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FAO REGIONAL WORKSHOP

FAO regional workshop for a network of practitioners on fishery stock assessment

23 - 25 January 2023, Bangkok, Thailand

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ABSTRACT

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ABBREVIATIONS

1 BACKGROUND TO THE WORKSHOP

The fisheries of Asia are a critical component 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% 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 been declining in the Northwest Pacific, nearly doubling but now stable in the Western Central Pacific, and a slower rise in the Eastern Indian Ocean, now stable.

Despite the importance of fisheries to the Asian economy, scientific monitoring and management are modest, with most stocks lacking modern scientific stock assessments. During the period from 1980 to 2000, stock assessment programmes were carried out in most countries assisted by regional and international scientists in the Asian region (e.g. Silvestre et al, 2003)[1]. Although there are still a number of stock assessment scientists in the region and national stock assessment programmes have continued,, very few stock assessment reports have been published in recent years. Part of the reason maybe confidentiality, but it is 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 into FAO's global analyses of the status of world fish stocks. These analyses are in turn, used to inform on the global progress towards achieving SDG14 to "Conserve and sustainably use the oceans, seas and marine resources for sustainable development", particularly targets addressing:

a) Natural resources and people with focus on: Sustainable fishing; conserving coastal and marine areas; Increasing the economic benefits from sustainable use of marine resources; and
b) How these outcomes above can be achieved through: Increasing scientific knowledge, research and technology for ocean health; supporting small-scale fishers.

Different teams of scientists relying on the same public databases of catch data using different methods (that make different assumptions and aggregate data in different ways) have come up with different overall assessment of the status of global fish stocks., ranging from around to one-third are overfished (FAO, 2022[2]) to two-thirds of global stocks are overfished (Worm et al. 2009[3]). These conclusions are not universally accepted and have been criticized for their reliance on a global stock assessment database (RAM Legacy) in which fisheries from developing countries are seriously under-represented (Ricard et al. 2012[4]).

Although this 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 stock assessments are not available. It is possible that the selection bias in favour of larger stocks with formal assessments is behind their relatively optimistic outlook compared to Worm's, global assessment. FAO's methodology also tends to aggregate stocks into larger units, versus the Worm et al. approach, which could be another factor explaining the differences.

This uncertainty highlights the fact that the database, and analyses based on it, remain limited by the lack of publicly available and reliable fisheries data and stock assessments from developing countries

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[1] G. Silvestre, L. Garces, I. Stobutzki, M. Ahmed, R.A. Valmonte-Santos, C. Luna, L. Lachica-Aliño, P. Munro, V. Christensen and D. Pauly (eds.) (2003) Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings (no.67).

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

[3] 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 2009, 325, 578–585.

[4] https://doi.org/10.1111/j.1467-2979.2011.00435.x

in Asia such as India, Thailand, Malaysia, Myanmar, Indonesia, Viet Nam and the Philippines. These countries represent some of the largest producers of capture fish in the world with four countries ranked in the top 10 capture fisheries producers globally (Indonesia [2], India [3], Viet Nam [7], Bangladesh [10]; FAO, 2022). Fisheries in these countries range from large-scale industrialized fisheries for demersal fish such as grouper, threadfin bream and pony fish and pelagic fish like oil sardine, herring, and tuna through to artisanal fisheries for nearshore and estuarine species such as blue swimming crab and shellfish. No single management approach is likely to be effective at all these scales. There have been efforts made by the Asian countries to improve their respective fisheries management policies and regulations towards sustainability and meet international commitments such as the SDGs, and relevant conventions for food security and the health of the oceans (inter alia: UNCLOS, UNFSA, SDGs, FAO CCRF, FAO VG-SSF)

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 highlights priority actions to establish reference points, and come up with estimated biomass or capacity level to determine the maximum sustainable yield, allowable biological catch, or allowable effort for marine fisheries in support of achieving sustainability.

With the lack of readily available and peer-reviewed stock assessments in Asia, it's impossible to determine whether fish populations are overexploited or, potentially, underexploited, relative to their ability to support sustainable yields. At a national level in the Asia region, fishery yields have been largely flat over the past decade, while the Asian population, and thus the need for sustainable protein sources, has continued to increase.

Does the current plateau in fishery yields represent the maximum sustainable yield or is greater harvest possible? If higher yields are possible, do we get there by fishing harder or by rebuilding overfished stocks? How will we know if we do not assess our stocks?

On international trade-related issues, 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 the SDG14 "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,".

Most countries in the region have several stock assessment scientists, but there is very little interaction among them and few opportunities to exchange experiences and learn from each other. FAO Regional Office for Asia and the Pacific (FAORAP) and the FAO Fisheries Division (NFI) in partnership with SouthEast Fisheries Development Centres (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 (e.g. Loneragan et al. 2021[5]).

There is a strong need to harmonize this activity, to benefit 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 typifies the regional developmental context.

The FAO Regional Office for Asia and the Pacific (FAORAP), with the support of the FAO Fishery and Aquaculture Division (NFI) is working towards a long-term goal of establishing an organized

5 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. Murdoch University, Western Australia, and IPB University, Indonesia, 185 pp. ISBN 978-0-646-82951-7

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 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 development 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 need for capacity development and improved cooperation in stock assessment have been identified as priorities for action by:

a) 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*" ;

b) 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*";

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

d) The 53rd Meeting of the SEAFDEC Council, and the "ASEAN-SEAFDEC Resolution and Plan of Action on Sustainable Fisheries for Food Security for the ASEAN Region Towards 2030"

1.1 PURPOSE AND OBJECTIVES OF THE WORKSHOP

FAO convened the "*Regional workshop for a network of practitioners on fishery stock assessment*" *("FAO Regional Assessment workshop")* from 23-25 January 2023, bringing together an identified group of regional stock assessment practitioners from across the Asian region, to review their methods and preliminary findings on the status of fisheries that they study in their countries.

There were 38 participants present at the workshop and a further 41 participants joined plenary online presentation and discussion sessions. All participants are active in the field of stock assessment in the Asian region, through their national programme or cooperation under projects.

This workshop built on two FAO and SEAFDEC co-organized regional training workshops on stock assessment, that developed the first level understanding of the current status and regional capacity on stock assessment and examined available data sets. It also drew on other complementary work under parallel initiatives funded by other donors and FAO.

The network group convened by the workshop will seek to reinvigorate some historic or existing networks of practitioners at regional and national levels. The primary target group is Government fishery research officers as they are the data holders and responsible for national activities related to the assessment of fishery resources. There are also associated fishery professional and regional organizations, universities, environmental organizations, and NGOs that are also engaged in support or collaboration with local or national initiatives. Academic researchers are most typically involved in developing analytical and modelling approaches and supervising the research which can be applied to the data collected. They are also involved in training the next generation of fisheries biologists, modellers and stock assessment practitioners.

The network group will provide overviews of the range of methods that are applied to different stocks and fisheries, encompassing fisheries with different levels of data (i.e. data-poor, data-limited to data-rich) that they are using in the region. These will be compared and contrasted with the ultimate goal of providing options for countries to apply these approaches in determining appropriate levels of exploitation of their fisheries, as well as providing updated reports on the status of the fish stocks covered by the assessments in the Asian region. This is currently poorly reported and is currently a major gap in the assessment of the state of global fish stocks prepared by FAO.

The objectives of the workshop were as follows:

1. To give a broad background on the status of stock assessments in Asia and an overview of the status of stocks in Asia;
2. To understand what assessments are being carried out in Southeast Asia, Southern Asia, and southern China, and the approaches being used to make these assessments;
3. To identify approaches that are best suited to different fisheries within the region, given the current resources available for assessments and level of data collection;
4. To identify human capacity development needs to enhance stock assessments in the region; and
5. For the long-term, to examine the value of forming a network of people for assessing Asian fish stocks and build a community of practice in stock assessment.

The agenda of the workshop is presented in Annex I.

2 SUMMARY FINDINGS OF THE REGIONAL WORKSHOP

The discussions findings and outputs of the plenary sessions and working groups are summarised here. These were reviewed in the final plenary session by the workshop participants.

Marine fish 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 number of factors such as increased attention and resourcing being directed towards aquaculture development and a sense that marine capture fisheries are too complex to manage effectively. 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, multi-gear fisheries and unable to provide useful advice for the management of such fisheries.

The workshop recognized that these 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 a function of a number of factors primarily related to:

i. Increased accessibility to modelling methodologies due to much greater computing power and ability to manipulate data and freely available, documented resources (e.g. through the increased use of R and GitHub).
ii. New multi-species 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.
iii. 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 south-eastern Asia, or data that easier to collect at low cost.
iv. 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 are 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 a use a range of metrics to assess stock status including those coming from surplus production models when a time series of catch and effort data are 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 declared country 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 provided to the workshop indicate that the stock assessments correspond more or less to the FAO assessments regarding the proportion of fisheries that are overfished, 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 a number of reasons relating to institutional disconnections, poor communication from science to policy communication and 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. The assessment communication does not often provide sufficient options for management action and likely impact of different decisions. Part of this is that 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 typically 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 have not been defined for the social and economic performance of fisheries.

An important strategy to increase impact is to link stock assessment results into a harvest strategy process, to create a stronger relationship between science, fishing industry, policy, 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 primarily in smaller geographic areas (e.g. such as Blue Swimmer Crabs in the north-west of Sri Lanka and Grouper fisheries in Saleh Bay, Indonesia). Harvest strategies have been or are being developed that involve information sharing and collaborations and partnerships among researchers, government, fishers, fishing industry and non-government organizations.

Single species assessment and single species management in isolation from the other species in the fishery is rarely applicable in the tropical/Asian context.

Single species models may not provide meaningful results for multispecies fishery management, it also creates questions about sustainability of a fishery when some species may be underfished, but others are overfished. The Regional Workshop identified the need for bio-economic modelling and ecosystem modelling approaches to inform management of fisheries, particularly the multi-species, multi-method fisheries that are common throughout the region. New exciting models have been developed and are available for addressing multi-species, multi-gear fisheries. These include multi-species maximum sustainable yield (MMSY), evaluating groups of species with similar trophic levels (the species hub), application of Ecopath with Ecosim and indicator species approaches. When a long, time-series of 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, changes in the mean size of the dominant species/taxa in the fishery.

Fishery data systems have been historically developed and designed for the purpose of a particular type of assessment and this may limit the application of other assessment models

The suite of models that are being used in the region fall into two major groupings: those based on catch, catch effort indicators and have biomass indicators and have a times series of catch and effort available (e.g. surplus production models); those using length distributions (e.g. length-based spawning potential ratio) and determine an estimate of spawning potential ratio (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., length data collected as part of a catch/effort data collection system may not be suitable for length-based assessment methods).

Fishery independent surveys are underutilized and under-appreciated at the moment.

The Regional 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. These are underutilized and under-appreciated at the moment.

Assessment results may need to be interpreted with caution, especially if there are many 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 errors in the outputs generated by the models. This requires more evaluation of priors and model assumptions and 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.

2.1.1 Identified needs for development

- There is a need for bio-economic modelling and ecosystem modelling approaches to inform management of fisheries, particularly the multi-species, multi-method fisheries that are common throughout the region
- New exciting models have been developed and are available for addressing multi-species, multi-gear fisheries. These include multi-species maximum sustainable yield (MMSY), evaluating groups of species with similar trophic levels (the species hub), application of Ecopath with Ecosim and indicator species approaches.
- Single species assessment and single species management in isolation from the other species in the fishery are rarely applicable in the multi-species tropical/Asian context and single-species assessment and management in multi-species fisheries of south and south-east Asia is likely to lead to over estimates of the total productivity of these fisheries.
- Single species approaches are appropriate when a single species is clearly targeted such as Blue Swimming Crabs in a number of countries
- More effective communication is needed of the stock assessment results to managers, fishers, fishing industry and the communities whose livelihoods are supported by fishing
- Surveys of fishers and fishing industry and carried out to understand their perspectives on stock status, issues in the fisheries and different management options. This can not only help get at the social and economic considerations relating to management objectives, but is also a source of local fisher/ecological knowledge to inform the interpretation of assessments.
- Communication strategies and mechanisms are developed to convey understanding of the findings from stock assessments and implications for managing fisheries
- Networking to promote understanding of stock assessments, the appropriate methods and data sources to be applied to different fisheries to meet different objectives. Choosing appropriate models for different circumstances and designing data collection systems to meet the assumptions and requirements of the models.

2.1.2 Main recommendations

- Evaluate data collection systems and their suitability for the stock assessment models e.g., length data collected as part of a catch/effort data collection system may not be suitable for length-based assessment methods
- Increase understanding of model assumptions and the influence of selecting parameter values and the distribution of these values (priors) for the models
- Increased understanding of the uncertainty in model predictions and incorporation of sensitivity analyses in modelling and presentation of the results from stock assessments
- Linking stock assessment results into harvest strategy process 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.
- Incorporate information on the social and economic importance of fisheries in the assessment process for presentation to managers
- Better communication of research findings, assessment results and the implications of these results from researchers responsible for stock assessments to managers, fishers, the fishing industry, and the broader community
- Develop training programs of benefit to researchers working on south and south-east Asian fisheries: a) stock assessments, model assumptions, interpreting outputs and uncertainties; b) survey design 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 the fisher

communities; e) incorporation of social and economic performance indicators and reference points in fisheries; f) communication training to audiences with different levels of knowledge and different backgrounds.

PENDING: Single species stock assessments for a range of data in Asia

Ricardo Amoroso (University of Washington, USA; National University of Comahue Argentina)

3 FISH STOCK STATUS ASSESSMENT OF FAO FISHING AREA 57

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 that time (FAO, 2020). In order to promote consistency and comparability across time, these analyses have used a fixed list of stocks (which account for over 70% 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 2022 is now appreciably different compared to that of the 1970s, as are the dominant fish stocks that comprise the majority of 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 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 fisheries sustainability. The has been accompanied by an increasing expectation and requirement for transparency in how stocks are assessed and recognition of the need to incorporate local knowledge. The adoption of the Sustainable Development Goals (SDGs) and SDG 'fish stocks sustainability' 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 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 FAO fishing regions level and is designed to narrow current gaps in assessment over time through a process of continuous improvement.

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;
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 biennial report on the State of the World 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 development programme that reinforces the capacity of fisheries institutions of member countries for collecting, managing, and processing data and information for assessing and reporting on the state of fisheries and fish stocks.
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 fishing areas (Area 37 & 31). FAO has also demonstrated the new index generated from Fishing Area 57, (Eastern Indian Ocean) (Figure 1, Table 1).

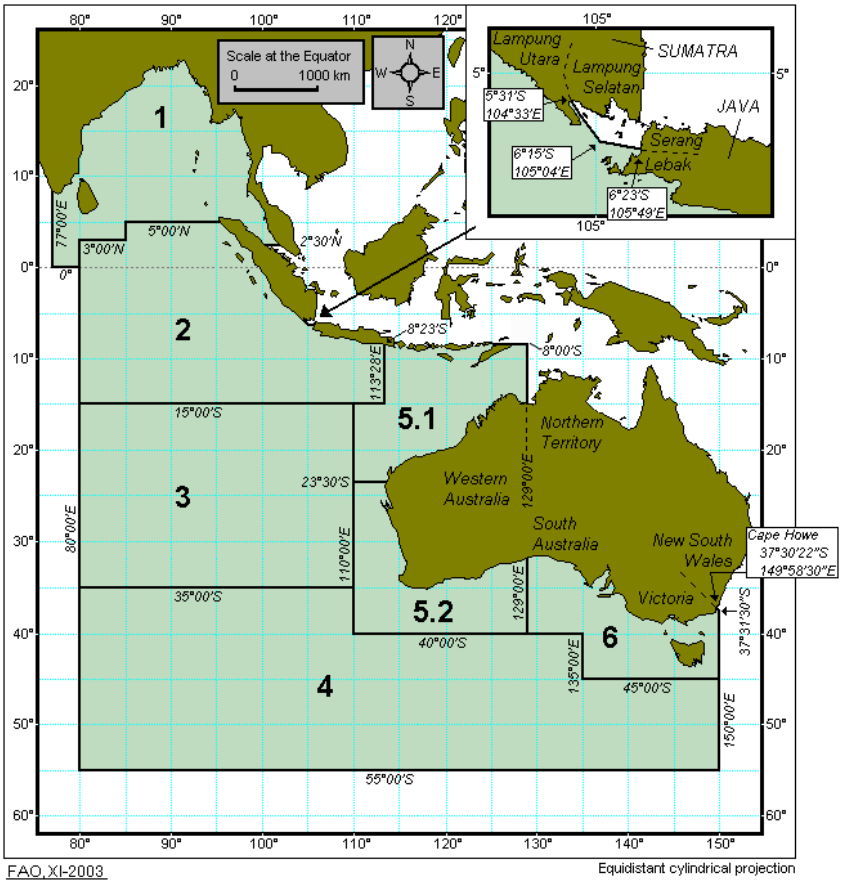


Figure 1: FAO Fishing Area 57 and its sub-areas covered for the new SOFIA State of Stocks in the region.

Table 1: The 6 subareas of FAO fishing Area 57, with 2 additional divisions in Western Australia

Sub Area		**Description**
Bay of Bengal	Sub area 57.1	Includes eastern waters of India, Sri Lanka, Bangladesh, Myanmar, West coast of Thailand and west coast of west peninsular Malaysia
Northern	Sub area 57.2	Includes waters of western and southern Indonesia
Central	Sub area 57.3	Open ocean area without coasts
Oceanic	Sub area 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	Sub area 57.6	

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 2).

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

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

Tier 3: Amount, detail and/or quality of data is 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"[6] coupled with a rigorous peer-review process. No stocks in Area 57 used this approach.

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 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 sraplus.	Medium - Low
Tier 3	Qualitative assessments based on the Weight of Evidence (WOE). **Note:** this was not done in Area 57, however, 11 stocks using CMSY were put in this category as they had very few years of data.	Medium to low based on the fit of the data

3.3 IMPROVEMENTS IN COVERAGE OF TIER 1 STOCKS

In late 2021, recent formal assessments of 134 fish 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 (FMA) which are part of Area 57, 36 stocks additional were assessed by the authors. Besides 33

[6]The Weight of Evidence (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, I, Larcombe, J., Woodhams, J and Patterson, H. (2015) "Stock status determination: weight- of-evidence decision-making framework" (https://daff.ent.sirsidynix.net.au/client/en_AU/search/asset/1027248/12).

fish stocks from Sri Lanka (5), Thailand (11) and Malaysia (west coast – 23) were added after the January 2023 Bangkok workshop making a total of 203 fish stocks in Tier 1[7] (Figure 2)

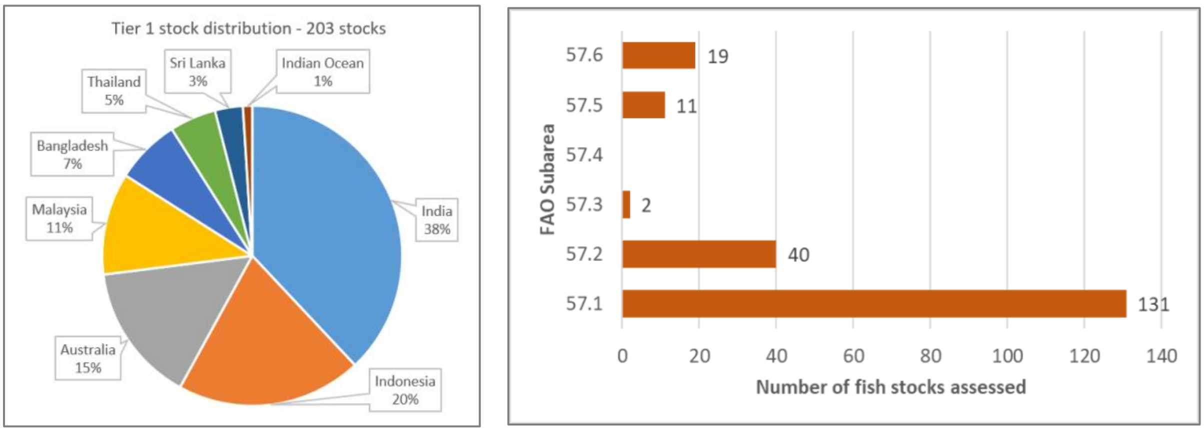


Figure 2: Distribution of assessed stocks by country and numbers of stocks assessed by sub area of FAO fishing area 57

The number of stocks assessed in Subarea 57.1 is high (India, Bangladesh, Thailand and Malaysia) and moderate in Indonesia (subarea 57.2) and Australia (sub areas 57.5 and 57.6). The open ocean subareas 57.3 reported 2 Indian Ocean stocks and 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% of the 203 fish stocks and medium for 21% of the stocks. There were no low-quality assessments. Demersal fish stocks accounted for 47% of the assessments, while pelagic and midwater fish stocks accounted for 32 and 21% respectively.

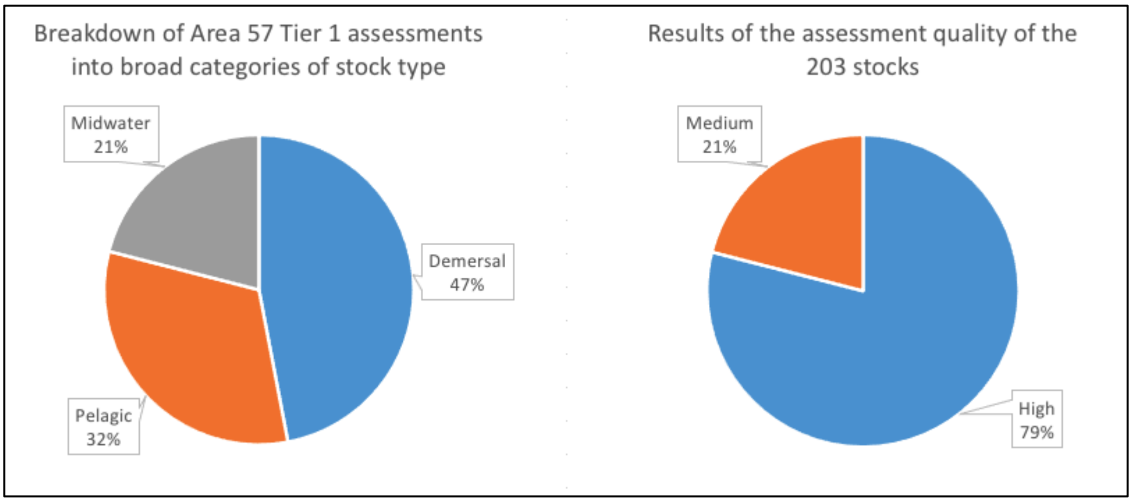


Figure 3: Percentage breakdown of the 203 Tier 1 assessments into broad categories of stock type and the quality of those assessments. Tier 1 assessment as formal country-based stock assessments using analytical models published in peer-reviewed journals or country reports.

[7] A complete listing of Tier 1 stocks and reference points is given in Annex 2.

3.4 IMPROVEMENTS IN TIER 2 STOCK ASSESSMENTS

Tier 2 fish stocks are those that have been assessed by 'sraplus'[8] (Ovando et. al. 2021, Sharma et. al. 2021) which allows users to extend the traditional catch only models. This method uses SRA (Stock Reduction Analysis, Kimura and Tagart 1982; Kimura et al., 1984) with surplus production approach, combining a biomass dynamics model with a variety of 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.

These Tier 2 stocks are the 121 stocks which were earlier placed in Tier 3, based on the FAO Catch-rule method (FAO-COM). This group also included 33 stocks which have been historically monitored by FAO.

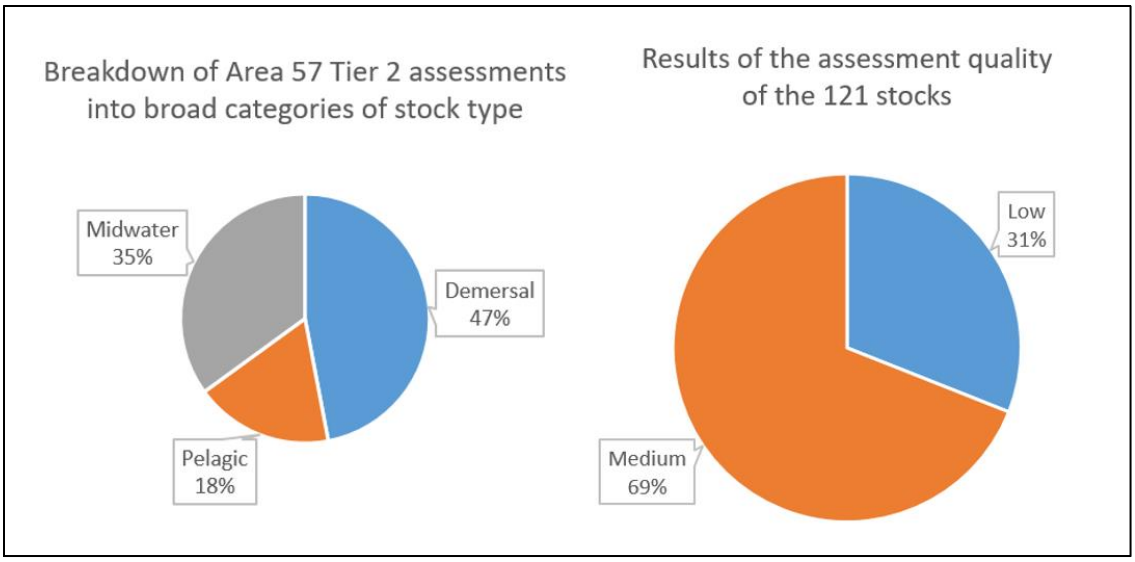


Figure 4: Percentage breakdown of the 121 Tier 2 assessments into broad categories of stock type and results of the assessment quality of the 121 stocks.

As part of the piloting activities FAO has developed 'proof of concept' reports for the updated analysis that has been completed in two fishing areas (Area 37 & 31). FAO has also demonstrated the new index generated from Fishing Area 57. The results for the new analysis for each group of stocks is shown for the Tier 2 Analysis in Figure 5.

[8] A complete listing of Tier 2 assessments given in Annex 3.

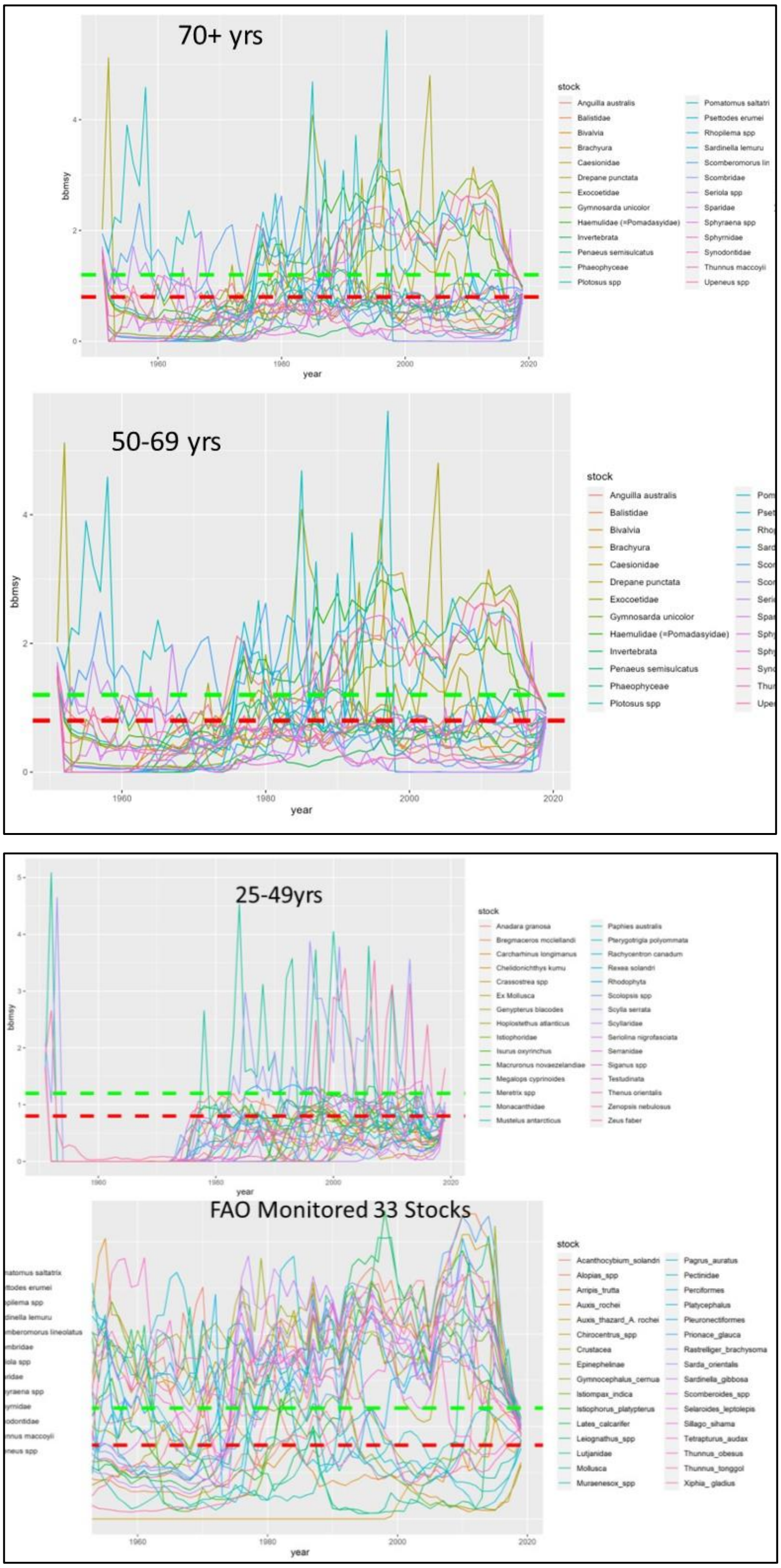


Figure 5: Analysis of different levels of catch data from FISHSTAT J using global effort as a covariate.

This analysis has added 88 new stocks from FishStatJ (Figure 5) to the existing 33 stocks which were previously used to inform the Area 57 assessment. The new analysis computed index is shown in Table 1, 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)[9] giving a total of 335 stocks[10].

Table 2: The number of stocks used in the New Index in Area 57 versus current SOFIA index

Final Categorization Area 57	**Underfished**	**Fully Sustianably fished**	**Overfished**	**Total number of stocks**
Previous SOFIA				
2022 Status (total number of stocks monitored in current SOFIA)	**5.1%**	**64.1%**	**30.8%**	**39**
Updated approach				
Tier 1 (stocks now assessed at 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				**335**

3.5 CONCLUSIONS

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% as opposed to 31% in 2022 SOFIA (Table 3).

The overall index based on the new SOFIA analysis as compared to the index previously used in current SOFIA 2022 is shown in Figure 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 did change significantly from 5 and 64% to 32% and 40% respectively. This was because the additional disaggregated stocks that were added were assessed as underfished in the region, but which represent 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.

[9] A complete listing of Tier 3 assessments given in Annex 4

[10] The results of the Tier 1, Tier 2 and Tier 3 analyses are provided in Annex 1.

Table 3: Comparison of status of stocks, SOFIA 2022 assessment and new assessment with increased number of stocks and higher resolution

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

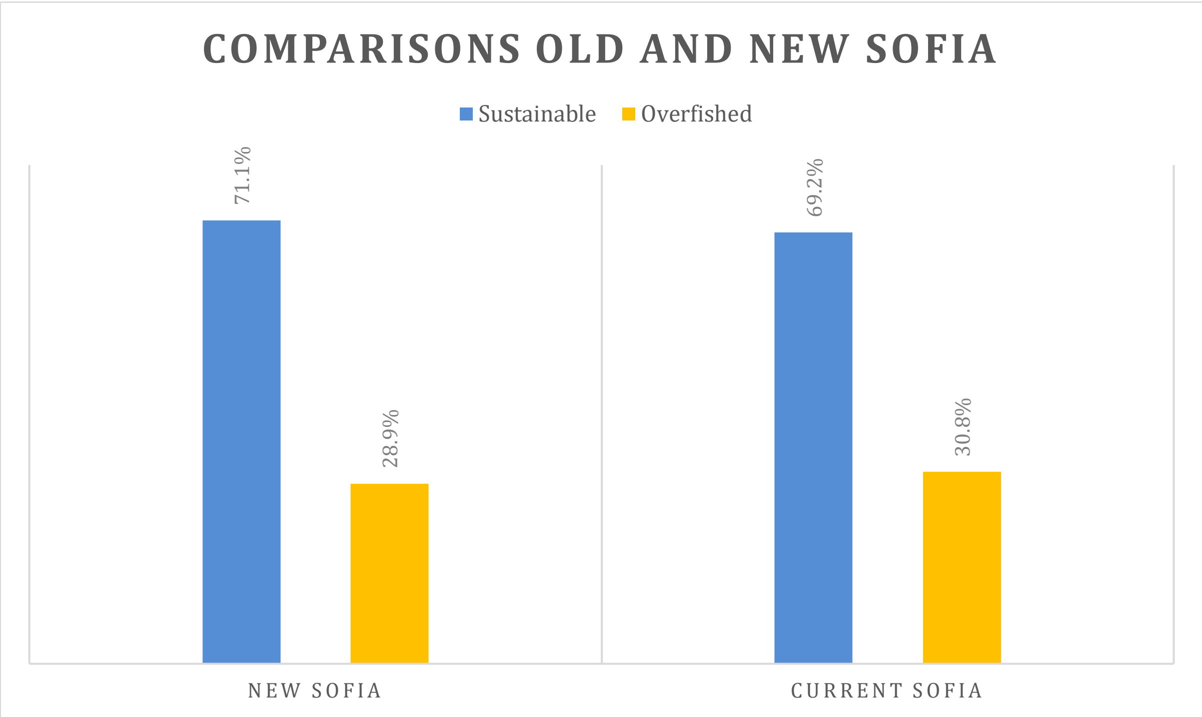


Figure 6: Comparison of the existing methods of SOFIA with the new approach.

3.6 REFERENCES

FAO 2020. The State of World Fisheries and Aquaculture Report. Rome, Italy

FAO 2011. Review of the state of world marine fishery resources. Fisheries and Aquaculture Technical Paper No. 569

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

Jaya, I 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., and Tagart, J.V. 1982. Stock reduction analysis, another solution to the catch equations. Can. J. Fish. Aquat. Sci.39: 1467–1472.

Kimura, D.K., Balsiger, J.W., and Ito, D.H. 1984. Generalized stock reduction analysis. Can. J. Fish. Aquat. Sci. 41: 1325–1333.

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

Sharma, R.; Winker, H.; Levontin, P.; Kell, L.; Ovando, D.; Palomares, M.L.D.; Pinto, C.; Ye, Y. Assessing the Potential of Catch-Only Models to Inform on the State of Global Fisheries and the UN's SDGs. *Sustainability* 2021, *13*: 6101; https://doi.org/10.3390/su13116101

Rousseau, Y., Watson, R W., Blanchard, J L., and Fulton, E A. 2019. Evolution of global marine fishing fleets and theresponse of fished resources. PNAS 116 (25): 12238–12243.

Walters C J., Martel S J D., and Korman J. 2006. A stochastic approach to stock reduction analysis. Can. J. Fish. Aquat. Sci. 63: 212–223

Annex 3-1: Results of the Tier 1 and Tier 2 assessments

	Number of stocks				Unweighted		Weighted		
Final Categorization Area 57	**Under-fished**	**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**

Annex 3-2: Tier 1 Fish Stocks Status - Area 57 2022

Tier 1 Stocks Area 57				Formal Country Assessments				
No	**Sp.group**	**Sub-Area**	**Country**	**Name**	**Ref Point**	**Latest value**	**Stock status**	**Reference**
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	0.15	Overfished	Haputhantri and Sharma 2021
3	35	57.1	Sri Lanka	Gold striped sardinella	Bmsy Fmsy	0.83	Recovering	Haputhantri and Sharma 2022
4	45	57.1	Sri Lanka	Spiny lobster	SPR%	20%	Overfished	Liyanage and Sharma 2021
5	45	57.1	Sri Lanka	Blue swimming crab	SPR%	37%	Sustainable	Prince et al., 2020
6	35	57.1	India	Anchovies	Bmsy Fmsy	0.702482	Recovering	Sathianandan et al., 2021
7	37	57.1	India	Barracudas	Bmsy Fmsy	1.541814	Sustainable	Sathianandan et al., 2021
8	37	57.1	India	Sawtooth barracuda	Exp Ratio	0.18	Sustainable	Ghosh et al., 2021
9	37	57.1	India	Black pomfret	Bmsy Fmsy	1.393829	Sustainable	Sathianandan et al., 2021
10	33	57.1	India	Bombayduck	Bmsy Fmsy	0.348182	Overfished	Sathianandan et al., 2021
11	33	57.1	Bangladesh	Catfishes	F-ratio	2.100000	Overfished	Fanning et al., 2019
12	33	57.1	India	Catfishes	Bmsy Fmsy	0.366997	Overfished	Sathianandan et al., 2021
13	33	57.1	Bangladesh	Bombayduck	F-ratio	3.500000	Overfished	Fanning et al., 2019
14	57	57.1	India	Cephalopods aggregate	Bmsy Fmsy	0.645526	Overfished	Sathianandan et al., 2021
15	57	57.1	India	Indian Squid	Exp Ratio	0.623000	Overfished	Chhandaprajnadarsini et al 2021
16	42	57.1	India	Crabs aggregate	Bmsy Fmsy	0.431169	Overfished	Sathianandan et al., 2021
17	42	57.1	India	Blue swimming crab	Bmsy Fmsy	0.790000	Recovering	Josileen et al., 2019
18	33	57.1	India	Croakers	Bmsy Fmsy	1.053751	Sustainable	Sathianandan et al., 2021
19	33	57.1	India	Croakers	Bmsy Fmsy	0.276113	Recovering	Sathianandan et al., 2021
20	33	57.1	India	Croakers	Bmsy Fmsy	1.139198	Sustainable	Sathianandan et al., 2021
21	33	57.1	Bangladesh	Indian threadfin	F-ratio	8.500000	Overfished	Fanning et al., 2019
22	33	57.1	Bangladesh	Lesser tigertooth croaker	F-ratio	6.000000	Overfished	Fanning et al., 2019
23	33	57.1	Bangladesh	Donkey croaker	F-ratio	0.800000	Recovering	Fanning et al., 2019
24	36	57.1	India	Frigate & Bullet tuna	Bmsy Fmsy	0.265722	Overfished	Sathianandan et al., 2021
25	33	57.1	India	Goatfishes	Bmsy Fmsy	0.731147	Recovering	Sathianandan et al., 2021
26	33	57.1	India	Goatfishes	Bmsy Fmsy	0.805025	Overfished	Sathianandan et al., 2021
27	33	57.1	India	Goatfishes	Bmsy Fmsy	0.185954	Overfished	Sathianandan et al., 2021
28	35	57.1	India	Grenadier anchovy	Bmsy Fmsy	1.541765	Sustainable	Sathianandan et al., 2021
29	35	57.1	India	Grenadier anchovy	Bmsy Fmsy	1.172015	Sustainable	Sathianandan et al., 2021
30	35	57.1	India	Hairfin anchovy	Bmsy Fmsy	1.381679	Sustainable	Sathianandan et al., 2021
31	24	57.1	India	Hilsa shad	Bmsy Fmsy	0.210000	Overfished	Das et al., 2019/ Sathianandan et al.,
32	24	57.1	Bangladesh	Hilsa shad	B/Bmsy	0.961000	Overfishing	Alam et al 2021/Dutta et al., 2021/ R
33	37	57.1	India	Horse mackeral	Bmsy Fmsy	0.376200	Overfished	Sathianandan et al., 2021
34	37	57.1	India	Horse mackeral	Bmsy Fmsy	0.055632	Overfished	Sathianandan et al., 2021
35	37	57.1	India	Indian mackeral	Bmsy Fmsy	0.524252	Overfished	Sathianandan et al., 2021
36	37	57.1	India	Indian mackeral	Bmsy Fmsy	0.859125	Overfishing	Sathianandan et al., 2021
37	33	57.1	India	Leatherjacket filefish	Bmsy Fmsy	0.952848	Recovering	Sathianandan et al., 2021
38	36	57.1	India	Little tunny	Bmsy Fmsy	0.353424	Recovering	Sathianandan et al., 2021
39	36	57.1	India	Little tunny	Bmsy Fmsy	0.569577	Recovering	Sathianandan et al., 2021
40	33	57.1	India	Lizardfishes	Bmsy Fmsy	0.607070	Recovering	Sathianandan et al., 2021
41	33	57.1	India	Lizardfishes	Bmsy Fmsy	0.246415	Overfished	Sathianandan et al., 2021
42	45	57.1	India	Non-penaeid prawns	Bmsy Fmsy	0.272540	Overfished	Sathianandan et al., 2021
43	45	57.1	India	Non-penaeid prawns	Bmsy Fmsy	0.865850	Recovering	Sathianandan et al., 2021
44	45	57.1	India	Non-penaeid prawns	Bmsy Fmsy	1.061188	Sustainable	Sathianandan et al., 2021
45	35	57.1	India	Oil sardine	Bmsy Fmsy	0.747633	Recovering	Sathianandan et al., 2021
46	37	57.1	India	Carangids	Bmsy Fmsy	1.111308	Sustainable	Sathianandan et al., 2021
47	37	57.1	India	Carangids	Bmsy Fmsy	1.092259	Sustainable	Sathianandan et al., 2021
48	35	57.1	India	Clupeids	Bmsy Fmsy	0.168557	Overfished	Sathianandan et al., 2021
49	35	57.1	India	Clupeids	Bmsy Fmsy	1.091353	Sustainable	Sathianandan et al., 2021
50	35	57.1	Bangladesh	Clupeids	F-ratio	1.500000	Overfished	Fanning et al., 2019
51	35	57.1	Bangladesh	Clupeids	Bmsy Fmsy	0.700000	Overfished	Barman et al., 2021
52	35	57.1	Bangladesh	Rainbow sardine	F-ratio/ Bmsy F	1.600000	Sustainable	Fanning et al., 2019/ Barman et al 20
53	35	57.1	Bangladesh	Slender Rainbow sardine	Bmsy Fmsy	1.700000	Sustainable	Barman et al., 2021
54	33	57.1	India	Perches	Bmsy Fmsy	0.984967	Sustainable	Sathianandan et al., 2021
55	33	57.1	India	Perches	Bmsy Fmsy	0.491650	Overfished	Sathianandan et al., 2021
56	33	57.1	India	Perches	Bmsy Fmsy	0.716766	Recovering	Sathianandan et al., 2021
57	35	57.1	India	Sardines	Bmsy Fmsy	0.622999	Recovering	Sathianandan et al., 2021
58	35	57.1	India	Sardines	Bmsy Fmsy	0.624332	Overfished	Sathianandan et al., 2021
59	45	57.1	India	Peaneid prawns	Bmsy Fmsy	0.239138	Overfished	Sathianandan et al., 2021
60	45	57.1	India	Peaneid prawns	Bmsy Fmsy	0.252108	Recovering	Sathianandan et al., 2021
61	45	57.1	India	Peaneid prawns	Bmsy Fmsy	0.222318	Overfished	Sathianandan et al., 2021
62	45	57.1	India	Peaneid prawns	Bmsy Fmsy	1.055654	Sustainable	Sathianandan et al., 2021
63	45	57.1	India	Peaneid prawns	Bmsy Fmsy	0.157266	Overfished	Sathianandan et al., 2021
64	45	57.1	Bangladesh	Brown shrimp	F-ratio	1.200000	Overfished	Fanning et al., 2019
65	45	57.1	Bangladesh	Tiger shrimp	Bmsy Fmsy	0.530000	Recovering	Barua et al., 2020
66	33	57.1	India	Pig-face breams	Bmsy Fmsy	0.667428	Recovering	Sathianandan et al., 2021
67	38	57.1	India	Rays	Bmsy Fmsy	1.003315	Sustainable	Sathianandan et al., 2021
68	38	57.1	India	Rays	Bmsy Fmsy	1.153866	Recovering	Sathianandan et al., 2021
69	38	57.1	India	Rays	Bmsy Fmsy	1.281363	Sustainable	Sathianandan et al., 2021
70	38	57.1	India	Rays	Bmsy Fmsy	0.406708	Overfished	Sathianandan et al., 2021

Tier 1 Fish Stocks Status - Area 57 2022 (contd)

No	Sp.group	Sub-Area	Country	Name	Ref Point	Latest value	Stock status	Reference
71	37	57.1	India	Ribbonfishes	Bmsy Fmsy	0.526959	Recovering	Sathianandan et al., 2021
72	37	57.1	India	Ribbonfishes	Bmsy Fmsy	1.137215	Sustainable	Sathianandan et al., 2021
73	33	57.1	India	Rock cod	Bmsy Fmsy	0.812261	Recovering	Sathianandan et al., 2021
74	37	57.1	India	Scads	Bmsy Fmsy	1.558932	Sustainable	Sathianandan et al., 2021
75	37	57.1	India	Scads	Bmsy Fmsy	0.143032	Recovering	Sathianandan et al., 2021
76	36	57.1	India	Spanish mackeral	Bmsy Fmsy	0.916213	Sustainable	Sathianandan et al., 2021
77	36	57.1	India	Spanish mackeral	Bmsy Fmsy	1.562017	Sustainable	Sathianandan et al., 2021
78	36	57.1	Indian Ocea	Spanish mackeral	Bmsy Fmsy	0.960000	Overfishing	IOTC, 2015
79	38	57.1	India	Sharks	Bmsy Fmsy	0.721548	Recovering	Sathianandan et al., 2021
80	38	57.1	India	Sharks	Bmsy Fmsy	1.791648	Sustainable	Sathianandan et al., 2021
81	38	57.1	India	Sharks	Bmsy Fmsy	1.534786	Sustainable	Sathianandan et al., 2021
82	38	57.1	India	Sharks	Bmsy Fmsy	1.512692	Sustainable	Sathianandan et al., 2021
83	37	57.1	India	Silver pomfrets	Bmsy Fmsy	0.611229	Recovering	Sathianandan et al., 2021
84	37	57.1	India	Silver pomfrets	Bmsy Fmsy	0.597132	Recovering	Sathianandan et al., 2021
85	37	57.1	Bangladesh	Silver pomfrets	F-ratio	1.300000	Overfished	Fanning et al., 2019
86	37	57.1	Bangladesh	Chinese pomfrets	F-ratio	0.450000	Sustainable	Fanning et al., 2019
87	33	57.1	India	Silverbellies	Bmsy Fmsy	0.593593	Recovering	Sathianandan et al., 2021
88	36	57.1	India	Skipjack tuna	Bmsy Fmsy	0.210550	Overfished	Sathianandan et al., 2021
89	36	57.1	Indian Ocea	Yellowfin tuna	Bmsy Fmsy	0.830000	Overfished	IOTC, 2020
90	31	57.1	India	Soles	Bmsy Fmsy	0.172394	Overfished	Sathianandan et al., 2021
91	31	57.1	India	Soles	Bmsy Fmsy	0.650363	Recovering	Sathianandan et al., 2021
92	31	57.1	India	Soles	Bmsy Fmsy	0.910298	Recovering	Sathianandan et al., 2021
93	36	57.1	India	Spotted seerfish	Bmsy Fmsy	0.821953	Sustainable	Sathianandan et al., 2021
94	36	57.1	India	Spotted seerfish	Bmsy Fmsy	0.459509	Overfished	Sathianandan et al., 2021
95	33	57.1	India	Threadfin breams	Bmsy Fmsy	0.417650	Overfished	Sathianandan et al., 2021
96	33	57.1	India	Threadfins	Bmsy Fmsy	1.479635	Sustainable	Sathianandan et al., 2021
97	35	57.1	India	Other anchovies	Bmsy Fmsy	0.458166	Overfished	Sathianandan et al., 2021
98	35	57.1	India	Other anchovies	Bmsy Fmsy	1.013223	Sustainable	Sathianandan et al., 2021
99	35	57.1	India	Wolf herring	Bmsy Fmsy	1.213273	Sustainable	Sathianandan et al., 2021
100	33	57.1	Thailand	Purple-Spotted Bigeye	F-factor	1.500	Not fully exp	Nootmorn, 2021
101	33	57.1	Thailand	Delagoa Threadfin Bream	F-factor	0.900	Fully exploite	Nootmorn, 2021
102	33	57.1	Thailand	Slender Lizardfish	F-factor	1.400	Not fully exp	Nootmorn, 2021
103	33	57.1	Thailand	Brushtooth Lizardfish	F-factor	0.900	Fully exploite	Nootmorn, 2021
104	45	57.1	Thailand	Banana Prawm	F-factor	1.200	Fully exploite	Nootmorn, 2021
105	45	57.1	Thailand	Blue Swimming Crab	F-factor	2.500	Not fully exp	Nootmorn, 2021
106	57	57.1	Thailand	Indian Squid	F-factor	0.800	Fully exploite	Nootmorn, 2021
107	35	57.1	Thailand	Anchovy	F-factor	1.300	Not fully exp	Nootmorn, 2021
108	37	57.1	Thailand	Short Mackerel	F-factor	2.000	Not fully exp	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 exp	Nootmorn, 2021
111	35	57.1	Pen Malaysia	Anchovies	Bmsy Fmsy	1.776	Not fully exp	Jamon et al 2022
112	33	57.1	Pen Malaysia	Lizard fish	Bmsy Fmsy	0.3305	Overfished	Jamon et al 2022
113	37	57.1	Pen Malaysia	Indian mackerel	Bmsy Fmsy	1.692	Not fully exp	Jamon et al 2022
114	33	57.1	Pen Malaysia	Threadfin bream	Bmsy Fmsy	0.918	Overfished	Jamon et al 2022
115	37	57.1	Pen Malaysia	Oxeye scad	Bmsy Fmsy	0.5753	Overfished	Jamon et al 2022
116	37	57.1	Pen Malaysia	Short mackerel	Bmsy Fmsy	1.573	Not fully exp	Jamon et al 2022
117	33	57.1	Pen Malaysia	Fourfinger threadfin	Bmsy Fmsy	0.9323	Overfished	Jamon et al 2022
118	35	57.1	Pen Malaysia	Sardine	Bmsy Fmsy	1.026	Overfishing	Jamon et al 2022
119	36	57.1	Pen Malaysia	Narrow barred Spanish m	Bmsy Fmsy	0.2634	Overfished	Jamon et al 2022
120	36	57.1	Pen Malaysia	Indo-Pacific King mackere	Bmsy Fmsy	0.8352	Overfished	Jamon et al 2022
121	33	57.1	Pen Malaysia	Gray eel catfish	Bmsy Fmsy	1.472	Not fully exp	Jamon et al 2022
122	45	57.1	Pen Malaysia	Paste shrimp	Bmsy Fmsy	0.9977	Overfished	Jamon et al 2022
123	36	57.1	Pen Malaysia	Kawakawa	Bmsy Fmsy	0.9803	Recovering	Jamon et al 2022
124	37	57.1	Pen Malaysia	Torpedo scad	Bmsy Fmsy	0.8035	Overfished	Jamon et al 2022
125	33	57.1	Pen Malaysia	Croaker	Bmsy Fmsy	0.6837	Overfished	Jamon et al 2022
126	33	57.1	Pen Malaysia	Soldier catfish	Bmsy Fmsy	0.418	Overfished	Jamon et al 2022
127	33	57.1	Pen Malaysia	Groupers	Bmsy Fmsy	0.2998	Overfished	Jamon et al 2022
128	33	57.1	Pen Malaysia	Goatfish	Bmsy Fmsy	1.708	Not fully exp	Jamon et al 2022
129	57	57.1	Pen Malaysia	Squid	Bmsy Fmsy	1.583	Not fully exp	Jamon et al 2022
130	33	57.1	Pen Malaysia	Red snapper	Bmsy Fmsy	1.312	Not fully exp	Jamon et al 2022
131	45	57.1	Pen Malaysia	Crabs	Bmsy Fmsy	0.2208	Overfished	Jamon et al 2022
132	45	57.1	Pen Malaysia	Prawns	Bmsy Fmsy	1.474	Not fully exp	Jamon et al 2022
133	33	57.1	Pen Malaysia	Brackishwater fish	Bmsy Fmsy	0.5326	Overfished	Jamon et al 2022

Annex 3-2: Tier 1 Fish Stocks Status - Area 57 2022 (contd)

No	Sp.group	Sub-Area	Country	Name	Ref Point	Latest value	Stock status	Reference
134	36	57.2	Indonesia	Spanish mackeral	C/Cmsy	0.9	Recovering	Fauziyah et al., 2020
135	36	57.2	Indonesia	Bullet/Frigate tuna	C/Cmsy	0.8	Overfishing	Fauziyah et al., 2020
136	37	57.2	Indonesia	Queen fish	C/Cmsy	1.12	Overfished	Fauziyah et al., 2020
137	37	57.2	Indonesia	Mackeral	C/Cmsy	1.2	Overfished	Fauziyah et al., 2020
138	35	57.1	Indonesia	Small pelagics	Exp Rate	0.83	Fully exploite	Jaya et al 2021
139	36	57.1	Indonesia	Large pelagics	Exp Rate	0.52	Sustainable	Jaya et al 2022
140	33	57.1	Indonesia	Demersal fish	Exp Rate	0.33	Sustainable	Jaya et al 2023
141	33	57.1	Indonesia	Coral fishes	Exp Rate	0.34	Sustainable	Jaya et al 2024
142	45	57.1	Indonesia	Penaeid shrimps	Exp Rate	1.59	Overfished	Jaya et al 2025
143	45	57.1	Indonesia	Lobster	Exp Rate	1.3	Overfished	Jaya et al 2026
144	42	57.1	Indonesia	Crab	Exp Rate	1.0	Fully exploite	Jaya et al 2027
145	42	57.1	Indonesia	Blue swimming crab	Exp Rate	0.93	Fully exploite	Jaya et al 2028
146	57	57.1	Indonesia	Squids	Exp Rate	0.62	Fully exploite	Jaya et al 2029
147	35	57.2	Indonesia	Small pelagics	Exp Rate	0.5	Sustainable	Jaya et al 2030
148	36	57.2	Indonesia	Large pelagics	Exp Rate	0.95	Fully exploite	Jaya et al 2031
149	33	57.2	Indonesia	Demersal fish	Exp Rate	0.57	Fully exploite	Jaya et al 2032
150	33	57.2	Indonesia	Coral fishes	Exp Rate	0.33	Not fully exp	Jaya et al 2033
151	45	57.2	Indonesia	Penaeid shrimps	Exp Rate	1.53	Overfished	Jaya et al 2034
152	45	57.2	Indonesia	Lobster	Exp Rate	0.93	Fully exploite	Jaya et al 2035
153	42	57.2	Indonesia	Crab	Exp Rate	0.18	Not fully exp	Jaya et al 2036
154	42	57.2	Indonesia	Blue swimming crab	Exp Rate	0.49	Not fully exp	Jaya et al 2037
155	57	57.2	Indonesia	Squids	Exp Rate	0.39	Not fully exp	Jaya et al 2038
156	35	57.2	Indonesia	Small pelagics	Exp Rate	1.5	Overfished	Jaya et al 2039
157	36	57.2	Indonesia	Large pelagics	Exp Rate	1.06	Overfished	Jaya et al 2040
158	33	57.2	Indonesia	Demersal fish	Exp Rate	0.39	Not fully exp	Jaya et al 2041
159	33	57.2	Indonesia	Coral fishes	Exp Rate	1.09	Overfished	Jaya et al 2042
160	45	57.2	Indonesia	Penaeid shrimps	Exp Rate	1.7	Overfished	Jaya et al 2043
161	45	57.2	Indonesia	Lobster	Exp Rate	0.61	Fully exploite	Jaya et al 2044
162	42	57.2	Indonesia	Crab	Exp Rate	0.28	Not fully exp	Jaya et al 2045
163	42	57.2	Indonesia	Blue swimming crab	Exp Rate	0.98	Fully exploite	Jaya et al 2046
164	57	57.2	Indonesia	Squids	Exp Rate	1.11	Overfished	Jaya et al 2047
165	35	57.5.1	Indonesia	Small pelagics	Exp Rate	0.51	Fully exploite	Jaya et al 2048
166	36	57.5.1	Indonesia	Large pelagics	Exp Rate	0.99	Fully exploite	Jaya et al 2049
167	33	57.5.1	Indonesia	Demersal fish	Exp Rate	0.67	Fully exploite	Jaya et al 2050
168	33	57.5.1	Indonesia	Coral fishes	Exp Rate	1.07	Overfished	Jaya et al 2051
169	45	57.5.1	Indonesia	Penaeid shrimps	Exp Rate	0.86	Fully exploite	Jaya et al 2052
170	45	57.5.1	Indonesia	Lobster	Exp Rate	0.97	Fully exploite	Jaya et al 2053
171	42	57.5.1	Indonesia	Crab	Exp Rate	0.85	Fully exploite	Jaya et al 2054
172	42	57.5.1	Indonesia	Blue swimming crab	Exp Rate	0.77	Fully exploite	Jaya et al 2055
173	57	57.5.1	Indonesia	Squids	Exp Rate	1.28	Overfished	Jaya et al 2056
174	43	57.5	Australia	Western Rock Lobster	Harvest rate %	30	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	0.64	Sustainable	Sporcic et al., 2019
178	33	57.5	Australia	Deepwater flathead	SSB2020/SSB0	0.45	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 Tr
183	36	57.5	Australia	Bigeye tuna	SB/SBmsy	1.29	Sustainable	IOTC, Pattersen et al., 2021
184	36	57.5	Australia	Yellowfin tuna	SSB	0.83	Overfishing	IOTC, Pattersen et al., 2021
185	35	57.6	Australia	Australian Sardine	SSBcurr/SSBtar	2.03	Sustainable	Ward et al. (2017)
186	37	57.6	Australia	Garfish	CPUE Biomass	NA	Recovering	McGarvey et al. (2007); Steer et al., 2
187	33	57.6	Australia	King George Whiting	Age compositio	NA	Sustainable	Steer et al. (2020)
188	56	57.6	Australia	Pipi	CPUE Biomass	NA	Sustainable	Smith et al., 2021/ Ferguson & Hoope
189	33	57.6	Australia	Snapper	Egg density	NA	Overfished	McGarvey et al. (2018); Steer et al. (2
190	33	57.6	Australia	Snapper	Egg density	NA	Overfished	McGarvey et al. (2018); Steer et al. (2
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
193	35	57.6	Australia	Australian Sardine	Egg density	NA	Sustainable	Ward et al. (2015)
194	33	57.6	Australia	Banded Morwong	Age compositio	>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	1.59	Sustainable	IOTC, Pattersen et al., 2021
203	36	57.6	Australia	Southern bluefin tuna	F/Fmsy	0.52	Sustainable	Pattersen et al., 2021

The work of Sathianandan et al (2021) assesses stocks based on maritime states which are the administrative management units in India. In the case of the demersal stocks these may be discrete stocks due to limited movement;

In the case of pelagic stocks, the stock classification has been integrated regionally (based on http://eprints.cmfri.org.in/13929/) and the more adverse stock status was taken as a measure of precaution.

Annex 3-3: Tier 2 Fish Stocks Status - Area 57 2022

No	stock	Ref Point	year	Mean value	Status	FAO Stock Type	Quality
1	Acanthocybium_solandri	B/Bmsy	2019	1.0823	Fully fished	70+ Non Monitored	Medium
2	Alopias_spp	B/Bmsy	2019	1.0062	Fully fished	70+ Non Monitored	Medium
3	Arripis_trutta	B/Bmsy	2019	0.6113	Overfished	70+ Non Monitored	Medium
4	Auxis_rochei	B/Bmsy	2019	0.8607	Fully fished	70+ Non Monitored	Medium
5	Auxis_thazard_A. rochei	B/Bmsy	2019	1.0685	Fully fished	70+ Non Monitored	Medium
6	Chirocentrus_spp	B/Bmsy	2019	1.1136	Fully fished	70+ Non Monitored	Medium
7	Crustacea	B/Bmsy	2019	0.9754	Fully fished	70+ Non Monitored	Medium
8	Epinephelinae	B/Bmsy	2019	0.9085	Fully fished	70+ Non Monitored	Medium
9	Gymnocephalus_cernua	B/Bmsy	2019	0.5797	Overfished	70+ Non Monitored	Medium
10	Istiompax_indica	B/Bmsy	2019	0.9223	Fully fished	70+ Non Monitored	Medium
11	Istiophorus_platypterus	B/Bmsy	2019	0.9934	Fully fished	70+ Non Monitored	Medium
12	Lates_calcarifer	B/Bmsy	2019	0.9961	Fully fished	70+ Non Monitored	Medium
13	Leiognathus_spp	B/Bmsy	2019	0.9012	Fully fished	70+ Non Monitored	Medium
14	Lutjanidae	B/Bmsy	2019	1.0201	Fully fished	70+ Non Monitored	Medium
15	Mollusca	B/Bmsy	2019	0.8995	Fully fished	70+ Non Monitored	Medium
16	Muraenesox_spp	B/Bmsy	2019	0.8632	Fully fished	70+ Non Monitored	Medium
17	Pagrus_auratus	B/Bmsy	2019	0.7671	Overfished	70+ Non Monitored	Medium
18	Pectinidae	B/Bmsy	2019	0.8534	Fully fished	70+ Non Monitored	Medium
19	Perciformes	B/Bmsy	2019	0.8542	Fully fished	70+ Non Monitored	Medium
20	Platycephalus	B/Bmsy	2019	0.9667	Fully fished	70+ Non Monitored	Medium
21	Pleuronectiformes	B/Bmsy	2019	1.0287	Fully fished	70+ Non Monitored	Medium
22	Prionace_glauca	B/Bmsy	2019	1.0940	Fully fished	70+ Non Monitored	Medium
23	Rastrelliger_brachysoma	B/Bmsy	2019	1.0105	Fully fished	70+ Non Monitored	Medium
24	Sarda_orientalis	B/Bmsy	2019	1.1857	Fully fished	70+ Non Monitored	Medium
25	Sardinella_gibbosa	B/Bmsy	2019	0.9939	Fully fished	70+ Non Monitored	Medium
26	Scomberoides_spp	B/Bmsy	2019	0.9733	Fully fished	70+ Non Monitored	Medium
27	Selaroides_leptolepis	B/Bmsy	2019	1.0293	Fully fished	70+ Non Monitored	Medium
28	Sillago_sihama	B/Bmsy	2019	0.9900	Fully fished	70+ Non Monitored	Medium
29	Tetrapturus_audax	B/Bmsy	2019	0.8947	Fully fished	70+ Non Monitored	Medium
30	Thunnus_obesus	B/Bmsy	2019	0.9172	Fully fished	70+ Non Monitored	Medium
31	Thunnus_tonggol	B/Bmsy	2019	0.9262	Fully fished	70+ Non Monitored	Medium
32	Xiphia_ gladius	B/Bmsy	2019	0.9091	Fully fished	70+ Non Monitored	Medium

Stock Types from FAO catch database

Monitored (for FAO SOFIA) & 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)

Annex 3-3: Tier 2 Fish Stocks Status - Area 57 2022 (contd)

No	stock	Ref Point	year	Mean value	Status	FAO Stock Type	Quality
33	Anodontostoma chacunda	B/Bmsy	2019	0.8502	Fully fished	Current FAO Monitored	Medium
34	Ariidae	B/Bmsy	2019	1.0833	Fully fished	Current FAO Monitored	Medium
35	Caranx spp	B/Bmsy	2019	0.9013	Fully fished	Current FAO Monitored	Medium
36	Carcharhinus falciformis	B/Bmsy	2019	0.8484	Fully fished	Current FAO Monitored	Medium
37	Cephalopoda	B/Bmsy	2019	0.8598	Fully fished	Current FAO Monitored	Low
38	Clupeoidei	B/Bmsy	2019	1.1223	Fully fished	Current FAO Monitored	Low
39	Decapterus russelli	B/Bmsy	2019	0.9970	Fully fished	Current FAO Monitored	Medium
40	Decapterus spp	B/Bmsy	2019	0.9521	Fully fished	Current FAO Monitored	Medium
41	Leiognathidae	B/Bmsy	2019	0.9956	Fully fished	Current FAO Monitored	Medium
42	Loliginidae Ommastrephidae	B/Bmsy	2019	0.8706	Fully fished	Current FAO Monitored	Low
43	Loligo spp	B/Bmsy	2019	0.9363	Fully fished	Current FAO Monitored	Medium
44	Megalaspis cordyla	B/Bmsy	2019	1.0026	Fully fished	Current FAO Monitored	Medium
45	Mugilidae	B/Bmsy	2019	1.0499	Fully fished	Current FAO Monitored	Medium
46	Natantia	B/Bmsy	2019	0.8787	Fully fished	Current FAO Monitored	Medium
47	Nemipterus spp	B/Bmsy	2019	0.9577	Fully fished	Current FAO Monitored	Medium
48	Octopodidae	B/Bmsy	2019	0.8542	Fully fished	Current FAO Monitored	Medium
49	Pellona ditchela	B/Bmsy	2019	0.6071	Overfished	Current FAO Monitored	Low
50	Penaeus merguiensis	B/Bmsy	2019	1.0509	Fully fished	Current FAO Monitored	Medium
51	Penaeus spp	B/Bmsy	2019	0.8974	Fully fished	Current FAO Monitored	Medium
52	Percoidei	B/Bmsy	2019	0.6904	Overfished	Current FAO Monitored	Medium
53	Rajiformes	B/Bmsy	2019	0.8760	Fully fished	Current FAO Monitored	Medium
54	Rastrelliger spp	B/Bmsy	2019	1.1775	Fully fished	Current FAO Monitored	Medium
55	Sardinella spp	B/Bmsy	2019	0.8564	Fully fished	Current FAO Monitored	Low
56	Scomberomorus spp	B/Bmsy	2019	0.8450	Fully fished	Current FAO Monitored	Low
57	Scombroidei	B/Bmsy	2019	0.8654	Fully fished	Current FAO Monitored	Low
58	Sepiidae Sepiolidae	B/Bmsy	2019	0.9790	Fully fished	Current FAO Monitored	Medium
59	Sergestidae	B/Bmsy	2019	0.8617	Fully fished	Current FAO Monitored	Low
60	Stolephorus spp	B/Bmsy	2019	0.9413	Fully fished	Current FAO Monitored	Medium
61	Stromateidae	B/Bmsy	2019	0.9433	Fully fished	Current FAO Monitored	Medium
62	Tenualosa toli	B/Bmsy	2019	0.8721	Fully fished	Current FAO Monitored	Low
63	Thyrsites atun	B/Bmsy	2019	0.6905	Overfished	Current FAO Monitored	Medium
64	Trichiuridae	B/Bmsy	2019	0.8419	Fully fished	Current FAO Monitored	Medium
65	Trichiurus lepturus	B/Bmsy	2019	0.9843	Fully fished	Current FAO Monitored	Medium
66	Anadara granosa	B/Bmsy	2019	0.8605	Fully fished	25-49 Non Monitored	Low
67	Bregmaceros mcclellandi	B/Bmsy	2019	0.8623	Fully fished	25-49 Non Monitored	Low
68	Carcharhinus longimanus	B/Bmsy	2019	0.8539	Fully fished	25-49 Non Monitored	Medium
69	Chelidonichthys kumu	B/Bmsy	2019	0.8273	Fully fished	25-49 Non Monitored	Low
70	Crassostrea spp	B/Bmsy	2019	0.8521	Fully fished	25-49 Non Monitored	Low
71	Ex Mollusca	B/Bmsy	2019	0.8578	Fully fished	25-49 Non Monitored	Low
72	Genypterus blacodes	B/Bmsy	2019	0.8678	Fully fished	25-49 Non Monitored	Medium
73	Hoplostethus atlanticus	B/Bmsy	2019	0.8520	Fully fished	25-49 Non Monitored	Medium
74	Istiophoridae	B/Bmsy	2019	0.8663	Fully fished	25-49 Non Monitored	Low
75	Isurus oxyrinchus	B/Bmsy	2019	0.8593	Fully fished	25-49 Non Monitored	Medium
76	Macruronus novaezelandiae	B/Bmsy	2019	0.8543	Fully fished	25-49 Non Monitored	Medium
77	Megalops cyprinoides	B/Bmsy	2019	0.8536	Fully fished	25-49 Non Monitored	Medium
78	Meretrix spp	B/Bmsy	2019	0.8549	Fully fished	25-49 Non Monitored	Low
79	Monacanthidae	B/Bmsy	2019	0.7031	Overfished	25-49 Non Monitored	Low
80	Mustelus antarcticus	B/Bmsy	2019	0.8556	Fully fished	25-49 Non Monitored	Medium
81	Paphies australis	B/Bmsy	2019	0.8642	Fully fished	25-49 Non Monitored	Medium
82	Pterygotrigla polyommata	B/Bmsy	2019	0.8983	Fully fished	25-49 Non Monitored	Medium
83	Rachycentron canadum	B/Bmsy	2019	0.8585	Fully fished	25-49 Non Monitored	Low
84	Rexea solandri	B/Bmsy	2019	0.8537	Fully fished	25-49 Non Monitored	Medium
85	Rhodophyta	B/Bmsy	2019	0.8614	Fully fished	25-49 Non Monitored	Low
86	Scolopsis spp	B/Bmsy	2019	0.8817	Fully fished	25-49 Non Monitored	Low
87	Scylla serrata	B/Bmsy	2019	1.0474	Fully fished	25-49 Non Monitored	Low
88	Scyllaridae	B/Bmsy	2019	0.9674	Fully fished	25-49 Non Monitored	Low
89	Seriolina nigrofasciata	B/Bmsy	2019	0.8637	Fully fished	25-49 Non Monitored	Medium
90	Serranidae	B/Bmsy	2019	0.8591	Fully fished	25-49 Non Monitored	Medium
91	Siganus spp	B/Bmsy	2019	0.8605	Fully fished	25-49 Non Monitored	Medium
92	Testudinata	B/Bmsy	2019	0.8476	Fully fished	25-49 Non Monitored	Medium
93	Thenus orientalis	B/Bmsy	2019	0.8557	Fully fished	25-49 Non Monitored	Medium
94	Zenopsis nebulosus	B/Bmsy	2019	1.6418	Underfished	25-49 Non Monitored	Low
95	Zeus faber	B/Bmsy	2019	0.8794	Fully fished	25-49 Non Monitored	Medium

Annex 3-3: Tier 2 Fish Stocks Status - Area 57 2022 (contd)

No	stock	Ref Point	year	Mean value	Status	FAO Stock Type	Quality
96	Anguilla australis	B/Bmsy	2019	0.8630	Fully fished	50-69 Non Monitored	Medium
97	Balistidae	B/Bmsy	2019	0.8543	Fully fished	50-69 Non Monitored	Medium
98	Bivalvia	B/Bmsy	2019	0.8602	Fully fished	50-69 Non Monitored	Low
99	Brachyura	B/Bmsy	2019	0.8517	Fully fished	50-69 Non Monitored	Low
100	Caesionidae	B/Bmsy	2019	0.9745	Fully fished	50-69 Non Monitored	Medium
101	Drepane punctata	B/Bmsy	2019	0.7414	Overfished	50-69 Non Monitored	Low
102	Exocoetidae	B/Bmsy	2019	0.8671	Fully fished	50-69 Non Monitored	Medium
103	Gymnosarda unicolor	B/Bmsy	2019	0.9257	Fully fished	50-69 Non Monitored	Medium
104	Haemulidae (=Pomadasyidae)	B/Bmsy	2019	0.9967	Fully fished	50-69 Non Monitored	Medium
105	Invertebrata	B/Bmsy	2019	0.8607	Fully fished	50-69 Non Monitored	Low
106	Penaeus semisulcatus	B/Bmsy	2019	0.8583	Fully fished	50-69 Non Monitored	Low
107	Phaeophyceae	B/Bmsy	2019	0.8586	Fully fished	50-69 Non Monitored	Low
108	Plotosus spp	B/Bmsy	2019	0.8646	Fully fished	50-69 Non Monitored	Low
109	Pomatomus saltatrix	B/Bmsy	2019	0.6734	Overfished	50-69 Non Monitored	Low
110	Psettodes erumei	B/Bmsy	2019	0.9737	Fully fished	50-69 Non Monitored	Medium
111	Rhopilema spp	B/Bmsy	2019	0.8557	Fully fished	50-69 Non Monitored	Low
112	Sardinella lemuru	B/Bmsy	2019	0.9021	Fully fished	50-69 Non Monitored	Medium
113	Scomberomorus lineolatus	B/Bmsy	2019	0.8371	Fully fished	50-69 Non Monitored	Low
114	Scombridae	B/Bmsy	2019	0.8664	Fully fished	50-69 Non Monitored	Low
115	Seriola spp	B/Bmsy	2019	0.7740	Overfished	50-69 Non Monitored	Medium
116	Sparidae	B/Bmsy	2019	0.8302	Fully fished	50-69 Non Monitored	Medium
117	Sphyraena spp	B/Bmsy	2019	0.8525	Fully fished	50-69 Non Monitored	Low
118	Sphyrnidae	B/Bmsy	2019	0.9146	Fully fished	50-69 Non Monitored	Medium
119	Synodontidae	B/Bmsy	2019	0.8636	Fully fished	50-69 Non Monitored	Low
120	Thunnus maccoyii	B/Bmsy	2019	0.8432	Fully fished	50-69 Non Monitored	Low
121	Upeneus spp	B/Bmsy	2019	0.9420	Fully fished	50-69 Non Monitored	Medium

Tier 3 Fish Stocks Status (CMSY/OCOM) - Area 57 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

4 ASSESSING STOCKS FOR MULTI-SPECIES FISHERIES: A MULTI-SPECIES APPROACH RELEVANT TO THE ASIAN REGION

Elizabeth Fulton

4.1 BACKGROUND

The vision of most national and international fisheries legislation is to guarantee 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, the majority of the world's fisheries are mixed species fisheries, where there are technological interactions, with many species are caught in a fishery, or multispecies, multifleet fisheries, where there are both technological and food web interactions between species. These circumstances characterise many of the fisheries in the Asian region.

In these types of fishery, the use of MSY and single species management can be challenging to deliver given the tens to hundreds, or more, of 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 the example below, by comparing the "sum of MSY" or "sum of individual maximum yield" and the "multispecies MSY" (MMSY) point in Figure 1. The MMSY is typically much lower than would be anticipated from following single species management advice alone.

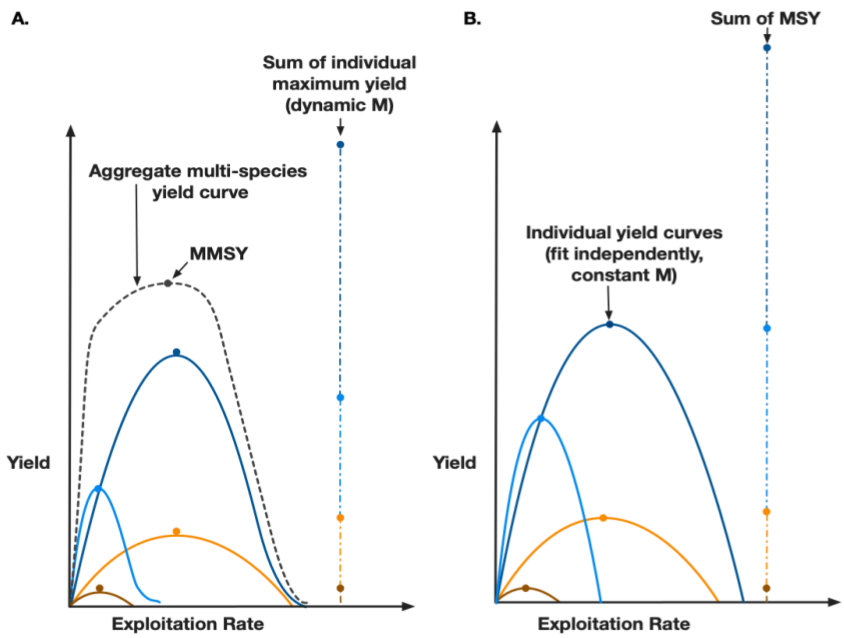


Figure 1: Example plot showing why summing individual maximum yields (whether with or without constant natural mortality) does not match the MMSY point. The coloured lines are the individual species curves (A) with interacting species (so there are dynamic natural mortalities) and (B) independent species curves.

Source: Reproduced from Fulton et al (2022) with permission.

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 does require a 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 types of information that are needed to inform an ecosystem approach for multispecies, multifleet fisheries include:

- System description: trophic and habitat connections
- Environmental drivers: such as productivity drivers, climate, seasonal cycles, river contributions etc.
- Human pressures: both fishing and non-fishing
- Catch composition: of the different fisheries (who catches what?)
- What affects management: this is best elucidated by looking for the most important system connections, such as fisheries interactions, or connections between predators-prey-habitat etc.
- Time series: what has changed through time in the fishery dynamics, management and catch composition?
- 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.

4.2 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 data sets. For example, catch per unit area ($t.km^{-2}$) 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.

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 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.

4.3 AGGREGATE PRODUCTION MODELS

Over the past few decades, but especially over the past 10 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 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 the approach to time series from the Gulf of Thailand, it was found that 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 persisted (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 2). This is because they represented different system states as the system changed over time.

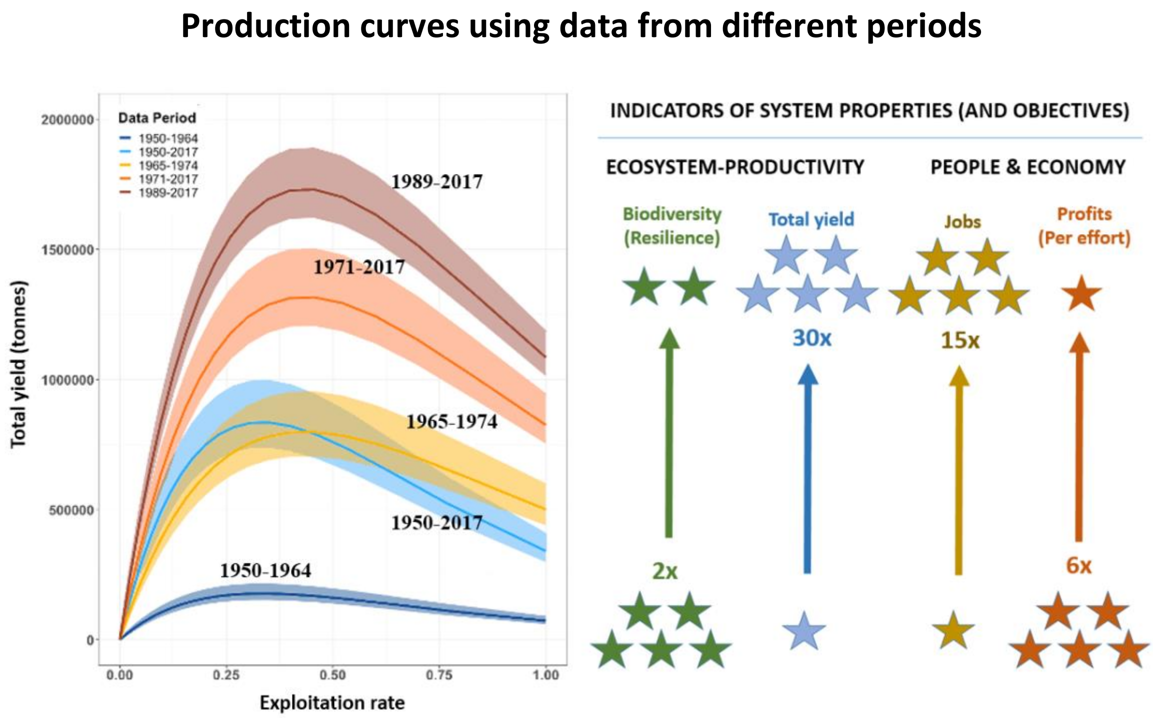


Figure 2: Aggregate production curves fit to various catch time series for the Gulf of Thailand. The different curves come from fitting to different time periods (and ecosystem states). The associated characteristics of those systems are summarised using indicators for biodiversity (and ecosystem resilience), total yield, jobs (employment) and profits per unit effort. The number of stars on the right of the plot show the relative size of the various indicators for system properties that people often care about or hold as objectives.

Source: Modified from Fulton et al (2022).

An important conclusion of this analysis is that fishery management and policies using this approach require a decision by managers and fishing communities select 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. In contrast, the system state associated with the upper most (brown) production curve (1989-2017) has the highest total yield and supports many fishers (jobs) but is much less biodiverse and resilient and has low profits per unit effort. The states supporting the other curves sit in between these two extremes.

4.4 MULTISPECIES AND ECOSYSTEM MODELLING

Other available multispecies assessment models resolve species or functional groups in more detail – whether using traits (such as maximum size, habitat use etc., as in the Mizer software; Scott et al., 2014), trophic feeding relationships (e.g. Ecopath with Ecosim; Christensen et al., 2000), multispecies production models (e.g. Gaichas et al., 2017) or "minimum realistic" or "models of intermediate complexity" (as described in Plagányi et al., 2014).

The value of these models is that the system can be broken up a little 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 piscovorous:planktivorous species, both of which are known to change in response to perturbation and indicate the dominate pathways operating in an ecosystem.

4.5 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 generalised modification of this approach would see all species that interact with a species classified into four types (Figure 3). Three of these four types are based on their life history characteristics and level of interaction with fisheries; the fourth marks out as 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).

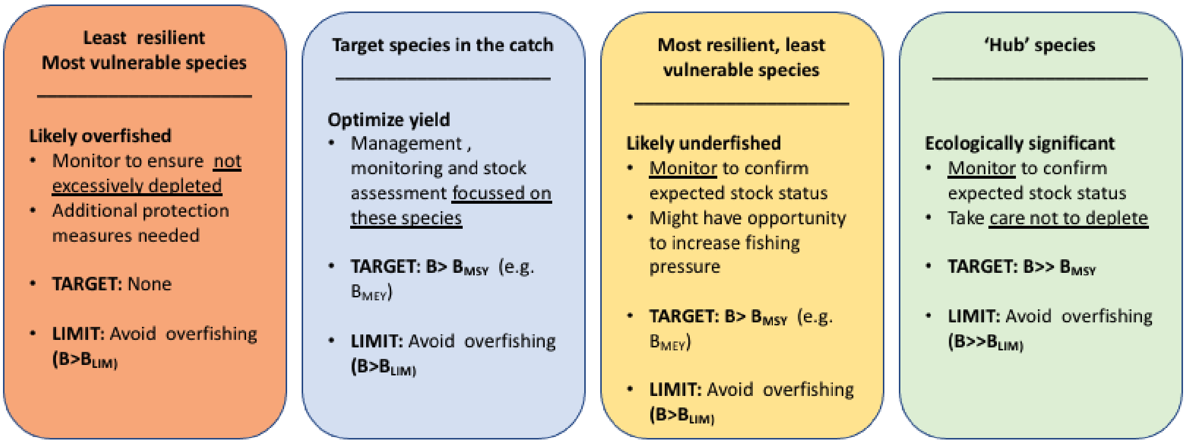


Figure 3: Categories of species for consideration in the indicator species-based harvest strategy (Newman et al (2018), Sainsbury et al (in prep))

From each of these four types a small number of representative indicator species are chosen (typically 3-4 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 (i.e. $B > B_{LIM}$ etc) 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 6-10) can be used to indirectly manage tens, to hundreds, of species. Variations on this approach can also focus on outcomes for different sub-sectors of fisheries, such as market fish, species that are used for fishmeal or surimi and the crustacean sector (Leadbitter et al., in press).

4.6 CONCLUSION

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 etc.

As a region with particularly species rich fisheries that use a wide diversity of gears, SE Asia is a region where these management approaches may be particularly useful.

4.7 REFERENCES

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

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

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. (in press). *Managing multispecies and multigear fisheries – a toolbox for scientists, managers and stakeholders.* FAO Fishery and Aquaculture Circular, FAO, Rome.

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 IndicatorsEcological 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

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

Newman S.J., Brown, J.I., Fairclough, D.V., Wise, B.S., Bellchambers, L.M., Molony, B.W., Lenanton, R.C.J., Jackson, G., Smith, K.A., Gaughan, D.J., Fletcher, W.J., McAuley, R.B., Wakefield, C.B. (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

5 TRAWL SURVEYS IN SOUTHEAST ASIA

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

5.1 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 data base (Gayanilo et al., 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 reports and data provided to the FAO in Malaysia, Thailand, Cambodia 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
- Vessel length overall (loa) and horse power (HP)

5.2 STANDARDIZED CPUE

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 only taking year and area into account (Figure 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% of virgin in all areas

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

1. (To the extent possible) Selecting trawl surveys conducted in waters <50m;
2. (To the extent possible) Correcting the cod-end mesh size to a standard 40mm, using surveys where both 25mm and 40mm codends were used simultaneously: and
3. Correcting for vessel loa and HP by reducing the cpue in proportion to the median size of vessels.

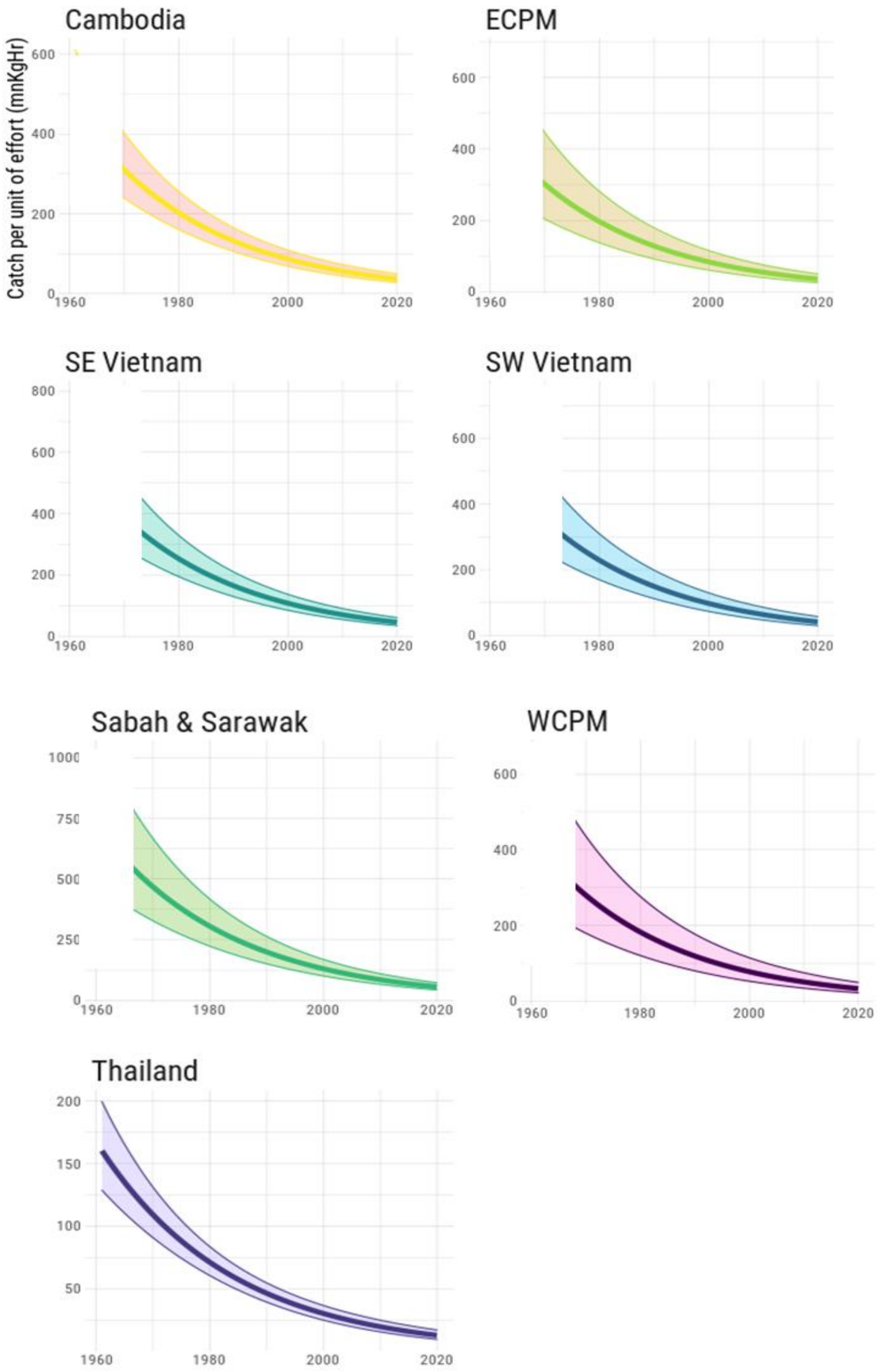


Figure 1: Standardized cpue for seven areas in Southeast Asia based on research surveys conducted from 1960 to 2020. *ECPM = East coast peninsular Malaysia WCPM = West coast peninsular Malaysia*

There were not enough comparisons to assess the effect of season and this was not included in this analysis. The results (Figure 2) showed:

- Relative biomass (kg/hour) declined in all areas with the onset of industrial fishing (increased catches);
- Timing differed among areas reflecting 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 1980s in Viet Nam; and
- Some signs of recovery, or at least stability, in ECPM, Thailand and Cambodia.

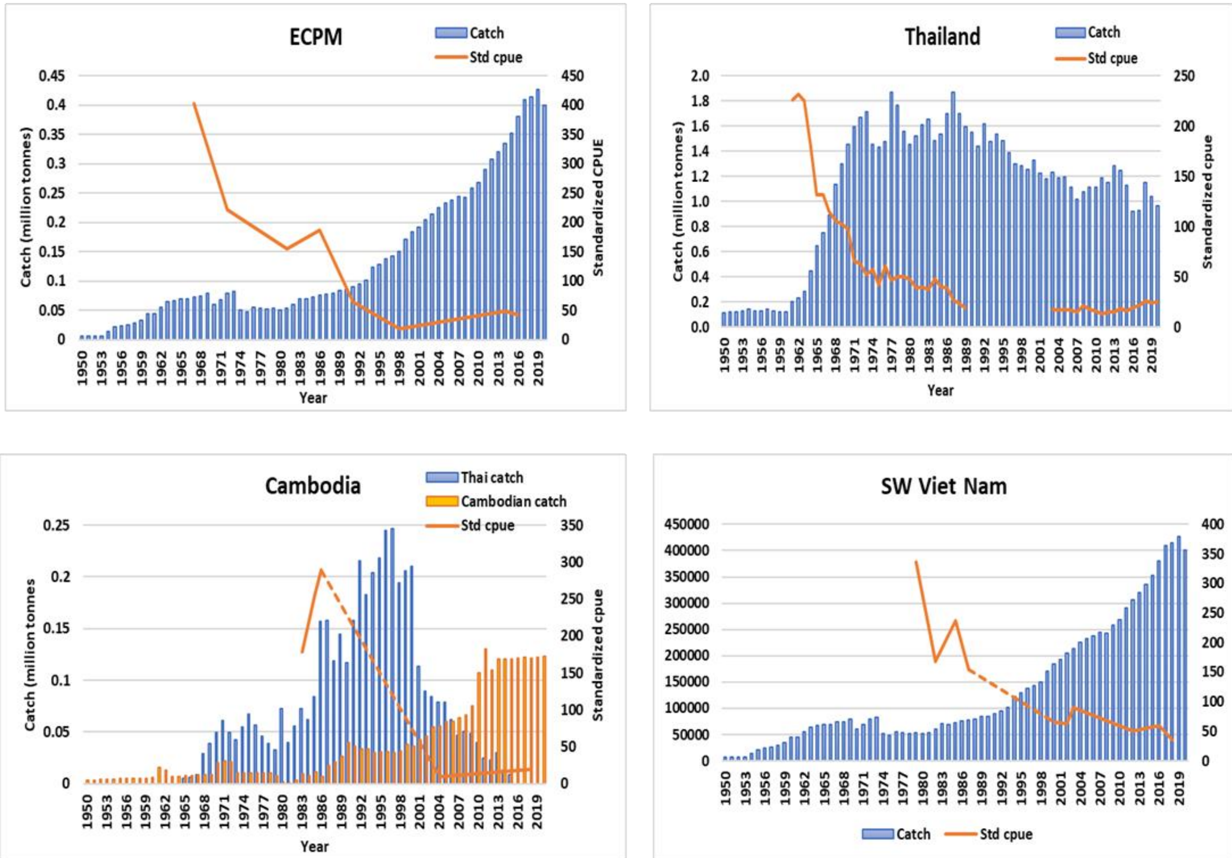


Figure 2: Catch and (manual) standardized CPUE for ECPM, Thailand, Cambodia and SW Vietnam.

5.3 THE FIRST 15 YEARS OF INDUSTRIAL FISHING, THE EXAMPLE OF GULF OF THAILAND

Figure 2 shows that the first 15 years of industrial fishing had a large impact on the fisheries resources in Thailand. The number of trawlers and purse seiners increased massively from 99 to 5,410 from 1961 – 1973 (Figure 3); and the total catch also massively increased from 200,000 tonnes to 1,345,000 tonnes (Figure 4).

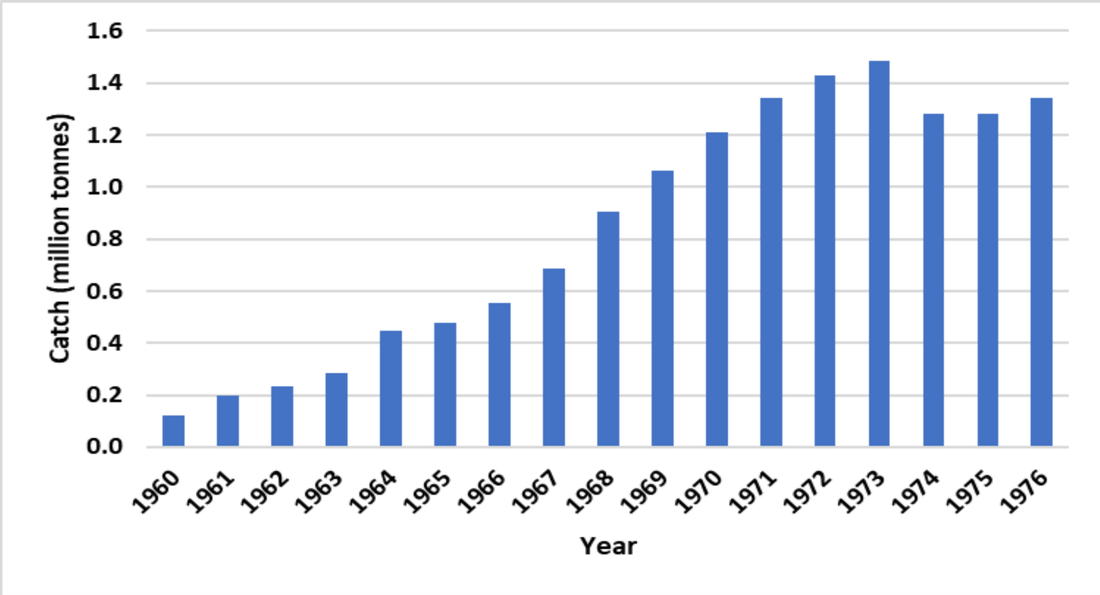


Figure 3: Number of trawlers and purse seiners and trawl and purse-seine catch from 1961-1976

Source: Menasveta (1980), FAO FishstaJ 2022

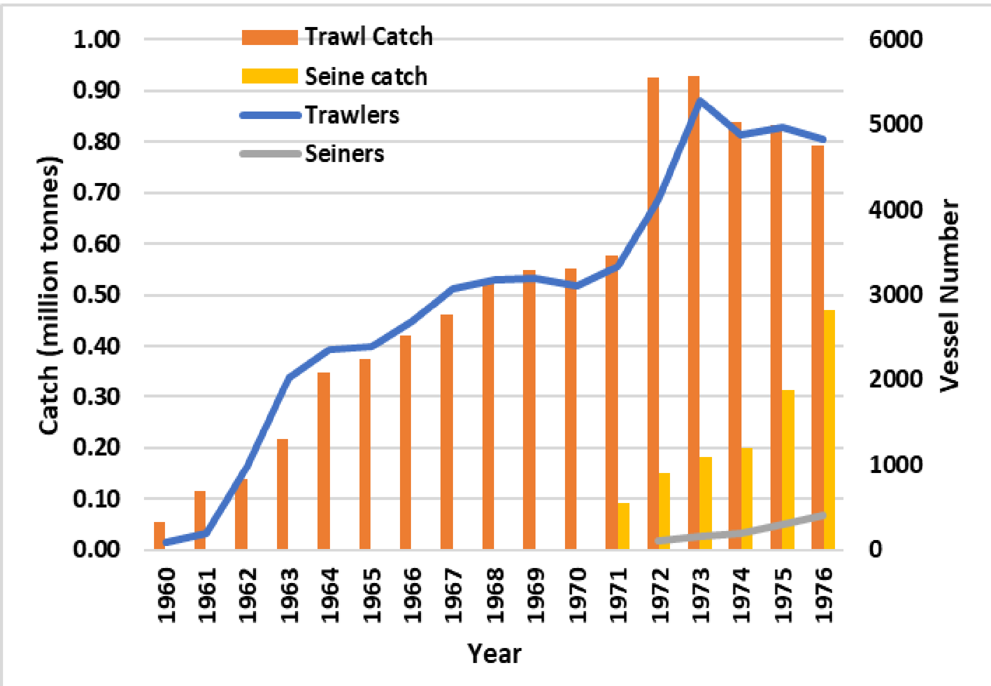


Figure 4: Total catch 1961-1971

Source: Menasvata (1980), FAO FishstaJ 2022

During this period 1961 to 1976, the fishery resources also changed significantly, with relative biomass decreasing from 297.8 to 75.1 kg/hour (a decline of 75%) (Figure 5). The proportion of vulnerable species also declined from 57% to 13% of the total biomass (Figure 6), and the proportion of less vulnerable species increased from 12% to 50% of the total biomass (Figure 6).

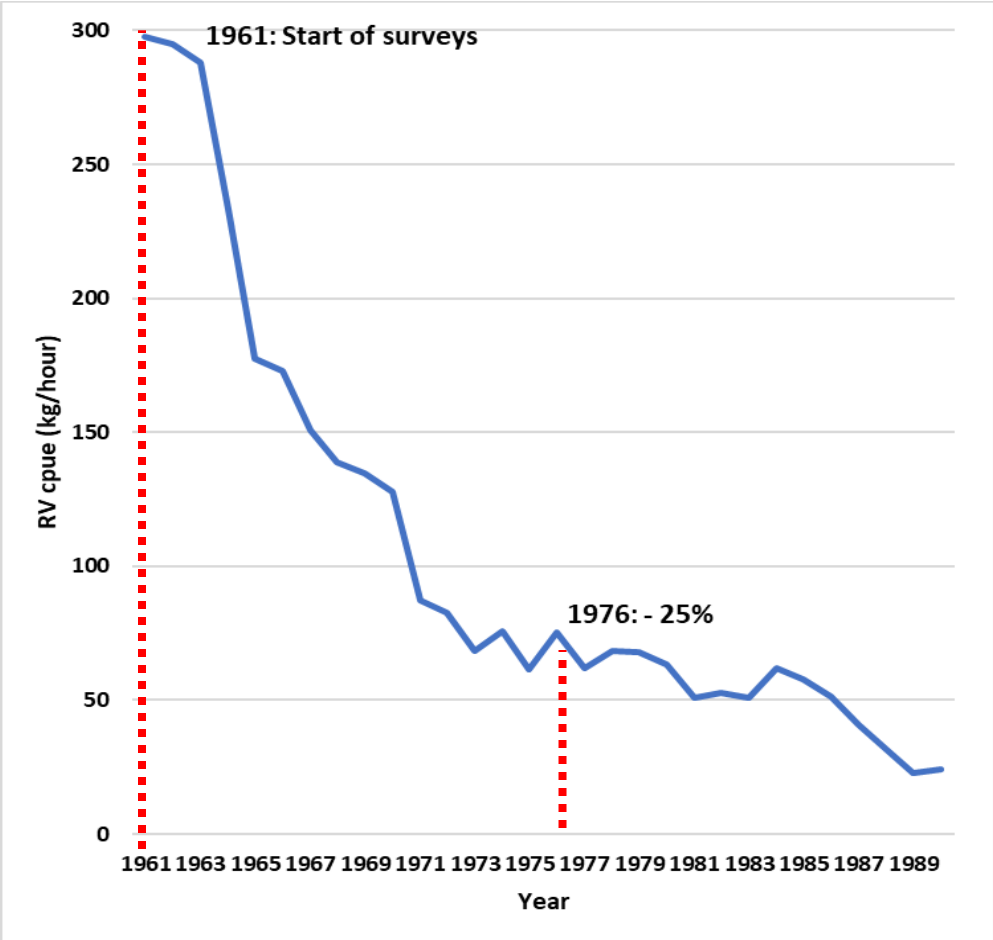


Figure 5: Decline in the relative biomass (research vessel cpue (kg/hour) from 1961 – 1990 in Thai waters of the Gulf of Thailand.

Source: Boonyubol and Pramokchutima 1982 (1961-1965), Thai DOF (1965-1990)

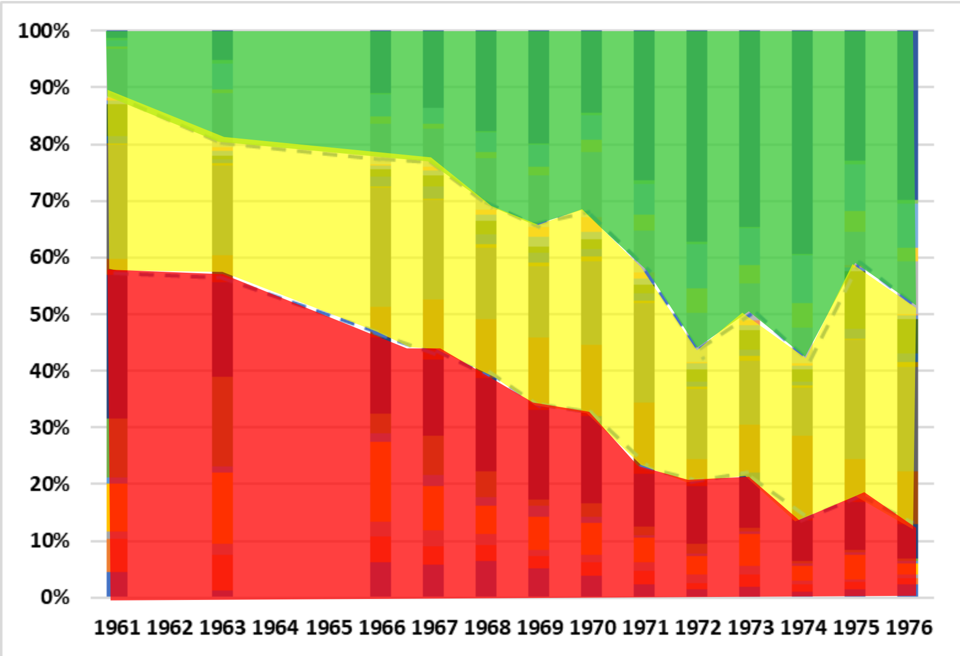


Figure 6: Changes in the species composition of the research vessel catch 1961- 1976. High vulnerability species (shaded in red) includes: snapper, sharks, rays, sweetlips, croakers and scads; Low vulnerability species (shaded in green) includes: lizardfish, swimming crabs, non-penaeid shrimp, cuttlefish and squid.

Source: Pauly 1987 and Thai Department of Fisheries

5.4 CONCLUSION

Past research surveys are an under-utilized source of information for stock assessments (both single and multi-species). 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 ICLARM/Worldfish – Fisheries Resources Information System and Tools (FIRST) (Trawlbase). The original database is no longer available in Worldfish and the data now resides 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 characterising the history of the fishery and providing standardized estimates of CPUE for the various regions. This could be accomplished through a new project or as part of the FAO/GEF projects working with the Gulf of Thailand countries.

5.5 REFERENCES

Boonyubol, M and Pramokchutima, S. 1982. Trawl fisheries in the Gulf of Thailand. ICLARM Translations 4, 12 pp. Center for Living Aquatic Resources Management, Manila, Philippines

FAO FishstatJ database: http://www.fao.org/fishery/statistics/software/fishstatj/en.

Gayanilo, FC Jr, Stromme, T and Pauly, D. 1997. Towards a generic trawl survey database management system. Pp 116-132 In: Silvestre GT and Pauly, D (Eds) Status and management of tropical coastal fisheries in Asia. ICLAR Conf. Proc. 53 208pp

Menasveta, D. 1980. Resources and fisheries of the Gulf of Thailand, Training Department Southeast Asian Fisheries Development Center.

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.

6 INTERPRETING SINGLE-SPECIES STOCK ASSESSMENT RESULTS IN A MULTI-SPECIES FISHERY

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

6.1 INTRODUCTION

This paper examines three important points that need to be considered when interpreting single-species stock assessments in a multi-species fishery and presents a way forward to taking these into account. It illustrates these considerations with case-study based on data and preliminary stock assessments of fish stocks in the Thailand waters of the Gulf of Thailand (Thai waters - Gulf of Thailand).

NOTE: The example stock assessment results used in this paper are used 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.

6.2 CASE-STUDY STOCKS

Nineteen stocks were selected as case-study examples. These were selected based on:

- Representation of marketing-determining species for surimi and market fish
- Covering a range of risk/vulnerabilities based on productivity/susceptibility analyses (PSA) as given in FAO (2014)
- Having sufficient time-series catch and abundance indices data to be able to conduct surplus production modelling for individual stocks (either single species or group of similar species) using:
    - Catch data 1971 – 2020. Source: Department of Fisheries, Thailand (Thai DOF);
    - Research vessel data 1966 – 2020. Source: Thai DOF; and
    - Early research vessel data 1961-1965. Source: Boonyubol and Pramokchutima (1982) and Pauly, D. (1987).

NOTE: No time-series abundance data available for sardines, anchovies or neritic tuna, but ideally, these should be included.

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 Productivity/Susceptibility analysis (PSA) scores (Table 1).

Stock assessments were carried out by fitting surplus production models based on the sraplus method (Ovando et al. 2021) and JABBA (Winker et al. 2018) for these individual stocks as well aggregated stocks. Details are at Appendix A. There are three important considerations which need to be taken into account when using this approach:

1. The sum of the individual stocks maximum sustainable yield (MSYs) is greater than the aggregate multi-species MSY (MMSY). s
2. In a multi-species 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 multi-species fishery.

Table 1: Selected case-study stocks and their productivity/susceptibility analyses scores (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 crabs	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		

6.3 THE SUM OF THE INDIVIDUAL STOCKS MSYS IS GREATER THAN THE AGGREGATE MULTI-SPECIES MSY (MMSY)

As shown in Figure 1, each individual stock has its own relationship between fishing effort and catch. Thus, the MSY for individual stocks occurs at different fishing effort levels and is not simultaneously available at any one effort level. Also, because of food-web interactions the MMSY is not the sum of the individual MSYs.

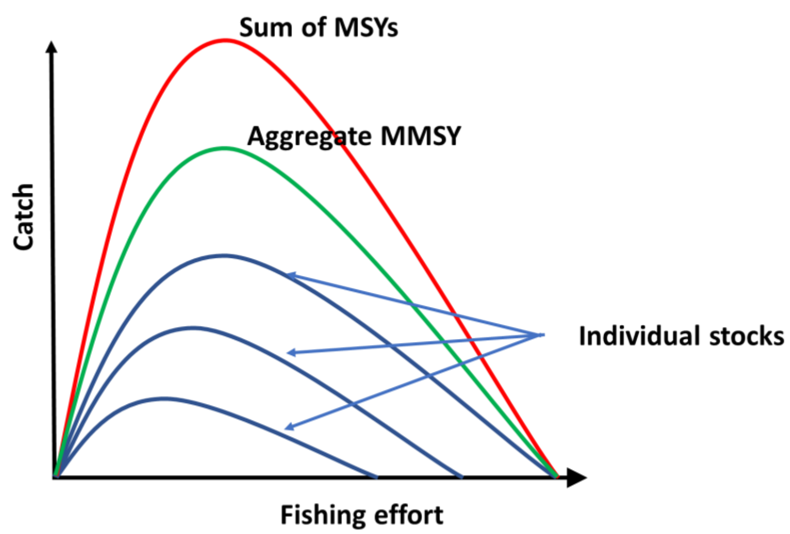


Figure 1: Relationship between catch and fishing effort of three individual stocks. The sum of the MSY curves is shown in red, while the aggregate MMSY fit of the stocks is shown in green.

Table 2 shows an example for the case-study stocks from the Thai GoT. The sum of the individual MSYs was 813,503 tonnes, while the aggregate Multi-species MSY (MMSY) was 415,134 tonnes. Simply summing the individual MSYs results in a 100 percent (two-fold) overestimation of the MSY. This demonstrates how managing a fishery based on the simplistic assumption that each species can be fished at its MSY and using this aggregate figures to determine the total catch, will result in substantial overfishing.

Table 2: Comparison of the sum of the MSYs for 19 individual stocks and the aggregate Multi-species MSY (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 crabs	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 100% over-estimation of the aggregate MSY					

6.4 IN A MULTI-SPECIES FISHERY FISHED AT MMSY, SOME STOCKS WILL BE BELOW THEIR MSY, SOME AT OR AROUND MSY AND SOME ABOVE 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 multi-species 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 3 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 point (OA)where no rent or profit also 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, and;
- Species 1 (the least resilient species, most vulnerable species) will be overfished (well beyond its MSY.
- The revenues in both beam and pair trawl fisheries will be considerably higher than their costs, and thus the fishery would operate profitably.

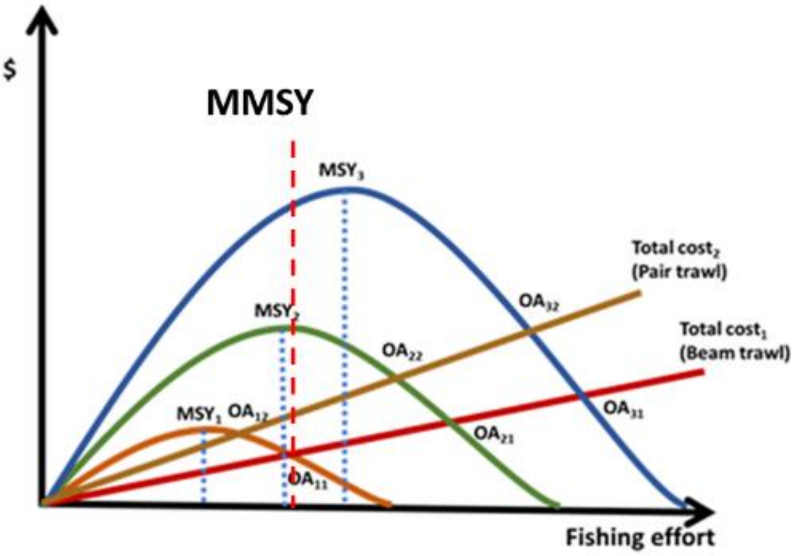


Figure 3: Revenue and cost curves for three individual stocks. The red dotted line is the Multi-species MSY (MMSY). The blue dotted lines indicate the individual stock's MSYs. OA = open access point where rent and profits are zero.

Figure 4 present Kobe plots for two risk groups in the case-study stocks (high and low risk group). This shows the different historical trends in the status of these groups over time. With the same fishing effort, the high-risk group were fished well above their biomass at MSY (BMSY) and fishing mortality at MSY (FMSY) since early 1980s. Conversely, the low-risk group were fished closer to their BMSY and FMSY. The high-risk group currently (2020) has a biomass (B) to BMSY (B/BMSY) ratio of only 0.29 and the low-risk groups has a B/BMSY of 0.62. Note that the FAO classify a ration of B/BMSY <.0.8 as "overfished", thus both groups are effectively overfished.

Figure 4 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 MSY and the less vulnerable/ low-risk stocks fished at levels less than their MSY.

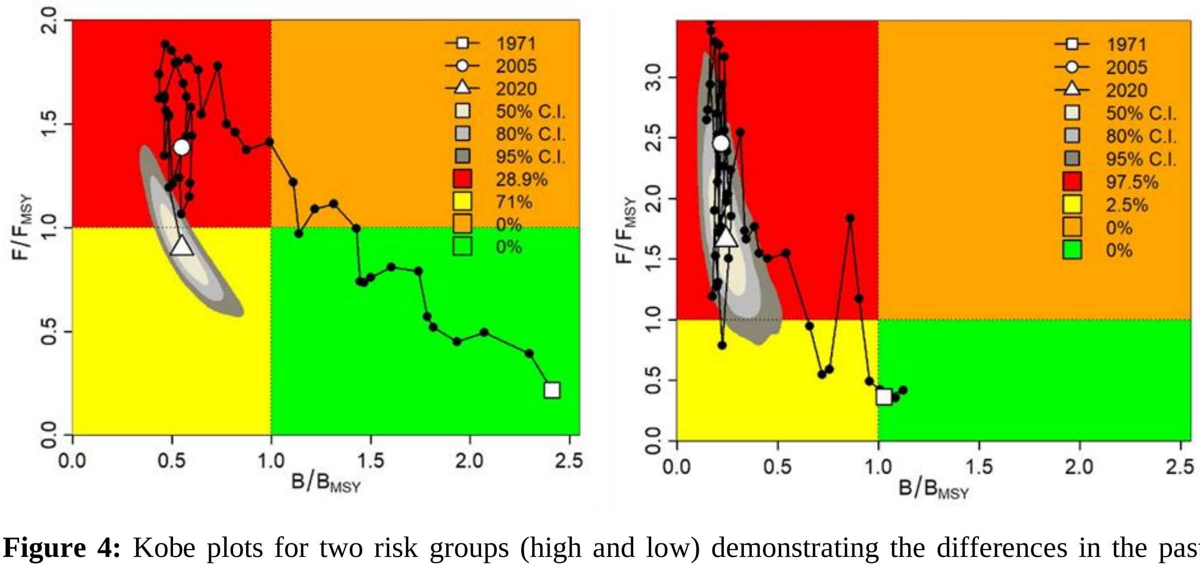


Figure 4: Kobe plots for two risk groups (high and low) demonstrating the differences in the past overfishing and fished status of the groups. Current status in 2020 is shown by the white triangle. The whit circle is the status in 2005 and white square the starting point in 1971.

6.5 FOCUSSING ASSESSMENTS ON A SMALL NUMBER OF COMMONLY-FISHED STOCKS WILL RESULT IN A BIASED UNDERSTANDING OF THE STATUS OF A MULTI-SPECIES FISHERY

Figure 5 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 crabs 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.

The assessment of a limited number of commonly-caught species in the current catch to indicate the status of a multispecies fishery is common practice. However, this focusses the assessment of those species are prevalent (and which are typically resilient and have low vulnerability) and will result in a biased picture of the fishery (indicating the fishery is reasonable) shape), whereas a fuller assessment would reveal many other stocks are in fact seriously overfished.

In this example of 19 stocks, Indian mackerel, lizardfish and swimming crabs are selected as representative of the fishery and assessed using single-species assessment methods. From the results it would be concluded that the fishery is sustainably fished. However, when a more representative selection of species in medium and higher risk groups is used, the picture is quite different (Figure 5).

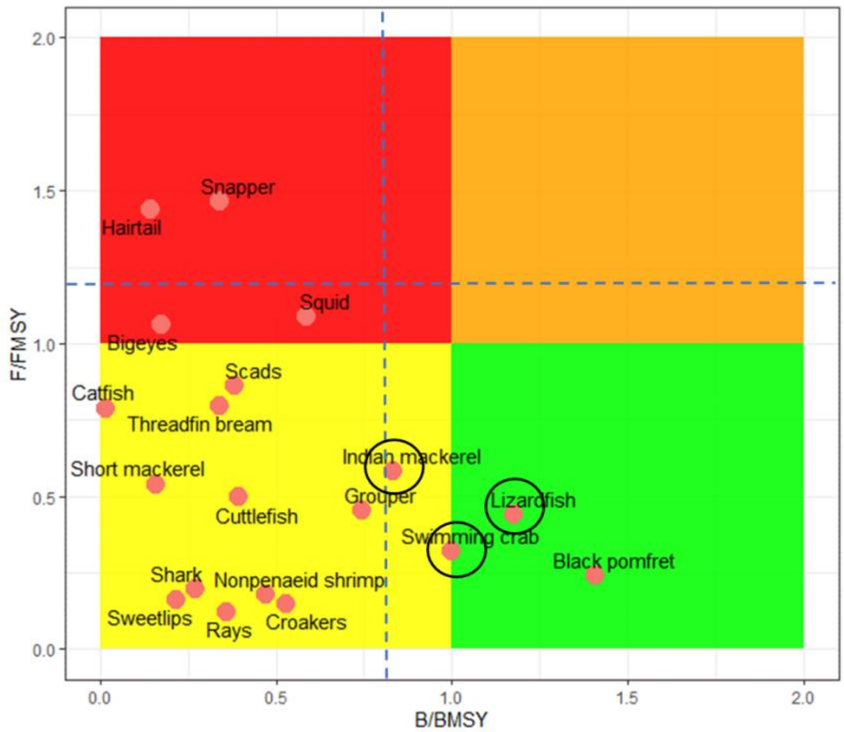


Figure 5: Status of the 19 case-study stocks in 2020. The circled stocks show that selecting common species for single-species assessment could result in a wrong assessment of the status of the fishery as a whole.

6.6 THE WAY FORWARD

We have shown that using a MMSY approach can give a better understanding of the realistic amount of effort and catch that can be applied in a multispecies fishery. It also shows that using this approach, the profitability of a multispecies fishery will be improved, but it will still result in some species being overfished and others underfished. We have also shown how selecting species that commonly occur in the catch can be misleading and that a proper representation of species is needed to make sense of multispecies fisheries management.

To be able to correctly interpret single-species assessments as part of multi-species assessments for fisheries, we recommend two related approaches:

1. Use multi-species assessments to give a picture of the overall state of a fishery, and;
2. Use indicator species from different risks groups to reduce the total number of assessments required but still give an objective overview of the fishery. Set a lower threshold of BLIM to

6.6.1 Multi-species stock assessments

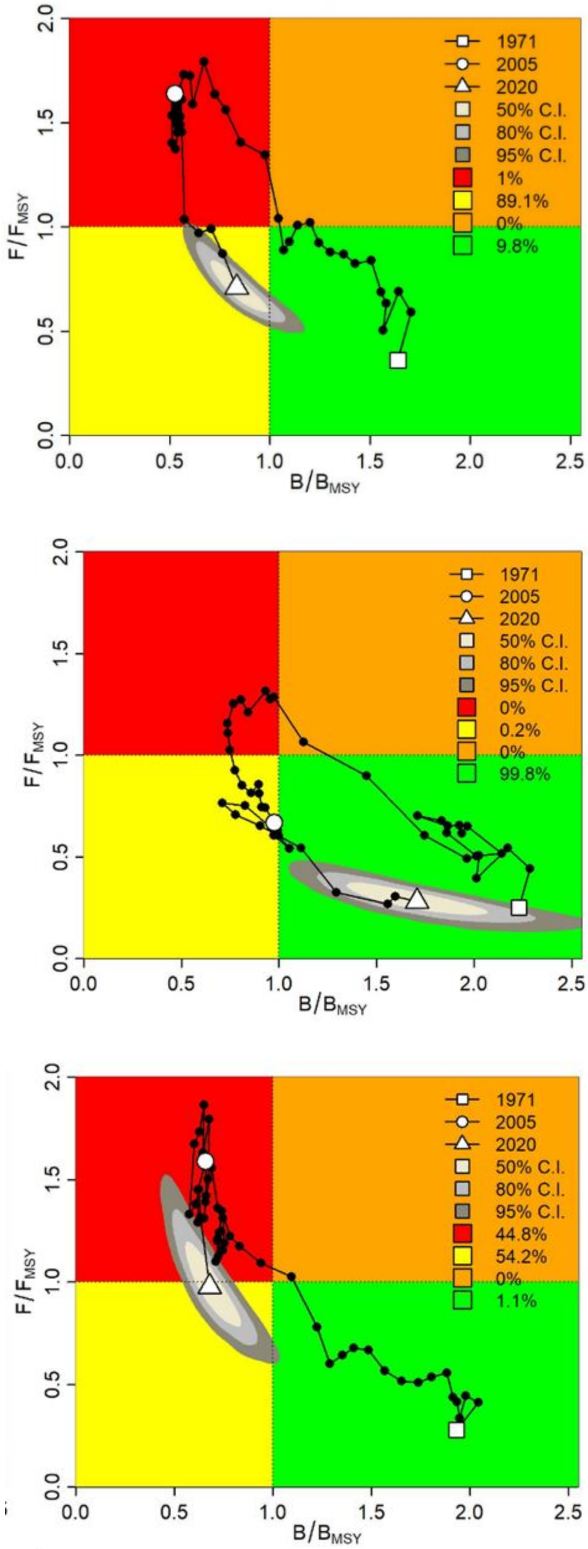
The main methods that could be used for assessment are:

Method	Comments
Ecosystem-level indicators;	???
Ecosystem models (e.g. Ecopath with Ecosim (EwE) [see paper in this report by Beth Fulton]	?? Accounts for interactions between species (especially , predator /prey relationships, predator release)?? Allows scenario analysis Data hungry /(until it is set up?)
Aggregate production models;	?? multiple individual species assessments aggregated (but not added!) to give MMSY estimate
Multi-species production models (trophic interactions and/or gear interactions)	??
Size-based and trait-based multi-species models	??
Risk assessment methods	?? PSA??

A full description of these multi-species assessments methods is in Leadbitter et al. (FAO 20xx).

As an example of an aggregated production model, the demersal trawl catch from the Thai GoT and the abundance index of the research vessels from 1971 to 2020 was fitted using JABBA (Figure 6).

Overfishing of the demersal trawl fishery started in late 1980s resulting in overfished stocks. It is also still overfished but fishing has returned to a sustainable level. The two main components of this fishery - trash fish and food fish (market and surimi) – were also assessed separately. The trash fish have never really been overfished and are currently underfished and subjected to underfishing. The market and surimi, on the other hand, reflect the pattern of the total trawl fishery with overfishing starting in the late 1980s resulting in overfished stocks.



Demersal trawl fishery

Trash fish

Food fish

Figure 6: Kobe plots for the trawl fishery and its two main components – trash and food (market and surimi) fish.

6.6.2 Indicator species approach with a focus on BLIM

An indicator species 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 should have ongoing assessments and there is a need to identify ongoing assessment method and ensure adequate monitoring.

It is useful to select three groups of species based their single-species MSY:

- Likely 'overfished' high-risk/vulnerability species
- Likely 'sustainably fished' medium-risk/vulnerability species
- Likely 'underfished' low-risk/vulnerability species (high resilience)

Table 2 shows an example of selecting indicator species based on the criteria of (i) inherent vulnerability, (ii) current risk, (iii) management importance.

Table 2: An example of selecting indicator species based on the criteria of (i) Inherent vulnerability, (ii) current risk, and (iii) 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 *et al.* (2018)

Management importance in this regard also includes selecting species that are high-risk and more vulnerable to fishing. Under the UN convention on the Law of the Sea (UNCLOS), all species belonging to the same ecosystem need to be maintained above levels at which their reproduction may become seriously threatened, that is the Point of Recruitment Impairment (PRI).

A common reference point for the PRI is the biomass limit (BLIM) defined as 20 percent of the virgin biomass (biomass before fishing started). For production models, this is B/K, where B = biomass and K = carrying capacity.

The use of indicators species and the BLIM threshold is important when managing a fishery for MMSY. This is because there will be some stocks that are overfished under the MMSY scenario and I tis 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.

Thus, as well as ensuring that a given fishery is fished at a level that produces the MMSY, it is also important to ensure that all species, including the more vulnerable species are at a level above BLIM. In this example case of the Gulf of Thailand trawl fishery, this is not the case (Table 3) as only 6 of the 19 case-study stocks were above 20 percent BLIM in 2020.

Table 3: Status of the 19 case-study stocks in relation to a BLIM of 20%.

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 crabs	Above BLIM (>20%)
	Cuttlefish	Below BLIM (<20%)
	Non-penaeid shrimp	Above BLIM (>20%)
	Squid	Above BLIM (>20%)

The indicator species can then be used for assessing and tracking the status of the fishery they represent. Two examples based on (i) B/BMSY and (ii) B/K are shown in figure 7. In both cases, the changes in status over time are clearly indicated and trends can be assessed.

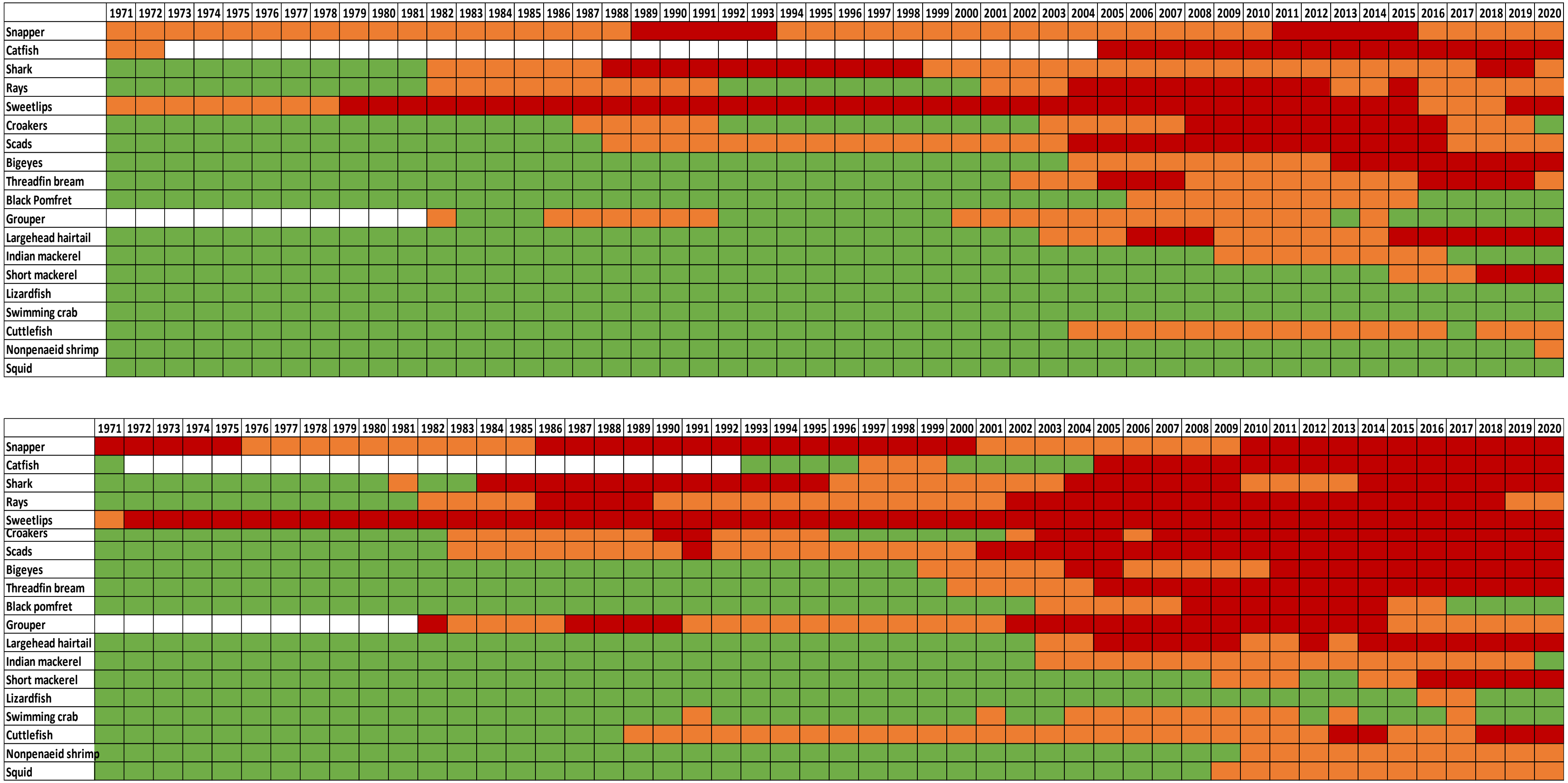


Figure 7: Examples of showing trends in the status of indicator species – changes in B/BMSY (1971-2020) in the top graph and changes B/K (1971-2020) in the bottom graph.

It is also possible to directly analyse recent trends, as in Table 4.

Table 4: Example of recent trends (2011-2020) in B/BMSY, B/K and F/FMSY

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 crabs	Increasing	Stable	Stable
	Cuttlefish	Stable	Stable	Stable
	Non-penaeid shrimp	Stable	Stable	Stable
	Squid	Decreasing	Decreasing	Stable

Summary	**Increasing**	**42%**	**26%**	**11%**
	Stable	**32%**	**58%**	**63%**
	Decreasing	**26%**	**16%**	**26%**

The indicator approach is particularly useful in predicting changes in species and /or market groups with changes in fishing mortality (Figure 8). For example, a 25 percent reduction in effort results in:

- 25% reduction in the catch of trash fish,
- 20% reduction in surimi species
- 15% reduction in market fish.
- Possible increase in profits

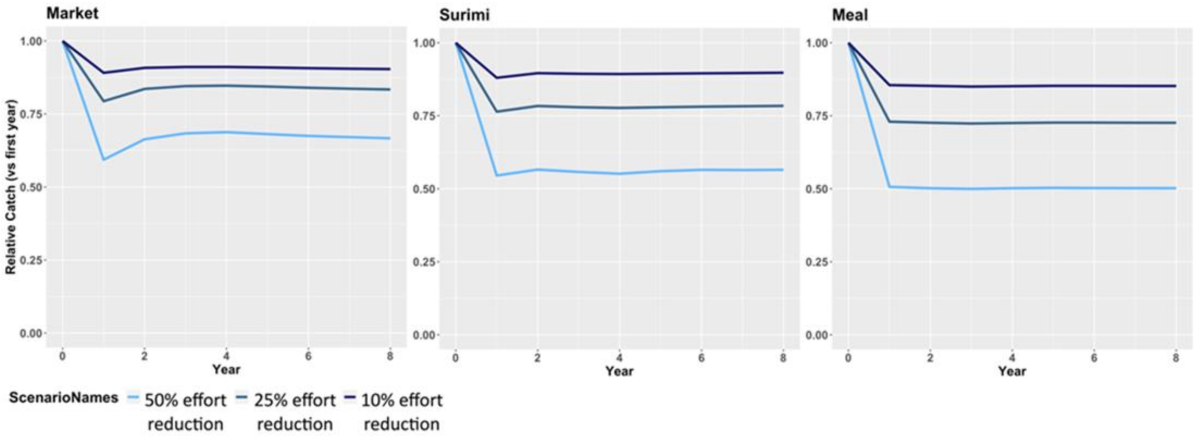


Figure 8: Example of predicting changes in relative catch of (i) market, (ii) surimi and (iii) trash (meal) fish.

Source: Leadbitter *et al*. (20xx)

6.7 CONCLUSIONS

The principal messages that emerge from this study is that to fully assess the status of a multi-species fishery, a combination of multi-species assessments couple with single-species assessments of key indicator species is recommended.

However, there is a need to care in using single species assessments:

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

To incorporate these considerations in to an assessment and management framework for multispecies fishery requires the use of multi-species assessments, linked to an indicator species approach. The selection of indicator species from different risk groups gives a better picture of the status of the fishery and can also demonstrate changes in the fishery status. This also enables examination of trends in status (e.g. B/BMSY, F/FMSY and B/K). When these analyses are used in concert, they can provides effective guidance on what is required for future management measures (e.g. effort reduction, mesh size restrict, closed seasons etc).

6.8 REFERENCES

Boonyubol, M. and Pramokchutima, S. 1982. Trawl fisheries in the Gulf of Thailand. ICLARM Translations 4, 12 pp. Center for Living Aquatic Resources Management, Manila, Philippines

FAO 2014. APFIC/FAO Regional Expert Workshop on Regional guidelines for the management of tropical trawl fisheries in Asia, Phuket, Thailand, 30 September-4 October 2013. *RAP Publication*, 2014/01

Newman, S.J., Brown, J.I., Fairclough, D.V., Wise, B.S., Bellchambers, L.M., Molony, B.W.,

Lenanton, R.C.J., Jackson, G., Smith, K.A., Gaughan, D.J., Fletcher, W.J., McAuley, R. and Wakefield, C.B. 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.

Ovando, D., Hilborn, R., Monnahan, C., Rudd, M., Sharma R., Thorson, J.T., Rousseau, Y. and Ye, Y. 2021. Improving estimates of the state of global fisheries depends on better data. *Fish and Fisheries Volume22, Issue 6, 1377-1391*

Leadbitter D., Fulton E.A., Kulanujaree N., Noranarttragoon P., Nguyen K.B., Phoonsawat R., Porobic J., Sainsbury K., Staples D., V.H. Vu and Ye Y. (20XX). Managing multispecies and multigear fisheries – a toolbox for scientists, managers and stakeholders. *FAO Fisheries Circular (In prep)*

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., and Kapur, M. 2018. JABBA: Just Another Bayesian Biomass Assessment. *Fisheries Research 204, 275–288*

APPENDIX 6-1

Catch and indices of abundance data were fitted to a Pella-Thompson surplus production model using both the sraplus method (Ovando et al. 2021) and JABBA (Winker et al. 2018). sraplus requires the setting of three priors (i) initial depletion, (ii) r, the intrinsic rate of increase and (iii) K, the carrying capacity, while JABBA requires two priors ((i) initial depletion and (ii) r, the intrinsic rate of increase.

Data used in the assessments included:

- Catch data 1971 – 2020. Source: Department of Fisheries, Thailand (Thai DOF);
- Research vessel data 1971 – 2020. Source: Thai DOF

Initial depletion

The prior for initial depletion was based on an analysis of the decline in relative biomass (kg/hour) of the example stocks between 1961 (start of industrial fishing in the Thai GoT) and 1971 (start of the disaggregated catch data) (Figure A1). The high-risk more vulnerable stocks (snapper, 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 10 years (i.e. 12% of virgin). 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% in the 10-year period. Low-risk less vulnerable stocks (lizardfish, swimming crab, cuttlefish, non-penaeid shrimp and squid), on the other hand increased to 120% presumable as a result of “prey release”.

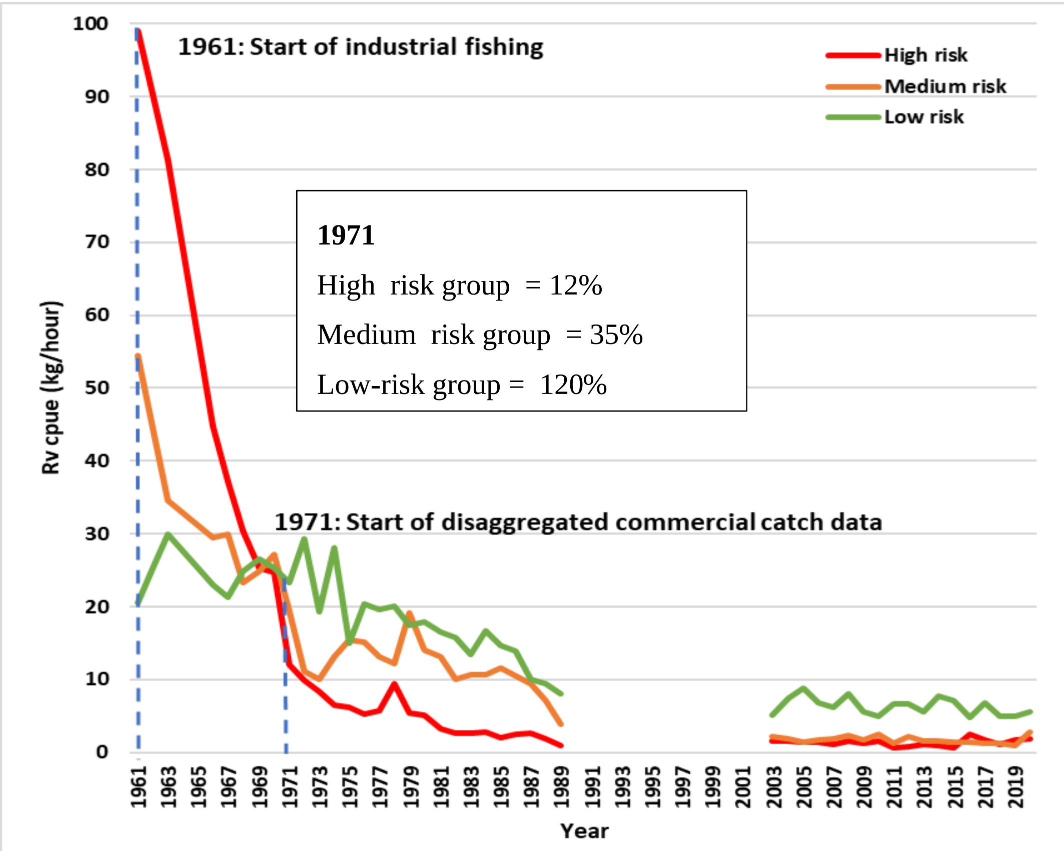


Figure A1: Research vessel relative biomass (kg/hour) for the period 1961 to 2020, showing the per cent depletion of the three risk groups (high, medium and low).

The initial depletion values used in the analysis ranged from 0.1 for snapper to 1.4 for squid (Figure A2)

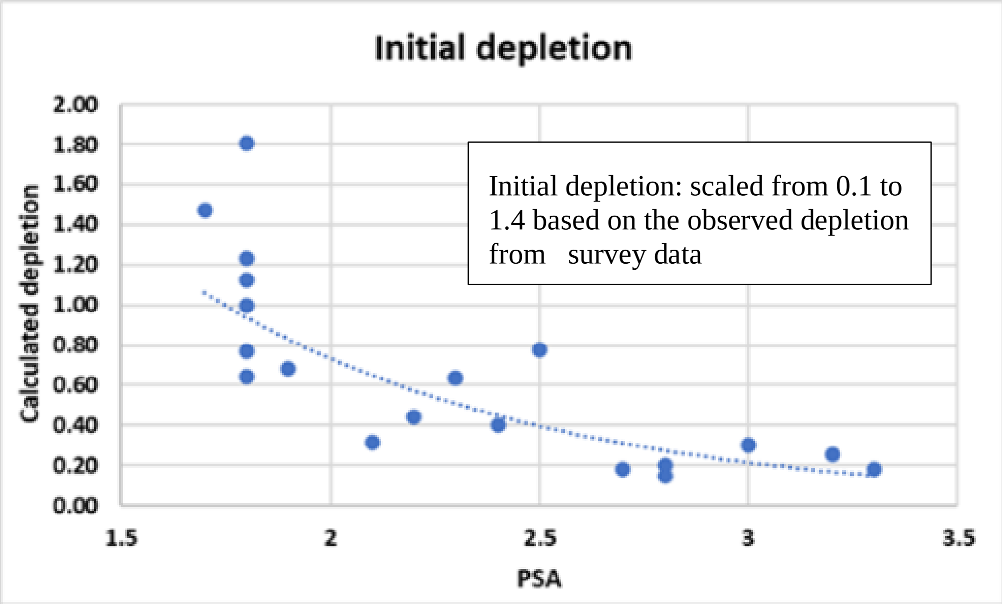


Figure A2: Initial depletion priors scaled to the stock's PSAs

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 A2), modified so that K did not fall below 3 times the maximum catch.

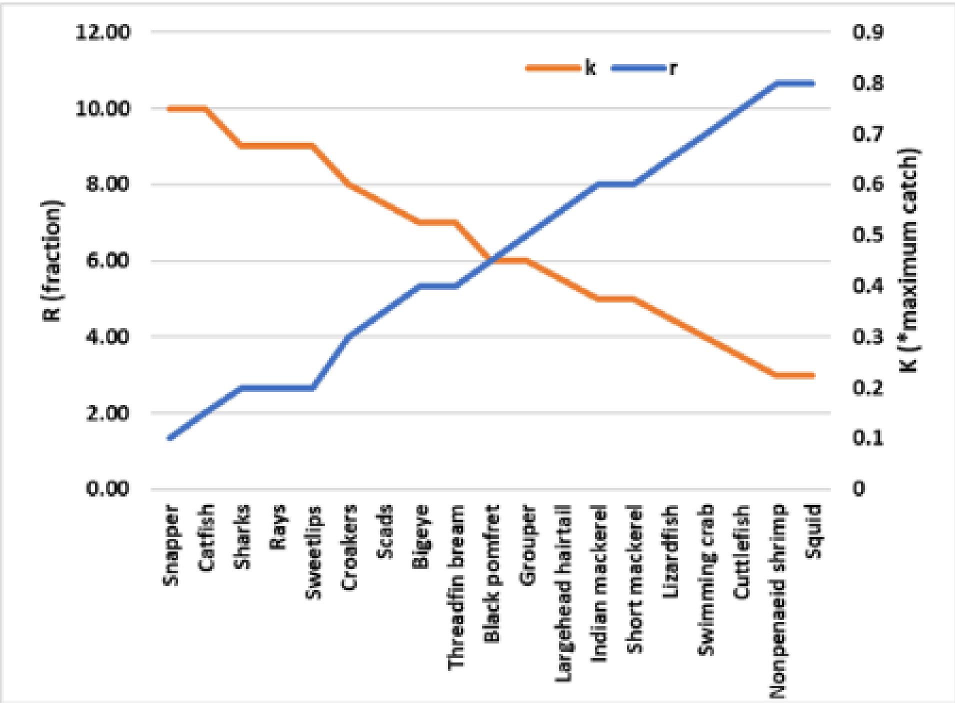


Figure A3: r and K priors scaled to the stock's PSA from a high K/low r (10* maximum catch/0.1) to low K/high r (3* maximum catch/ 0.8)

The complete set of priors and coefficient of variations used the stock assessments are shown in Table 1 and 2.

Table 1: Priors used in the fitting of sraplus for individual stocks

	PSA	Initial prior	c.v	r	c.v	K *Max catch	c.v
Snapper	3.3	0.10	0.1	0.1	0.2	10	0.5
Catfish	3.2	0.10	0.1	0.15	0.2	10	0.5
Sharks	3	0.15	0.2	0.2	0.2	9	0.5
Rays	2.8	0.15	0.2	0.2	0.2	9	0.5
Sweetlips	2.8	0.20	0.2	0.2	0.2	9	0.5
Croakers	2.7	0.20	0.2	0.3	0.2	8	0.5
Scads	2.4	0.40	0.2	0.35	0.2	8	0.5
Bigeye	2.3	0.50	0.2	0.4	0.2	7	0.5
Threadfin bream	2.2	0.55	0.2	0.4	0.2	7	0.5
Black pomfret	2.5	0.60	0.2	0.45	0.2	6	0.5
Grouper	2.1	0.10	0.2	0.5	0.2	6	0.5
Largehead hairtail	1.9	0.65	0.2	0.55	0.2	6	0.5
Indian mackerel	1.8	0.70	0.2	0.6	0.2	5	0.5
Short mackerel	1.8	0.70	0.2	0.6	0.2	5	0.5
Lizardfish	1.8	0.80	0.2	0.65	0.2	5	0.5
Swimming crab	1.8	1.20	0.2	0.7	0.2	4	0.5
Cuttlefish	1.8	1.30	0.2	0.75	0.2	4	0.5
Nonpenaeid shrimp	1.8	1.35	0.2	0.8	0.2	3	0.5
Squid	1.7	1.40	0.2	0.8	0.2	3	0.5

Table 2: Priors used in the fitting of sraplus for aggregated stocks

	Initial prior	c.v	r	c.v	K *Max catch	c.v
High-risk group	0.30	0.2	0.2	0.2	10	0.2
Medium-risk group	0.60	0.2	0.4	0.2	5	0.2
Low-risk group	1.00	0.2	0.8	0.2	3	0.2
Total catch	0.40	0.2	0.3	0.2	7	0.5
Trawl	0.60	0.2	0.4	0.2	7	0.5
Trawl trash	0.80	0.2	0.6	0.2	3	0.5
Trawl food	0.60	0.2	0.4	0.2	7	0.5
Purse seine	0.8	0.2	0.4	0.2	7	0.5

An example of the sraplus output is shown in Figure A4.

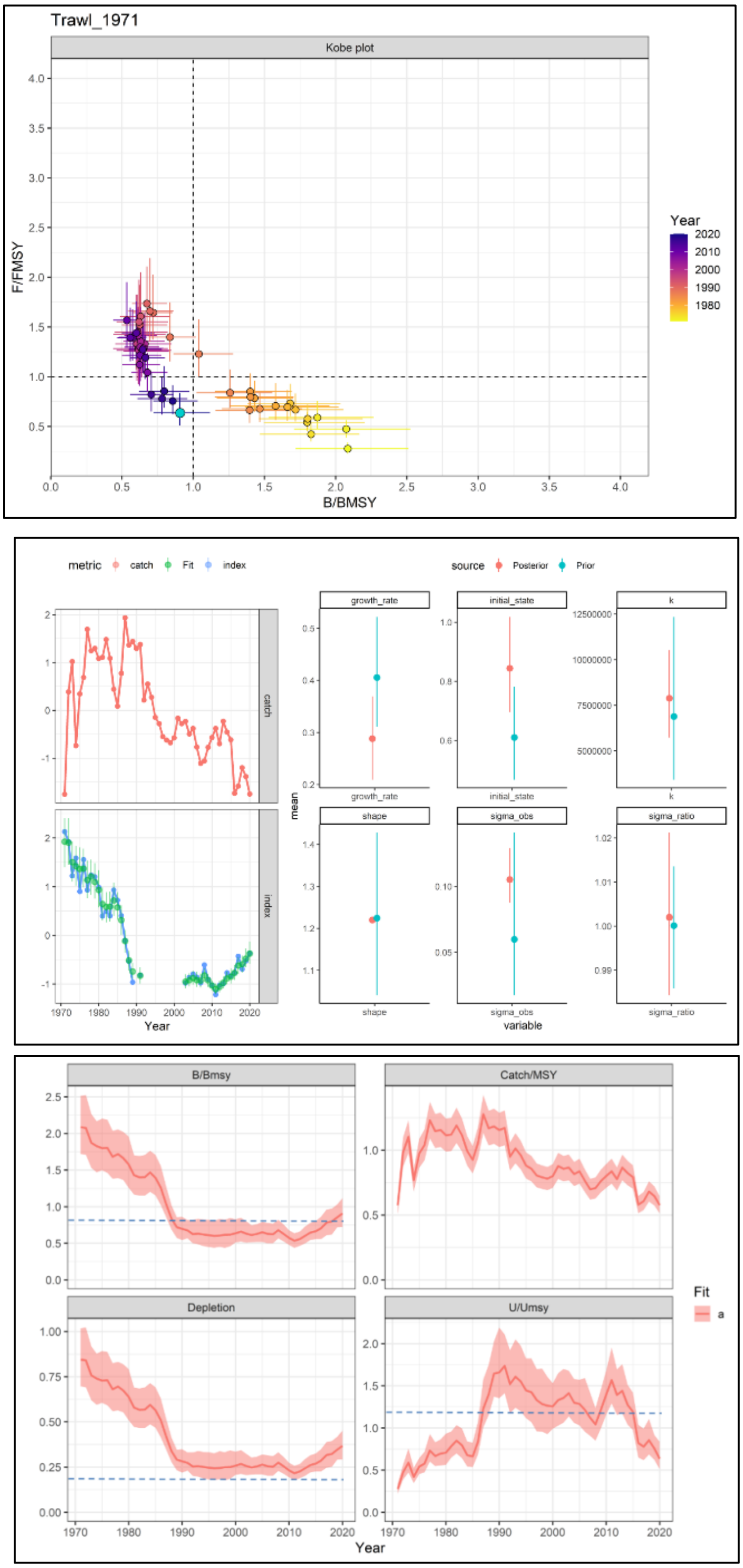


Figure A4: Example output of the sraplus model fit for the Thai GoT trawl fishery 1971 - 2020. Dotted lines show various target and limit reference points. *Note: B/BMSY target reference point = 0.8, U/UMSY target reference point =1.2 and BLIM = 0.2.*

An example of the Jabba output is shown in Figure A5.

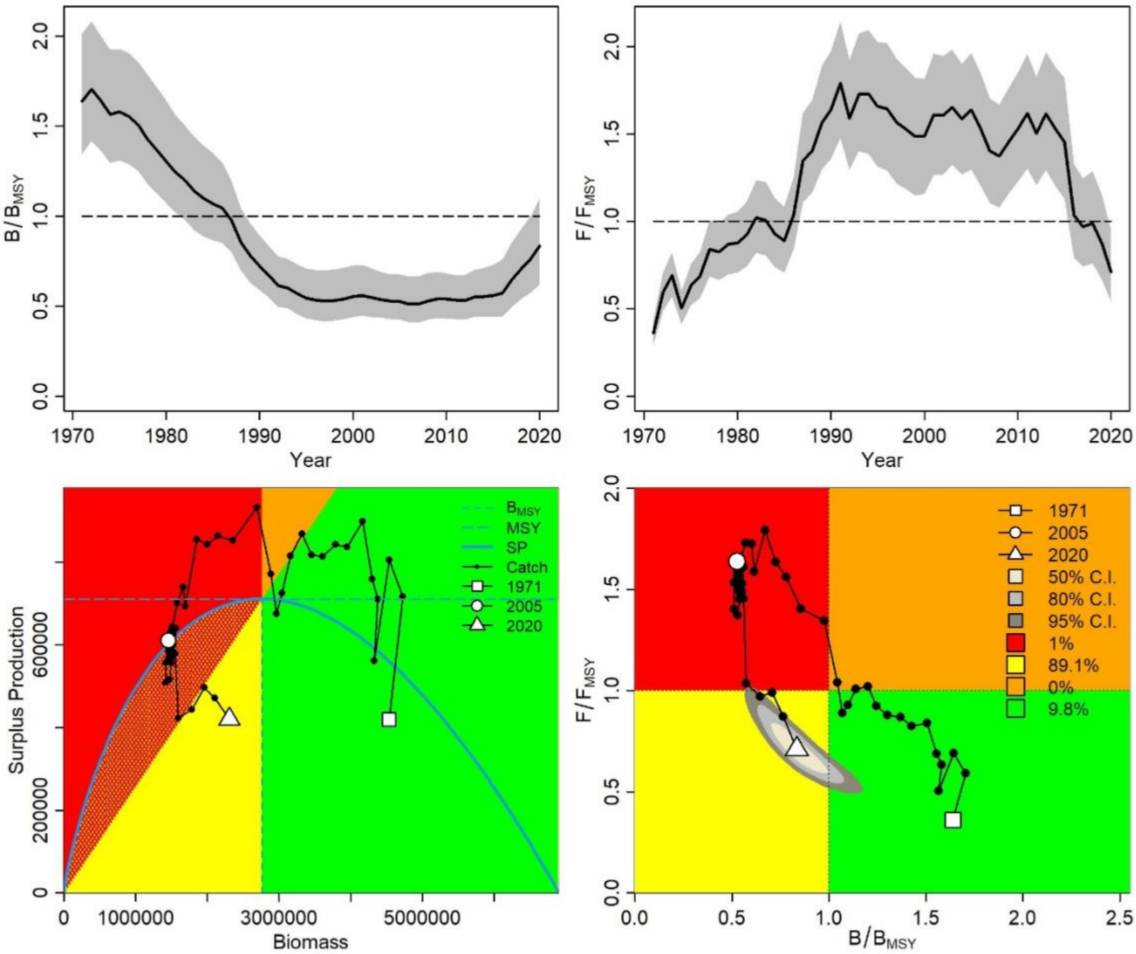


Figure A5: Example output of the JABBA model fit for the Thai GoT trawl fishery 1971 **-** 2020. Dotted lines show various target reference points. *Note: B/BMSY target reference point = 1.0 and F/FMSY target reference point =1.0.*

7 COUNTRY OVERVIEWS

Nine country overviews were presented with one regional overview for the South China Sea, which was treated as one fishery management area (Table 1).

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

Multi-gear and multi-species 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 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 the Maldives and those planned to be developed for Cambodia.

Species groups are assessed using surplus production models in six of the countries (Bangladesh, India, Indonesia, Western Peninsular Malaysia, Philippines and Thailand) with the number of groups in the FMAs ranging from two in Bangladesh (finfish excluding *Hilsa* and all shrimp) to nine in Indonesia and 12 in Malaysia using groupings based on finfish (e.g., demersal fish, small pelagics, large pelagics,…) and invertebrates (e.g., shrimp, crabs, lobster, cephalopods, …) (Table 1).

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

- Surplus production models for individual species
- Length-based methods such as: length-based virtual population analysis, length-based catch-curve analysis, length-based spawning potential ratio (LB-SPR), length-based bayesian biomass estimation (LBB)

Currently, no countries are completing multi-species assessments (e.g. Multispecies MSY) or ecosystem modelling to evaluate fisheries and their ecosystems. These topics were covered in the three overview presentations by Fulton, Staples and the evaluation of trawl survey monitoring by Haywood and Staples respectively.

Typically, stock assessments are carried out by the competent national research institute for fisheries and the results are reported and reviewed by the national government agency competent for fishery management, before the assessment and recommendations are made to the government ministry (Table 2).

In Indonesia, although the assessments were completed by the Marine Fisheries Research Center (now housed within the national Bureau of Research and Innovation, BRIN), they are evaluated by a National Commission on Stock Assessment who repost to the Ministry for Maritime Affairs and Fisheries (Table 2).

In the Philippines, management boards for each FMA have 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 sub-committees 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 take into account the socio-economic impacts of fisheries regulations and in some countries, harvest strategies are being implemented, or being considered for implementation, for areas within FMAs e.g.

- Bangladesh, grouper, snapper
- Blue swimming crabs in Indonesia
- Grouper in the Maldives
- Blue swimming crabs in Sri Lanka

More details are provided in the next section on the Individual Fishery Poster Sessions (Table 2).

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

Country/Region [Number of fishery management areas]	Fisheries	Data sources	Assessments
Bangladesh [2 FMA]	**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: 2017-20, 2022 3. Artisanal fisheries: length frequency data 2012-2018	Bayesian surplus production models (JABBA) **Multi-species:** 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 [2 FMA]	**FMA 1:** inshore <20 m depth **FMA 2:** offshore >20 m depth Specific fisheries have not been defined within each zone. **Historical assessments:** Inshore – an assessment of coastal gillnet and trawl fishery; offshore – an assessment of purse seine fishery	Fishery independent surveys starting from the 1960s, up until 2018.	Catch rates, size distribution **Single species:** An assessment of Short Mackeral *Rastrelliger brachysoma* – surplus production estimation of MSY, MEY and B_0
China South China Sea (regional)	Multi-gear fisheries. 10 fish species are assessed from the demersal trawl fishery. (*Trichiurus lepturus*, *Priacanthus macracanthus*, *Nemipterus virgatus*, *N. bathybius*, *Saurida undosquamis*, *Evynnis cardinalis*, *Trachurus japonicus*,	Length data from trawl surveys during 2016-2017	**Single Species** assessments 1. Length-based Bayesian biomass estimation method (LBB) 2. Length-based virtual population analysis (FiSAT II)

Country/Region [Number of fishery management areas]	Fisheries	Data sources	Assessments
	Decapterus maruadsi, Pennahia macrocpehalus)		
India [9 states and 4 union territories, UTs]	Stocks are assessed in each **State or Union of territory**. **Species groups** assessments – range from 9 (Goa) to 20 in Tamil Nadu. **Single species assessments** – range from 2 in Goa to 19 in West Bengal. Assessments cover from 56.9% of the catch (Gujarat & Daman Diu) to 89.4% (Karnataka).	Time series of a) catch of species in each gear; b) fishing effort (h) for each gear; c) total catch in each fishing gear.	**Historical:** length based assessments using VBGF, CPA and Thompson Bell Model since 1980. 51 singles species stocks assessed in 1990-91. Effort is standardised for each great. ML used to estimate parameters using ADMB Kobe plots are produced 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 [11 FMA]	Multiple gear fisheries 9 **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 – 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. Hydro-acoustic estimator
Malaysia (Western Peninsular Malaysia, not including Sabah) [4]	12 **species groups** across the 4 FMAs (# of FMAs assessed): small pelagics – (4); neritic tunas – (3); Anchovies (2); large pelagics (4); Demersal fish (4); Shellfish (4); Shrimp (4); Sergestid shrimp (2); Cephalopods (4); Brackish water fish (4); Crabs (4); Lobster (3) **Single species** assessments for 5 species: *Euthynnus affinis; Rastrelliger*	**Species groups**: 1. Recent Catch, effort, 2. Biological data **Single Species assessments** 1. Recent biological data	**Species groups**: 1. Surplus production models (Fox/Schaefer; with covariates) 2. Catch at Maximum Sustainable Yield **Single Species assessments** 1. Length-based virtual population analysis (FiSAT II) 2. Surplus production models (with covariates) 3. Catch at Maximum Sustainable Yield

Country/Region [Number of fishery management areas]	Fisheries	Data sources	Assessments
	kanagurta; R. brachysoma; Amblygaster sirm; Photololigo duvaucelii		
Maldives [1]	**Reef-based fisheries** and tuna fisheries. Tuna fisheries are assessed within RFMOs. **5 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
Philippines [12 FMA]	Multi-gear fisheries. **species groups** assessed across FMAs – small pelagics, tuna, demersal fish, reef fish, blue swimming crabs **Single species** assessments for some FMAs	1. Catch & some effort statistics 2. Fishery independent trawl surveys in a few specific grounds 3. Biology & population parameters	**Single Species** assessments 1. Length-based virtual population analysis (FiSAT II) 2. Surplus production models
Sri Lanka [7]	14 fisheries are recognised and 5 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 Cumber) 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 swimmer crab and Giant mud crab 3. Leslie-Delury estimation – applied to two species of Sea Cucumber
Thailand [7 Management areas]	2 management areas in the Gulf of Thailand (GoT); 5 management areas in the Andaman Sea (AnS).	1. Catch and effort data starting in 1971 2. Fishery independent trawl survey data from 1961 to 2022	**Multispecies assessments** for each fishery (Demersal, Pelagic and Anchovies) in each 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.

Country/Region [Number of fishery management areas]	Fisheries	Data sources	Assessments
	3 Fisheries are assessed in each of the GoT and AnS – Demersal, Pelagic, Anchovies	3. Length-frequency data for single species assessments	Length-based Thompson and Bell model (FiSAT ii and Excel).

Table 2: Institutions and agencies responsible for stock assessments, reporting frequency and management agency for fisheries

Country/Region	Agency responsible for assessments	Frequency of assessments and reporting	Reports sent to	Management Agency
Cambodia	Fisheries Adminstration (FiA) (national) Marine Fisheries Research and Development Institute (MaFReDI) (sub-national) Assessments supported by SEAFDEC and FAO	*Ad hoc*	Not yet assigned as no regular assessments are in place	MaFReDI is being considered as the responsible agency
Bangladesh	Marine Fisheries Survey Management Unit, Department of Fisheries Targetted or local assessments are also carried out by Bangladesh Fisheries Research Institute (BFRI) and National Universities Supported by World Bank/FAO	**Multispecies:** Fish and shrimp – every 3 years **Single species:** Every 3 years, except *Tenualosa ilisha* which is *ad hoc*	Department of Fisheries?	Department of Fisheries? Fisheries Management Plans are being considered and this may include harvest strategies
China – South China Sea	South China Sea Fisheries Research Institute (SCSFRI), Chinese Academy of Fishery Science (CAFS)	Stock assessments every 5 years. First assessments completed in 2021. Catch composition, catch rate, and biomass distribution are reported annually	Bureau of Fisheries (BoF), Ministry of Agriculture and Rural Affairs (MARA)	BoF
India	Central Marine Fisheries Research Institute (CMFRI), Indian Council of Agricultural Research (ICAR)		State and Central government	

Country/Region	Agency responsible for assessments	Frequency of assessments and reporting	Reports sent to	Management Agency
Indonesia	National Commission for Fishery Resources Assessment (assessments by Research Center for Fisheries (PURISKAN), Research Institute for Marine Fisheries (BRPL)	Annual assessments; reporting every five years	Ministry for Maritime Affairs and Fisheries (MMAF)	MMAF (fishing licenses, total allowable catch and investigating harvest strategies)
Malaysia (Western Peninsular Malaysia)	Fisheries Research Institute (FRI), Department of Fisheries (DOF)	**12 species groups** every two years **5 individual species** - annual	DOF, Ministry of Agriculture and Fisheries (MAF) and the National Committee for Fish Stocks	MAF
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 3 years. **Tuna:** Assessments as part of the Indian Ocean Tuna Commission (IOTC)	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 Agriculture Research (BFAR)	Annual	BFAR & Fisheries Management Area Committees	BFAR and FAM Management Board (recent) Formerly BFAR only
Sri Lanka	National Aquatic Resources Research and Development Agency (NARA)	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 Crabs

Country/Region	Agency responsible for assessments	Frequency of assessments and reporting	Reports sent to	Management Agency
Thailand	Department of Fisheries (DOF) national assessments Marine Fisheries Research and Development Division, DOF (sub-national) 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 socio-economic impacts on fishers. No harvest strategies are currently in place.

8 POSTER SESSION INDIVIDUAL FISHERY ASSESSMENTS

In addition to the thematic presentations and those on country interviews, 11 short powerpoint poster presentations on individual species assessments (Table 3) and 3 on broader topics (SEAFDEC research in south-east Asia, an assessment of a number of species in the Gulf of Thailand, and moving towards an adaptive, climate-resilient, multi-species Fisheries Management Plan in the Philippines) were made at the workshop.

The single species assessments covered a range of stocks from short lived fast recruiting species in coastal waters (hilsa, lizardfish, swimming crab) to deeper waters (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,
- Length-based Bayesian biomass estimation method (LBB), Length-based spawning potential ratio (LB-SPR)

The presented posters described what was done with an assessment, the results and outcome. While there was some diversity in the analysis used, the majority were based on 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 it was 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 Shiny. FAO is currently working on developing such tools for examining data, their validity and use.
2. Although FISAT is good, and has its utility, 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 used 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 to be put on: model fits, diagnostics, misspecification, alternative models 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 and management advice

Table 3: Summary of assessments for single species within fishery management areas of southern and south-east 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)* Gill nets (<2% in trawl) Bangladesh, Megna River *Jalilur Rahman*	Monthly size data from 8 landing sites (n = 16,000) Research surveys: 2017-20, 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 – 9-12 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 3 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 trawl surveys during 2012-14 and 2019-21 Elefan, Logistic for maturity, Length-based Bayesian biomass estimation method (LBB) Length-based spawning potential ratio (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)* Mini-purse seine fishery Indonesia, Sulawesi Sea *Rian Prasetia*	Catch and length data from 8 landing sites for 2019-21 (n = ~37,000) Length-based spawning potential ratio (LB-SPR)	L_∞ = 377 mm K = 0.85y M = 1.10/y M/K = 1.29 L at 1st capture = 133 mm L at 1st maturity = 239 mm	LB-SPR = 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 2017-21 (n = 5,207) • ELEFAN • Length-based spawning potential ratio (LB-SPR) • Catch at MSY	Max. age ~25 y L_∞ = 719 mm *K* = 0.12y *M* = 0.16/y *M/K* = 1.29 SL_{50} = 355 to 398 mm, depending on the method of capture L_{50} = 388 mm	LB-SPR = ~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 purchases that they only purchase fish of an agreed size • Increase compliance on banned fishing methods (e.g. bomb, cyanide, speargun with hookah)
Grouper *Plectropomus* spp. (4 species) Speargun with hookah (85%), Trap Indonesia, Karimun Jawa National Park, north Java Sea *Rian Prasetia*	Catch and length data from landing sites for 2015, 2018, 2020 • ELEFAN • Length-based spawning potential ratio (LB-SPR)	L_∞ = 622 to 936 mm *K* = 0.10 to 0.13 mm *M* = 0.14 to 0.18/y *M/K* = 1.27 to 1.44	LB-SPR = ~0.15 to 0.31	• Stocks of 3 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 Marine Protected Areas
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; >10,000 for reproductive biology)	Max. age <5 y L_∞ = 232 mm *K* = 1.02y *M* = 0.16/y *M/K* = 1.29 SL_{50} = 151 mm, SL95 = 174 mm	Length-based virtual population analysis (FiSAT II) Froese % mature *F/Z* = ~0.7 to 0.8	• Adjust timing of closed seas • 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**
		L_{50} = 151 mm, L_{95} = 174 mm	*F/M* = ~2.6 to 3.8 % mature in catch = 31 to 45%	
Greater Lizardfish (*Saurida tumbil)* Trawl (3 cm mesh codend) Philippines, Lingayen Gulf *Greg Buccat*	Catch and length data from 3 landing sites.	L_∞ = 390 mm *K* = 0.70/y	LBSPR Beverton and Holt Y/R (Growth & Mortality) LBAR AMSY LBB FROESE Simple Indicator *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 codend
Blue Swimmer Crab (*Portunus pelagicus)* Crab entangling net, crab pots Philippines, Visayan Sea *Sheryll V. Mesa*	Near shore habitats of sandy-mud near reef, mangroves and seagrass. Monthly catch, effort, length and reproductive data from 36 landing sites for 2011-2021		Shaeffer and Fox surplus production models Abundance ratio, MSY, CMSY LBAR AMSY LBB	• The stock is overfished and overfishing is occurring. • Reduce number of panels in the fishery by ~50% over 5 years • Local government to regulate the specifications of crab entangling nets • Switch from gillnet to other ecofriendly gears such as bamboo crab pots Roll

Species and main fishing gear(s) Country, area, presenter	**Data and analyses**	**Biology and population parameters**	**Estimates, assessment**	**Recommendations**
			FROESE Simple Indicators MSY = 12,545 tonnes (Schaeffer) FMSY = 406,152 panels of net B/BMSY = 0.92 F/FMSY = 1.47	out the BSC national management plan using the adopt a village concept
Blue Swimmer Crab (*Portunus reticulatus*) Crab entangling net Sri Lanka, Palk Bay *Steve Creech*	Near shore habitats of sandy-mud near reef, mangroves and seagrass. 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 – 143 mm SL_{50} ~130 mm	LB-SPR mean size in the catch % crabs at optimum size % mature females (i.e. > L_{50}) Mean size ~130 to 145 mm % mature females ~93 to 100% % optimum crabs ~45 to 65% SPR ~0.35-0.46 *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)	Living in river mouths and coastal areas on sandy mud and muddy substrates.	Lmax females = 205 mm L_∞ females = 198 mm *K* = 1.47 L_{50} females = 94 mm L_{95} females = 112 mm	LB-SPR SPR = 0.23 to 0.27	• Introduce a seasonal spawning closure • Reduce the length of gill nets in the fishery • Prohibit fishing in nursery areas

Species and main fishing gear(s) Country, area, presenter	**Data and analyses**	**Biology and population parameters**	**Estimates, assessment**	**Recommendations**
Thailand, Gulf of Thailand *Orawan Prasertsook*	Monthly catch, effort and length data from small-scale and commercial vessels	SL_{50} ~130 mm		

9 OUTCOMES OF THE WORKING GROUPS

Three working groups (Table II) were established for this part of the workshop. The working groups were split into three thematic groups:

i. Coastal inshore fisheries, including reef fisheries [Facilitators: Budy Wirywan & Neil Loneragan]
ii. Multi-species fisheries [Facilitators: Derek Staples & Rishi Sharma]
iii. Small-medium pelagic species (non-large tuna) fisheries [Facilitators: Ricardo Amoroso & Wily Campos]

The working groups were tasked to review submitted papers and posters split by three themes and summarise the assessment processes, methods and data sources for the theme and 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 (see Table III) were combined into a final summary of the workshop, presented in plenary.

9.1 COASTAL INSHORE FISHERIES, INCLUDING REEF FISHERIES

Budy Wirywan & Neil Loneragan

PENDING TO BE INSERTED

9.2 DEMERSAL MULTI-SPECIES FISHERIES

Derek Staples & Rishi Sharma

The demersal multi-species working group met twice during the workshop. In the first session, the working groups was asked to summarize the assessment process, methods and data sources for the theme and country reports in the region. The group presented their findings during the plenary session on the same day. In the second session, the group identified the major gaps and looked at ways of strengthening human capacity building, improving accessibility to data and possible harmonization and also presented their findings that day.

9.2.1 Fisheries data

The working group recognized a number of quality issues in the data that is used as input into sock assessment. For catch and effort data, for example, many countries have two sets of data – Statistical Office/Department of Fisheries and Research Institute data sets 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, despite the fact that they can distort the results of stock assessments that use catch data as an input.

Length-based data is mainly collected by research institutes and they require frequencies to be raised to the catch but these calculations are often not accessible to all. Species covered are often caught by many gears and sampling is often inadequate to address this multi-gear 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 etc - is an important tool that is not commonly used. The results of fishery independent data (surveys) and catch based data is 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. These need to consider technological improvements in gear as well as other changes in fishing activity. Most importantly, there is often insufficient dialog with fishers who can assist in interpreting time series data. More interaction with fishers through improved co-management 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.

9.2.2 Data analyses and models

A wide range of models and packages for fitting the models are being used across the region, including those based on catch and effort, length frequencies and catch only. In the presentations given at the workshop, there did not seem to be enough emphasis given on the checking that the model used is accurate and reliable and that its assumptions are being met. There was also insufficient emphasis being given 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 (e.g. ELEFAN, LBB, LBSPR etc).

9.2.3 Demersal Stock status

Despite the shortcomings in data and model fitting, it was concluded that all the evidence shows that the status of demersal stocks in the region is not good.

Further, 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 - multispecies aggregate MSY may be a good approach for the future.

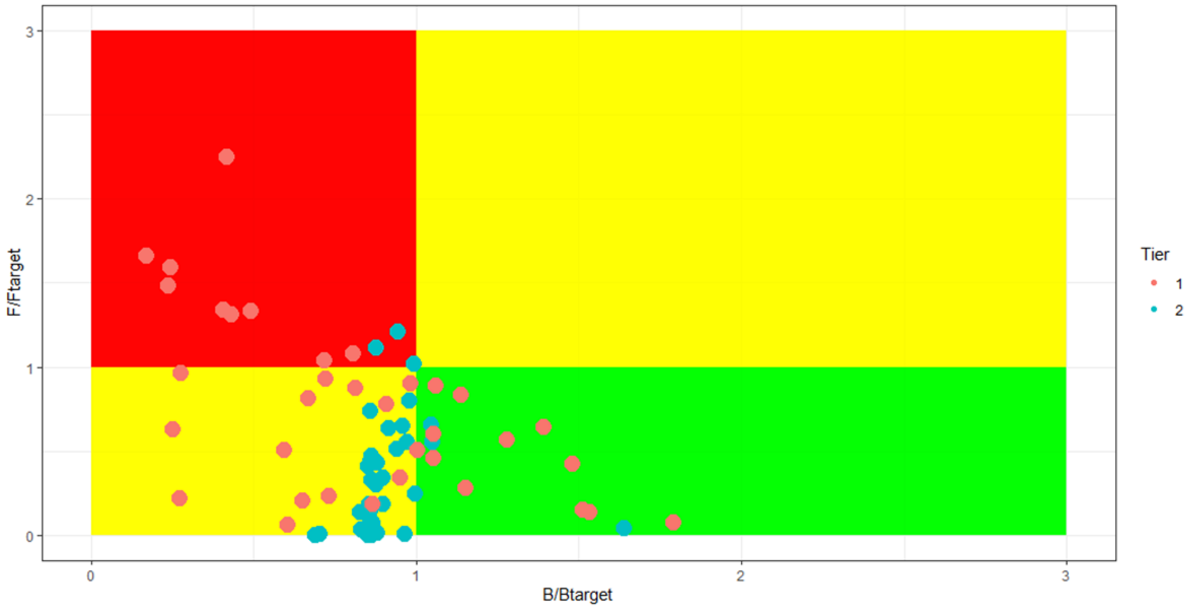


Figure xx: xxxxxxxxx

9.2.4 Better models for assessing stocks

The use of other models e.g. multispecies models that estimate MMSY and species interactions needs to be encouraged. 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 (e.g. Ecopath with Ecosim (EwE)) and use of eecosystem indicators should also be expanded and used across the region.

9.2.5 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 sub-regional) 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 practiced in the region and if done by every country communication of stock assessment results would be greatly improved. Countries who 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 review checking progress against objectives to support adaptive management.

Institutional structures that foster dialogues between management and science e.g. co-management councils and committees, have found to be 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 development of model free management is an option for the future.

9.2.6 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 needs to be included, including past fisheries acoustics-based biomass surveys that are currently under-utilized.

It was recognized that each country has different capacities and tailored capacity building will be necessary that in include training, peer reviews and the development of practitioner networks appropriate to that country. However, the 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.

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. fishers/fishery managers/ policy makers. Fisheries management training could be made more interactive (e.g. online/games/case studies/physical) for fishery managers/ policy makers 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 are available, albeit scattered, but there is an urgent need for guidelines for model diagnostics.

Rishi - notes on multispecies (Demersal) Group

The effect of different trawl bans needs to be examined. In the region bottom trawl is effectively largely banned and how midwater trawls effect some groups is not understood properly. Regardless, the ecosystem habitat should be a lot better currently then when bottom trawled. The compositional changes will be evident when these changes happened.

The effect of how good the estimates of TC are in countries was discussed and whether harvest control rules would be effective if goalposts changed.

Regardless mostly input controls would work in these fisheries. M&E, compliance and monitoring needs to improve in all countries.

The issue of data resolution by area and type was discussed.

Notes on MMSY Approaches

The issues of keystone species/hub species could effect the TAC by a large amount. In addition objectives of what you manage and how well we do with respect to reference points was also discussed. Both issues need to be examined carefully when deciding what species mix should be targeted as objectives for food security/social costs/employment can differ substantially from economic benefits.

The need for a workshop dealing with these issues in the region will be dealt with by FAO in the future.

9.3 SMALL-MEDIUM PELAGIC (NON-TUNA) SPECIES

Ricardo Amoroso, Wilfredo Campos and Rishi Sharma

9.3.1 Introduction

The assessment and management of small pelagic species pose several challenges due to their unique life history and the role they play on 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 prey abundance 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 the appropriate spatial scales.

The working group on small pelagic species was tasked with the following activities:

1. Summarize the assessment process, data sources and overall results and status in the region;
2. Identify critical capacity building needs for the region to form the basis for a training program, and a regional project or a recommendation on the content that University/fishery courses should cover;
3. Identify, if possible, other approaches to assessing stocks;
4. Investigate how stock assessments feed into management and do we need better communication on stock assessment to policy makers.

9.3.2 Summary of stock status

The working group compiled a list of ~27 small-medium pelagic species stocks in the region that have been assessed (Table 1). For each species, the following information was recorded and summarised in Table 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 spawning potential ratio (SPR) and the ratio of fishing to natural mortality, *F/M*.
4) The type of reference point used as a B or F target;
5) The values of F/Ftarget and B/Btarget.

The working group noted that there are several species that have been assessed but the values of stock status were not available during the meeting. These species were included in Table 1 and **the group recommended** that a comprehensive synthesis on stock status should be performed in the future.

Table 1: Summary of stocks assessed in the south Asia and south-east Asian region compiled during the workshop. For some stocks the values for stock status were not available for during the workshop. ASPIC = a stock production model incorporating covariates; LBB = length-based Bayesian; LBSPR = length-based spawning potential ratio; Cmsy = catch based msy; JABBA = just another Bayesian biomass assessment; SPR04 = spawning potential ratio of 0.4.

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 and Indonesia	2018	ASPIC	1	Bmsy	Fmsy	0.82	1.39
Long tail tuna	South China Sea	2018	ASPIC	1	Bmsy	Fmsy	1.52	0.53
	Andaman 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 & internal waters	2021	Catch curve/LB SPR	2	SPR04	F_M_1		
Big Eye Scad	Sulu Sea & internal waters	2021	Catch curve/LB SPR	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 & internal waters	2021	Catch curve/LB SPR	2	SPR04	F_M_1		
Shortfin scad	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	0.57	1.32
	Sulu Sea & internal waters	2021	Catch curve/LB SPR	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		
	Sulawesi Sea	2021	LBSPR	2	SPR04	F_M_1	1.6	0.67

Species	Country/ Region	Last Assessed	Method	Tier	Btarget type	Ftarge type	B/Btarget	F/Ftarget
Goldstripe sardinella	Sulu Sea & internal waters	2021	Catch curve/LB SPR	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 & internal waters	2021	Catch curve/LB SPR	2	SPR04	F_M_1		

A Kobe plot was constructed to summarise the preliminary findings for those 15 stocks that have been assessed recently (Figure xx). This preliminary analysis suggests that most of the stocks (10) 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).

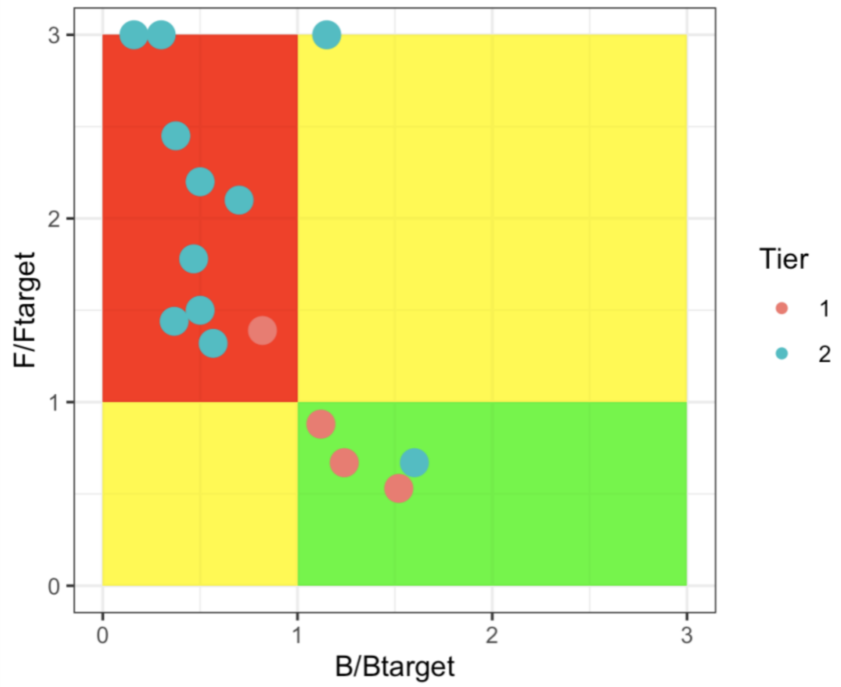


Figure XX: A Kobe plot for 15 small-medium pelagic species assessed during the workshop. Species and assessment results are summarised in Table 1.

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 serve as an illustration only of an approach that might be adopted.

9.3.3 Issues for assessing small-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. In some cases, very short time-series are used.
- The CPUE indices are, in general, standardized using Generalized Linear Models. However, there are concerns that the use of fish aggregation devices may cause hyperstability for fishery-dependent derived indexes.
- The stock assessments using a stock production model incorporating covariates (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 model (LBB). 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.

9.3.4 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.

9.3.5 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 socio-economic indicators should also be used to complement single-species stock assessments.

9.3.6 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 licenses is adjusted as a function of F/FMSY (Figure 2). If F/FMSY is lower than 0.8, 90% of the licenses that should operate to produce MSY

are allowed. If F/FMSY is higher than 0.8, only 50% of the licenses are allowed to operate.

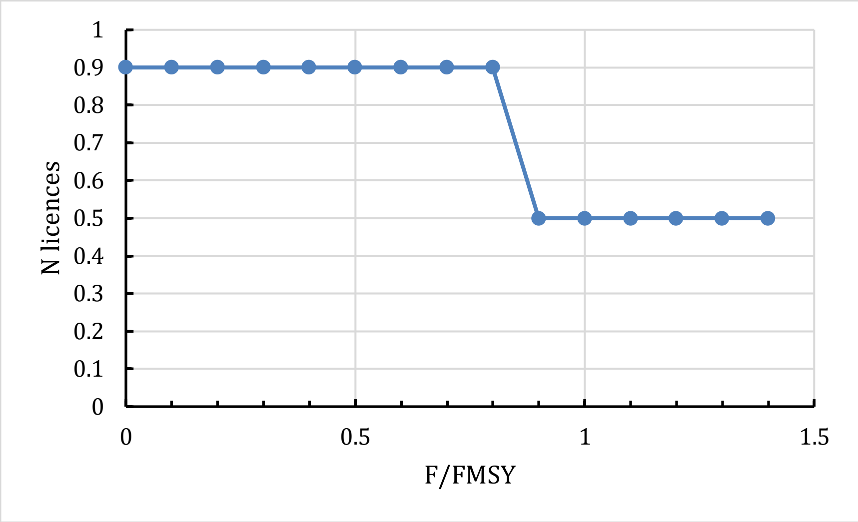


Figure 2: Harvest control rule for fisheries in Indonesia.

2. Case 2, SEAFDEC: Results of stock assessments are used to provide management advice to the countries. There is not a formal harvest control rule. Fishing effort reduction may take place, but usually there is a delay from the time of the assessment to the implementation of the recommendations.

3. Case 3, Malaysia: A spatial zoning is being implemented. For each zone the CPUE trend is calculated and effort reallocation takes places based on these results.

9.3.7 Recommendations on assessing small-medium pelagic species

The use of CPUE data should be critically examined when using it in surplus production models (SPM) as most data are gathered from Fish Aggregating Devices (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 length based Bayesian (LBB), or length-based spawning potential ratio (LBSPR) methodologies.

Further thought on collecting samples relevant to the approach to examine for inference needs to be thought and designed from the onset.

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.

10 THE NEED FOR IMPROVED AWARENESS OF THE VALUE OF STOCK ASSESSMENTS

10.1 IMPROVING COMMUNICATION

TURN INTO A PARAGRAPH

- Need to raise awareness about the central importance of stock assessment to fishery management and sector governance
- Communication of stock assessment information is key and the audiences are different so this needs to be tailored to suit their needs as well as capacity to understand complex technical messages
- Use of simple indices of maturity to introduce size limits – successful for some species e.g., anchovies in India, BSC in Sri Lanka, grouper in Indonesia
- Use language to connect with the audience and use participation/consultation on Stock Assessment and Management Measures

10.2 LINKING STOCK ASSESSMENT TO ECONOMICS

DRAFT A PARAGRAPH

There is a need to tie assessment to economic information - this is important as part of communicating to policy and decision-making, as well as understanding implications for fishers and the livelihoods of coastal communities.

In order to deal with this a total profit and social cost Kobe will need to be developed on the aggregate of species caught and evaluate the tradeoffs (shown below).

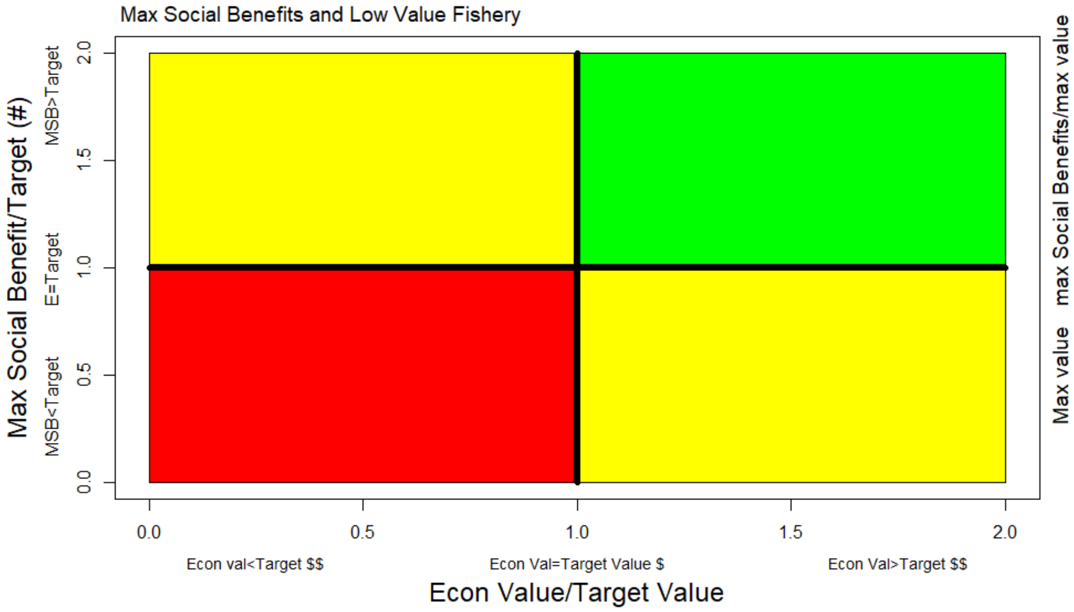


Figure xx: An economic Kobe style plot that evaluates total profits of the mix stock fishery on the x-axis vs social costs on the y-axis.

11 REGIONAL AND SUB-REGIONAL NETWORKING

TURN INTO PARAGRAPH TEXT

Some needs

- Fishery stock assessment network
  - Technical level (less political)
  - Support technical sharing and networking
  - Can this be institutionalized?
  - Regional examples of establishing cross-country collaborations and information sharing have typically emerged from projects (e.g., FAO Bay of Bengal projects …)
  - Funding support? market-based i.e involving industry in supporting a network of this type?
- Work on data quality
- Develop a common database or common database structure to allow easier sharing of data?
- Identify and work 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 (common set?)
- Standard procedures, guidance
- Feed into harvest strategies

11.1 REGIONAL AND INTERNATIONAL ORGANIZATIONS FISHERY RESEARCH AND CAPACITY BUILDING

Fisheries research, assessment and management are entering an exciting era in the region and there is a clear need in the region to move towards an ecosystem approach to fisheries management that is capable of addressing the needs for multi-species assessments of fisheries within a multi-gear and often multi-scale (small-scale fisheries, large-scale fisheries operating in the same context or on the same stocks). There is scope for greater engagement in research and capacity building to provide of tools and training for fisheries assessment and management. These would target solutions to issues or allocation between gears and scales as well as situating stock assessment into broader fishery governance as well as 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 form 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 1980-1990s, particularly in the realm of stock assessment, although 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 role of science. However, capture fisheries research and management is under-represented in the AFS and its regular conference the Asian Fisheries and Aquaculture Forum (AFAF). Establishing a Section within AFS could provide a mechanism to revitalise connections, promote best practice and provide capacity development opportunities for scientists within the region. As there is potential interest from regional actors such as WorldFish, SEAFDEC, Bay of Bengal IGO, it is worth exploring the possibility of creating a "*Fisheries Assessment and Management*" Partnership Section within the framework of the Asian Fisheries Society.

In **south Asia**, the establishment of a stock assessment network aligns with the objectives of the Bay of **Bengal Programme Inter-governmental Organization (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 BOBP-IGO. There are a number of 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 assessment for useful information and best practices in stock assessment. Other networking opportunities include convening of technical webinars and a regular virtual network meeting. 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 the involvement **of SouthEast Asian Fisheries Development Center (SEAFDEC)** engagement with regional LME GEF-IW projects that focus on EAFM fishery management. Activities might include arranging webinars on best practices or techniques for different topics in stock assessment. Topics identified include: data exploration; sensitivity analyses; presenting information on stock assessments to managers and fishers; designing data collection programs 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 on our new data platforms to act as a 'one-shop stop' for stock assessment toolkits and datasets. Possibly building on capacity in WorldFish
- Mentoring network and support to young scientists, possibly though a dedicated section within the Asian Fisheries Society
- BOBP-IGO will cooperate with CMFRI to convene a side event on stock assessment at the 14^{th} Asian Fisheries and Aquaculture Forum (2025 in New Delhi)

ANNEX I - AGENDA OF THE REGIONAL WORKSHOP

Workshop Programme	
Day 1 (Monday, January 23, 2023)	
08.45-09.00	**Short opening of workshop** Quick introductions and workshop objectives,
09.00-11.00	**Plenary Session 1:** Thematic presentations (20 mins + 10 mins Q&A) (with on-line participants)
09.00-09.15	Scene setting: High level picture of Asian marine fisheries, where they are and their value, characteristics and diversity *Simon Funge-Smith (FAO Regional Office)*
09.15-09.45	Single species stock assessments for a range of data in Asia *Ricardo Amoroso (University of Washington, USA; National University of Comahue Argentina)*
09.45-10.15	Assessing stocks for multi-species fisheries: a multi-species approach relevant to the Asian region *Beth Fulton (CSIRO, Australia)*
10.15-10.45	The status of Asian fish stocks and why FAO is gathering information *Rishi Sharma (FAO, Italy)*
10.45 – 11.15	**Morning Tea**
11.15 -12.30	**Plenary Session 1 continued:** Thematic presentations (20 mins + 10 mins Q&A) (with on-line participants)
11.15 – 11.45	Model implementation and management of resources in the South China Sea (SCS) – Fishing industry and recent assessment of 8- 10 stocks. Suggestions for sustainable fishing on the resources of the SCS. *Zuozhi Chen (South China Sea Fisheries Research Institute, China Academy of Fisheries Science)*
11.45-12.30	**Plenary Session 2:** Short country overview presentations of stock assessments **and status of fish stocks** (with on-line participants), using the powerpoint template provided. **Brief overview of 12 minutes +3 mins Q&A per country**
	Southeast Asia: • Indonesia (*Indra Jaya*) • Malaysia (*Sallehudin Jamon & Effarina bt. M Faizal Abdullah*) • Philippines (*Francisco Torres & Melanie Villarao*)
12.30 – 13.30	**LUNCH**
13.30 – 15.00	**Plenary Session 2 (cont.)** • Thailand (*Pavarot Noranarttragoon & Nipa Kulanujaree*) • Cambodia (*Chea Tharith & Ly Kunthy)*
	South Asia: • Bangladesh (*Al Mamun & Mohammed Shriful Azam)* • India (*Jayasankar*) • Maldives (*Mohammed Ahusan and Mohammed Shimal*) • Sri Lanka (*Sisira Haputhantri*)
15.00 -	**Plenary discussion** – lessons from the posters
15.00 – 15.30	**Afternoon tea**

15.30-17.00	**Plenary Session 2: Poster Session** 14 Posters from in-person and online participants presented using 5 slide PPT template, with absolute maximum of 5 minutes for each presenter. **<u>Note: Automatic cut off at 5 minutes</u>**
 15.30-15.35 15.40-15.45	***Multi-species demersal fisheries (WG facilitators)*** Asian trawl surveys (*Mick Haywood*) Greater lizardfish (Saurida tumbil) (Bloch, 1795) of FMA 6 (Sub- FMA Lingayen Gulf) (*Greg Buccat*)
 15.45-15.50 15.50-15.55 15.55-16.00 16.00-16.05	***Small-medium pelagic species (non-large tuna) fisheries (WG facilitators)*** SEAFDEC (*Supapong Pattarapongpan)* Philippines *Sardinella* (*Divine Ignacio*) Small Pelagic Species (*Decapterus macarellus*) from North Sulawesi (*Rian Prasetia*) Population parameters estimation and length-based assessment for data-poor Mackerel scad in the South China Sea (*Kui Zhang*)
 16.05-16.10 16.10-16.15 16.15-16.20 16.20-16.25 16.25-16.30 16.30-16.35 16.35-16.40 16.40-16.45	***Coastal inshore fisheries, including reef fisheries (WG facilitators)*** Philippine 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, Multi-species Fisheries Management Plan (*Jose Ingles*) Hilsa shad from the Meghna river, Bangladesh (*Jalilur Rahman*) Thailand single species assessment *(Weerapol Thitipongtrakul)* Thailand Blue Swimming crab *(Orawan Prasertsook)*
17.00-17.05	5 minute wrap-up for housekeeping (as working groups continue)
Day 2 (Tuesday January 24, 2023)	
08.30-08.45	**Overview of objectives of Working Group Session 1** *(offline - face-to-face participants only)* Introductions to each other and groups forming for working group session **Facilitators review the points emerging from the poster sessions and country papers related to their themes**
08.45 – 10.00	**Working group Session 1** *(offline - face-to-face participants only)* **Purpose/activity:** Review submitted papers and posters split by three themes and summarise the assessment processes, methods and data sources for the theme and the overall results of the assessments and status of resources in the region. Prepare of Powerpoint summary for each working group. *Working groups* iv. Multi-species demersal fisheries [Facilitators: Derek Staples & Rishi Sharma] v. Small-medium pelagic species (non-large tuna) fisheries [Facilitators: Ricardo Amoroso & Wily Campos] vi. Coastal inshore fisheries, including reef fisheries [Facilitators: Budy Wirywan & Neil Loneragan]
10.00 – 10.30	**Morning tea**
10.30 – 12.00	**Plenary Session 3: Working group presentations** (with on-line participants) Presentation by three working groups summarising the findings from WG Session 1 (*Each group has* 20 *minutes presentation plus 10 minutes Q&A*)
10.30-11.00	Multi-species demersal fisheries
11.00-11.30	Small-medium pelagic species (non-large tuna) fisheries

11.30-12.00	Coastal inshore fisheries, including reef fisheries
12.00-12.30	**Discussion**
12.30-13.00	**Plenary Session 5: Single and multi-species assessments** (with on-line participants) "Interpreting single-species assessments in a multispecies fishery – the use of indicator species". *Derek Staples* (Fisheries Consultant)
13.00 – 14.00	**LUNCH**
14.00 – 15.30	**Working Group Session 2** *(offline - face-to-face participants only)* *It is expected that the working groups will remain the same to maintain momentum. However, membership may be adjusted to reflect specific thematic interests of individuals* **Purpose/activity:** review advantages and disadvantages of the approaches being applied for the themes and identify gaps and needs for future assessments (e.g. capacity building, accessibility to data, harmonization etc.) for the theme. The working group will address the following questions: *1) Identify critical capacity building needs for the region to form the basis for a training program, a regional project or a recommendation on University/fishery courses should cover.* *2) Identify if possible, other approaches to assessing stocks e.g. small pelagics - better models or better methods, can indicator species be used for mixed stocks* *3) How do these assessments feed into management and do we need better communication on stock assessments to policy makers* **Prepare Powerpoint summary for each working group**.
15.30 – 16.00	**Afternoon tea**
16.00 - 17.00	**Plenary Session 6: Working Group presentations** (with on-line participants) Summary of findings from the working group Session 2 on Identifying gaps, needs and issues for stock assessment in Asia.
16.00-16.20	Multi-species demersal fisheries
16.20-16.40	Small-medium pelagic species (non-large tuna) fisheries
16.40-17.00	Coastal inshore fisheries, including reef fisheries
17.00	5 minute wrap-up for housekeeping (as working groups continue)
Day 3 (Wednesday January 25, 2023)	
08.30 – 9.30	**Plenary Session 7: Conclusions of the workshop to date** (with on-line participants) Discussion and overall conclusions from Working Group Sessions 1 and 2 from each of the three working groups
09.30 – 11.00	**Working group Session 3** *(offline - face-to-face participants only)* **Purpose/activity:** Theme for the working groups is "Future networking and capacity-building for enhancing stock assessment in Asia". 1. South Asia - Facilitators: Krishnan Pandian (Bay of Bengal IGO) , Rishi Sharma (FAO) and Sunil Mohammed (ex-CMFRI) 2. Southeast/East Asia- Facilitators: Supapong Pattarapongpan (SEAFDEC), Wily Campos, Zuozhi Chen (SCSFRI)
11.00 – 11.30	**Morning tea**
11.30 - 12.30	Working groups to prepare presentations for Final Plenary Session
12.30 – 13.30	**LUNCH**
13.30 -14.30	**Plenary Session 8: Working group presentations** (with on-line participants) Summary of findings on future networking.
14.00 -15.30	**Final plenary wrap up: Final conclusions and next steps (Online)**
15.30	**Closing**

ANNEX II - WORKING GROUP COMPOSITION

Group 1	Group 2	Group 3
Nearshore-demersal	**Multispecies**	**Pelagics**
Neil Loneragan	Derek Staples	Wilfredo Campos
Budy Wiryawan	Rishi Sharma	Ricky Amoroso
Mohammed Shriful Azam	Al Mamun	Indra Jaya
Ly Kunthy	Nipa Kulanujaree (Ms.)	Mohammed Shimal
Mohammed Ahusan	Chea Tharith	Sisira Haputhantri
Orawan Prasertsook (Ms.)	Sallehudin Jamon	T. Sathianandan
Irfan Yulianto	Sunil Mohammed	Eddie Allison
Dr. J. Jayasankar,	R. Jeyabaskaran	Melanie C. Villarao (Ms.)
Jose Ingles	Krishnan Pandian	Supapong Pattarapongpan
T. K. Sinesha Karunarathne (Ms.)	Pattaratjit Kaewnuratchadasorn (Ms.)	Effarina bt. Mohd. Faizal Abdullah (Mrs.)
Agustina, Siska	Suwanee Sayan (Ms.)	Weerapol Thitipongtrakul
Jalilur Rahman	Francisco Sb Torres, Jr.	Rian Prasetia

ANNEX III – LIST OF PARTICIPANTS

FAO regional workshop for a network of practitioners on fishery stock assessment

23-25 January 2023

List of participants (in-person)

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Sathianandan Thayyil Valappil

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