Multispecies Fisheries Best Practice Review

Consultancy Report

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This is a working paper, and hence it represents work in progress. This report is part of ongoing policy development.

The views and opinions expressed in parts of this report are those of stakeholders and do not necessarily reflect the official policy or position of the Marine Stewardship Council.

Executive Summary

A significant proportion of fisheries worldwide have a multispecies mixed character (Rindorf et al 2013). Alternative methods of stock assessment exist specifically for multispecies fisheries. Considerable progress is being made in these methods and groundbreaking new methods are available. Some progress has also occurred in management approaches since MSC last commissioned a review in 2015 (Nakamura 2015). Progress has been uneven and reflects a slow shift towards ecological risk assessment.

The results of this review suggest that, while hybridized approaches are typical in multispecies fisheries, where single and multiple species assessment models and harvest controls are combined, there is a major difference in how multispecies are managed compared to single target fisheries. Quite simply, catch targets and limits are intended to achieve wider objectives. In 2017, Rindorf et al. put forward a coupled notion that (a) setting catch targets and limits in multispecies fisheries should include all four of ecological, ecomomic, social and institutional considerations, and requires a collaborative framework (Rindorf et al., 2017a) and (b) integrating advice across stocks can support a 'Pretty Good Multispecies Yield' (Rindorf et al., 2017b). The two papers together sum the latest scientific thinking up nicely.

From a practical standpoint, however, there are large differences in how data are collected in multispecies fisheries and for what purposes when setting catches. For the MSC, alternative scoring raises several interesting questions like, what is success at management across stocks, if not exceeding biological reference point of MSY for all commercial stocks? Recent papers illustrate if not an archetype then positive case studies for setting catch limits and targets on the basis of interaction effects, ecological risk and wider objectives. Ecological risk management appears to be the leading goal, which will certainly affect scoring guideposts for management strategy, harvest control rules and stock assessment (indicators 1.2.1, 1.2.2, 1.2.4). Guideposts for stock assessment will need to change if to consider how the species indicators were chosen, if they are indicative of the species assemblage, and taken up in the management. Participatory processes appear to be a close second priority, affecting also Principle 3 scoring guideposts. Current guideposts are written generically but the specific ways stakeholders participate in setting and enforcing catches to achieve wanted versus unwanted outcomes will be key to discern (indicators for consultation, fishery specific objectives, monitoring and performance evaluation, 3.1.2, 3.2.1 and 3.2.4).

The review suggests that indicator species or 'index-species' approaches for stock assessment are being applied around the world in various ways and have promise for application in alternative scoring for the MSC Standard. In addition to the approach described by Newman et al. in 2018, Karr et al. (2021) have described a 'fish baskets' approach that uses participatory processes and data-limited assessments to define stock complexes that simplify multispecies management.

The review results suggest that, among other things, the selection of indicator species, and their monitoring, must be backed by participatory processes and ecological risk assessment. The management framework must be applicable to the choice of indicator species as well. Best practices are noted with considerations and implications.

Finally, a summary of current multispecies fisheries approaches and challenges in China, Malaysia, Thailand, India, Indonesia and Vietnam is given.

Background

The purpose of this review is to inform the MSC drafting process with a summary of current approaches in multispecies fisheries, especially changes since 2015 and application of new risk-based and index-species approaches. The Marine Stewardship Council has drafted an alternative scoring tree for Principle 1 for multispecies fisheries which would complement the current MSC Default Assessment Tree based on single-species, single-stock fisheries.

The review considered, in particular, whether the index-species approach described by Newman et al. (2018) could be widely applicable for assessment in multispecies fisheries. In the Newman et al. approach:

> 'Indicator' species are used to assess the risk to sustainability of all 'like' species susceptible to capture within a fishery resource. Indicator species are determined via information on their (1) inherent vulnerability, i.e. biological attributes; (2) risk to sustainability, i.e. stock status; and (3) management importance, i.e. commercial prominence, social and/or cultural amenity value of the resource. These attributes are used to determine an overall score for each species which is used to identify 'indicator' species. The risk status (i.e. current risk) of the indicator species then determines the risk-level for the biological sustainability of the entire fishery resource and thus the level of priority for management, monitoring, assessment and compliance (Newman et al., 2018).

Among the resources available to this review, four articles were exceptionally helpful and deserve notice. These include articles by Kritzer et al. (2022), Karr et al. (2021), Rindorf et al. (2017a), Rindorf et al. (2017b).

Items addressed in this review, from the Terms of Reference, include:

1. Overview of multispecies fisheries science and management from 2015-present
    a. Alternative methods of stock assessment specifically for multispecies fisheries (e.g., MMSY, aggregate assessments, EBFM)
    b. Management approaches adopted by multispecies fisheries management and how fisheries are using the indicator species approach (Newman et al 2018)
2. Considerations and implications
    a. In China, Vietnam, India, Thailand, Indonesia, and Malaysia
    b. Consultant's view of areas in the MSC standard where alternative scoring could be needed to be inclusive of best practices in multispecies fisheries

Best Practice

Alternative methods of stock assessment exist specifically for multispecies fisheries. Considerable progress is being made in these methods and groundbreaking new methods are available. Some progress has also occurred in management approaches since 2015 and, while uneven, reflects a slow shift towards ecological risk assessment.

Methods for stock assessment

Managing multi-species multi-gears fisheries requires a shift in focus from single species to multiple species outcomes. Multi-species management requires some level of data to be available, firstly in order to characterise the fisheries and species impacted and its level of impact, and secondly to determine if there is any change occurring. Therefore the fisheries need to be monitored to some level, either by having basic information about the biology of the species and functioning of the fishery, to having a comprehensive monitoring programme. The data available may however condition the approach taken to evaluate the species status and the level of impact of the fishery. In this context, there are several methods to assess indicator species/stock status, depending on its data requirements and its complexity (based mainly on Kritzer et al., 2022):

1. Productivity-Susceptibility Analysis (PSA) – only basic biological data is used to score the risk of species and/or stocks being below a certain threshold (ex Australia Southern and Eastern scalefish & shark fishery: shark gillnet, Sporcic et al., 2021).
2. Aggregated Production models – aggregated catch data over species and/or stocks and abundance indexes over several species (catch or swept area abundance surveys or CPUEs) are used to estimate the status of the aggregated species (Indonesian lobster, Tirtadanu et al., 2022).
3. Multi-Species Production models – species and/or stocks catch data per fishery and survey index are used to estimate the status of the species and/or stocks which are linked by technical (fisheries interactions) and trophic connections (coral reef species, McClanahan, 2022).
4. Length-Age Structured models – are used in combination with index surveys to estimate species/stocks status in relation to reference points of indicators species (eg. North Sea sole, ICES, 2021a).
5. Length-Age Structured models with Ecosystem Aspects – are used in combination with index surveys to estimate species/stocks status in relation to reference points of indicators species, but considering ecosystem aspects in some features of the assessment. An example is the estimation of natural mortality based on a predation model (e.g. Baltic Sea sprat, ICES, 2021b or North Sea cod, ICES, 2021c).
6. Management Strategy Evaluation – the stock assessment is based on length-age structured models with or without ecosystem aspects, but the evaluation of the harvest control rules (HCR) is done within the MSE (e.g. North Atlantic albacore tuna, Merino et al., 2017).
7. Ecosystem Assessment models – where predator - prey abundance is explicitly considered in the stock assessment model and an MSE is used to evaluate the HCR (USA Atlantic herring, Townsend et al., 2019)
8. Multispecies Size-based models – it is a multispecies size-spectrum models of fish communities and fisheries, using data on growth, consumption, mortality and a time series of fishing pressure (Mizer R package, e.g. coastal ecosystem of the North Yellow Sea, China, Wo et al., 2020 and coral reef fisheries, Carvalho & Humphries, 2022).

9. Models of Intermediate Complexity for Ecosystem assessments (MICE) - models that have structural complexity intermediate between single-species and end-to-end ecosystem models, and estimate population parameters for a subset of key interacting species from time-series of data while accounting for spatial variation (Gulf of Alaska, Thorson et al., 2019 or Gulf of Carpentaria, Australia, Plagányi et al., 2022).
10. Ecosystem models – where mainly trophic connections are studied and fisheries impact on trophic dynamics are specifically considered (e.g. Ecopath with Ecosim – EwE, Portuguese sardine, Szalaj et al., 2022).
11. Ecosystem Frameworks – where species (or aggregate) stock assessments are used first to estimate target fishing mortalities (Fs), then an ecosystem model rescales the target Fs according to ecosystem indicators, and then the stock assessment model computes management advice based on the rescaled target F (called F_{eco}, ex. Irish Sea, Howell et al., 2021).
12. Ensemble modelling - running multiple independent models of the same system and synthesizing the results into a single outcome with uncertainty spread, where e.g. multispecies MSY (MMSY) were calculated based on EwE, Mizer and other models for the North Sea (Spence et al., 2020) or several MICEs for the Gulf of Carpentaria, Australia (Plagányi et al., 2022).

The more simple models have been widely adopted, for example PSAs, aggregated or multispecies size-based models, as well as ecosystem modeling (ECOPATH and ECOSIM). The newer approach is ensemble modelling, where different models are combined into a single result. It has been used extensively to study climate change impacts.. All approaches have different advantages and some encompass different models, simple to complex, because they answer different questions. None are obsolete. All of the ecosystem models work on the basis of total catch either by species or aggregated species, and include discards.

The choice of model in a fishery may depend on the available information, the management objective, resources available, and other factors. Nevertheless, regardless of the final model chosen, multiple models should still be applied and the results, either in biomass or fishing mortality estimates or in the management action predictions, be compared (Duncan Leadbitter, personal communication, 2022).

Management Approaches

Management approaches in multispecies fisheries vary with what is being monitored and why, how much data are captured, how it is combined to arrive at fishery rules, and how the industry complies. Although few multispecies fisheries appear to be managed primarily with an ecosystem approach, there are indications that more are shifting away from combining single species assessments toward managing a ‘stock complex’ for indicative outcomes for ecological risk.

On the basis of thirteen case studies, Kritzer et al. (2022) recently depicted four general models for managing multispecies fisheries as seen in the world today (Figure 1), including hybrid approaches.

Figure 1: Generalized spectrum of multispecies fishery management strategies by Kritzer et al. (2022) and reference fisheries:

Aggregated species models + multispecies harvest controls Data: Limited; likely aggregate catch or surveys enabling simple biomass indices Value: Low; indiscriminate fishery with high non-target but retained bycatch Status: Uncertain; possibly poor depending upon history & effort of the fishery Management: Capacity limitations (e.g., monitoring) necessitates aggregate measures Industry: Fleet and/or markets do not target or discriminate species	Western Europe slope deep sea sharks, Thailand trawl, the China Fujian swimming crab TAC pilot, and the deep-water sharks sub-fishery in the Southeast Australia shark and scale-fish fishery
Single-species scientific models + multispecies harvest controls Data: Moderate; species discerned in catch with surveys and/or life history data Value: Increasing; new markets, possibly differentiated, are developing Status: Concerns; aggregate approach does not attend to decline of some species Management: Limited capacity & aggregate measures remain despite data resolution Industry: Fishing might not discriminate species, although markets might	New England skates, North Sea skates and rays, Northern Australia prawn, Canada groundfish, Northwest Australia reef fish, and the scorpaenid sub-fishery in the Southeast Australia shark and scale-fish fishery
Single-species scientific models + single-species harvest controls Data: Rich; catch-at-age & other sources enable analytical assessments Value: High; targeted catch for specialized or high-volume commodity markets Status: Mixed; reference points reveal positive & negative status within complexes Management: Capacity improves enabling species-specific TACs & other measures Industry: Fishing & markets discriminate species; could face ‘weak stock’ challenges	New England groundfish, North Sea groundfish, and the sub-fishery for most finfish species in the Southeast Australia shark and scale-fish fishery
Multispecies scientific models + single-species harvest controls Data: Very rich; trophic, habitat & other data enable use of ecosystem models Value: Very high; economic importance motivates higher resolution science Status: Mixed; consideration of species interactions due to poor status of some Management: Value & conflicts → focus on trade-offs & scrutiny by improved monitoring Industry: Contentious interactions with other fleets & users affected by same species	USA New England Atlantic herring fishery only

The defining feature of management approaches in multispecies fishery is responsiveness to interaction effects among species impacted by fishing or due to predation, climate, market drivers and other factors, but always considering ecological risk to the assemblage. This means that alternative P1 scoring will need to consider how ecological risk is measured and how it is mitigated by the harvest strategy and rules.

Theoretically, there are two main approaches for reducing the risk of serial depletion for multispecies fisheries. The first is setting catch limits for each of the species that are caught by the fishery individually (Hilborn, 2017). Then there are individual species MSY which may be combined into MMSY, although no consensus on how this should be done because models vary widely (Spence et al., 2020). This could change as more fisheries scientists experiment with the new ensemble approaches for stock assessment (Spence et al., 2020). The second approach is for managing the fishery as a stock complex that is accountable to the ecological limits for each species; as a stock complex (Karr et al., 2021), for example in the Yucatan grouper stock complex, or with a single aggregated catch limit (Kritzer et al., 2021), for example in the Fujian complex of four swimming crab species.

Both approaches aim for a 'pretty good multispecies yield' (PGMY) (Rindorf et al., 2017b) but the second approach pushes the fisheries management further towards a pretty good multidimensional yield to accommodate situations where the yield from a stock affects the ecosystem, economic and social benefits, or sustainability (Rindorf et al, 2017a). In a follow-on paper, Rindorf et al. emphasized that a collaborative management framework is essential to achieving PGMY (Rindorf et al., 2017b).

In practice, the main difference in how multispecies fisheries are managed differently from single species fisheries has to do with setting catch targets and limits to achieve wider objectives. The latest scientific thinking on best practice is that all four of ecological, economic, social, and institutional considerations are needed when setting targets and limits for multispecies fisheries (Rindorf et al., 2017a). Options for applying wide objectives in multispecies stock models are expanding considerably with new assessment methods that are ecosystem-based, like the MICE method (Plagányi et al., 2022). However, the management framework must be applicable and accountable to the results with the needed capabilities to adjust fishing decisions to maintain multiple species-specific outcomes within agreed thresholds.

Data considerations

At one end of the fisheries diversity spectrum, where data are good and availability is excellent for numerous impacted species, a small group of multispecies fisheries are managed with catch rates that are adjusted as the individual species/stocks statuses change. Within this small group of fisheries, some fishery scientists are even recombining stock assessment methods as fishery conditions change in what is known as a portfolio approach, for example in Australia's multispecies shark fisheries (Braccini et al., 2021).

At the other end of the spectrum, not a lot of data are available to evenly monitor the status of multiple species impacted by the fishery but catch rates are adjusted when various indicators of resource status point to wanted or unwanted outcomes, including ecological risk. This group is far bigger and includes a range of multispecies fisheries like Thailand's trawl fishery characterized by full retention of highly diverse catches that are harvested using unselective gears, and where an aggregate TAC considers the co-dependent status of demersal, pelagic and anchovy species (Kulanujaree et al., 2020), as well as like Australia's Northern Prawn Fishery characterized by a five stocks model with very high discards, where fishing pressure is exerted or released on some species over others as statuses change or as conditions change like climate and pricing (Rindorf et al., 2017a). In these fisheries, stakeholder engagement and agreement on objectives and targets compensates in part for data limitations.

In the middle are stock complexes like grouper or groundfish where management is 'weak' or 'strong' depending on laws and/or policies for ecosystem-based stock assesments and collaborative management.

Regarding the specific case of European fisheries, the current state of fisheries management illustrates the need not only for species-specific data but also stakeholder accountability to fishery decisions. Europe has numerous multispecies fisheries and, in the 2015 review, there had been signs that stocks would be assessed with new, combined approaches set in a regional context. There had been hope that the consequences of interaction effects would be managed at last with Europe's discard ban (also known as the landing obligation), but these have not materialised. Despite TACs being increased in average by 30% in Europe annually for all species, to account for the unwanted catch that would be landed following the discard ban, catches are not yet being monitored and controlled. Progress has also not been made to widen stock assessment considerations to include the status of any bycatch species, and management continues without good data for 'bycatch' and discarded species to consider interaction effects. In addition, quota disparities within species in a multispecies fishery have likely increased the incentive for discarding (Lisa Borges, personal communication, 2022; citation forthcoming).

Overall, the literature on best practices in multispecies fisheries since 2015 suggests that stakeholder acountability to ecological risk assessments in a multispecies fishery might be a more limiting factor for 'Pretty Good Multispecies Yield' management than data. In contrast to Europe's highly competitive multispecies fisheries, other competitive fisheries with less resources and data have adopted catch limits for sustaining a multispecies aggregate, like the Thai trawl fishery. Based on a Fox production model for all species aggregated, the total fishing days that are allowable to catch 80% of a multispecies MSY is estimated, which are then allocated among vessels (Kritzer et al., 2022). The multispecies MSY includes and combines pelagic (including anchovy) and demersalstocks.

MSC Standard considerations and implications

To apply alternative scoring to a multispecies fishery, in Principle 1 scoring it would be necessary to measure the degree to which catch limits and targets are set within a management framework for mitigating ecological risk. In Principle 3 scoring it would be necessary to measure the degree to which catch limits and targets are set also within a management framework for achieving a balance of ecologic, economic, social, and institutional objectives. Furthermore, it would be necessary to measure how wider objectives are built into the harvest strategy explicitly, again in P1.

Ecological risk management appears to be the leading goal, which will certainly affect scoring guideposts for management strategy, harvest control rules and stock assessment (indicators 1.2.1, 1.2.2, 1.2.4). Guideposts for stock assessment will need to change if to consider how the species indicators were chosen, if they are indicative of the species assemblage, and taken up in the management. Participatory processes appear to be a close second priority, affecting also Principle 3 scoring guideposts. Current guideposts are written generically but the specific ways stakeholders participate in setting and enforcing catches to achieve wanted versus unwanted outcomes will be key to discern (indicators for consultation, fishery specific objectives, monitoring and performance evaluation, 3.1.2, 3.2.1 and 3.2.4).

To apply alternative scoring to a multispecies fishery in the manner described by Newman et al. (2018), which is narrower in scope than advised by Rindorf et al. (2017a) for achieving a 'Pretty Good Multispecies Yield' (Rindorf et al. 201b), the fishery must either be managed within an ecological risk framework already, like Australia's Commonwealth fisheries, or else a preliminary risk-based ecological assessment would be required to select an indicator species in a transparent process.

The implications of the Newman et al. (2018) approach for the MSC Standard and program will depend on how the selection of indicator species drives the direction of catch trends toward wanted and away from unwanted outcomes. There is much debate about species selection in multispecies fisheries when it comes to which species status(es) will lead catch decisions most, and particularly about managing for 'choke' species (McQuaw and Hilborn, 2020; Mortensen et al., 2018). This debate appears to divide stakeholders down the middle with everyone feeling poorly (choke species are viewed both as ecologically catastrophic and as leaving too many fish in the water). This debate has implications for how the MSC intends to clarify the criteria for a sustainable multispecies fishery.

Here, the key concept of 'Management Determining Species' is particularly important for the scientific management and assessment of multispecies fisheries. These are individual species, or groups of species, that are key to the operation of the fishery and are usually optimally managed both individually and within an aggregated context in order to achieve wanted outcomes and avoid unwanted outcomes (Duncan Leadbitter, personal communication, 2022). Before alternative scoring could be utilized, in the manner of Newman et al. (2018), the MSC would likely need a process to confirm the selection criteria of index-species, specifically:

1. Does the fishery have decent knowledge of total fishing mortality?
2. Has an index-species been selected in a transparent process with justification?
3. Is the fishery managed on the basis of ecological risk, or is there a supportive context for it?
4. Does the fishery have risk-based harvest controls?
5. Does the fishery have species-specific harvest controls for commercial and bycatch species?
6. Who selected the indicator species and for what objectives?
7. Is the fishery managed to maximize the sustainability of the multiple target species, or is it managed to avoid population collapse (MSY vs PRI basis)?

The suitability of the Newman et al. (2018) is pretty good if it is applicable to the management framework that exists in a candidate fishery. While theoretically an indicator species can be selected in an independent assessment, the possibilities of mis-selection and biased results could be high, for example where it is not indicative of ecological risk for the assemblage or where the catch decisions are not based on the status of that species. Selection issues include, and are not limited to: (1) data availability, for example by choosing a commercial species instead of a bycatch species with less data available, (2) charisma, for example by choosing a charismatic or protected species instead of a predator or prey species whose status is critical to sustaining the food web, or (3) trade advantage, for example by choosing a species that is more important to the certificate holder's business at the time of selection instead of a less valuable species playing a relatively larger ecological role.

Country Analysis

In this section, we check the standing of multispecies fisheries approaches in China, Malaysia, Thailand, India, Indonesia and Vietnam.

China

P1: Specific attention is beginning to be paid to catch volume controls for the first time in Chinese fisheries (Kritzer et al., 2022). This follows from an objective to improve catch traceability in China's 13th Five Year Plan (2016-2020) (Cao et al., 2017). Chinese trawl fisheries are still managed primarily with input controls intended to limit the fishing effort, like limited entry. However, fishery managers are being encouraged to try different approaches through pilot projects in Shandong and Zhenjiang.

China launched pilot projects in management by Total Allowable Catch (TAC) in five coastal provinces in 2017 and 2018 to build experience with output controls and stronger engagement with coastal communities. The pilot launched in Fujian province for its swimming crab fishery was the first multispecies approach with a combined multispecies TAC. The fishery is closed when fishing reaches 95% of the multispecies TAC (Boenish et al., 2021).

P3 China hosted an international workshop on approaches for multispecies fisheries in 2021 reflecting China's current 14th Five Year Plan and emphasizing participatory approaches. Building institutional capacity in a collaborative manner among different levels of government, affected industries, technical experts, and other stakeholders is a key objective of pilot projects in China (Kuhn et al, 2016 in Kritzer, 2022). With its modest number of species with similar and productive life history traits, and having a similar market demand for all species, the multispecies TAC Fujian swimming crab fishery can be governed with large input from a relatively small number of stakeholders. Crabs caught by gillnets and especially trawls, on the other hand, would likely experience lower survival rates, which would limit the effectiveness of management by multispecies TACs if management and market factors increased targeting, high-grading, and discarding from those gears (Kritzer et al 2020 in Kritzer et al, 2022). These factors underscore the importance of effective at-sea monitoring in the implementation of TAC management to ensure that all catch is accounted for, and also to improve scientific assessments and shape fishing behavior.

Malaysia

P1: Malaysia's tropical location in the Coral Triangle means that its fisheries are multispecies with diverse catches. Harlyan et al. (2021) concluded that it is likely impractical to manage species individually with a single-species quota system for management of a multispecies purse seine fishery off the East Coast of Peninsular Malaysia after they could not find or discern any specific spatial or temporal patterns structuring the fishing grounds used by purse-seiners after an individual quota system was introduced. This is corroborated in a comparative study of SE Asian purse seine fisheries by Saleh et al. (2020) for SEAFDEC. The fisheries were compared based on assessment findings from a Fox Production Model using scarce data from Malaysia and noting that it's fishery MSY was exceeded already in 2014.

P3: Performance is suboptimal in Malaysia's multispecies trawl fisheries in the Straits of Malacca, according to Wong and Young (2020), due to limited knowledge of the distribution patterns of fish assemblages combined with a top-down management approach and generalist enforcement.

Thailand

P1: The MMSY assessment for Thailand's trawl fishery was conducted for three species groups: demersal fishes, pelagic fishes, and anchovies and combined for an aggregated Total Allowable Catch (TAC), as described above. This fishery does not have perfect species data but interaction effects are increasingly considered in its management decisions. In Thailand, MMSY was used as a reference point for management, while TAC was converted to the total allowable effort (TAE) to stipulate the fishing effort and allocate the resources for individual fishing vessels. The Department of Fisheries expects to eliminate unauthorized fishing by implementing the new license procedure to manage the Thai fishing vessels but its approach is also expanding from one based purely on input controls (2015-2020) to one that includes output controls (since 2020). In essence, the Thai multispecies fisheries are in transition from poorly unregulated (pre-2015) to regulated (See Figure 2).

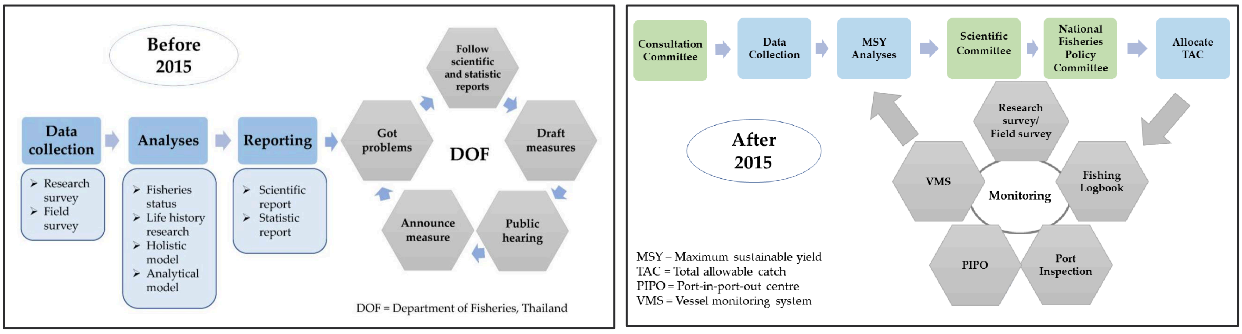

Figure 2: Thailand multispecies fisheries management before (left) and after (right) 2015, transition from unregulated to regulated. Source: Kulanujaree et al., 2020

P3: Industry consultation is influential in fisheries management in early stages of management in Thailand as illustrated in Figure 2. Legislative changes in Thailand also promote the participation of all stakeholders in the management and conservation of aquatic animal resources.

India

P1: By digitizing and categorizing many years of fishery catch data in Kerala, from the national CMFRI database, Varghese et al. (2021) recently derived guidelines for determining the number of species for which stock assessment is to be carried out in the context of a multigear and multispecies fisheries sector. This national-level database will be very useful to policy makers for preparing fisheries management plans for the sustainable harvest of marine fishery resources. It additionally provides an empirical basis for the identification of stock complexes or indicator species. Using 3132 records for 644 fish stocks along the coast of India, Mohamed et al. (2021) have calculated resilience (R) and vulnerability (V) for 133 tropical marine finfish, crustacean and mollusc species. Mini et al (2016) evaluated a multispecies marine fishery in West Bengal, India using diversity indices. Initially, they planned to use threshold values based on biological reference points to define the extinction risk of marine fishes (per Musick, 1999 for temperate fishes). However they changed course after realizing the values may not be consistent within all productivity estimates because of the great diversity in life-history strategies among fishes. Instead, different threshold values appropriate for tropical stocks were identified and used for siFISH analysis. They added three modifications to the siFISH analysis. Species coverage was increased to 133 including the 98 species covered for siFISH assessment; (ii) data coverage was extended from the period 1985–2008 to 1954–2015, and (iii) method of analysis was revised to calculate resilience (R) and vulnerability (V) and further to develop an Index of Resilience and Vulnerability (IRV).They then calculated a Simpson's index and Shannon's index from the season-wise estimated marine fish landings for the period 2007-2010 in order to assess the diversity.

P3: Dr.s Beth Fulton and Keith Sainsbury lead a Lensfest project to develop ecosystem based indicators for managing multispecies off the Southwest coast of India. The selection of indicators is being made collaboratively with managers and policy makers and the major management objectives are food security, employment and sustainability. No publications yet.

Indonesia

P1: The results from a decade of monitoring Indo-Pacific multispecies grouper assemblages in Indonesian waters by Sadovy de Mitcheson et al. (2020) highlighted a need for caution when fish density is used as a proxy for abundance in studies when entire aggregations cannot be surveyed, because the two measures may not be correlated at higher abundances. Monitoring the numbers of individuals/unit area by the acoustic method, like a underwater visual census, is one of 32 indicators within Indonesia’s EAFM Assessment Guidelines methodology and specific to reef fishes and invertebrates. The methodology has six domains: Fisheries Resources, Habitat and Ecosystems, Fishing Technology, Social, Economy, and Governance, with 32 indicators. The Fisheries Resources Domain indicators are CPUE, fish size, proportion of juveniles caught, species composition, ETP species, range collapse, and density/biomass for reef fish and invertebrates.

P3: Indonesia is one of the largest exporters of groupers. In an analysis of trade contributions to declining grouper populations, Khasanah et al. (2019) have pointed to a need for better oversight of vessel activity to control the trade, especially exports. To maintain viable stocks, they said, industry collaboration with government is essential to safeguard adequate spawning capacity and reduce the illegal fishing methods (particularly potassium cyanide and compressor diving).

Vietnam

P1: Species groups have been defined with individual species assessments and scientific surveys in southern Vietnam but data contributions are relatively weak from the commercial fishery (Duncan Leadbitter, personal communication, 2022). This is being trialled in a Fishmeal Fishery Improvement Project registered with Marin Trust. Trends in indicator groups of species and the individual species can be assessed from the survey monitoring data and management decisions for the fishery could be driven by trends.

P3: In 2017 the Vietnamese government signed into law measures designed to institutionalize co-management in Vietnamese fisheries.

Conclusions

Based on this review, catches in multispecies fisheries are managed for wider objectives than in single species fisheries especially for mitigating ecological risk and achieving a balance of ecologic, economic, social, and institutional objectives. For Principle 1 scoring to reflect this, it would be necessary to measure how ecological risk assessment is built into harvest control rules and how wider objectives are built into the harvest strategy explicitly. Principle 3 scoring would necessarily measure the degree to which catch limits and targets are set also within a management framework for achieving a balance of ecologic, economic, social, and institutional objectives.

The implications of the Newman et al. (2018) approach for the MSC Standard and program will depend on how the selection of indicator species drives the direction of catch trends toward wanted and away from unwanted outcomes. The approach described by Newman et al. (2018) is narrower in scope than advised by Rindorf et al. (2017a) for achieving a 'Pretty Good Multispecies Yield' (Rindorf et al. 201b), the fishery must either be managed within an ecological risk framework already, like Australia's Commonwealth fisheries, or else a preliminary risk-based ecological assessment would be required to select an indicator species in a transparent process.

Options for applying wide objectives in multispecies stock models are expanding considerably with new assessment methods that are ecosystem-based, like the MICE method (Plagányi et al., 2022). However, the management framework must be applicable and accountable to the results with the needed capabilities to adjust fishing decisions to maintain multiple species-specific outcomes within agreed thresholds. The catch rates in fisheries managed with the 'fish baskets' approach described by Karr et al. (2021) derive from participatory processes and ecological risk assesment. This may be the best available benchmark for defining stock complexes that simplify multispecies management. At this time it reflects a much larger group of multispecies fisheries, based on the country considerations for Thailand, India, Indonesia, Malaysia and Vietnam.

In conducting an update to the 2015 review, four key articles provide rigorous scientific thinking on sustainable multispecies fisheries that will certainly be helpful for MSC in developing an alternative scoring concept. The most recent is the 2022 *Aquaculture and Fisheries* paper on advancing multispecies fishery management in China that was written by Kritzer et al. and depicts a generalized view of management approaches based on thirteen international case studies. The October, 2021 paper by Karr et al. in *Frontiers in Marine Science* provides a conceptual framework for multispecies fisheries management called a 'Fish Baskets' approach. It is a risk-based index-species approach that is drawn from, and intended to be suitable for, fisheries with diverse data, governance and management resources. The coupled 2017 papers by Rindorf et al. in the *ICES Journal of Marine Science* describes how ecological, economic, social and institutional considerations are to be included when setting catch targets and limits in multispecies fisheries (Rindorf et al., 2017a) and can be combined for a 'Pretty Good Yield' concept by Rindorf et al. (2017b).

More than a 'nice to have', Rindorf et al. (2017a) have emphasized that a collaborative management framework is required in multispecies where stakeholders are required to respect wide objectives. That is because catch rules based on biological criteria alone are challenged continuously in fisheries by competition for short-term gains, which undermines risk mitigation; like in Europe, where TACs were raised 30% in anticipation of a discards ban that failed to materialize because it is not enforced.

In conclusion, alternative scoring to the MSC Standard in multispecies fisheries will necessarily require alternative indicators for Principle 1 and Principle 3.

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