadbitter *et al.* (forthcoming) replotted based on data used in Fulton *et al*. (2022).

5.3.1 Multispecies harvest strategies

Multispecies harvest strategies are also being proposed or used in more locations. One approach that has been used to successfully manage marine systems in Western Australia is the "indicator species-based approach" (Newman *et al*., 2018).

A generalized modification of this approach would see all species that interact with a species classified into four types (Figure 5.9). Three of these four types are based on their life history characteristics and level of interaction with fisheries; the fourth are species with particularly important ecological roles (such as keystone species or "hub" species, which network analysis show to be connectors across the entire food web).

Figure 5.9. Categories of species for consideration in the indicator species-based harvest strategy



Source: Adapted from Newman, S.J., Brown, J.I., Fairclough, D.V., Wise, B.S., Bellchambers, L.M., Molony, B.W., Lenanton, R.C.J. *et al.* 2018. A risk assessment and prioritisation approach to the selection of indicator species for the assessment of multi-species, multi-gear, multi-sector fishery resources. *Marine Policy*, 88: 11–22.

From each of these four types a small number of representative indicator species are chosen (typically three to four species), tracked and used as a basis for management responses. By choosing the most sensitive species from each category as the indicator species, managers can have some confidence that if the indicator species is performing acceptably (such as $B > B_{LIM}$) then all other species in that category are likewise performing acceptably.

This means that the direct management of a small number of species (for example six to ten) can be used to indirectly manage tens, to hundreds, of species. Variations on this approach can also focus on outcomes for different subsectors of fisheries, such as market fish, species that are used for fishmeal or the surimi and the crustacean sector (Leadbitter *et al.*, forthcoming).

5.4 Conclusions

Experience from around the world demonstrates that these methods can be applied in any fishery and that due to the nature of fisheries there is no need to wait for the “perfect dataset” before commencing.

Adding more data streams only becomes critical as the number of management interventions and regulations increases, as it becomes increasingly hard to use landings data alone to disentangle biological status from the influence of regulations and market forces and so forth.

As regions with particularly species-rich fisheries that use a wide diversity of gears, South Asia and Southeast Asia are where these management approaches may be particularly useful.

References

Christensen, V., Walters, C.J. & Pauly, D. 2000. *Ecopath with Ecosim: A user's manual.* Canada, Fisheries Centre, University of British Columbia & Malaysia, ICLARM.

Gaichas, S.K., Fogarty, M., Fay, G., Gamble, R., Lucey, S. & Smith, L. 2017. Combining stock, multispecies, and ecosystem level fishery objectives within an operational management procedure: simulations to start the conversation. *ICES Journal of Marine Science*, 74: 552–565.

Leadbitter, D., Fulton, E.A., Kulanujaree, N., Noranarttragoon, P., Nguyen, K.B., Phoonsawat, R., Porobic, J., Sainsbury, K., Staples, D., Vu, V.H. & Ye, Y. (forthcoming). *Managing multispecies and multigear fisheries – a toolbox for scientists, managers and stakeholders.* FAO Fishery and Aquaculture Circular. Rome, FAO.

Libralato, S., Pranovi, F., Zucchetta, M., Monti, M.A. & Link, J.S. 2019. Global thresholds in properties emerging from cumulative curves of marine ecosystems. *Ecological Indicators*, 103: 554–562.

Link, J.S. & Watson, R.A. 2019. Global ecosystem overfishing: Clear delineation within real limits to production. *Science Advances*, 5: eaav0474.

Newman, S.J., Brown, J.I., Fairclough, D.V., Wise, B.S., Bellchambers, L.M., Molony, B.W., Lenanton, R.C.J. ***et al.*** 2018. A risk assessment and prioritisation approach to the selection of indicator species for the assessment of multi-species, multi-gear, multi-sector fishery resources. *Marine Policy*, 88: 11–22.

Scott, F., Blanchard, J.L. & Andersen, K.H. 2014. Mizer: an R package for multispecies, trait-based and community size spectrum ecological modelling. *Methods in Ecology and Evolution*, 5: 1121–1125.

6 TRAWL SURVEYS IN SOUTHEAST ASIA

Derek Staples, Mick Haywood, Javier Porobic and Simon Funge-Smith

6.1 Introduction

There have been many fisheries research surveys carried out in Asian waters over the past 40 years. Although there was an attempt in the late 1990s to try and collate the trawl surveys into one database (Gayanilo, Stromme and Pauly, 1997), the results of the surveys remain scattered in the grey literature, in files held by scientists in research institutes or have been lost. Fisheries independent trawl surveys, especially those carried out during the early phases of the development of a fishery, are important for providing estimates of:

1) Biomass:

- stock biomass at different points in time (swept area); and
- relative abundance indices as input into stock assessments

2) Information for setting priors for Bayesian stock assessment modelling.

In this study we collated estimates of relative biomass (kg/hour) of the total catch (all species combined) of trawl surveys from published reports, scientific papers and data provided to FAO in Cambodia, Malaysia, Thailand and Viet Nam – a total of 139 surveys. We standardized as much as possible using generalized linear modelling (GLM) for:

- gear (mesh size, headrope length);
- depth and season; and
- vessel length overall (LOA) and horsepower (HP).

6.2 Standardized catch per unit effort

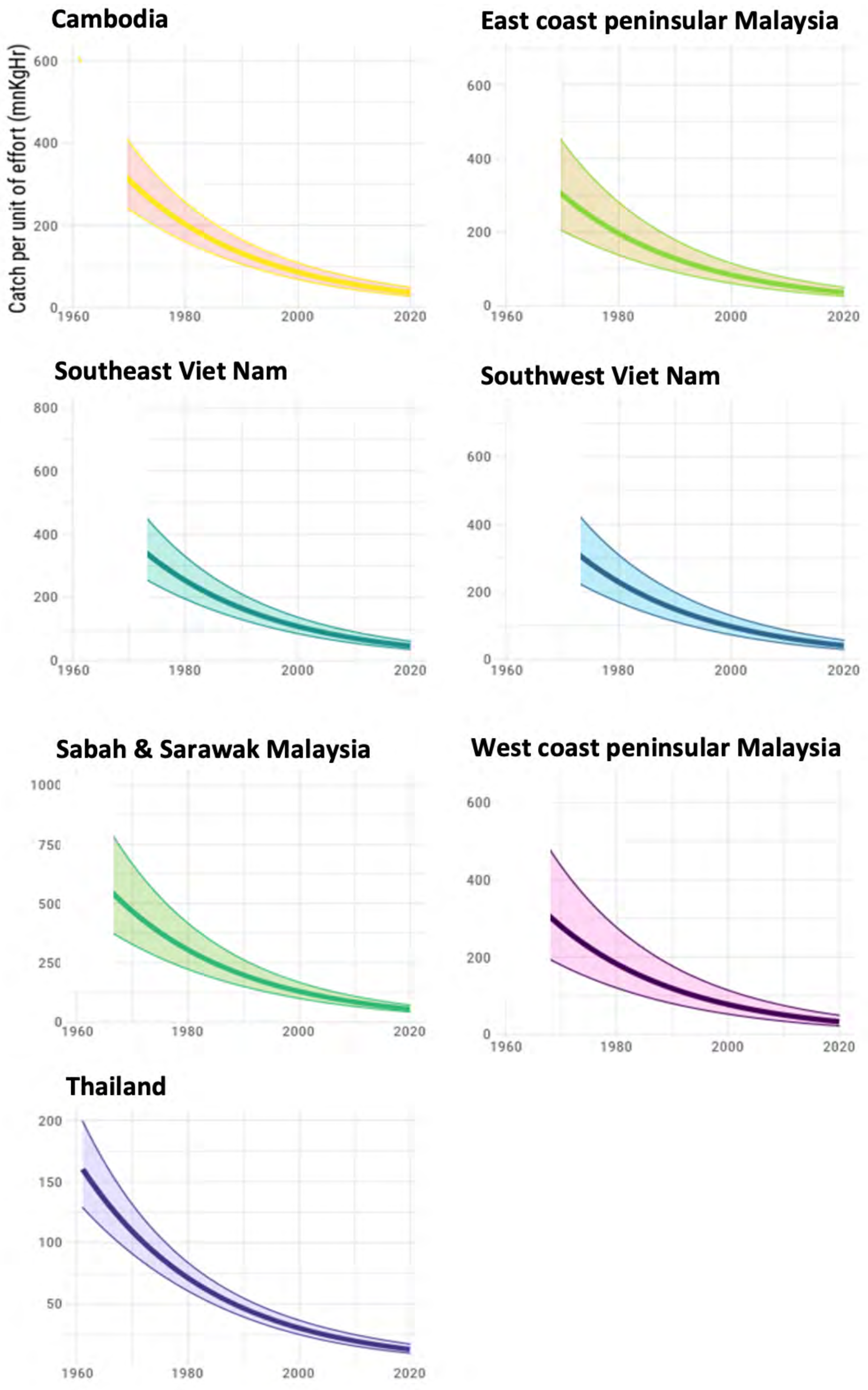
All available trawl resources surveys (139 surveys) were subjected to a GLM analysis. Due to a large amount of missing data, the results are based on taking only year and area into account (Figure 6.1). This showed that:

- All areas showed similar patterns of depletion.
- The median virgin biomass was around 300 kg/hour across all areas.
- The relative biomass is now around 10 percent of virgin in all areas i.e. 30 kg/hour.

An attempt was also made to carry out a manual standardization. This involved:

1. (to the extent possible): selecting trawl surveys conducted in waters <50 m;
2. (to the extent possible): correcting the cod end mesh size to a standard 40 mm, using surveys where both 25 mm and 40 mm cod ends were used simultaneously as a correction factor; and
3. correcting for vessel LOA and HP by reducing the catch per unit effort (CPUE) in proportion to the median size of the vessels.

Figure 6.1. Standardized CPUE for seven areas in Southeast Asia based on research surveys conducted from 1960 to 2020



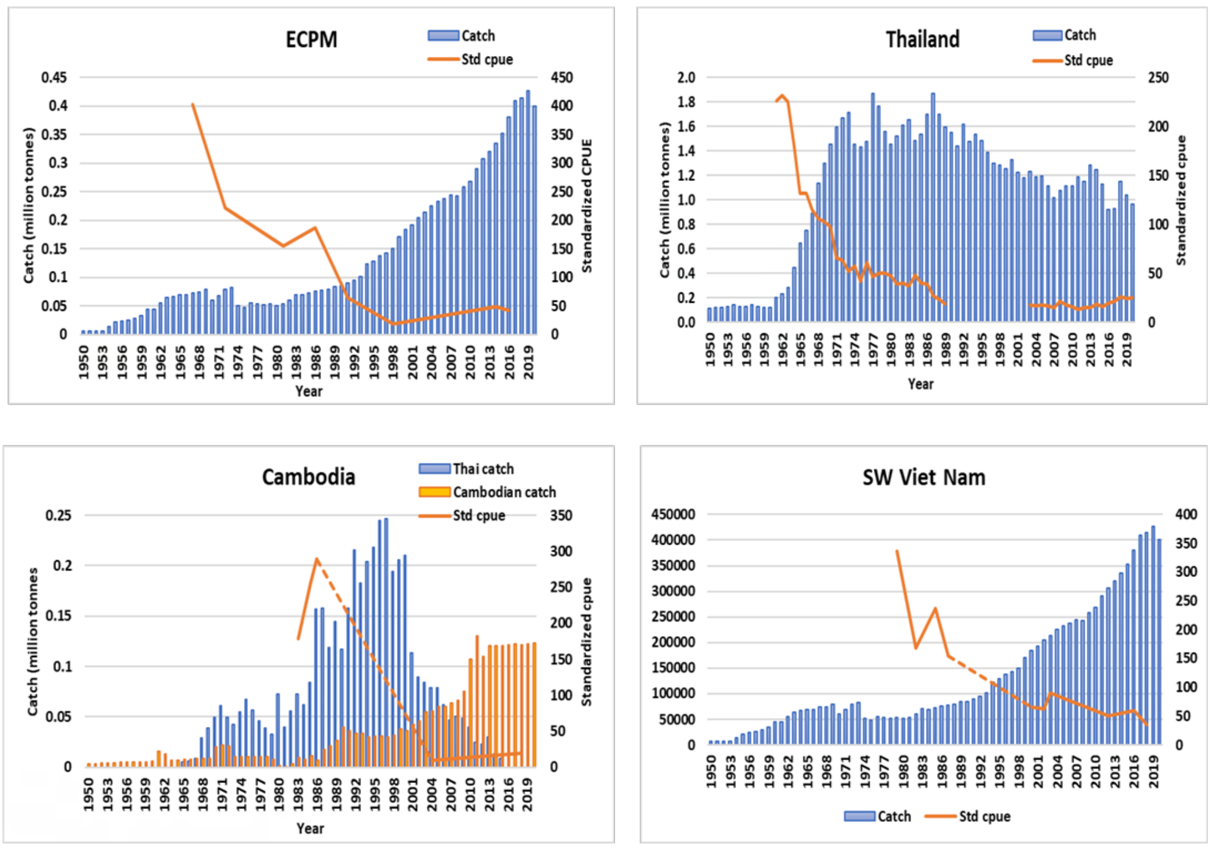
Notes: ECPM = East Coast Peninsular Malaysia; WCPM = West Coast Peninsular Malaysia.

Source: Authors' own elaborations.

There were not enough comparisons to assess the effect of season and this was not included in this analysis. The results (Figure 6.2) showed that:

- Relative biomass (kg/hour) had declined in all areas with the onset of industrial fishing (increased catches).
- The timing of this decline differed among areas reflecting the different development histories of the fisheries. For example, the CPUE declined rapidly in the 1960s in Thailand, the 1970s in Cambodia and ECPM and WCPM and not until the 1980s in Viet Nam.
- Now there are some signs of recovery, or at least stability, in ECPM, Thailand and Cambodia.

Figure 6.2. Catch (million tonnes) and (manual) standardized CPUE for ECPM, Thailand, Cambodia and southwest Viet Nam



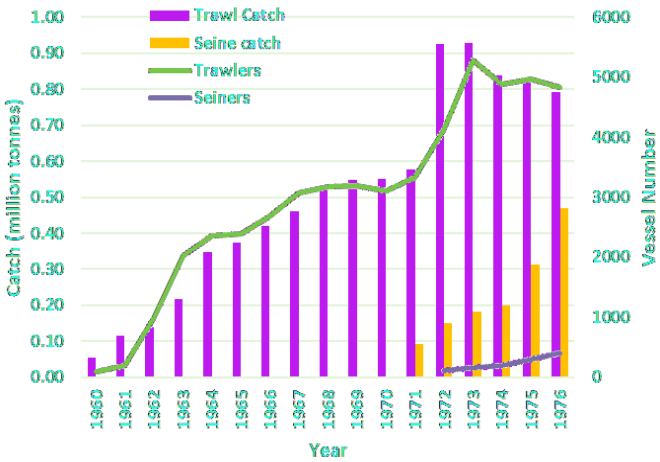
Notes: Catch data modified from FAO (2022) to correct for catches taken outside of the respective exclusive economic zones and disaggregated to differing areas based on national catch data.

Source: Authors' own elaborations using FAO catch data (FAO FishStaJ, 2022).

6.3 The first 15 years of industrial fishing, the example of the Gulf of Thailand

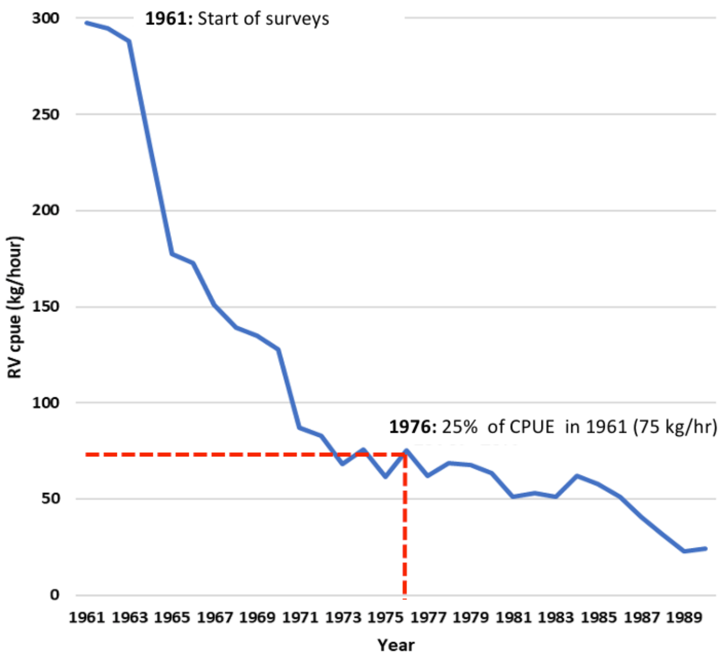
The first 15 years of industrial fishing had a large impact on the fisheries resources in Thailand as shown in Figure 6.2. Between 1961 and 1973 there were massive increases in the number of trawlers and purse seiners (from 99 to 5 410) and the total catch (from 200 000 tonnes to 1 345 000 tonnes) (Figure 6.3).

Figure 6.3. Trawl and purse seine catch and number of trawlers and purse seiners from 1961 to 1976



Source: Authors' own elaboration adapted from Menasveta (1980) using FAO catch data (FAO FishStaJ, 2022).

Figure 6.4. Decline in the relative biomass based on research vessel trawl CPUE (kg/hour) from 1961 to 1990 in Thai waters of the Gulf of Thailand

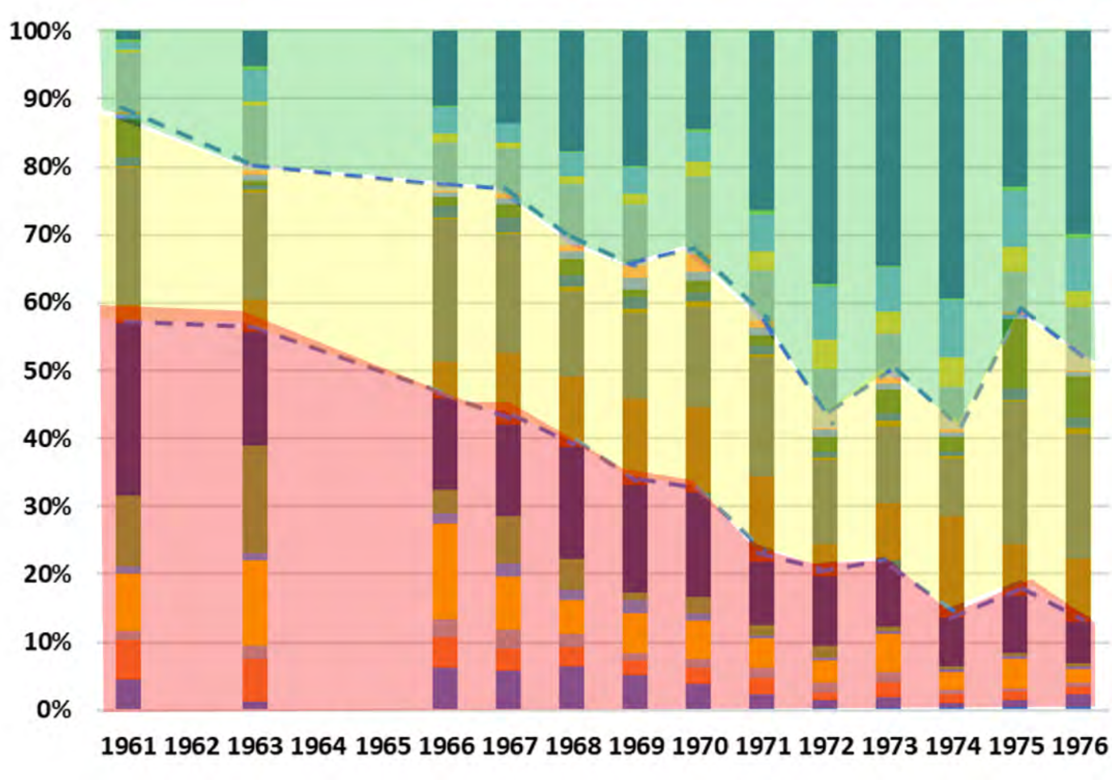


Sources: Authors' own elaboration redrawn and modified from Boonyubol, M. & Pramokchutima (1984) based on data (1965-1990) provided by Thai Department of Fisheries.

From 1961 to 1976, the data from the fishery independent trawl surveys show that the fishery resources also changed significantly, with relative biomass decreasing from 297.8 kg/hour to 75.1 kg/hour (a decline of 75 percent) (Figure 6.4).

The proportion of vulnerable species also declined from 57 percent to 13 percent of the total biomass and the proportion of less vulnerable species increased from 12 percent to 50 percent of the total biomass (Figure 6.5). High vulnerability species (shaded in light red) include snappers, sharks, rays, sweetlips, croakers and scads; moderate vulnerability species (shaded in pale yellow) include bigeyes, threadfin bream, Black pomfret, grouper, Largehead hairtail, Indian mackerel and Short mackerel; low vulnerability species (shaded in light green) include lizardfish, swimming crab, cuttlefish, non-penaeid shrimp and squid.

Figure 6.5. Changes in the species composition of the research vessel trawl catch, 1961 to 1976. Light red shading are high vulnerability species (including snappers, sharks, rays, sweetlips, croakers and scads); Pale yellow shading are moderate vulnerability species (including bigeyes, threadfin bream, Black pomfret, grouper, Largehead hairtail, Indian mackerel and Short mackerel); Light green shading are low vulnerability species (including lizardfish, swimming crab, cuttlefish, non-penaeid shrimp and squid).



Sources: Adapted from Pauly, D. 1987 by the author based on data provided by Thai Department of Fisheries.

6.4 Conclusions

Past research surveys are an underutilized source of information for stock assessments (both single and multispecies). This study has shown their potential as input into both single species and multispecies stock assessments.

The study had to rely on both details in published reports and unpublished survey results and was hampered by missing data. A concerted effort to recover past survey results is needed to inform stock assessment efforts in Asia. A good place to start would be the Fisheries Resources Information System and Tools (FIRST) (Trawlbase) of the International Center for Living Aquatic Resources Management (ICLARM)/Worldfish. The original database is no longer available at WorldFish and the data now reside with the participating countries.

We recommend that the historical trawl survey data be collated from the various countries as this would allow us to provide further robust and detailed analyses better characterizing the history of the fishery and providing standardized estimates of CPUE for the various regions.

References

Boonyubol, M. & Pramokchutima, S. 1984. *Trawl fisheries in the Gulf of Thailand.* ICLARM Translations 4. 12 pp. Manila, the Philippines, International Center for Living Aquatic Resources Management.

FAO. 2022. FishStatJ - Software for Fishery and Aquaculture Statistical Time Series. FAO Fisheries and Aquaculture Division [online]. Rome.

Gayanilo, F.C. Jr., Stromme, T. & Pauly, D. 1997. Towards a generic trawl survey database management system. In: G.T. Silvestre & D. Pauly, eds. *Status and management of tropical coastal fisheries in Asia*, pp. 116–132. ICLARM Conference Proceedings 53. 208 pp.

Menasveta, D. 1980. *Resources and fisheries of the Gulf of Thailand.* Training Department, Southeast Asian Fisheries Development Center. http://hdl.handle.net/20.500.12067/503

Pauly, D. 1987. *Theory and practice of overfishing: A Southeast Asian perspective.* ICLARM Contribution No. 356. Prepared for presentation at the 22nd Session of the Indo-Pacific Fishery Commission. Darwin; Authors' own elaborations based on data provided by Thai Department of Fisheries.

7 INTERPRETING SINGLE SPECIES STOCK ASSESSMENT RESULTS IN A MULTISPECIES FISHERY[7]

Derek Staples, Nipa Kulanujaree, Pavarot Noranarttragoon, Weerapol Thitipongtrakul and Orawan Prasertsook

7.1 Introduction

This paper examines three issues that need to be considered when interpreting single species stock assessments in a multispecies fishery and presents a way forward that takes them into account. It illustrates the issues with case studies based on data and preliminary stock assessments of fish stocks in Thai waters of the Gulf of Thailand.

The three issues that need to be taken into account when interpreting single species stock assessments in a multispecies fishery are:

1. The sum of the individual stocks maximum sustainable yields (MSYs) is greater than the aggregate multispecies MSY (MMSY) (see Fulton, this report).
2. In a multispecies fishery fished at MMSY, some stocks will be below their MSY, some at or around MSY and some above MSY.
3. Just considering the status of a small number of common species results in a biased view of the status of a multispecies fishery.

7.2 Case study stocks

Nineteen stocks were selected as case study examples. They were selected on the basis of:

- representation of marketing-determining species for surimi and market fish;
- coverage of a range of risk/vulnerabilities based on productivity/susceptibility analyses (PSAs) as given in FAO (2014);
- providing sufficient time-series catch and abundance indices data to be able to conduct surplus production modelling for individual stocks (either single species or a group of similar species) using:
  - o catch data 1971–2020 from the Department of Fisheries, Thailand (Thai DOF);
  - o research vessel data 1966–2020 from the Thai DOF; and
  - o early research vessel data 1961–1965 (Boonyubol and Pramokchutima, 1984) and Pauly (1987).

Some of the stocks were single species, for example the Largehead hairtail (*Trichiurus lepturus*) and some were groups of similar species (for example snappers). The case study species were divided into three risk groups, based on their PSA scores (Table 7.1).

Stock assessments were carried out by fitting SPMs based on using the sraplus (Ovando *et al.,* 2021) and Just Another Bayesian Biomass Assessment or JABBA (Winker *et al.,* 2018) R packages for these individual stocks as well for aggregated stocks. Details are given in Appendix A7.1.

7 The example stock assessment results used in this paper are for demonstration purposes only and should not be interpreted as statements of the status of the actual fisheries or stocks shown, without further diagnostic analyses.

Table 7.1. Selected case study stocks and their PSAs

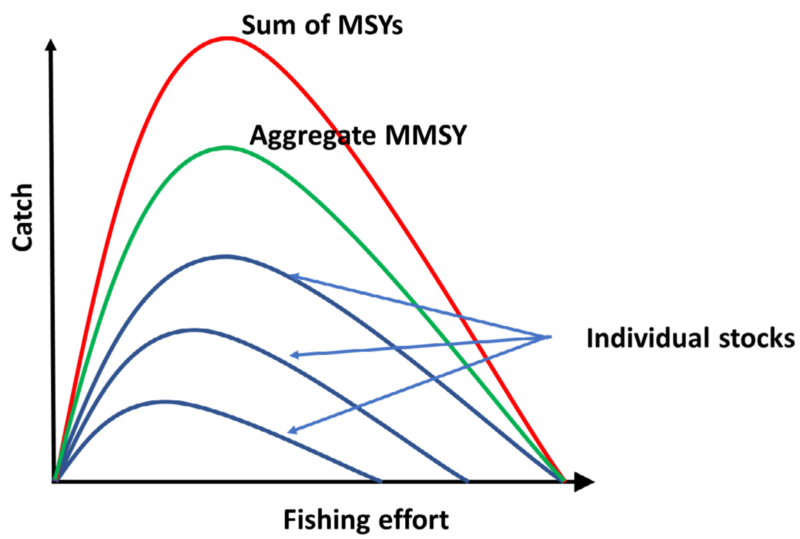
Species/species group					
High risk/highly vulnerable	PSA score	Medium risk/moderately vulnerable	PSA score	Low risk/low vulnerability	PSA score
Snapper	3.26	Bigeyes	2.29	Lizardfish	1.83
Sea catfish	3.21	Threadfin bream	2.20	Swimming crab	1.82
Sharks	2.95	Black pomfret	2.20	Cuttlefish	1.84
Rays	2.77	Grouper	2.11	Non-penaeid shrimp	1.80
Sweetlips	2.75	Largehead hairtail	1.85	Squid	1.73
Croakers	2.74	Indian mackerel	1.84		
Scads	2.40	Short mackerel	1.83		

Source: Authors' own elaborations.

7.3 The sum of the MSY of individual stocks is greater than the aggregate MMSY

As shown in Figure 7.1, each individual stock has its own relationship between fishing effort and catch. Because of food-web interactions the MMSY is not the sum of the individual MSYs.

Figure 7.1. Relationship between catch and fishing effort of three individual stocks. The sum of the MSY curves is shown in red, while the aggregate MMSY fit of the stocks is shown in green



Source: Authors' own elaborations.

Table 7.2 shows the example for the case study stocks from Thai waters of the Gulf of Thailand. The sum of the individual MSYs was 813 503 tonnes, while the aggregate MMSY was 415 134 tonnes. Simply summing the individual MSYs results in a two-fold overestimation of the MSY. Managing a fishery based on the simplistic assumption that each species can be fished at its MSY and using the sum of the MSYs to control catches will result in substantial overfishing.

Table 7.2. Comparison of the sum of the MSYs for 19 individual stocks and the aggregate MMSY calculated for the group as a whole

Species/species group					
High risk	**MSY**	**Medium risk**	**MSY**	**Low risk**	**MSY**
Snapper	11 983	Bigeyes	57 368	Lizardfish	22 961
Sea catfish	15 261	Threadfin bream	80 444	Swimming crab	10 693
Sharks	7 696	Black pomfret	6 335	Cuttlefish	49 330
Rays	14 174	Grouper	5 914	Non-penaeid shrimp	113 576
Sweetlips	447	Largehead hairtail	14 058	Squid	56 723
Croakers	42 298	Indian mackerel	58 260		
Scads	108 259	Short mackerel	137 723		
Sum of MSYs = 813 503 tonnes; **aggregate MSY of stocks** = 415 813 tonnes.					
Conclusion: Using the sum of MSYs leads to a two-fold overestimation of the aggregate MSY.					

Source: Authors' own elaborations.

7.4 In a multispecies fishery fished at MMSY, there will be stocks at their MSY and others that are above or below their MSY

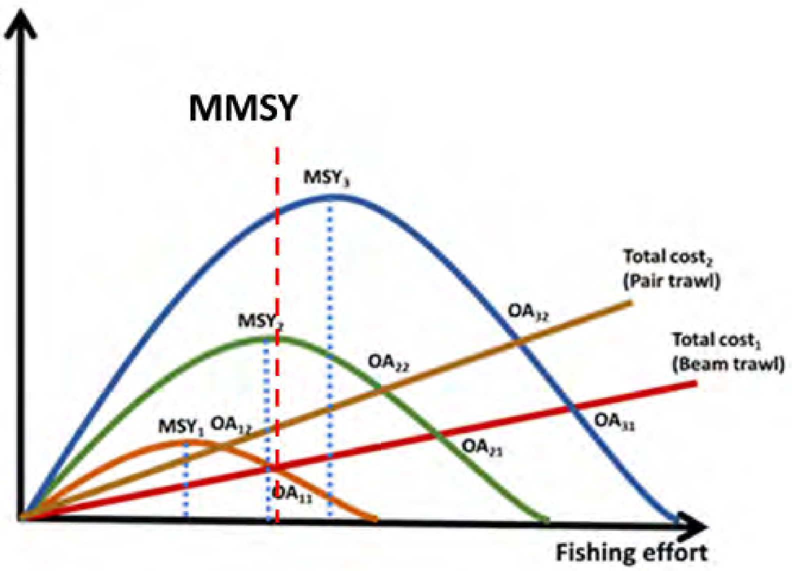
The MSY for individual stocks occurs at different fishing effort levels relative to the MMSY, it is not possible, or in fact, desirable to have all stocks fished at MSY. To ensure that all stocks in a multispecies fishery were fished at a level below their MSY would require such a low fishing effort that the fishery would be uneconomic and considerable amounts of the commercial stock would be greatly underfished.

Figure 7.2 demonstrates the relationship between fishing effort and catch for three stocks, each of which have their own MSYs and cost curves. The point at which the cost lines cut across the production curves is the open access (OA) point where there is no rent or profit. This occurs at different fishing efforts for different gears.

This illustrates how managing effort in a pair trawl or beam trawl fishery at MMSY, will result in the following outcomes:

- slight underfishing (below MSY) of species 3 (the most productive and least vulnerable species);
- species 2 (moderately resilient and medium vulnerability) will be fished at around its MSY;
- species 1 (the least resilient species, most vulnerable species) will be overfished (well beyond its MSY; and
- the revenues in both beam and pair trawl fisheries will be considerably higher than their costs, and thus the fishery would operate profitably.

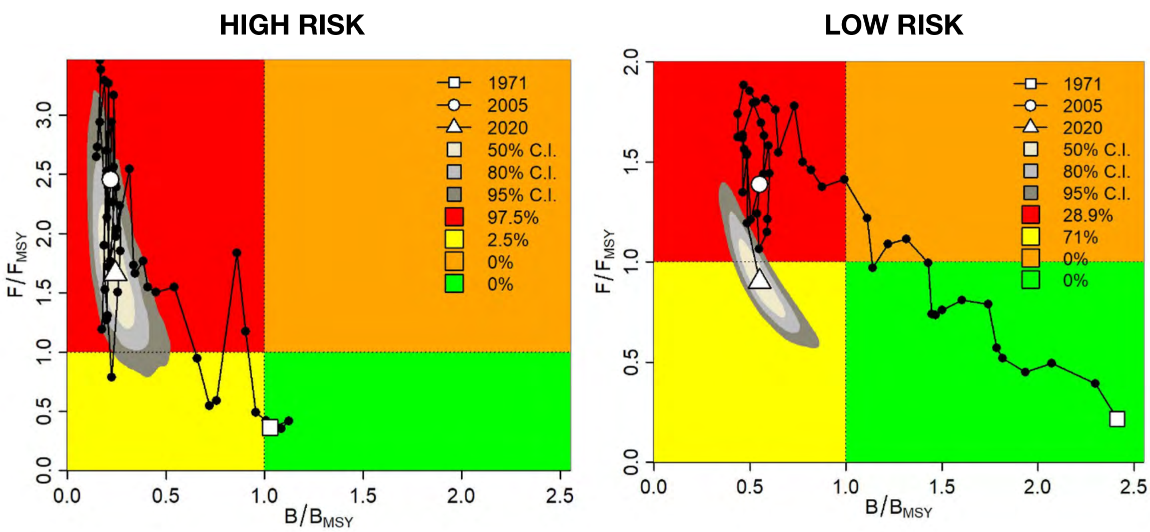
Figure 7.2. Revenue and cost curves for three individual stocks. The red dotted line is the MMSY. The blue dotted lines indicate the individual stock's MSYs. OA = where rent and profits are zero



Source: Authors' own elaborations.

For the case study stocks, Figure 7.3 illustrates that when the total fishery is being fished at MMSY, the more vulnerable/high-risk stocks are more likely to be fished at levels greater than their MSYs and the less vulnerable/low-risk stocks fished at levels less than their MSYs. The high-risk groups on the left of the figure were fished well above their biomass at MSY (B/MSY) and the fishing mortality was higher than that at MSY (Fmsy) since the early 1980s. On the other hand, the low-risk groups were fished closer to their B/MSY and F/MSY. The high-risk groups currently (2020) have a B/Bmsy ratio of only 0.29, whereas the low-risk groups have a ratio of 0.62.

Figure 7.3. Kobe plots for the two risk groups (high and low) demonstrating the differences in the past overfishing and fished status of the groups. Current status in 2020 is shown by the white triangle. The white circle is the status in 2005 and the white square the starting point in 1971



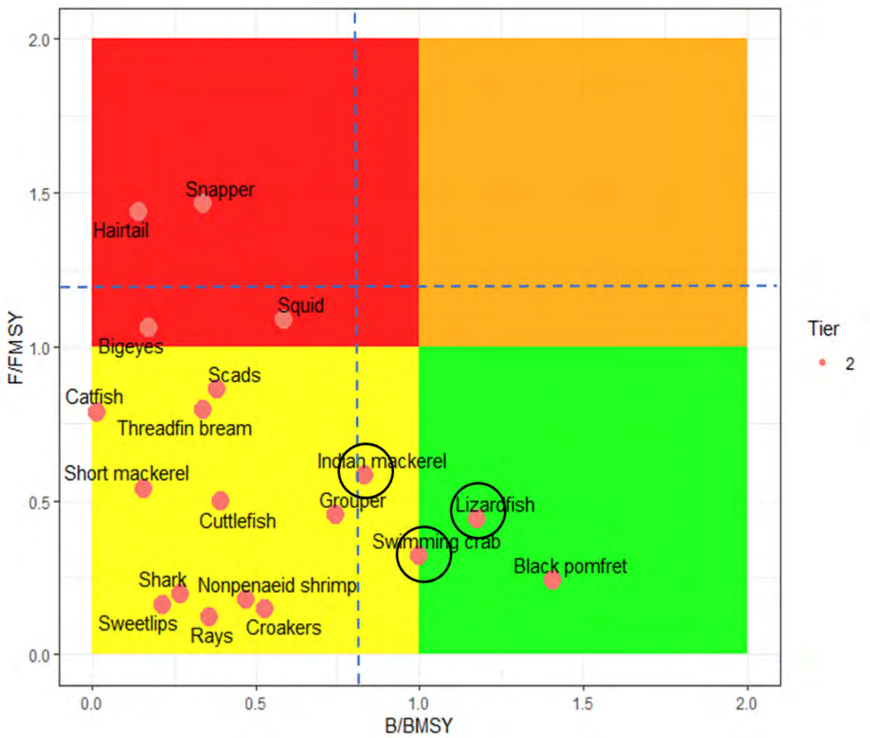
Source: Authors' own elaborations.

7.5 Focusing assessments on a small number of commonly fished stocks will result in a biased understanding of the status of a multispecies fishery

Figure 7.4 shows the status of the 19 case study species/species groups in 2020. The stocks with higher PSA scores (e.g. sharks, rays, snapper, catfish and sweetlips) tend to be more overfished that those with lower scores (e.g. Indian mackerel, swimming crab and lizardfish).

Confining the analysis of the status of a multispecies fishery to only a few species (especially if they are all from the same risk group) will result in a very different conclusion on the overall status of the fishery. In this example of 19 stocks, if Indian mackerel, lizardfish and swimming crab were selected as representative of the fishery and assessed using single species assessment methods it would be concluded that the fishery is sustainably fished. However, when a more complete selection of species in medium and higher risk groups is used, the picture is quite different (Figure 7.4).

Figure 7.4. Status of the 19 case study stocks in 2020. The circled stocks show that selecting common species for single species assessment could result in a wrong assessment of the status of the fishery as a whole



Source: Authors' own elaborations.

7.6 The way forward

To be able to correctly interpret single species assessments as part of multispecies fishery, we recommend a combination of multispecies and single species approaches:

1. multispecies assessments to give a picture of the overall state of a fishery.
2. single species assessments for indicator species from different risks groups to reduce the total number of assessments required but still give an objective overview of the fishery.

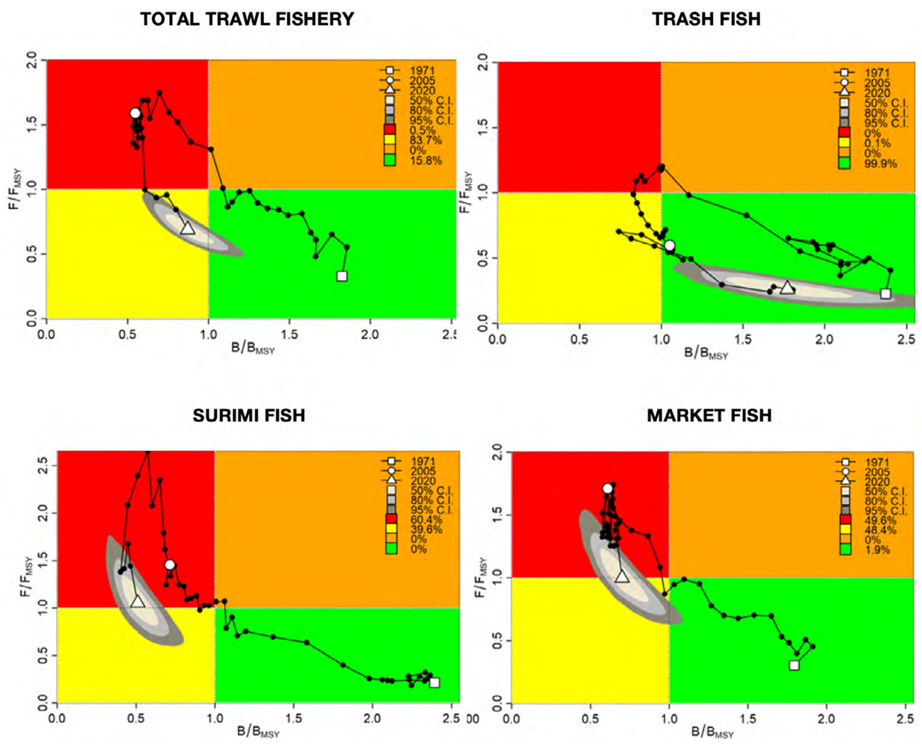
7.6.1 Multispecies stock assessments

The main methods that could be used for multispecies assessment are presented by Fulton (this document) and a full description of these multispecies assessments methods is given in Leadbitter *et al.*, forthcoming. The advantage of a multispecies assessment is that it provides an overview of the status of the fishery in relation to the MMSY that can be used to frame management advice.

As an example, an aggregated production model was fitted to the demersal trawl fishery data of Thai waters of the Gulf of Thailand using JABBA based on catch records and research vessel abundance indices from 1971 to 2020 (Figure 7.5). The analysis shows that the overall trawl fishery is overfished but has not been subjected to overfishing in recent years (since 2016 when management reforms were introduced). Further analyses shows that it is the surimi and market fish that are overfished (bottom left and right plots), with trash fish being underfished and subjected to underfishing (right hand top plot).

Depending on the management objective, the assessment is important to inform decision-making. For example, managing the fishery to maximize the catch of market and/or surimi fish at the expense of trash fish.

Figure 7.5. Kobe plots for the demersal trawl fishery in Thai waters of the Gulf of Thailand separated into three main components – trash, surimi and market fish



Source: Authors' own elaborations.

7.6.2 The indicator species approach with a focus on limit reference points such as biomass limit

Assessments for single species can be added through an indicator species approach. This approach is a way to choose what is monitored and analysed to help focus on the linkage between fishery status and management response. The first step is to select indicator species based on PSA/vulnerability scores and importance for management (management determining species).

It is important that the selected indicator species have ongoing assessments and there is a need to identify the ongoing assessment methods and ensure adequate monitoring. It is useful to select three groups of species based on their single species MSY (Newman *et al.,* 2018):

- likely "overfished" high-risk/vulnerability species;
- likely "sustainably fished" medium-risk/vulnerability species; and
- likely "underfished" low-risk/vulnerability species (high resilience).

Table 7.3 shows an example of selecting indicator species based on the criteria of (1) inherent vulnerability, (2) current risk and (3) management importance.

Table 7.3. An example of selecting indicator species based on the criteria of (1) inherent vulnerability, (2) current risk and (3) management importance

Species chosen for assessment by population model	Species	Inherent vulnerability	Current risk	Management importance	Combined
***	Species 1	4	4	**5**	**80**
***	Species 2	4	3	**5**	**60**
***	Species 3	3	2	**3**	**18**
***	Species 4	3	2	2	12
***	Species 5	3	3	**4**	**36**
	Species 6	2	2	2	8

Source: Modified from Newman, S.J., Brown, J.I., Fairclough, D.V., Wise, B.S., Bellchambers, L.M., Molony, B.W., Lenanton, R.C.J. *et al.* 2018. A risk assessment and prioritisation approach to the selection of indicator species for the assessment of multi-species, multi-gear, multi-sector fishery resources. *Marine Policy,* 88: 11–22.

Management importance in this regard also includes selecting species that are high risk and more vulnerable to fishing. Under the United Nations Convention on the Law of the Sea, all species belonging to the same ecosystem need to be maintained above levels at which their reproduction may become seriously threatened – the point of recruitment impairment (PRI). A common reference point for the PRI is the biomass limit (BLIM) often defined as 20 percent of the virgin biomass (biomass before fishing started).

The use of indicator species and the BLIM threshold is important when managing a fishery for MMSY because there will be some stocks that are overfished under the MMSY scenario and it is important that these stocks be maintained above the 20 percent BLIM threshold. If the vulnerable stocks fall below this level, then it is not possible to claim that the fishery managed at MMSY is sustainably managed.

Using the case study stocks as example indicator species for the Gulf of Thailand trawl fishery (Table 7.4) only 6 of the 19 case study stocks were above 20 percent BLIM in 2020 (for production models, this is based on B/K, where B = biomass and K = carrying capacity).

Table 7.4. Status of the 19 case study stocks in relation to a BLIM of 20 percent

Risk grouping	Species/group	B/K
High risk	Snapper	Below BLIM (<20%)
	Sea catfish	Below BLIM (<10%)
	Sharks	Below BLIM (<20%)
	Rays	Below BLIM (<20%)
	Sweetlips	Below BLIM (<10%)
	Croakers	Below BLIM (<20%)
	Scads	Below BLIM (<20%)
Medium risk	Bigeyes	Below BLIM (<20%)
	Threadfin bream	Below BLIM (<20%)
	Black pomfret	Above BLIM (>20%)
	Grouper	Below BLIM (<20%)
	Largehead hairtail	Below BLIM (<10%)
	Indian mackerel	Above BLIM (>20%)
	Short mackerel	Below BLIM (<10%)
Low risk	Lizardfish	Above BLIM (>20%)
	Swimming crab	Above BLIM (>20%)
	Cuttlefish	Below BLIM (<20%)
	Non-penaeid shrimp	Above BLIM (>20%)
	Squid	Above BLIM (>20%)

Source: Authors' own elaborations.

The indicator species can also be used for assessing and tracking the status of the fishery they represent (Table 7.5). The desired result would be for the high-risk and medium-risk groups to have a decreasing F/Fmsy, and an increasing B/Bmsy and B/K.

Table 7.5. Example of recent trends (2011–2020) in B/Bmsy, B/K and F/Fmsy of the Gulf of Thailand case study stocks

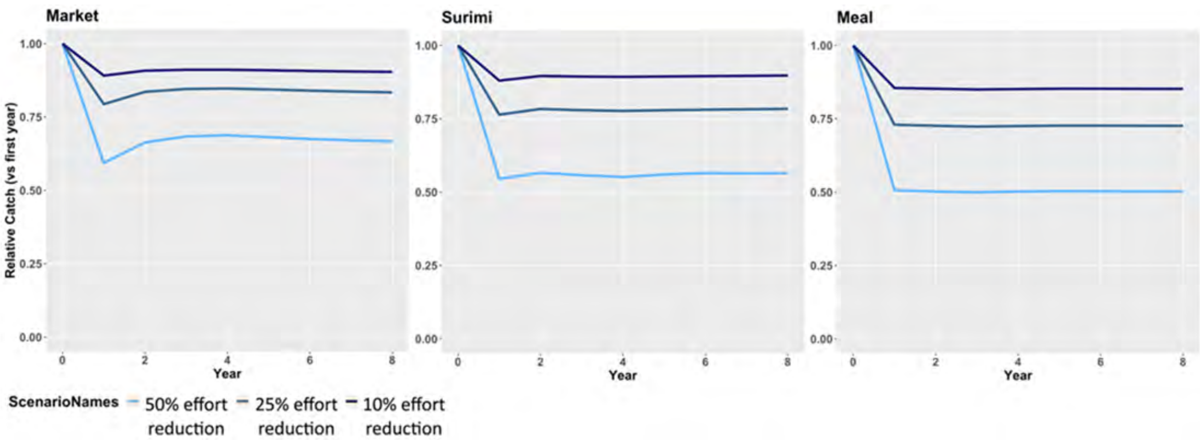
Risk grouping	Species/group	B/Bmsy	B/K	F/Fmsy
High risk	Snapper	Increasing	Stable	Decreasing
	Sea catfish	Stable	Stable	Increasing
	Sharks	Decreasing	Stable	Stable
	Rays	Increasing	Increasing	Decreasing
	Sweetlips	Increasing	Stable	Stable
	Croakers	Increasing	Increasing	Stable
	Scads	Stable	Stable	Decreasing
Medium risk	Bigeyes	Decreasing	Stable	Stable
	Threadfin bream	Stable	Stable	Stable
	Black pomfret	Increasing	Increasing	Stable
	Grouper	Stable	Stable	Decreasing
	Largehead hairtail	Decreasing	Decreasing	Increasing
	Indian mackerel	Increasing	Increasing	Stable
	Short mackerel	Decreasing	Decreasing	Stable
Low risk	Lizardfish	Increasing	Increasing	Decreasing
	Swimming crab	Increasing	Stable	Stable
	Cuttlefish	Stable	Stable	Stable
	Non-penaeid shrimp	Stable	Stable	Stable
	Squid	Decreasing	Decreasing	Stable

Source: Authors' own elaborations.

The indicator approach is particularly useful in predicting changes in species and/or market groups with changes in fishing mortality (Figure 7.6). For example, a 25 percent reduction in effort results in:

- 25 percent reduction in the catch of trash fish;
- 20 percent reduction in surimi species;
- 15 percent reduction in market fish; and
- possible increase in profits.

Figure 7.6. Example of predicting changes in relative catch of (1) market, (2) surimi and (3) trash (meal) fish



Source: Leadbitter *et al.* (forthcoming).

7.7 Conclusions

The principal message that emerges from this study is that care is needed in using the single species assessments in a multispecies fishery because:

- Interpreting single species stock assessments for multispecies fisheries needs to consider that the sum of individual MSYs is greater than the aggregate MMSY.
- Not all stocks can be fished at MSY (some more resilient stocks will be below their MSY and the higher risk/less resilient stocks will be above their MSY).
- Focusing stock assessments on a small number of commonly caught species in the fishery results in a biased picture of the fishery.

Incorporating these considerations into an assessment and management framework for a multispecies fishery requires a combination of multispecies assessments linked to an indicator species approach.

The multispecies assessments give a better picture of the status of the fishery and can also demonstrate changes in the overall fishery status. The selection of a set of indicator species that covers the range of vulnerability in the fished species enables further insight into the status of these species based on single species assessment.

Of particular relevance is the status of the more vulnerable species in relation to BLIM. When these analyses are used in concert, they can provide effective guidance on what is required for future management measures (e.g. effort reduction, mesh size restrictions, closed seasons, etc.), and can help focus on achieving better economic and social outcomes for management.

References

Boonyubol, M. & Pramokchutima, S. 1984. *Trawl fisheries in the Gulf of Thailand.* ICLARM Translations 4. 12 pp. Manila, the Philippines, International Center for Living Aquatic Resources Management. https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/9565/74571.pdf?sequence=1

FAO. 2014. *APFIC/FAO Regional Expert Workshop on Regional Guidelines for the Management of Tropical Trawl Fisheries in Asia, Phuket, Thailand, 30 September to 4 October 2013.* RAP Publication. 2014/01. Bangkok, FAO RAP. https://www.fao.org/publications/card/fr/c/f64766d6-7097-48cf-84fc-8fab66efb807/

Leadbitter, D., Fulton, E.A., Kulanujaree, N., Noranarttragoon, P., Nguyen, K.B., Phoonsawat, R., Porobic, J., Sainsbury, K., Staples, D., Vu, V.H. & Ye, Y. (forthcoming). *Managing multispecies and multigear fisheries – a toolbox for scientists, managers and stakeholders.* FAO Fishery and Aquaculture Circular. Rome, FAO.

Ovando, D., Hilborn, R., Monnahan, C., Rudd, M., Sharma, R., Thorson, J.T., Rousseau, Y. & Ye, Y. 2021. Improving estimates of the state of global fisheries depends on better data. *Fish and Fisheries*, 22(6): 1377–1391.

Pauly, D. 1987. *Theory and practice of overfishing: A Southeast Asian perspective.* ICLARM Contribution No. 356. Prepared for presentation at the 22nd Session of the Indo-Pacific Fishery Commission. Darwin.

Winker, H., Carvalho, F. & Kapur, M. 2018. JABBA: Just Another Bayesian Biomass Assessment. *Fisheries Research,* 204: 275–288.

Appendices

Appendix A7.1. Fitting surplus production models for the case studies

Catch and indices of abundance data (research vessel CPUEs) were fitted to a Pella-Thompson surplus production model using both the sraplus (Ovando *et al.,* 2021) and JABBA (Winker *et al.,* 2018) R packages. Sraplus requires the setting of three priors: (1) initial depletion, (2) *r*, the intrinsic rate of increase and (3) *K*, the carrying capacity, while JABBA requires two priors (1) initial depletion and (2) *r*, the intrinsic rate of increase (JABBA sets the prior *K* to 8 x the maximum catch).

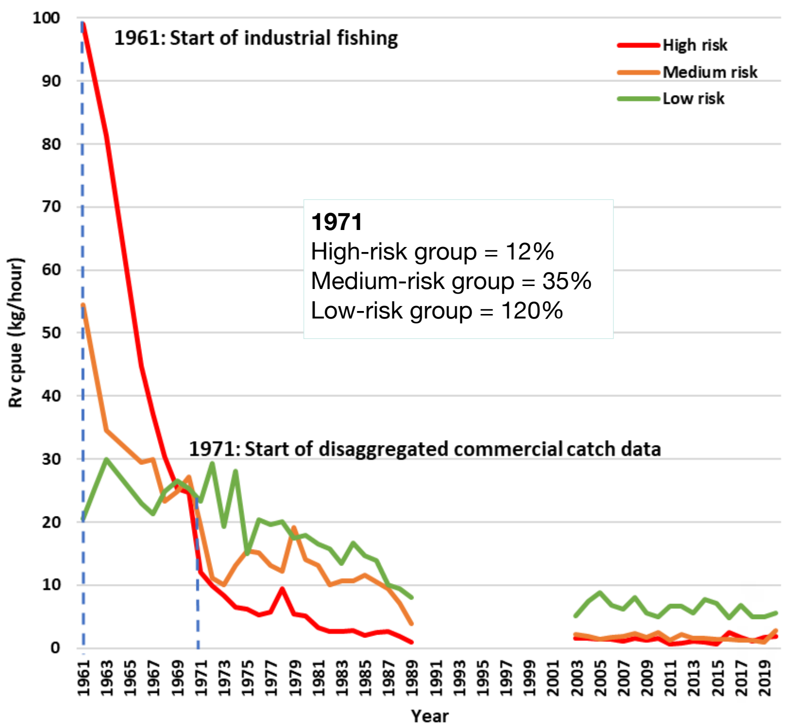
Data used in the assessments comprised:

- catch data 1971–2020 from the Thai DOF;
- research vessel data 1971–2020 from the Thai DOF.

Initial depletion

The prior for initial depletion was based on an analysis of the decline in relative biomass (kg/hour) of the case study stocks between 1961 (start of industrial fishing in Thai waters of the Gulf of Thailand and 1971 (start of the disaggregated catch data) (Figure A7.1). The high-risk more vulnerable stocks (snappers, sharks, rays, sweetlips, croakers and scads) declined rapidly with the onset of industrial fishing, declining from 99.0 kg/hour to 12 kg/hour in just ten years (i.e. 12 percent of virgin stock). The medium-risk stocks (bigeyes, threadfin bream, Black pomfret, grouper, Largehead hairtail, Indian mackerel and Short mackerel) also declined, but at a slower rate, declining to 35 percent in the ten-year period. Low-risk less vulnerable stocks (lizardfish, swimming crab, cuttlefish, non-penaeid shrimp and squid), on the other hand, increased to 120 percent, presumably as a result of "prey release".

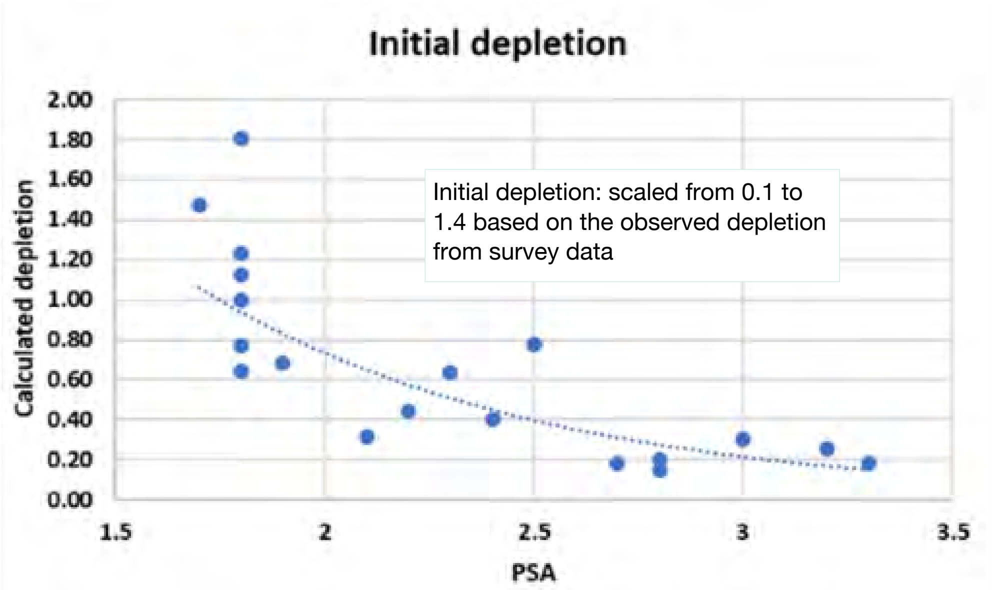
Figure A7.1. Research vessel relative biomass (kg/hour) for the period 1961 to 2020, showing the percent depletion in 1971 of the three risk groups (high, medium and low)



Source: Authors' own elaborations based on data provided by Thai Department of Fisheries.

The initial depletion values based on this analysis ranged from 0.1 for snapper to 1.4 for squid (Figure A7.2)

Figure A7.2. Initial depletion priors scaled to the stocks' PSAs

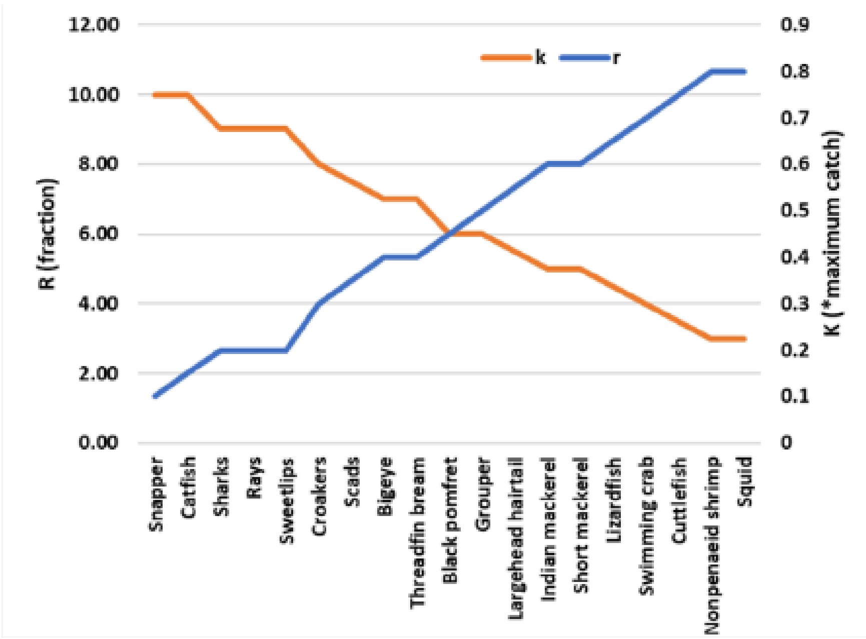


Source: Authors' own elaborations.

Prior values of *r* and *K*

Prior values of *r* were set as a function of the PSA score, starting with 0.1 for snapper and finishing with 0.8 for squid. *K* values were based on the premise that *K* = 1/*r* * maximum catch (Figure A7.3), modified so that *K* did not fall below three times the maximum catch.

Figure A7.3. *r* and *K* priors scaled to the stock's PSA from a high *K*/low *r* (10* maximum catch/0.1) to low *K*/high *r* (3* maximum catch/ 0.8)



Source: Authors' own elaborations.

The complete set of priors and coefficients of variation (c.v.) used in the stock assessments are shown in Table A7.1 and Table A7.2.

Table A7.1. Priors used in the fitting of sraplus and JABBA for individual stocks (JABBA does not require a prior K)

Species	PSA	Initial prior	c.v	*r*	c.v	*K**Max catch	c.v
Snapper	3.26	0.10	0.1	0.10	0.2	10	0.5
Catfish	3.21	0.10	0.1	0.15	0.2	10	0.5
Sharks	2.95	0.15	0.2	0.20	0.2	9	0.5
Rays	2.77	0.15	0.2	0.20	0.2	9	0.5
Sweetlips	2.75	0.20	0.2	0.20	0.2	9	0.5
Croakers	2.74	0.20	0.2	0.30	0.2	8	0.5
Scads	2.40	0.40	0.2	0.35	0.2	8	0.5
Bigeye	2.29	0.50	0.2	0.40	0.2	7	0.5
Threadfin bream	2.20	0.55	0.2	0.40	0.2	7	0.5
Black pomfret	2.20	0.60	0.2	0.45	0.2	6	0.5
Grouper	2.11	0.10	0.2	0.50	0.2	6	0.5
Largehead hairtail	1.85	0.65	0.2	0.55	0.2	6	0.5
Indian mackerel	1.84	0.70	0.2	0.60	0.2	5	0.5
Short mackerel	1.83	0.70	0.2	0.60	0.2	5	0.5
Lizardfish	1.83	0.80	0.2	0.65	0.2	5	0.5
Swimming crab	1.82	1.20	0.2	0.70	0.2	4	0.5
Cuttlefish	1.84	1.30	0.2	0.75	0.2	4	0.5
Nonpenaeid shrimp	1.80	1.35	0.2	0.80	0.2	3	0.5
Squid	1.73	1.40	0.2	0.80	0.2	3	0.5

Source: Authors' own elaborations.

Table A7.2. Priors used in the fitting of sraplus and JABBA for aggregated stocks

Species	Initial prior	c.v	*r*	c.v	*K**max catch	c.v
High-risk group	0.3	0.2	0.2	0.2	10	0.5
Medium-risk group	0.6	0.2	0.4	0.2	5	0.5
Low-risk group	1.0	0.2	0.8	0.2	3	0.5
Trawl	0.6	0.2	0.4	0.2	7	0.5
Trawl trash	1.0	0.2	0.8	0.2	3	0.5
Trawl surimi	0.6	0.2	0.2	0.2	5	0.5
Trawl market	0.4	0.2	0.3	0.2	7	0.5

Source: Authors' own elaborations.

8 COUNTRY STOCK ASSESSMENT OVERVIEWS

This section summarizes overviews from nine countries in the Asian region and one regional overview for the South China Sea, which was treated as one fishery management area (Table 8.1).

The number of fishery management areas (FMAs) where fish stocks are assessed ranged from 1 for Maldives and 2 for Cambodia to 11 for Indonesia and 12 in the Philippines (Table 8.1). These management areas are defined by depth contours for Bangladesh (≤40 m and >40 m) and Cambodia (≤20 m and >20 m) and by geographic location extending to the exclusive economic zone in other countries where more than 1 FMA was defined.

Multigear and multispecies fisheries are dominant in all countries. The sources of data used in the assessments included catch and effort statistics, fishery-independent surveys in some cases (e.g. the long-running demersal trawl surveys in Thailand, 1961–2022) and acoustic surveys in Indonesia, and data on length distributions from landing sites (Table 8.1).

The data collection systems in some countries have been in place for many years which contrasts with recently implemented systems in Sri Lanka and Maldives and those planned to be developed for Cambodia.

Multispecies aggregate SPMs were applied to different species groups in six of the countries (Bangladesh, India, Indonesia, Western Peninsular Malaysia, the Philippines and Thailand) with the number of species groups in the FMAs ranging from 2 in Bangladesh (finfish excluding hilsa and all shrimp) to 9 in Indonesia and 12 in Malaysia using groupings based on finfish and invertebrates (Table 8.1).

All of these countries, except for Indonesia, also complete national stock assessments on individual species using a variety of approaches based on catch and length frequency data:

- SPMs for individual species; and
- length-based methods such as: length-based virtual population analysis, length-based catch-curve analysis, length-based spawning potential ratio (LBSPR), length-based Bayesian biomass estimation (LBB).

Currently, no countries are using ecosystem modelling to routinely evaluate fisheries and their ecosystems. These topics were covered in the three overview presentations by Fulton *et al.* and the evaluation of trawl survey monitoring by Staples *et al.* respectively (presented earlier in this report).

Typically, stock assessments are carried out by the relevant national research institute for fisheries and the results are reported and reviewed by the national government agency responsible for fisheries management before the assessment and recommendations are made available to the government ministry (Table 8.2).

In Indonesia, although the assessments were completed by the Marine Fisheries Research Center (now housed within the National Research and Innovation Agency, BRIN), they are evaluated by a National Commission on Stock Assessment who report to the Ministry for Maritime Affairs and Fisheries (Table 8.2).

In the Philippines, management boards for each FMA have been established recently and reporting now goes from the National Fisheries Research and Development Institute to the Bureau of Fisheries and Aquatic Resources and the FMA Board, who consider the recommendations from subcommittees of these agencies.

Annual assessments are carried out in some countries but reporting periods may be less frequent e.g. every two years (Malaysia), three years (Bangladesh, planned for Maldives) and five years (Indonesia, planned for South China Sea). The frequency of assessment and reporting has yet to be determined for Cambodia and Sri Lanka.

When considering the assessment recommendations, governments often consider the socioeconomic impacts of fisheries regulations and in some countries, harvest strategies are being implemented, or being considered for implementation, for areas within FMAs such as:

- Bangladesh, grouper, snapper;
- Indonesia, Blue swimming crab and grouper;
- Maldives, grouper; and
- Sri Lanka, Blue swimming crab.

More details are provided in Table 8.2.

Table 8.1. Summary of country and major regional overviews of fisheries, data sources and assessments presented at the workshop

Country/region (number of FMAs)	Fisheries	Data sources	Assessments
Bangladesh Two FMAs	**FMA 1:** <40 m depth, artisanal: gillnet, set bagnet, hook and line **FMA 2:** >40 m depth, industrial: mid-water trawl, shrimp trawl, demersal fish trawl, gillnet, hook and line	1. Catch and effort data from 2010 to 2020 2. Research surveys: 2017–2020, 2022 3. Artisanal fisheries: length frequency data 2012–2018	Bayesian surplus production models (JABBA) **Multispecies:** 1. Finfish (all fish, excluding hilsa) – total finfish in each FMA. 2. Shrimp (all shrimp) – total shrimp in each FMA **Single species:** Five species in each FMA: *Tenualosa ilisha, Harpadon nehereus, Pampus argenteus, Aurius aurius, Lepturacanthus savala* Length-based catch curve analysis (fishblicc on GitHub) also used for single species
Cambodia Two FMAs	**FMA 1:** inshore <20 m depth **FMA 2:** offshore >20 m depth Specific fisheries have not been defined within each zone	Fishery independent surveys starting from the 1960s up until 2018	**Historical:** Multispecies: Offshore – a number of trawl resource surveys **Single species:** An assessment of short mackerel (*Rastrelliger brachysoma*) surplus production estimation of MSY, MEY and $B_{0:}$ and catch rates of crabs in coastal gillnet and trap fisheries
China South China Sea (regional)	Multigear fisheries Ten fish species are assessed from the demersal trawl fishery (*Trichiurus lepturus, Priacanthus macracanthus, P. tayenus, Nemipterus virgatus, N. bathybius, Saurida undosquamis, Evynnis cardinalis, Trachurus japonicus, Decapterus maruadsi, Pennahia macrocephalus*)	Length data from trawl surveys during 2016–2017	**Single species**: 1. LBB 2. Length-based virtual population analysis (FiSAT II)

Country/region (number of FMAs)	Fisheries	Data sources	Assessments
India Nine states and four union territories (UTs)	Stocks are assessed in each **state** or **UT Species group** assessments – range from 9 (Goa) to 20 in Tamil Nadu **Single species assessments** – range from 2 in Goa to 19 in West Bengal Assessments range from 56.9% of the catch (Gujarat and Daman Diu) to 89.4% (Karnataka)	Time series of a) catch of species in each gear; b) fishing effort (hours) for each gear; c) total catch for each fishing gear	**Historical:** Length-based assessments using VBGF, CPA and the Thompson Bell Model since 1980; 51 single species stocks assessed in 1990–1991 Effort is standardized for each gear. Machine learning models used to estimate parameters using ADMB Kobe plots of B/Bmsy vs. F/Fmsy are produced for each state A total of 223 stocks have been assessed and classified as sustainable or unstainable in each state (Sathianandan *et al.,* 2021)
Indonesia Eleven FMAs	Multiple gear fisheries Nine **species groups** are assessed across all fisheries – small pelagics, large pelagics, demersal fish, reef fish, shrimp, lobster, crabs and squid (large tuna are part of RFMO assessments) **No single species** assessments for FMAs (only within regions of FMAs)	1. Catch and effort statistics 2. Biomass surveys – hydroacoustic surveys 3. Biology and population parameters	Each **species group** is assessed in each FMA (99 assessments). 1. Biomass dynamic models (equilibrium and non-equilibrium) – F/Fmsy and B/Bmsy 2. Hydroacoustic estimator
Malaysia (Western Peninsular Malaysia, not including Sabah) Four FMAs	Twelve **species groups** across the four FMAs (# of FMAs assessed): small pelagics – (4); neritic tunas – (3); anchovies (2); large pelagics (4); demersal fish (4); shellfish (4); shrimp (4); sergestidae shrimp (2); cephalopods (4); brackishwater fish (4); crabs (4); lobster (3) **Single species** assessments for five species: *Euthynnus affinis; Rastrelliger kanagurta; R. brachysoma; Amblygaster sirm; Photololigo duvaucelii*	**Species groups**: 1. Recent catch, effort 2. Biological data **Single species assessments** 1. Recent biological data	**Multispecies groups**: 1. SPM (Fox/Schaefer; with covariates) 2. CMSY **Single species assessments** 1. Length-based virtual population analysis (FiSAT II) 2. SPMs (with covariates) 3. CMSY
Maldives One FMA	**Reef-based fisheries** and tuna fisheries. Tuna fisheries are assessed within RFMOs **Five grouper species** are assessed. No species groups are assessed	**Single species** 1. Catch trends 2. Scientific monitoring for reef fish and grouper – catch, effort, composition and size distribution of catch	**Five grouper species** (2 *Ephinephelus;* 3 *Plectropomus*): 1. Bayesian length-interval and catch curve estimation 2. Estimation of spawning potential ratio and *F* ratio

Country/region (number of FMAs)	Fisheries	Data sources	Assessments
Philippines Twelve FMAs	Multigear fisheries **Species groups** assessed across FMAs – small pelagics, tuna, demersal fish, reef fish, Blue swimming crab **Single species** assessments for some FMAs	1. Catch and some effort statistics 2. Fishery independent trawl surveys in a few specific grounds 3. Biology and population parameters	**Single species** assessments 1. Length-based virtual population analysis (FiSAT II) 2. SPMs
Sri Lanka Seven FMAs	Fourteen fisheries are recognized and five are assessed **using single species assessments** (#FMAs): herring (1); sardinella (two species) (1); Blue swimming crab (2); sea cucumber (2); lobster (1); giant mud crab (2)	**Single species data** 1. Catch and effort data (herring and sardinella, sea cucumber) 2. Size distribution	Single species assessments 1. Bayesian surplus production model (JABBA) – applied to two sardinella species 2. Length-based spawning potential ratio for spotted sardinella, scalloped spiny lobster, Blue swimming crab and giant mud crab 3. Leslie-Delury estimation – applied to two species of sea cucumber
Thailand Two FMAs	Two management areas Gulf of Thailand (GoT) Andaman Sea (AnS) **Three fisheries** are assessed in each FMA – demersal, pelagic, anchovies	1. Catch and effort data starting in 1971 2. Fishery independent trawl survey data from 1961 to 2022 3. Length-frequency data for single species assessments	**Multispecies assessments** for each fishery (demersal, pelagic and anchovies) in each fishery of the GoT and AnS. Assessments using the Fox Production model **Single species** assessment for 14 species. Demersal fish (5); shrimp (3); crab (1); squid (2); cuttlefish (2); anchovies (1). All except two species in both GoT and AnS Length-based Thompson and Bell model (FiSAT ii and Excel)

Source: Authors' own elaborations.

Table 8.2. Institutions and agencies responsible for stock assessments, reporting frequency and fishery management

Country/ region	Agency responsible for assessments	Frequency of assessments and reporting	Reports sent to	Management agency
Cambodia	Fisheries Administration (FiA) (national) Marine Fisheries Research and Development Institute (MaFReDI) (subnational) Assessments supported by SEAFDEC and FAO	Ad hoc	Not yet assigned as no regular assessments are in place	MaFReDI is considered the agency responsible
Bangladesh	Marine Fisheries Survey Management Unit, Department of Fisheries Targeted or local assessments are also carried out by the Bangladesh Fisheries Research Institute and national universities Supported by World Bank/FAO	**Multispecies:** Fish and shrimp – every three years **Single species:** Every three years; *Tenualosa ilisha* also had ad hoc assessments	Department of Fisheries	Department of Fisheries Fisheries Management Plans are being considered and they may include harvest strategies
China – South China Sea	South China Sea Fisheries Research Institute, Chinese Academy of Fishery Science	Stock assessments every five years. First assessments completed in 2021. Catch composition, catch rate, and biomass distribution are reported annually	Bureau of Fisheries, Ministry of Agriculture and Rural Affairs (MARA)	Bureau of Fisheries
India	Central Marine Fisheries Research Institute (CMFRI), Indian Council of Agricultural Research (ICAR)		State and central government	
Indonesia	National Commission for Fishery Resources Assessment (assessments by Research Center for Fisheries, Research Institute for Marine Fisheries, now within BRIN)	Annual assessments; reporting every five years	Ministry for Maritime Affairs and Fisheries (MMAF)	MMAF (fishing licences, TAC and investigating harvest strategies)
Malaysia (Western Peninsular Malaysia)	Fisheries Research Institute (FRI), Department of Fisheries (DOF)	**Twelve species groups** every two years **Five individual species** annually	DOF, Ministry of Agriculture and Fisheries (MAF) and the National Committee for Fish Stocks	MAF

Country/ region	Agency responsible for assessments	Frequency of assessments and reporting	Reports sent to	Management agency
Maldives	Maldives Marine Research Institute (MMRI), Ministry of Fisheries, Marine Resources and Agriculture (MIMRA)	**Reef fish:** five species assessments – first assessments have just been completed; plan for assessments every three years **Tuna:** Assessments as part of the Indian Ocean Tuna Commission	Fishery Management Plan Committee, MIMRA The minister and senior policy officials within the government	MIMRA (consideration of harvest strategies)
Philippines	National Fisheries Research & Development Institute (NFRDI) and regional offices of the Bureau of Fisheries and Aquatic Resources (BFAR)	Annual	BFAR & FMA committees	BFAR and FMA management board (recent) Formerly BFAR only
Sri Lanka	National Aquatic Resources Research and Development Agency	The first report is being completed (based on assessments in 2020 and 2021 The frequency of assessments and reporting is to be determined	Department of Fisheries and Aquatic Resources (DFAR)	DFAR, harvest strategies are being developed for Blue swimming crab
Thailand	Department of Fisheries (DOF) national assessments Marine Fisheries Research and Development Division, DOF (subnational) Supported by Hokkaido University, SEAFDEC, FAO	Multispecies and single species assessments are completed each year	National Committee on Fisheries Policy (for multispecies assessments) Single species assessments are considered for monitoring important economic species	National Committee on Fisheries Policy Considers impacts on the fish resources and socioeconomic impacts on fishers. No harvest strategies are currently in place

Source: Authors' own elaborations.

9 INDIVIDUAL FISHERY ASSESSMENTS

This chapter presents summarized information from eleven short powerpoint and poster presentations on individual species assessments (Table 9.1) and three broader topics (SEAFDEC research in Southeast Asia, an assessment of a number of species in the Gulf of Thailand and moving towards an adaptive, climate-resilient, multispecies fisheries management plan in the Philippines).

Single species assessments covered a range of stocks from short-lived, fast recruiting species in coastal waters (e.g. hilsa, lizardfish, swimming crab) to deeper waters (e.g. sardines, scad mackerels). There were several examples of longer-lived demersal species (groupers). These stocks are from fisheries of diverse scale (small scale to commercial/large scale) and fishing gear types (targeted handheld gears, to gillnets to trawls and purse seines).

The assessments used a range of approaches:

- FiSAT, Elefan, Logistic for maturity;
- LBB and LBSPR.

The posters described what was done with an assessment, the results and outcome. While there was some diversity in the analysis used, most were based on FAO-ICLARM Fish Stock Assessment Tool (FiSAT) analysis. FiSAT was originally developed to estimate growth and is not very accurate at estimating *F* or *M* (*M* estimated by Pauly's temperature equation). It was noted that there was a need to critically examine the data used and how they were collected (i.e. with what objective) and whether FiSAT was an appropriate tool to examine the data. Some observations and conclusions that emerged from the poster session were:

1. Attention needs to be paid to examining the data to assess if it is fit for purpose and to determine the correct assessment tool to apply. This will require development and testing of examination tools using standard scripts in *R* and the Shiny app. It was noted that FAO is currently working on developing such tools for examining data, their validity and use.
2. Although FiSAT is good and is useful, it would be desirable to move beyond FiSAT and look at alternatives and additional ways to examine data and how they may influence estimates of fishing mortality, alternative reference points and ultimately influence management.
3. Few presentations examined the sensitivity of the model to its parameters and how it performed with respect to the key assumptions applied. This should be the norm, rather than the exception and there is a need for greater emphasis on: model fits, diagnostics, misspecification, alternative model examinations and uncertainty.
4. The utility of the model results as advice for management and its effectiveness, was only covered in a few cases. There is a need to strengthen the linkage between assessment results and management advice which requires good communication on the model findings, their uncertainties and options for management action.

Table 9.1. Summary of assessments for single species within fishery management areas of South and Southeast Asia, presented in posters and short powerpoint presentations

Species and main fishing gear(s) Country, area, presenter	Data and analyses	Biology and population parameters	Estimates, assessment	Recommendations
Hilsa shad (*Tenualosa ilisha)* Gillnets (<2% in trawl) Bangladesh, Megna River *Jalilur Rahman*	Monthly size data from eight landing sites (n = 16 000) Research surveys: 2017–2020, 2022 Artisanal fisheries: length frequency data, 2012–2018 Length-based methods, catch information and FiSAT	Spawning and juveniles in freshwater Larger juveniles and adults – estuary and marine waters Max. Age, length ~ 6 y, 630 mm Age, size at 1st maturity (9 to 12 months), 180 mm L_∞ = 587 mm K = 0.90/y L at 1st capture = 250 mm	M = 0.36/y F = 2.83/y F/Z = 0.48 MSY = 526 000 tonnes	• Improve compliance for fishing closures (spawning) and on the size limit (>250 mm) • Improve coverage of incentive-based management • Assess stocks every three years • Determine carrying capacity based on MSY
Mackerel scad (*Decapterus macarellus)* Light fall-net fishery in deep waters China – South China Sea *Kui Zhang*	Length data from light fall-net fishery surveys during 2012–2014 and 2019–2021 ELEFAN, Logistic for maturity LBB LBSPR	L_∞ = 360 mm K = 0.37/y M = 0.74/y L_{50} = 243 mm L_{95} = 267 mm M/K = 2.00	$Lc/Lopt$ = 1.2 $B/Bmsy$ = 0.7 (0.55–0.86) F/M (LBB, LBSPR) = 2.1, 3.06 SPR = 0.12	• Spawning stock is depleted and overfishing is taking place • Reduce fishing effort • Reduce fishing on immature fish by increasing mesh size • Establish collaboration with other countries for research, assessment and management of stocks
Mackerel scad (*Decapterus macarellus)* Minipurse seine fishery Indonesia, Sulawesi Sea *Rian Prasetia*	Catch and length data from eight landing sites for 2019–2021 (n = ~37 000) Length-based spawning potential ratio (LBSPR)	L_∞ = 377 mm K = 0.85/y M = 1.10/y M/K = 1.29 L at 1^{st} capture = 133 mm L at 1^{st} maturity = 239 mm	LBSPR = 0.15 F/M = 2.45	• Stock is overfished and overfishing is occurring • Increase size at first capture • Reduce fishing during the spawning season

Species and main fishing gear(s) Country, area, presenter	Data and analyses	Biology and population parameters	Estimates, assessment	Recommendations
Coral leopard grouper **(*Plectropomus leopardus)*** Bottom longline, speargun, handline Indonesia, Saleh Bay, West Nusa Tenggarah *Irfan Yulianto*	Monthly catch and length data from landing sites for 2017–2021 (n = 5 207) ELEFAN LBSPR Catch at MSY	Max. age ~25 y L_∞ = 719 mm *K* = 0.12/y *M* = 0.16/y *M/K* = 1.29 SL_{50} = 355 mm to 398 mm, depending on the method of capture L_{50} = 388 mm	LBSPR = ~0.28 MSY = 4.62 tonnes B/Bmsy = 1.07 F/Fmsy = 0.97	• Stock is overfished (SPR <0.3) based on SPR • CMSY results suggest stock is fully fished (B/Bmsy ~1 and F/Fmsy ~1) • Reduce catch of immature fish • Initiate agreement with purchasers that they only purchase fish of an agreed size • Increase compliance on banned fishing methods (e.g. dynamite, cyanide use, speargun with hookah)
Grouper ***Plectropomus* spp. (4 species)** Speargun with hookah (85%), traps Indonesia, Karimun Jawa National Park, north Java Sea *Rian Prasetia*	Catch and length data from landing sites for 2015, 2018, 2020 ELEFAN LBSPR)	L_∞ = 622 mm to 936 mm *K* = 0.10 mm to 0.13 mm *M* = 0.14/y to 0.18/y *M/K* = 1.27 to 1.44	LBSPR = ~0.15 to 0.31	• Stocks of three species are overfished (but not *P. aerolatus*) • Limit the allowed catch • Ban fishing during the spawning season • Prohibit catching fish <size at 50% maturity • Regulate the use of compressor spearfishing • Increase surveillance and enforcement in MPAs
Bali sardine (*Sardinella lemuru*) Purse seine (90%), Ring net, bag net Philippines, Sulu Sea *Divina Ignacio*	Schooling species, short-lived Length and catch data from 33 landing sites (n >165 000 for lengths; n >10 000 for reproductive biology)	Max. age <5 y L_∞ = 232 mm *K* = 1.02/y *M* = 0.16/y *M/K* = 1.29 SL_{50} = 151 mm, SL95 = 174 mm L_{50} = 151 mm, L_{95} = 174 mm	Length-based virtual population analysis (FiSAT II) Froese % mature *F/Z* = ~0.7 to 0.8 *F/M* = ~2.6 to 3.8 % mature in catch = 31 to 45	• Adjust timing of closed season (note that this is determined from Fishbase data and not determined from actual samples) • Reduce the catch of small, immature sardines to 20% • Determine the distribution of the stock • Control fishing effort on sardines

Species and main fishing gear(s) Country, area, presenter	Data and analyses	Biology and population parameters	Estimates, assessment	Recommendations
Greater lizardfish (*Saurida tumbil)* Trawl (3 cm mesh cod end) Philippines, Lingayen Gulf *Greg Buccat*	Catch and length data from three landing sites.	L_∞ = 390 mm *K* = 0.70/y	LBSPR Beverton and Holt yield per recruit (growth and mortality) LBAR AMSY LBB Froese simple indicators *F/Z* = 0.65 *F/M* = 2.62 B/Bmsy = 0.155 (0.25 by LBB) F/Fmsy = 1.41 SPR = 0.04 % mature in catch = 4.76	• The stock is overfished and overfishing is occurring. • Reduce fishing effort • Reduce catch of small immature fish by increasing the mesh size of the cod end
Blue swimming crab (*Portunus pelagicus)* Crab entangling net, crab pots Philippines, Visayan Sea *Sheryll V. Mesa*	Near shore habitats of sandy mud near reefs, mangroves and seagrass beds Monthly catch, effort, length and reproductive data from 36 landing sites for 2011–2021		Shaeffer and Fox SPMs Abundance ratio, MSY, CMSY LBAR AMSY LBB Froese simple indicators MSY = 12 545 tonnes (Schaeffer) Fmsy = 406 152 panels of net B/Bmsy = 0.92 F/Fmsy = 1.47	• The stock is overfished and overfishing is occurring. • Reduce number of panels in the fishery by ~50% over five years • Local government to regulate the specifications of crab entangling nets • Switch from gillnet to other ecofriendly gears such as bamboo crab pots. Roll out the Blue swimming crab national management plan using the “adopt a village” concept

Species and main fishing gear(s) Country, area, presenter	Data and analyses	Biology and population parameters	Estimates, assessment	Recommendations
Blue swimming crab (*Portunus reticulatus)* Crab entangling net Sri Lanka, Palk Bay *Steve Creech*	Near shore habitats of sandy mud near reefs, mangroves and seagrass beds Annual length data from representative landing sites since 2015. Monthly length data in 2022	Lmax females = 205 mm Wmax females = 413 g L_∞ females = 187 mm W_∞ females = 187 mm L_{50} females = 104 mm L_{95} females = 121 mm Optimum size = 117 to 143 mm SL_{50} ~130 mm	LBSPR mean size in the catch % crabs at optimum size % mature females (i.e. >L_{50}) Mean size ~130 mm to 145 mm % mature females ~93 to 100 % optimum crabs ~45 to 65 SPR ~0.35 to 0.46 *F/M* ~1.0 to 6.0 (2015)	• Regulations on types of net, mesh sizes and vessels in the fishery • No processing or export of crabs <100 g wet weight • A fishery management plan is in place that includes the scope of the fishery, management mechanisms, a harvest strategy, ecological impact mitigation and a fishery improvement plan
Blue swimming crab *(Portunus pelagicus)* Trap, gillnet and trawl (13.4% commercial catch, 86.6% small-scale catch) Thailand, Gulf of Thailand *Orawan Prasertsook*	Living in river mouths and coastal areas on sandy mud and muddy substrates Monthly catch, effort and length data from small-scale and commercial vessels	L_{max} females = 205 mm L_∞ females = 198 mm K = 1.47/y L_{50} females = 94 mm L_{95} females = 112 mm SL_{50} ~130 mm	LBSPR SPR = 0.23 to 0.27	• Introduce a seasonal spawning closure • Reduce the length of gillnets in the fishery • Prohibit fishing in nursery areas

Source: Authors' own elaborations.

10 THEMATIC REVIEW OF THE SUBMITTED ASSESSMENT INFORMATION

This chapter covers the thematic review of the submitted assessment information developed by three thematic working groups which were established for the workshop:

1. coastal inshore fisheries, including reef fisheries (facilitators: Neil Loneragan and Budy Wiryawan);
2. multispecies demersal fisheries (facilitators: Derek Staples and Rishi Sharma); and
3. small to medium pelagic species (non-large tuna) fisheries (facilitators: Ricardo Amoroso and Wilfredo Campos).

The working groups were tasked with reviewing submitted papers and posters split into these three themes and 1) summarize the assessment processes, methods and data sources for the theme; and 2) report on the overall results of the assessments and status of resources in the region.

Each group nominated a presenter for the feedback session. Rapporteurs were appointed from the resource persons. After the working group period was concluded there was a report back session with questions and answers. The findings of the plenary presentations were combined into a final summary of the workshop, presented in plenary.

10.1 Coastal inshore fisheries, including reef fisheries

Neil Loneragan and Budy Wiryawan

This summarizes the fisheries considered, the assessment process, methods and data sources for coastal inshore fisheries, including reef fisheries, and identifies data gaps and ways of strengthening human capacity. It also investigates how stock assessments feed into management and addresses the question of the effectiveness of communication on stock assessment to policymakers and fishers.

10.1.1 The nature of coastal inshore fisheries, including reef fisheries

This presentation included many species with different life histories, ranging from Blue swimming crab in Sri Lanka, Thailand and the Philippines to sea cucumber in Sri Lanka, hilsa in Bangladesh and India, and long-lived grouper and snapper in Indonesia. The species groups within the coastal inshore fisheries, including reef fisheries (CIFRF) used to assess stocks within FMAs as part of national stock assessments include crabs, lobster, sea cucumber and reef fish. It is also likely to include cephalopods, particularly octopus and cuttlefish, but these groups were not covered in any detail during the workshop discussions.

The species within the CIFRF have markedly different life history strategies including growth trajectories, natural mortalities, reproductive potential, recruitment variability, response to environmental fluctuations, habitat dependencies and consequently vary in their resilience to fishing pressure.

Fish are also caught using a variety of gears with different selectivities that influence the estimation of size at capture and the length distribution derived from fishery-dependent sampling. This consideration is particularly important for those species caught using a range of gears, such as grouper in Indonesia that are caught with longlines, speargun and handlines.

These are important parameters in many of the length-based estimates of stock status and will affect the estimation of size at 50 percent capture and the estimate of the spawning potential ratio.

The group questioned whether the models that are currently used are really applicable for this wide range of species.

10.1.2 Data sources

A range of data sources is used in the stock assessment process and many of these are common across the region. Data on landings, catch and effort are collected by national and state/provincial government departments that also collect information on biological data, particularly length distributions, for some species.

Some of these government datasets cover a very long time series (e.g. India has had commercial landings by month and fishing zone since the 1950s and length and weight information since the 1960s). This contrasts with Cambodia and Maldives who are just initiating more detailed data collection systems.

Non-government organizations are also involved in collecting more detailed information for specific species in important locations within the national FMAs, e.g. Blue swimming crab in Sri Lanka and Indonesia, and grouper and snapper in Indonesia. In Indonesia, the NGO data have been integrated with the government data in an electronic data system for use by fisheries researchers.

All data in the CIFRF presented at the workshop appeared to come from fishery-dependent sources – either landing centres, port authorities or processers. The group did not identify any sources of fishery-independent data used in stock assessments or evaluations of change in fisheries, such as the fishery-independent trawl data collected by Thailand and Malaysia.

The sampling designs for data collection and scaling up of fishery-dependent data from selected landing sites to regions and FMAs and how data gathered from multigear fisheries were weighted for incorporation in assessments, were not presented or discussed during the workshop.

10.1.3 Data exploration, assessment methods and issues identified

Two broad categories of assessments are applied to CIFRF fisheries, as they are to the demersal and pelagic fisheries (section 10.2 and section 10.3): those based on a time series of data which are primarily SPMs and those where data are limited and rely on length-based methods such as the LBSPR.

During the workshop, scant information was presented on the evaluation of sampling design for data sources and their suitability for the suite of stock assessment models being applied. Nor were the areas of data collection, evaluation of priors and data distributions and their influence on choice and performance of different models covered in the country or species presentations.

During discussions of the assessment process various questions were raised. One participant stated that "people know the methods and know how to use them but do not know the madness behind the methods", (i.e. people do not understand the assumptions, biases and the important steps of data exploration). This part of the assessment process needs to be incorporated in training.

It was also felt that researchers did not know how to talk to fishers to understand their perceptions of change in the fishery and status of fish stocks, nor how to incorporate this information to improve data collection and reduce uncertainties in stock assessments. The financial arrangements of the vessel captains in terms of who owns the vessel and funds its operations are also important drivers of fisher behaviour, e.g. they could determine when and where vessels fish instead of the fishers who have more intimate knowledge of the abundance and distribution of fish.

The working group identified issues that should be addressed in considering the results of the stock assessments presented at the workshop. These were:

1. The models presented at the workshop are equilibrium models and the workshop did not discuss how the results from these models should be used, whether these models are always appropriate and how their results are affected by highly variable recruitment or fluctuations in the environment.
2. The issues of setting priors for model parameters and evaluating uncertainty in the model results were also identified as important.
3. Estimating the gear selectivity and the shape of the selectivity curve (logistic or dome shaped) are factors that influence the results of assessments and were not covered in depth during the workshop.
4. It was asked whether the length distributions were representative of the fished population.
5. There is a need to identify the sources of unreported catch in the fishery, including the catches of larvae/juveniles of reef fish, crab, grouper, lobster that are caught and exported or “farmed” in cages. i.e. whether they are removed from the fish population before maturity and capture in the fishery.

10.1.4 Status of coastal inshore, including reef fisheries

Some of the poster presentations on CIFRF provided interesting contrast. For example, three examples of Blue swimming crab fisheries were presented from Sri Lanka, the Philippines and Thailand. The Palk Bay fishery in Sri Lanka, which is managed by regulations on types of gear, mesh sizes, vessel sizes and minimum size (100 g) of crabs (Table 9.1) that can be processed or exported, had SPRs maintained above the target (0.40) for several years, which contrasts with the same fisheries in the other two countries. In these countries, recommendations to reduce the length of fishing gear (entangling nets in the Philippines) and regulate the size of the nets have been made (Table 10.1.1). Three of the five grouper stocks in Indonesia were below the target SPR (0.3 in Indonesia) and one was close to this target, indicating that these stocks are heavily exploited. Recommendations for rebuilding these stocks include better compliance with size limits and stricter control of illegal fishing methods.

10.1.5 Assessment process and communication with policymakers

In general, stocks are assessed by government officers in a research institute or centre and the results of the assessment and recommendations for the assessment are reported for review before recommendations are sent to the ministry responsible for fisheries. For example, in India, the CMFRI provides assessment reports to the Ministry of Fisheries for exclusive economic zone fisheries or to the 11 state ministries with marine coastlines. Indonesia has a variation on this process where the stock assessment reports from the Centre for Fisheries Research and related institutes (now located within BRIN), are reviewed by the Indonesian National Commission for Fisheries Stock Assessment who then provide advice to the Ministry of Marine Affairs and Fisheries.

10.1.6 Other performance indicators and opportunities for enhancing assessments

It is possible that other sources of data collected by conservation agencies could be valuable for stock assessment and that these data sources might be complemented with additional data collection at relatively little cost. For example, in the Philippines, extensive underwater visual surveys are carried out inside marine reserves that collect data on species abundance (counts) and size. Is it possible to complement these surveys with data collected outside the reserves? Acoustic surveys are used in Indonesia and the Philippines. Might these surveys be extended and how best are the findings from these surveys incorporated in stock assessments?

Some simple indices were presented at the workshop including the percentage of immature and mature fish landed that are likely to be valuable in understanding the extent of growth overfishing. More routine presentation of these findings may be valuable, particularly as they are readily understood by a diverse range of people with different backgrounds. Other modelling approaches to understand ecosystem function (e.g. Ecopath with Ecosim) would add a valuable dimension to current assessments by providing information on the broader system. This includes models that link primary production to high production/trophic levels (such as Vertical Generalized Production Models – VGPM/OSMOSE).

10.1.7 Communication of assessment results

The use of simple indices of maturity to introduce size limits has been successful for some species e.g. anchovies in India, Blue swimming crab in Sri Lanka and grouper in Indonesia. The process of investigating, developing and implementing harvest strategies requires clear communication among researchers, government officers, fishers, the fishing industry and coastal communities. This has been very successful for Blue swimming crab in Sri Lanka and grouper in Saleh Bay Indonesia. It highlights the importance of connecting the findings from fishery assessments to on-the-ground fishing operations and the need for appropriate language and communication networks to be successful. Although no harvest strategies were presented for any of the country FMAs, this is being explored for grouper in one of Indonesia's FMAs (FMA713). The process involves researchers from government and universities, policymakers and managers from local, provincial and central government, NGOs, fishers, fish collectors and processors.

Table 10.1.1. Summary of coastal inshore, including reef fisheries

Country	FMA	Species/species group	Data sources
Bangladesh	FMA1 <40 m	All finfish (excluding hilsa), all shrimp, five species in each FMA. *Tenualosa ilisha, Harpadon nehereus, Pampus argenteus, Aurius aurius, Lepturacanthus savala*	Catch and effort data, research survey data (2017–2020, 2022), artisanal length data
	Hilsa	98% caught in gillnets, monthly length data from eight landing sites, artisanal length data	Production models to determine MSY and *F/Z* (0.48), stocks appear satisfactory, improve compliance on spawning closures and size limit
Cambodia	FMA1 <20 m	Catch rates, size distribution, short mackerel	
China	South China Sea	Ten species from demersal trawl	
India 9 states and 4 UTs		Species groups 9 to 20 and singles species from 2 to 19	Time series of catch and effort by fishing gear. Length data from some stocks
Indonesia	11 FMAs	Nine species groups, four CIFRF groups = reef fish, lobster, crabs and squid	Catch and effort statistics, biomass surveys, length and reproductive data
	Coral leopard grouper	Saleh Bay, Sumbawa Monthly catch and length data from landing sites	LBSPR – overfished and overfishing Compliance on size limits and illegal fishing methods
	Four species of *Plectropomus*	Karimun Jawa NP Monthly catch and length data from landing sites	LBSPR Three species are overfished
Malaysia (WPM)	Four FMAs	12 species groups – three CIFRF groups – cephalopods, crabs, lobster, single species assessments – *Photololigo duvaucelii*	Recent catch and effort data Biological data
Maldives	One FMA	Reef-based fisheries – five grouper species are assessed	Catch trends Catch effort, species composition for reef fish and grouper and length data from landing areas
Philippines	12 FMAs	CIFRF groups – reef fish and blue swimming crab Single species for some FMAs	Catch and some effort statistics
	Blue swimming crab	Visayan Sea Entangling nets and crab pots Monthly catch and effort data Length and reproductive data from 36 landing sites	Shaeffer and Fox SPMs, CMSY, LBB Stock is overfished and overfishing is occurring Reducing #panels in the fishery, introduce gear specifications for the entangling nets Switch from gillnets to ecofriendly gears

Country	FMA	Species/species group	Data sources
Sri Lanka	Seven FMAs	Blue swimming crab, sea cucumber, lobster, giant mud crab	Catch and effort data Size distribution
	Blue swimming crab	Palk Bay Entangling nets Annual length data from representative landing sites Monthly length data in 2022	LBSPR No overfishing and stocks are not overfished Type of net, mesh size and vessels are under regulation No processing or export of crabs <100 g wet weight A fishery management plan is in place
Thailand	Two FMAs	Crab, squid, cuttlefish	Catch and effort data, length data for single species
	Blue swimming crab	Monthly catch, effort and length data from small-scale and commercial vessels	LBSPR of 0.23 to 0.27 indicates stock is overfished

Source: Authors' own elaborations.

10.2 Demersal multispecies fisheries

Derek Staples and Rishi Sharma

This report summarizes the assessment processes, methods and data sources for demersal multispecies fisheries and identifies major gaps in and ways of strengthening human capacity building, improving accessibility to data and possible harmonization of the findings from different assessment approaches.

10.2.1 Fisheries data

The working group recognized various quality issues in the data that are used as input into stock assessment. For catch and effort data, for example, many countries have two sets of data – Statistical Office/Department of Fisheries and Research Institute datasets that are not consistent. Misreporting of catch and effort data is a common issue across the region resulting from under-reporting of artisanal fisheries, IUU fishing, catch being landed in another country and in some cases over-reporting to boost allocation of catch. It was noted that many of the analyses presented at the workshop did not consider any corrections for these biases, although they can distort the results of stock assessments that use catch data as an input.

Length-based data are mainly collected by research institutes and they require frequencies to be raised for the catches, but these calculations are often not accessible to everyone. Species covered are often caught by many gears and sampling is often inadequate to address this multigear nature of the fishery. There is a need for more transparency and a need for publicly accessible databases, e.g. length frequency data for growth and mortality estimates used to assess stock status along the lines of the now defunct Trawlbase.

Cross-referencing of different datasets, e.g. catch, effort, imports/exports, surveys and so forth, is an important tool that is not commonly used. The results of fishery independent data (surveys) and catch-based data are often not readily available to the stock assessment community and should be used in cross-referencing. Related to this is the fact that the history of catch trends is often ignored, although this information is critical for setting priors for biomass dynamic models.

Standardization of effort and CPUE is often necessary to obtain a true reflection of the trends in stock abundance. This needs to consider technological improvements in gear as well as other changes in fishing activity. Most importantly, there is often insufficient dialogue with fishers who can assist in interpreting time series data. More interaction with fishers through improved co-management or more inclusive surveying methods is needed.

Lastly it was noted that each country also has its own system of data collection (including identification of fish species) and there is a need for standardization among countries, especially for transboundary analyses. Although not discussed sufficiently, it was pointed out that data collection is often not aligned with management objectives.

10.2.2 Data analyses and models

A wide range of models and packages for fitting the models is being used across the region, including those based on catch and effort, length frequencies and catch only. In the presentations, there was not enough emphasis on checking whether the model used was accurate and reliable and that its assumptions were being met. There was also insufficient emphasis on sensitivity analysis to test the model and also presentations on how well the models fit the data, especially sensitivity to priors in Bayesian analyses.

Many of the assessments are still based on older equilibrium models that may be erroneous (such as ELEFAN, LBB and LBSPR).

10.2.3 Demersal stock status

A Kobe plot was constructed to summarize the preliminary findings for Tier 1 and Tier 2 assessments of trawl-caught species that have been assessed recently (Figure 10.2.1). This preliminary analysis suggests that despite the shortcomings in data and model fitting, the evidence shows that the status of demersal stocks in the region is not good (Figure 10.2.1).

Figure 10.2.1. Kobe plot for F/Ftargets and B/Btargets for Tier 1 (orange circles) and Tier 2 (purple circles) assessments of trawl-caught species collated at the workshop in January 2023.

F/Ftarget

B/Btarget

Source: Authors' own elaborations.

A further conclusion of the analysis was, that despite the multispecies/multigear nature of most of the fisheries in the region, many stock assessments were based on a limited number of single species assessments. It is suggested that multispecies aggregate MSY may be a good approach for the future.

The effect of different trawl bans in different countries presents an opportunity to examine what effect these bans have on the sustainability of different stocks, the ecosystem structure and habitats.

10.2.4 Better models for assessing stocks

The use of other models, multispecies aggregate production models that estimate stock and species interactions, needs to be encouraged; especially in countries where they have not been used. Stock assessment across the region could be enhanced by identifying subregional indicator species for MMSY. Trophic ecological models should be used for policy exploration and scenario testing (such as Ecopath with Ecosim [EwE]) and ecosystem indicators should also be used or expanded in their use across the region.

10.2.5 Informing management

The stock assessment practitioners concluded that management has difficulty in understanding and accepting scientific advice. On the other hand, it was recognized that scientific advice needs to be made more understandable to managers. Communication strategies are needed for different stakeholders. A regional (or subregional) communication strategy would be useful and increased use of effective communication tools such as:

- Kobe plots – multispecies/economic value; and
- trade-off plots.

One tool, used successfully in several developed countries, is based on a regular status report on stocks. This is seldom practised in the region and if done by every country, communication of stock assessment results would be greatly improved. Countries that have developed national fisheries management plans (FMPs) also pointed out how FMPs provide another mechanism to improve the dialogue among stakeholders, especially when these FMPs contain a mechanism for checking progress against objectives to support adaptive management.

Institutional structures that foster dialogues between management and science, for instance co-management councils and committees, are an effective communication tool in some countries. The development of harvest strategies is another good option for the future as they involve bringing together different stakeholders and provide a forum for scientists to have input into decision-making. Developing harvest strategies and communicating the benefits of the strategies could be an effective next step in communicating stock assessment results with other stakeholders.

The need for clearer objectives of management as a mean of improving communication was also discussed. What you manage and how well it is done with respect to reference points, needs to be examined carefully when deciding what species mix should be targeted as objectives; food security/social costs/employment can differ substantially from economic benefits. Stock assessment results need to be tailored into these different management outcomes.

The development of model-free management is an option for the future.

10.2.6 Capacity building

Because database creation is currently tailored to each country's needs, there is an overall need for a regional system of data collection and reporting based on a database portal to improve both the accessibility and quality of data and assessments. Past resource survey data need to be included, including past fisheries acoustics-based biomass surveys that are currently underutilized.

It was recognized that each country has different capacities and tailored capacity building will be necessary that includes training, peer reviews and the development of practitioner networks appropriate to that country. However, the Asian region does have considerable analytical capability on both single and multispecies modelling among researchers that could be better shared. Training of trainers is an option to enhance capacity and expertise in the region.

One current weakness in existing stock assessment approaches is in converting model outputs to practical catch and/or effort management advice, especially advice that considers the multispecies/multigear nature of many of the demersal fisheries. Targeted communication to different user groups is required to be able to successfully translate stock assessment into decision-making, e.g. by fishers/fishery managers/policymakers. Fisheries management training could be made more interactive (e.g. use of online/in person training that includes games, case studies challenges) for fishery managers/policymakers to promote better understanding.

There is a need to attract young researchers into fisheries assessments and biology and fisheries university curricula require updating to include a more comprehensive curriculum on fisheries management.

It was recognized that a considerable amount of guideline materials is available, albeit scattered, but there is an urgent need for guidelines for model diagnostics.

10.3 Small to medium pelagic (non-tuna) species

Ricardo Amoroso, Wilfredo Campos and Rishi Sharma

This report summarizes the assessment processes, methods and data sources for small pelagic species fisheries and identifies major gaps and ways of strengthening human capacity building, improving accessibility to data and possible harmonization. It also investigates how stock assessments feed into management and if we need better communication on stock assessment to policymakers.

10.3.1 The nature of small pelagic fisheries

The assessment and management of small pelagic species pose several challenges due to their unique life history and the role they play in the ecosystem.

These species exhibit high natural mortality variability and population growth rates that lead to large fluctuations in abundance even in the absence of fishing. Environmental regime shifts are common, resulting in periods of low and high abundance.

The asynchrony of abundance of sardines and anchovies in many regions around the world has led to the hypothesis that such asynchrony may have biological causes and lead to stability in the total abundance of small pelagic fish, suggesting that the effect of fishing on the abundance of small pelagic prey species may be better understood by looking at groups of species instead of a single species approach.

Fisheries impacts on predators are a concern and usually management targets of these species differ substantially from MSY reference points. These management targets can change in periods of low and high productivity.

The stocks of transboundary species need to be assessed at appropriate spatial scales.

10.3.2 Summary of stock status

The working group compiled a list of ~27 small to medium pelagic species stocks in the region that have been assessed (Table 10.3.1). For each species, the following information was recorded and is summarized in Table 10.3.1:

1) the geographic area of the assessment;
2) the year of the last assessment;
3) the assessment methods applied to the stocks in two tiers: Tier 1 included assessments that use catch and abundance-based indices to estimate biomass and reference points based on Bmsy and Fmsy; Tier 2 assessments are based on length frequency data and/or catch history – they use indicators of SPR and the ratio of fishing to natural mortality, *F/M*;
4) the type of reference point used as a B or F target; and
5) the values of F/Ftargets and B/Btargets.

Several species that have been assessed in fisheries have been covered, but the values of stock status were not available during the meeting. These species are included in Table 10.3.1 and it is recommended that a comprehensive synthesis on stock status should be performed in the future.

Table 10.3.1. Summary of stocks assessed in the South Asia and Southeast Asian region compiled during the workshop. For some stocks the values for stock status were not available during the workshop

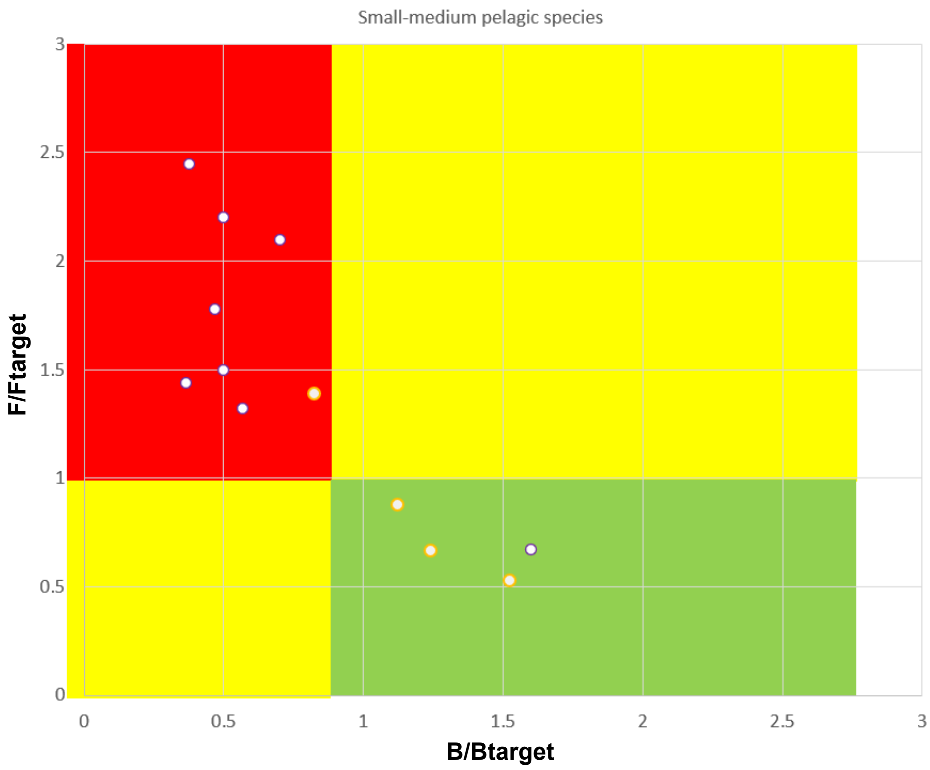
Species	Country/region	Last assessed	Method	Tier	Btarget type	Ftarge type	B/Btarget	F/Ftarget
Kawakawa	South China Sea	2018	ASPIC	1	Bmsy	Fmsy	1.12	0.88
	Andaman Sea and Indonesia	2018	ASPIC	1	Bmsy	Fmsy	0.82	1.39
Longtail tuna	South China Sea	2018	ASPIC	1	Bmsy	Fmsy	1.52	0.53
	Andaman Sea and Indonesia	2018	ASPIC	1	Bmsy	Fmsy	1.24	0.67
Mackerel scad	South China Sea	2021	LBB	2	Bmsy	Fmsy	0.7	2.1
	South China Sea	2021	LBSPR	2	SPR04	F_M_1	0.3	3.06
Indian mackerel	South China Sea	2020	ASPIC	1	Bmsy	Fmsy		
	Andaman Sea	2020	ASPIC	1	Bmsy	Fmsy		
	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	0.47	1.78
	Sulu Sea and internal waters	2021	Catch curve/ LBSPR	2	SPR04	F_M_1		
Bigeye scad	Sulu Sea and internal waters	2021	Catch curve/ LBSPR	2	SPR04	F_M_1		
	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	0.5	2.2
Redtail scad	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	0.37	1.44
	Sulu Sea and internal waters	2021	Catch curve/ LBSPR	2	SPR04	F_M_1		
Shortfin scad	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	0.57	1.32
	Sulu Sea and internal waters	2021	Catch curve/ LBSPR	2	SPR04	F_M_1		
TBD (scad)	Java Sea	2021	CMSY	2	SPR04	F_M_1		
Jack mackerel	Andaman Sea	2021	ASPIC	1	Bmsy	Fmsy		
	Gulf of Thailand	2021	ASPIC	1	Bmsy	Fmsy		
Goldstripe sardinella	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	1.6	0.67
	Sulu Sea and internal waters	2021	Catch curve/ LBSPR	2	SPR04	F_M_1	0.5	1.5
	West coast of Sri Lanka	2021	JABBA	2				
Bali sardine	Sulu Sea	2020	LBSPR	2	SPR04	F_M_1	1.15	3.09
	Southern Java	2021	CMSY	2	Bmsy	Fmsy	0.16	3.07
Spotted sardinella	West coast of Sri Lanka	2021	JABBA/ LBSPR	2				
Shorthead anchovy	Sulu Sea and internal waters	2021	Catch curve/ LBSPR	2	SPR04	F_M_1		

Notes: ASPIC = a stock production model incorporating covariates; LBB = length-based Bayesian biomass estimation; LBSPR = length-based spawning potential ratio; CMSY = catch at MSY; JABBA = Just Another Bayesian Biomass Assessment; SPR04 = spawning potential ratio of 0.4.

Source: Authors' own elaborations.

A Kobe plot was constructed to summarize the preliminary findings for those 15 stocks that were assessed recently (Figure 10.3.1). This preliminary analysis suggests that most of the stocks (ten) are overfished and overfishing is occurring (top left-hand part of the Kobe plot) – four were assessed as not overfished and overfishing is not occurring (bottom right-hand corner of the plot).

Figure 10.3.1. A Kobe plot for 15 Tier 1 (orange circles) and Tier 2 (purple circles) small to medium pelagic species assessed during the workshop. Species and assessment results are summarized in Table 10.3.1



Source: Authors' own elaborations.

Interestingly, most of the stocks (11) were assessed using Tier 2 assessments. Note that these findings were developed quickly during the first two days of the workshop and only serve as an illustration of an approach that might be adopted.

10.3.3 Issues for assessing small to medium pelagics

The group identified issues with the data and methods used both for Tier 1 and Tier 2 assessment types.

Tier 1 assessments:

- Catch history needs to be revised wherever possible. In some cases, very short time series are used. In many cases there is little, or no, historical data.
- The CPUE indices are, in general, standardized using GLMs. However, there are concerns that the use of fish aggregation devices (FADs) may cause hyperstability for fishery-dependent derived indices.
- The stock assessments using ASPIC need priors on model parameters and current depletion. The influence of the choice of priors on the model results is not evaluated.

Tier 2 assessments:

- Reproductive parameters are usually estimated locally, but growth and mortality parameters are extracted from the literature or internally estimated by the LBB model. Sensitivity analysis on life history information parameters is not conducted in the stock assessments.

The procedures to decide which length composition data are used in the assessment are very variable. Some countries use the dominant gear, while other countries pool all the length frequency data. No country reported using a weighting process for the length data. The sensitivity of the results to the choice and weighting of input data has not been assessed. For example, FADs may also have an effect on size representations on length-based parameter estimates. There is also a need to assess the representation of population size distribution from using length data from only a single gear for length-based parameter estimates.

10.3.4 Capacity-building needs

The group recognized that there are no "silver bullets", or methods that can be applied to all cases. However, training opportunities are based on specific methods or techniques without proper understanding of the behaviour of exploited populations, information content in the data, data exploration and statistical analysis of the data prior to model fitting. This hinders the ability to critically understand the advantages and disadvantages of different techniques and how data and assumptions affect model results.

Data exploration is not done exhaustively before conducting any kind of analysis because it is too time-demanding if programming skills have not been developed for rigorous data exploration. The group recognized that formal training in R and approaches to data exploration would be very valuable.

10.3.5 New approaches to stock assessment

The group recognized that while other approaches can be adopted, there is room to improve the quality/pertinence of current assessments. For Tier 1 assessments, the influence of the priors on results has not been assessed and should be done routinely. Also, the quality of CPUE indicators should be evaluated. For Tier 2 assessments, the representativeness of the length composition and their information content should be critically assessed. Also, sensitivity analysis on the parameters should be performed. Additionally, practitioners should evaluate how the equilibrium assumption and assumption of logistic selectivity influences model results and whether they are appropriate.

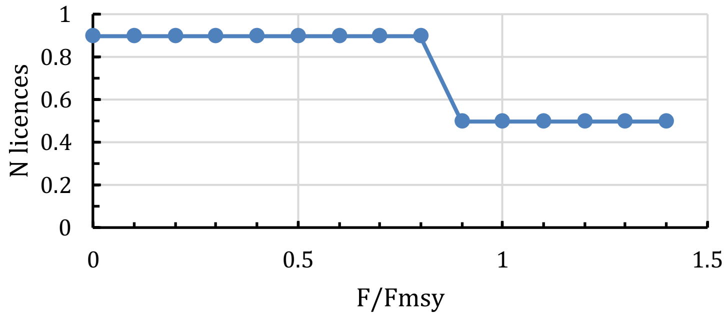
The group also suggested that ecosystem and socioeconomic indicators should also be used to complement single species stock assessments.

10.3.6 From assessment to management

For most fisheries, management relies heavily on static management measures (i.e. the measures do not change as a function of stock status). These measures include gear regulations, minimum legal sizes, limited entry, spatial zoning and seasonal closures. Only three examples of management that responds to stock status were identified:

1. Case 1, Indonesia: The number of licences is adjusted as a function of F/Fmsy (Figure 10.3.2). If F/Fmsy is lower than 0.8, 90 percent of the licences that should operate to produce MSY are allowed. If F/Fmsy is higher than 0.8, only 50 percent of the licences are allowed to operate.

Figure 10.3.2. Harvest control rule based on F/Fmsy for fisheries in Indonesia. The Y axis shows the proportion of licences allowed to operate depending on F/Fmsy



Source: Authors' own elaborations.

2. Case 2, Malaysia: A spatial zoning system is being implemented. For each zone, the CPUE trend is calculated and effort reallocation takes place based on the trend in CPUE.

10.3.7 Recommendations on assessing small to medium pelagic species

The use of CPUE data should be critically examined when using them in SPMs as most data are gathered from FADs or floating objects.

The data for these models needs to be representative of the population – data from the FADs or floating objects is likely to be biased (e.g. in tuna, smaller fish are found around these attraction devices and larger fish are in open waters). Alternative methods to evaluate and quantify effort creep with FAD data could be examined and used to evaluate the sensitivity of models to effort specification evaluated.

Sampling issues with respect to length data were rarely discussed, and whether they are even appropriate for inference when using the LBB or length-based LBSPR methodologies.

Further thought on collecting samples relevant to the assessment approach being applied needs to be given and the sampling programme designed with this in mind.

Fluctuations in environment and variability in sardine and anchovy abundance need to be examined on a larger basin scale.

Environmental indices based on large global chlorophyll data could be examined and then used to relate to the recruitment of small pelagic stocks. This would improve our understanding of the dynamics of these stocks, as they are largely driven by recruitment variability.

11 REGIONAL AND INTERNATIONAL FISHERY RESEARCH, NETWORKING AND CAPACITY BUILDING

Fisheries research, assessment and management are entering an exciting era in the region and there is a clear need to move towards an ecosystem approach to fisheries management that is capable of addressing the needs for multispecies assessments of fisheries within a multigear and often multiscale (small-scale fisheries, large-scale fisheries operating in the same context or on the same stocks). There are also emerging areas for single stock assessments in data poor fisheries that were previously considered too challenging to assess.

There is scope for greater engagement in research and capacity building to provide tools and training for fisheries assessment and management. The goals would be to improve the sharing of assessment information and supporting greater regional capacity building around the need to improve assessment designs and address data quality and analyses. This could be promoted by identifying and working on shared stocks, as well as some national stocks of the same species, to share stock assessment approaches and sharing of information on the assessments as well as facilitating discussions of different management options.

Outcomes of this might be standard procedures, guidance for stock assessments and also increased linkage between stock assessment and harvest strategies. Longer term, the development of a common database or common database structure would allow easier sharing of data or anonymized analytics to support regional level tracking of the status of stocks. These would target solutions to issues of allocation between gears and scales as well as situating stock assessment into the broader fishery governance framework as well as the broader blue economy, food security and nutritional policies.

FAO is encouraged to seek resourcing to develop a regional stock assessment, capacity-building programme. Potential resourcing could be leveraged from ongoing FAO programmes, but a dedicated initiative is considered desirable.

WorldFish (formerly ICLARM) was a significant provider of tools and coordinator of regional fishery research in the 1980s and 1990s, particularly in the realm of stock assessment. This role has diminished since then. While many practitioners are still using tools and concepts that were developed by ICLARM in the 1980s and 1990s, these tools have been repackaged or upgraded to take advantage of increased computing and computer modelling power to address more complex assessment challenges.

The Asian Fishery Society (AFS) has the twin goals of fostering effective interaction and cooperation among scientists and technicians and increasing awareness of the importance of fish and other aquatic resources in the region and the role of science. However, capture fisheries research and management are under-represented in the AFS and in presentations at its regular conference, the Asian Fisheries and Aquaculture Forum. Establishing a new section within the AFS could provide a mechanism to revitalize connections, promote best practices and provide capacity-building opportunities for scientists within the region. As there is potential interest from regional actors such as WorldFish, SEAFDEC and the **Bay of Bengal Programme Inter-Governmental Organisation (BOBP-IGO)**, it is worth exploring the possibility of creating a "Fisheries Assessment and Management" Partnership Section within the framework of the AFS.

In South Asia, the establishment of a stock assessment network aligns with the objectives of the BOBP-IGO) as it has an appropriate mandate and linkages to government fishery research institutions. This offers the potential for the creation of a South Asia assessment network through the BOBP-IGO. There are a various regional and country initiatives that could be linked to this. As a first step, it may be possible to develop a South Asia regional programme with the support of India/ CMFRI. BOBP-IGPO could also establish a website resource for stock assessment where useful information and best practices in stock assessment are shown. Other networking opportunities include convening technical webinars and a regular virtual network meeting. In the longer term, BOBP-IGO may initiate a marine fisheries research platform (HD-BOBP-IGO).

In Southeast Asia there is potential to support networking and capacity building by leveraging or co-opting ongoing processes and initiatives, particularly through **SEAFDEC** engagement with regional projects that focus on the ecosystem approach to fishery management (e.g. the Global Environment Facility funded the International Waters projects). Activities might include arranging webinars on best practices or techniques for different topics in stock assessment. Topics could include: data exploration; sensitivity analyses; presenting information on stock assessments to managers and fishers; designing data collection programmes for effective stock assessment; examples of developing successful harvest strategies; and designing surveys to collect information from fishers to contribute to assessing the status of fish stocks.

Some potential areas for capacity building and networking include:

- regional training programmes for ecosystem approaches to stock assessment;
- development of scenario modelling and decision-making support tools;
- establishing or supporting a fisheries assessment and management portal to act as a "one-shop stop" for stock assessment toolkits and datasets. Possibly building on capacity in WorldFish; and
- establishing a mentoring network and support mechanisms for young scientists, possibly though a dedicated section within the AFS.

As a first step, BOBP-IGO will cooperate with CMFRI to convene a side event on stock assessment at the 14th Asian Fisheries and Aquaculture Forum in 2025 in New Delhi.

APPENDIX 1. LIST OF PRESENTATIONS AT THE FAO REGIONAL ASSESSMENT WORKSHOP

Thematic presentations on stock assessment approaches

Single species stock assessments for a range of data in Asia	*Ricardo Amoroso*
Assessing stocks for multispecies fisheries: a multispecies approach relevant to the Asian region	*Elizabeth Fulton*
The status of Asian fish stocks and why FAO is gathering information	*Rishi Sharma*
Model implementation and management of resources in the South China Sea – fishing industry and recent assessment of 8 to 10 stocks. Suggestions for sustainable fishing on the resources of the South China Sea	*Zuozhi Chen*

Short country overview presentations of stock assessments and status of fish stocks

Southeast Asia:	Indonesia	*Indra Jaya*
	Malaysia	*Sallehudin Jamon and Effarina bt. M. Faizal Abdullah*
	Philippines	*Francisco Torres and Melanie Villarao*
	Thailand	*Pavarot Noranarttragoon and Nipa Kulanujaree*
	Cambodia	*Chea Tharith and Ly Kunthy*
South Asia:	Bangladesh	*Al Mamun and Mohammed Shriful Azam*
	India	*Jayasankar*
	Maldives	*Mohammed Ahusan and Mohammed Shimal*
	Sri Lanka	*Sisira Haputhantri*

Thematic presentations on multispecies demersal fisheries

• Greater lizardfish (*Saurida tumbil*) (Bloch, 1795) of FMA 6 (subFMA Lingayen Gulf)	*Greg Buccat*
• Asian trawl surveys	*Mick Haywood*

Thematic presentations on coastal inshore fisheries, including reef fisheries

• Philippines Blue swimming crab	*Sheryl Mesa*
• Grouper (*Plectropomus* sp.) from Karimun Jawa National Park	*Agustine Siska*
• Snapper (*Lutjanus malabaricus*) from Saleh Bay, West Nusa Tenggara	*Irfan Yulianto*
• Sri Lanka Blue swimming crab	*Steve Creech*
• Towards an adaptive, climate-resilient, multispecies fisheries management plan	*José Ingles*
• Hilsa shad from the Meghna River, Bangladesh	*Jalilur Rahman*
• Thailand single species assessment	*Weerapol Thitipongtrakul*
• Thailand Blue swimming crab	*Orawan Prasertsook*

APPENDIX 2. LIST OF PARTICIPANTS AT THE FAO REGIONAL ASSESSMENT WORKSHOP

List of participants (in person)

Bangladesh

Al Mamun
Fisheries Quarantine Officer, BCS (Fisheries)
Shah Amanat International Airport, Potenga, Chattogram
(attached with the Marine Fisheries Survey Management Unit, Agrabad, Chattogram)
Department of Fisheries, Ministry of Fisheries & Livestock
Bangladesh

Mohammed Shariful Azam
PhD (Food & Life Science, PKNU, Republic of Korea)
Deputy Project Director
Sustainable Coastal and Marine Fisheries Project, Department of Fisheries, Dhaka
Bangladesh

Cambodia

Chea Tharith
Deputy Director
Marine Fisheries Research and Development Institute (MaFReDI)
Fisheries Administration, PO Box: 582
186, Norodom Blvd., Phnom Penh
Cambodia

Ly Kunthy
Deputy Chief of Social-Economic Division
Marine Fisheries Research and Development Institute (MaFReDI)
Fisheries Administration, PO Box: 582
186, Norodom Blvd., Phnom Penh
Cambodia

Indonesia

Indra Jaya
Department of Marine Science and Technology
Faculty of Fisheries and Marine Sciences
IPB Bogor
Indonesia

India

Kolliyil Sunilkumar Mohamed
Retired Principal Scientist & Head of Division
Central Marine Fisheries Research Institute
Chair, Sustainable Seafood Network of India (SSNI)
Kochi
India

Sathianandan Thayyil Valappil
Principal Scientist (retired) & Head FRAD
Central Marine Fisheries Research Institute
Kochi
India

Jayasankar Jayaraman
Principal Scientist
Fishery Resources Assessment, Economics and Extension Division
Indian Council of Agricultural Research - Central Marine Fisheries Research Institute
Kochi
India

Jeyabaskaran Rajapandian
Director General
Fishery Survey of India (FSI)
New Fishing Harbour
Sassoon Dock, Coloba
Mumbai-40005
Maharashtra
India

Malaysia

Sallehudin Jamon
Director of Fisheries Research Institute Kg. Acheh
Department of Fisheries Malaysia
Putrajaya
Malaysia

Effarina binti Mohd Faizal Abdullah
Senior Research Office
Fisheries Research Institute Kg. Acheh
Department of Fisheries Malaysia
Putrajaya
Malaysia

Maldives

Mohamed Shimal
Marine Biologist
Maldives Marine Research Institute
Ministry of Fisheries, Marine Resources and Agriculture
Maldives

Mohamed Ahusan
Senior Research Officer
Maldives Marine Research Institute
Ministry of Fisheries, Marine Resources and Agriculture
Maldives

Philippines

Melanie Villarao
Project Leader of the National Stock Assessment Program (BFAR-NSAP)
Regional Office No. 02
Government Complex, Carig Tuguegarao City
Philippines

Francisco Jr. Torres
Department of Agriculture National Fisheries Research and Development Institute Corporate 101 Bldg., 101 Mother Ignacia Avenue South Triangle, Quezon City 1103
Philippines

Sri Lanka

Sujeewa Sisira Kumara Haputhantri Haputhantrige
Principal Scientist
Marine Biological Resources Division
National Aquatic Resources Research and Development Agency (NARA)
Crow Island, Colombo 15
Sri Lanka

Sinesha Nuwan Karunarathne Tele Korala
Assistant Director
Management Division
Department of Fisheries & Aquatic Resources
Colombo
Sri Lanka

Thailand

Pavarot Noranarttragoon
Fishery Biologist
Marine Fisheries Research and Development Division
Department of Fisheries
Bangkok
Thailand

Nipa Kulanujaree
Fishery Biologist
Marine Fisheries Research and Development Division
Department of Fisheries
Bangkok
Thailand

Weerapol Thitipongtrakul
Fishery Biologist
Marine Fisheries Research and Development Division
Department of Fisheries
Bangkok
Thailand

Orawan Prasertsook
Fishery Biologist
Marine Fisheries Research and Development Division
Department of Fisheries
Bangkok
Thailand

BOBP-IGO

Krishnan Paulpandian
Director
Bay of Bengal Programme Inter-Governmental Organisation (BOBP-IGO)
91, St. Mary's Road, Abhirampuram
Chennai - 600 018, Tamil Nadu
India

Environmental Defense Fund

José Ingles
Consultant
Environmental Defense Fund
100-A Road 1 Bagong Pagasa
Philippines

Rekam Nusantara Foundation

Irfan Yulianto
Senior Advisor for Marine and Fisheries
Rekam Nusantara Foundation
Jl. Sempur No. 35
Sempur, Bogor – 16129
Jawa Barat
Indonesia

SEAFDEC

Supapong Pattarapongpan
Fishery Oceanographer, SEAFDEC Training Department
Samut Prakarn
Thailand

Suwanee Sayan
Senior Officer of Project Planning and Management Division, SEAFDEC Training Department
Samut Prakarn
Thailand

Pattaratjit Kaewnuratchadasorn
Senior Policy Officer of Policy and Program Coordinator Office, SEAFDEC Secretariat
Bangkok
Thailand

Wildlife Conservation Society

Rian Prasetia
Wildlife Conservation Society (WCS)
Jalan Malabar 1 No. 11, Babakan, Bogor
Tengah - Bogor West Java 16128
Indonesia

Siska Agustina
Wildlife Conservation Society (WCS)
Jalan Malabar 1 No. 11, Babakan, Bogor
Tengah - Bogor West Java 16128
Indonesia

WorldFish

Mohammad Jalilur Rahman
Scientist (Fish Population Biology)
ECOFISH II Project
WorldFish Bangladesh and South Asia Office
House # 335/A –Gift, Road 114
Gulshan-2, Dhaka-1212
Bangladesh

Edward H. Allison
Acting Director - Sustainable Aquatic Food Systems
WorldFish
Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas Penang
Malaysia

Technical experts

Ricardo Amoroso,
Fisheries Consultant
José Maria Ibarraran 38, apt. 301,
Mexico City
Mexico 03900

Budy Wiryawan
Professor
IPB University, Bogor Komplek IPB4, Blok B/36
Jalan Pawon, Bogor
16154
Indonesia

Wilfredo Campos
University of the Philippines
Quezon Hall, UP Diliman
Quezon City 1101
Philippines

Neil Loneragan
Professor Emeritus of Marine Ecology and Conservation
School of Environmental and Conservation Sciences, College of Environmental and Life Sciences and Centre for Sustainable Aquatic Ecosystem Research, Harry Butler Institute
Murdoch University, WA 6150
Australia

Derek Staples
Consultant
Brisbane
Australia

FAO

Simon Funge-Smith
Senior Fishery Officer
Module Leader Fishery and Aquaculture
Regional Office for Asia and the Pacific
39 Phra Athit Road
Bangkok 10200
Thailand

Rishi Sharma
Senior Fishery Resources Officer
Assessment and Management Team, NFIFM
Viale delle Terme di Caracalla
00153 Rome
Italy

Angela Lentisco
Fishery and Aquaculture Officer
Regional Office for Asia and the Pacific
39 Phra Athit Road
Bangkok 10200
Thailand

List of participants (virtual)

Elizabeth Fulton
Senior Principal Research Scientist
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Building 101, Clunies Ross Street
Black Mountain ACT 2601
Australia

Michael Haywood
Consultant/Marine Researcher
94 Wongawallan Drive
Australia

K.M. Shahriar Nazrul
Assistant Director
Department of Fisheries
Bangladesh

Dario Pinello
International Marine Fisheries Management Officer
FAO CAPFISH Project
Phnom Penh
Cambodia

Kui Zhang
Associate Professor
South China Sea Fisheries Research Institute
Chinese Academy of Fisheries Sciences
231 Xingang Road West
Guangzhou 510300
China

Zuozhi Chen
Professor
South China Sea Fisheries Research Institute
Chinese Academy of Fisheries Sciences
231 Xingang Road West
Guangzhou 510300
China

Antony Xavier Antony
Fisheries Development Commissioner
Department of Fisheries
Ministry of Fisheries, Animal Husbandry & Dairying
New Delhi-110001
India

Sanjay Pandey
Deputy Commissioner (Fisheries)
Department of Fisheries
Ministry of Fisheries, Animal Husbandry & Dairying New Delhi-110001
India

H.D. Pradeep
Fisheries Scientist
Mormugao Base of Fishery Survey of India
Post Box No. 05
Opp. Microwave Tower, Bogda
Mormugao-403803
India

Sijo P. Varghese
Zonal Director
Cochin Base of Fishery Survey of India
Post Box No. 853
Kochangady, Cochin- 682005
Kerala
India

Eldho Varghese
Senior Scientist
Central Marine Fisheries Research Institute
FRAE Division
India

Shoba Kizhakudan
Principal Scientist
ICAR-Central Marine Fisheries Research Institute
Madras Regional Station of ICAR-CMFRI
75 Santhome High Road, Chennai,
India

Geetha Sasikumar
Principal Scientist
ICAR-Central Marine Fisheries Research Institute
India

Muktha Menon
Senior Scientist
ICAR-Central Marine Fisheries Research Institute
India

Rajan Kumar
Scientist
Central Marine Fisheries Research Institute
Kochi
India

Karuppasamy
Assistant Professor
TNJFU-Dr MGR Fisheries College and Research Institute, Ponneri
India

Rajdeep Mukherjee
Policy Analyst
Bay of Bengal Programme Inter-Governmental Organisation
91 St. Mary's Road
Chennai
India

Sri Hari Murugesan
Project Scientist
Bay of Bengal Programme Inter-Governmental Organisation
91 St. Mary's Road
Chennai
India

Shubhadeep Ghosh
Scientist
Central Marine Fisheries Research Institute
Visakhapatnam Regional Centre of ICAR CMFRI
India

Anthony Sisco Panggabean
Aparatur Sipil Negara
Badan Riset Dan Inovasi Nasional (BRIN)
Perumahan Bumi Sani Permai Bolk E3 No 36
Indonesia

Prihatiningsih Prihatiningsih
Researcher
National Research and Innovation Agency
Jalan Raya Bogor KM 47
Cibinong, Nanggewer Mekar
Indonesia

Muhammad Taufik
Researcher
National Research and Innovation Agency
Jl. Sindang 1 No 3, Kelurahan Jati – Kecamatan Pulogadung
Indonesia

Guillermo Moreno
Independent Consultant
Jl Tukad Badung XVI, Bali
Indonesia

A. Riza Baroqi
Governance Officer
MDPI Foundation
Indonesia

Efin Muttaqin
ETP Specialist
Rekam Nusantara Foundation
Bogor
Indonesia

Intan Hartati
Fisheries Officer
Rekam Nusantara Foundation
Bogor
Indonesia

Isnaini Marliana
Resource Use Database Officer
Wildlife Conservation Society (WCS)
Mataram City
Indonesia

Mokhamad Dahri Iskandar
Dept Pemanfaatan Sumberdaya Perikana FPIK
IPB
Perm Alam Sinarsari, Jl Asriraya No. 72
Sinarsari Dramaga Bogor
Indonesia

Achmad Zamroni
Researcher
National Research and Innovation Agency
Indonesia

Moh Fauzi
Researcher
National Research and Innovation Agency
Indonesia

Tri Ernawati
IPB University
Villa Bogor Indah 3
Bogor Utara
Indonesia

Prihatin Wahyuningrum
Lecturer
IPB University
Bogor
Indonesia

Yopi Novita
Lecturer
IPB University
Indonesia

Darmawan Darmawan
Associate Professor
IPB University
Indonesia

Regi Darmawan
PhD Student
IPB University
Indonesia

Aris Budiarto
Fisheries Manager
Jakarta
Indonesia

Am Azbas Taurusman
Associate Professor
IPB University
Indonesia

Sugeng Hari Wisudo
Lecturer
IPB University
Indonesia

Mohd Tamimi Ali Ahmad
Research Officer
SEAFDEC/MFRDMD
Malaysia

Syed Yusuf Wan Drahman
Fisheries Officer
Department of Fisheries Malaysia
Putrajaya,
Malaysia

Edward H. Allison
Acting Director - Sustainable Aquatic Food Systems
WorldFish
Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang
Malaysia

Alexander Tilley
Senior Scientist
WorldFish
Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas Penang
Malaysia

Masahito Hirota
Deputy Chief
SEAFDEC/MFRDMD
Terengganu
Malaysia

Johanne Fremstad
Adviser
NORAD, Department of Fisheries
Norway

Francis Greg Buccat
Agricultural Center Chief II
Bureau of Fisheries and Aquatic Resources
Government Center, Sevilla, San Fernando City
La Union
Philippines

Divina Ignacio
Project Leader, National Stock Assessment Program
Bureau of Fisheries and Aquatic Resources
BFAR 9, R.T. Lim Blvd., Zamboanga City
Philippines

Sheryll Mesa
Bureau of Fisheries and Aquatic Resources
Regional Field Office VI
Muelle Loney St., Iloilo City
Philippines

Antonio Leon, Jr.
Aquacultural Technologist
Zone 1, Bureau of Fisheries and Aquatic Resources Regional Office No. 2
Philippines

Rea Mae Casco
NSAP Data Analyst
Bureau of Fisheries and Aquatic Resources
Philippines

Jimely Flores
Science and Policy Consultant
Environmental Defense Fund (EDF)
Kalayaan Suites, Quezon City
Philippines

Nicko Amor Flores
Capture Fisheries Research and Development Division
National Fisheries Research and Development Institute
Manila
Philippines

Suzette Barcoma
Senior Science Research Specialist
Capture Fisheries Research and Development Division
National Fisheries Research and Development Institute
Manila
Philippines

Steve Creech
Executive Director
Pelagikos Private Limited
16 Welikadawatte Road
Rajagiriya
Sri Lanka

Mallikage Marcus
Director
Department of Fisheries & Aquatic Resources (DFAR)
Colombo
Sri Lanka

Jeeratorn Yuttharax
Fisheries Biologist
Department of Fisheries
Bangkok
Thailand

Paul Medley
FAO Consultant, Fisheries Scientist
MMRI
United Kingdom of Great Britain and Northern Ireland

Cao Văn Hùng
Researcher
Research Institute for Marine Fisheries
No. 224, Le Lai, Ngo Quyen, Hai Phong
Viet Nam

FAO Regional Office for Asia and the Pacific
FAO-RAP@fao.org
https://www.fao.org/asiapacific/en/

Food and Agriculture Organization of the United Nations
Bangkok, Thailand

ISBN 978-92-5-138437-4

9 789251 384374

CC9002EN/1/12.23