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GLOBAL BLUE SHARK MANAGEMENT STRATEGY EVALUATION - WORKSHOP REPORT

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[1] Food and Agriculture Organization of the United Nations

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WORKSHOP REPORT

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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CONTENTS

ABBREVIATIONS

CMM	conservation and management measure
CPUE	catch per unit effort
CMP	candidate management procedure
HCR	harvest control rule
IATTC	Inter-American Tropical Tuna Commission
ICCAT	International Commission for the Conservation of Atlantic Tunas
IOTC	Indian Ocean Tuna Commission
LRP	limit reference point
MO	management objective
MP	management procedure
MSE	management strategy evaluation
OM	operating model
PI	performance indicator
RCM	rapid conditioning model
RFMO	regional fisheries management organization
RP	reference point
TAC	total allowable catch
TRP	target reference point
WCPFC	Western and Central Pacific Fisheries Commission

EXECUTIVE SUMMARY

The Workshop on Global Blue Shark management strategy evaluation (MSE) (Harveststrategies.org, 2025a) took place in Rome, Italy, from 14 to 16 October 2025. The three-day event gathered 24 attendees, including leading experts in MSE and blue shark (*Prionace glauca*) science. The primary objective of the workshop was to advance progress towards sustainable and responsive management procedures (MPs), also known as harvest strategies (Harveststrategies.org, 2025b), for highly valuable blue shark stocks worldwide.

The highly migratory and transboundary nature of blue sharks complicates management approaches and requires dedicated efforts across multiple regional fisheries management organizations (RFMOs). Despite high economic and ecological value globally, blue sharks are not as well managed as other high-value species. Current management, where it exists, depends on stock assessments that are frequently constrained by data limitations and other sources of uncertainty. While many regions have implemented finning bans and gear restrictions, few have direct fishery controls such as catch limits; only the Atlantic Ocean blue shark stocks, managed by the International Commission for the Conservation of Atlantic Tunas (ICCAT, n.d. [a]), currently enforces catch limits for blue shark.

To advance the sustainable management of global blue shark stocks, this workshop featured cross-RFMO collaboration, examining key challenges and feasible pathways for the development of MSE-tested MPs that are robust to key uncertainties. Experts in attendance included representatives from all tuna RFMOs that oversee blue shark stocks, including the ICCAT, the Inter-American Tropical Tuna Commission (IATTC, 2022–2025), the Western and Central Pacific Fisheries Commission (WCPFC, 2025a), and the Indian Ocean Tuna Commission (IOTC, n.d.).

Key workshop outcomes included knowledge sharing between regions, increased familiarity with the MSE process, and the development of preliminary MSE operating models (OMs) and hypothetical candidate management procedures (CMPs) in the openMSE modelling framework for five blue shark stocks. This marks a significant, collaborative step towards robust, science-based global management.

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INTRODUCTION

Blue sharks are of high economic and ecological importance, representing roughly 60 percent of all reported shark catches globally and valued at over USD 400 million in 2019 (Oceana, 2022). Their highly migratory nature and transboundary movements complicate management, requiring cooperation among member nations within regional fisheries management organizations (RFMOs) and among the multiple RFMOs that oversee blue shark stocks, including the IATTC, WCPFC, ICCAT and IOTC. Despite their high economic value, direct fishery control measures are rare; only the North and South Atlantic stocks managed under ICCAT currently implement catch limits (see Table 1). Additionally, traditional stock assessments for blue shark are often hampered by data limitations and biological uncertainties.

Table 1. A list of global blue shark stocks, indicating the RFMO overseeing each stock's management and whether catch limits have been adopted

Blue shark stock	Associated RFMO	Catch limits in place (Y/N)
North Atlantic	ICCAT	Y
South Atlantic	ICCAT	Y
Mediterranean	ICCAT	N
Indian	IOTC	N
North Pacific	WCPFC/IATTC	N
Southwest Pacific	WCPFC/IATTC	N
Southeast Pacific	WCPFC/IATTC	N

Management strategy evaluation (MSE) is a simulation-based framework used to test how well different candidate management procedures (MPs), also known as harvest strategies, perform under key system uncertainties, including uncertainties in data, stock dynamics, observation error, and implementation error (Harveststrategies.org, 2025b). An MP is a pre-defined process, typically including data collection and processing methods, and a harvest control rule (HCR) that specifies a management action based on the processed data. The HCR may be empirical (e.g. a total allowable catch [TAC] is determined directly from standardized catch per unit effort [CPUE] indices) or model-based (e.g. a TAC is determined from a stock assessment model integrating catch data and standardized CPUE indices).

Evaluating the simulated performance of multiple MSE-tested MPs enables scientists, managers and stakeholders to identify strategies that are most likely to achieve management objectives (MOs) and are most robust to uncertainties. Developing and applying MSE-tested MPs is therefore a positive step towards the responsible and adaptive management of blue shark stocks.

The Workshop on Global Blue Shark MSE took place in Rome, Italy, over three days in October 2025. It facilitated critical knowledge exchange on the current status of regional blue shark assessment and management, highlighted common scientific and management challenges, and provided intensive, hands-on training using the openMSE software framework (Blue Matter Science, 2023). The workshop agenda is included in Appendix 1. Scientists from all four of the tuna RFMOs that manage fisheries catching blue shark attended, including stock assessment analysts for five blue shark stocks (North/South Atlantic, Indian, and Southwest/Southeast Pacific Oceans). The lead analyst for the most recent North Pacific stock assessment contributed presentation materials to the workshop. The list of workshop participants is provided in Appendix 2.

WORKSHOP OBJECTIVES

This workshop was designed to progress efforts towards the sustainable management of blue shark populations by gathering experts from around the world to explore potential collaborations and brainstorm challenges and feasible solutions to developing and implementing MSE-tested MPs for global blue shark stocks.

Common goals identified by the attendees at the start of the workshop included:

- facilitating inter-RFMO knowledge sharing on blue shark-specific assessment and management processes and common issues;
- improving technical proficiency with the MSE process, including the modelling process with openMSE;
- enhancing the ability to communicate complex MSE concepts effectively to managers and stakeholders; and
- making progress toward existing MSE mandates for blue shark at ICCAT and IOTC.

SECTION 1

THE CURRENT STATE OF REGIONAL BLUE SHARK SCIENCE AND MANAGEMENT

A review of the current science, including stock status derived from assessments, and existing management measures across regions highlighted both progress and shared issues.

1.1 ATLANTIC OCEAN (ICCAT)

A summary of existing blue shark management in the Atlantic Ocean was provided by Dr Rodrigo Sant'Ana. Blue sharks in the Atlantic are assessed for the north and south stock areas. Between 2021 and 2024, the average annual catch was approximately 23 000 tonnes in the North and 30 000 tonnes in the South. The most recent stock assessments (ICCAT, 2023a) concluded that the North Atlantic stock was not overfished nor undergoing overfishing, while the South Atlantic stock was not overfished but subject to overfishing. ICCAT has established TACs for both stocks under Recommendations 23-10 (ICCAT, 2023b) and 23-11 (ICCAT, 2023c), namely 30 000 tonnes for the North stock and 27 711 tonnes for the South stock. Recommendations 23-10 and 23-11 also call for ICCAT's scientific body, the Standing Committee on Research and Statistics (ICCAT, n.d. [b]), to deliver a feasibility study and roadmap for developing a blue shark MSE framework, including candidate harvest control rules and reference points, by 2025. Because the Mediterranean blue shark stock currently lacks sufficient data for assessment or management, it was not modelled at the workshop. The next stock assessment for the North and South Atlantic stocks is not yet scheduled.

1.2 PACIFIC OCEAN (WCPFC/IATTC)

On behalf of Dr Michael Kinney (National Oceanic and Atmospheric Administration), Dr Shuya Nakatsuka gave a presentation on current blue shark management in the North Pacific Ocean. In the North Pacific, the stock remains in the green quadrant of the Kobe matrix, with a 62 percent probability of being neither overfished nor undergoing overfishing, according to the most recent 2022 assessment (ISC, 2022). However, it was noted that uncertainty in stock status in the current assessment is likely underestimated, as the model ensemble did not account for key sources of uncertainty such as natural mortality or the stock-recruitment function, which remain poorly understood for many shark species. Future research needs include improving historical catch reconstruction and improving data for key biological processes for better life history parameter estimation. The next assessment is scheduled for 2027.

Dr Phil Neubauer presented a summary of the current status of blue shark management in the Southwest Pacific Ocean. The Southwest Pacific stock was also found not to be overfished nor undergoing overfishing in the most recent 2021 stock assessment (WCPFC, 2021). Fishing mortality has declined over the past decade and remained low as many sharks are released upon capture in longline fleets. Blue sharks are caught widely across the Southwest Pacific and are thought to comprise a single stock, and the current assessment model covers only the WCPFC area south of the equator where blue sharks are mainly taken as bycatch in tuna and swordfish fisheries. Highest catches (by numbers) occur around New Zealand and Tasmania, where most landings are juveniles and small individuals. Data limitations persist due to the absence of species-specific observer data before 2010 and short catch time series, resulting in high uncertainty prior to 1995. Unreported catches and discards add further uncertainty, particularly in catch per unit effort (CPUE) indices. Suggestions for further research include developing dynamic reference points (e.g. relative to the unfished spawning biomass (SBF=0), expanding tagging and growth studies, and improving historical catch reconstructions. The next assessment is planned to commence in 2027.

The first assessment for Southeast Pacific blue shark stock is planned for the next triennial by the IATTC and the CPPS (Permanent Commission for the South Pacific). The IATTC recognizes blue shark as one of the shark priority species for research and management (IATTC Resolution C-25-08).

There are no specific measures for blue shark implemented in either Pacific RFMO (WCPFC or IATTC). WCPFC's conservation and management measure (CMM) 2024-05 prohibits the retention of oceanic whitetip and silky sharks but does not set specific catch limits for blue shark (WCPFC, 2025b). The measure only requires full utilization with fins naturally attached, and includes some gear restrictions such as a prohibition on shark lines and wire traces to reduce shark bycatch in tuna and billfish fisheries. IATTC Resolution C-25-08 also requires full utilization with fins naturally attached, establishes best handling practices, and calls for further development of a shark research plan by the IATTC staff including timelines and financial considerations for stock assessments, ecological risk assessments, and recommended management strategy evaluations.

1.3 INDIAN OCEAN (IOTC)

Dr Dan Fu discussed the current state of blue shark management in the Indian Ocean. Blue sharks in the Indian Ocean are managed as bycatch under the Working Party on Ecosystems and Bycatch (IOTC, n.d. [b]). The most recent stock assessment (IOTC, 2025a) indicates that the stock is neither overfished nor undergoing overfishing. Recent average annual catches are estimated at around 24 000 tonnes. However, he highlighted that catch estimates remain highly uncertain due to poor data resolution (e.g. catches aggregated as "shark"), sparse discard data, processing error at a national level (e.g. dressed versus live weight, finning), and limited spatial and size-frequency information. Many shark species are still not reported at the species level or across all gears, though overall reporting quality has improved, and blue shark continues to represent the majority of recorded shark catches.

Resolution 18/02 tasked the Scientific Committee with developing candidate limit and target reference points for sharks (IOTC, 2018) and has since been superseded by Resolution 25/08, which includes a retention ban for thresher and whale sharks, best handling practices, full utilization and fins naturally attached requirements, mitigation measures (including a ban on shark lines and wire traces depending on the areas of operation from 2026), and a shark research plan to address key data and knowledge gaps (IOTC, 2025b). While there is currently no catch limit for blue shark, the Commission will consider a blue shark-specific CMM in 2026 to include a TAC and potential catch limits by contracting parties. Additionally, in 2024, the IOTC requested the Scientific Committee to initiate an MSE for blue shark to support the development of an MP, which was formalized under Resolution 25/08.

SECTION 2

KEY MANAGEMENT AND SCIENTIFIC CHALLENGES

Technical presentations from regional experts discussed challenges in managing blue shark stocks and highlighted how MSE can address many of these issues by developing MPs that are robust to a range of uncertainties.

2.1 DATA UNCERTAINTY AND KNOWLEDGE GAPS

Presentations by Dr Joel Rice on *Challenges for Blue Shark Assessments & Management* and *Identifying Blue Shark Biological Parameters and Other Uncertainties* provided a foundation for discussions that highlighted shared regional challenges in monitoring and managing blue shark stocks. The group noted that across RFMOs there are widespread issues with both the quantity and quality of catch data – as well as the resulting CPUE indices – and with uncertainties in key biological parameters. Blue shark stocks are generally considered data poor, with limited composition data in many regions and catches frequently not reported at the species level (e.g. catches often aggregated as "shark"). Nominal catches are believed to be under-reported, and estimates of unreported catch are often extrapolated based on limited data and broad assumptions. Uncertainty related to key biological parameters, such as natural mortality and stock–recruitment relationships, further complicates assessment model development. The group also noted a consistent spatial pattern across RFMOs: larger blue sharks tend to occur in lower latitudes, whereas younger and smaller sharks are more common at higher latitudes. A comprehensive, global review of blue shark biological parameters, which was compiled by Dr Rice and Dr Yasuko Semba of the Japan Fisheries Research and Education Agency, can be found in Appendix 3.

The group also discussed challenges in how blue shark CPUE data are treated in stock assessments and MSEs, given the fact that blue shark can be both a target species or bycatch depending on the fishery. Contracting parties at RFMOs often provide their own pre-standardized indices, which may show opposite or conflicting trends. This may arise from the pelagic nature and basin-wide ranges of blue shark stocks, localized versus regional fisheries, or a combination of these and other factors. Several participants supported developing a combined CPUE index from raw data to improve CPUE indices, and therefore assessment model consistency, and to support the development of OMs, while noting the value of continuing to examine individual indices to understand their influence on model behaviour. Because CPUE indices often show conflicting trends, analysts' choices about which indices to include implicitly reflect assumptions about the most plausible state of nature. Overall, the group stressed the need for improved treatment of CPUE indices and noted that many modelling challenges could be mitigated if MSE OMs were fit to well-constructed combined CPUE series.

2.2 MANAGEMENT CHALLENGES IN MIXED FISHERIES

Blue sharks are treated as bycatch in some regions (e.g. the Southwest Pacific) but are highly targeted in others such as ICCAT and IOTC (e.g. at least three-quarters of reported blue shark catch in the Atlantic is classified as targeted). The group discussed the difficulty of balancing conservation-based MOs with yield-based MOs, particularly in fisheries where blue sharks are commonly caught with other valuable target species. They noted potential stakeholder concerns if management controls for blue shark – such as catch limits – restrict opportunities for other target species such as swordfish. Given this potential conflict, participants highlighted the potential importance of considering species ratios in catches when setting management measures, and suggested that size-based limits could be a viable option for managing bycatch species or species frequently caught with other valuable targets. The group emphasized that such limits are only effective when post-release mortality is sufficiently low; while some studies suggest longline-caught blue sharks have relatively low post-release mortality (around 17 percent; Musyl and Gilman, 2018), these rates may be higher in fisheries using more aggressive methods (e.g. longer soak times).

Blue sharks are relatively productive for sharks. Steepness is estimated to be relatively high for both Atlantic stocks, ranging from about 0.46 to 0.96 (median h ≈ 0.86 for the North Atlantic and 0.80 for the South Atlantic) (Cortes and Taylor, 2023). Accordingly, this shark species can support some level of targeted fisheries, but careful management remains essential for long-term sustainability.

2.3 THE CASE FOR MSE

Presentations by Dr Hilario Murua and Dr Joel Rice on *Why MSE for Blue Sharks?* noted that a common challenge in the stock assessment process is the large quantity of hypotheses brought forward regarding catch trends, stock biology, and key uncertainties, combined with difficulties reaching agreement on which should be incorporated or prioritized in model development. The development of abundance indices was highlighted as another major obstacle, often making assessments lengthy, difficult and prone to unsatisfactory

outcomes. The presentation emphasized that, in principle, a well-designed MSE can help address many of these issues by identifying MPs that perform well across – or are robust to – a range of uncertainties about the stock.

The presentations noted that MSEs can:

- account for biological and observational uncertainties and identify management approaches that can meet performance objectives despite uncertain or conflicting indices;
- evaluate the resilience of MPs under climate variability and regime shifts;
- model movement and landings across jurisdictional boundaries; and
- assess trade-offs between risk and yield using pre-defined performance thresholds.

The group noted that there is increasing interest from both managers and stakeholders in developing MSEs for blue shark stocks, and that existing requests for MSE efforts at both ICCAT and IOTC have been made at the Commission level. Additionally, there is stakeholder interest from some targeting fisheries in order to achieve Marine Stewardship Council (MSC) certification (Marine Stewardship Council, 2025), as Section SE of the Fisheries Standard Ver3.1 lists "evidence that the RFMO is committed to the development of a harvest strategy that includes a management procedure (MP) tested within a management strategy evaluation (MSE) framework" as an entry requirement for fisheries to achieve MSC certification (MSC, 2024).

In his presentation on MSEs at RFMOs, Dr Shuya Nakatsuka noted that a key roadblock to the progression of MSE efforts at RFMOs is limited funding, personnel capacity and meeting time. To increase efficiency and enhance transparency, collaboration and understanding, the group stressed the importance of engaging stakeholders and managers early and often throughout MSE efforts, as they are key in defining the objectives for the management of the stocks, the first step in an MSE process. This proactive approach, as opposed to merely presenting CMPs at the end of the process, is critical for building trust, producing a useful MSE, and improving the likelihood of a successful MP adoption.

SECTION 3

ADVANCING MSE FOR BLUE SHARKS

Initiatives to develop MSEs for blue sharks exist at ICCAT and IOTC but have yet to be formally mandated at the remaining tuna RFMOs. Workshop participants discussed MSE efforts for blue shark to-date, alongside key considerations and tools for designing future blue shark MSEs.

3.1 ONGOING REGIONAL MSE EFFORTS

Atlantic (ICCAT)

Dr Nathan Taylor delivered a presentation detailing existing work to progress MSE efforts for Atlantic blue shark stocks. In response to ICCAT's request for investigating the feasibility of conducting MSEs for the North and South Atlantic blue shark stocks (Recommendations 23-10 (ICCAT, 2023b) and 23-11) (ICCAT, 2023c), two proof-of-concept studies were conducted using openMSE and recent (i.e. 2023) stock assessment models as operating models (OMs). Carruthers (2024a) developed a suite of OMs based on varying key biological parameters in the assessment model and demonstrated the technical feasibility of running blue shark MSEs through grid-based sensitivity analyses and empirical management procedures (constant fishing mortality (F), index-target and slope-based rules). Taylor (2024) used the rapid conditioning model (RCM) – a compact Bayesian framework that samples from multivariate priors, fits a simplified age-structured production model to CPUE data, and produces a multivariate posterior distribution of coherent life history parameters compatible with the CPUE data – to test both empirical and model-based MPs for blue shark. This RCM approach was well-received by workshop attendees. A feasibility study requested by ICCAT and conducted in 2025 considered this initial work and detailed the logistics and budgets required to complete the MSE efforts for the North and South Atlantic stocks, providing both 2-year and 3-year timeframe options (Taylor *et al.*, 2025).

Indian Ocean (IOTC)

In 2024, the IOTC tasked the Scientific Committee with beginning MSE efforts to develop an MP for blue shark, which is now formalized under Resolution 25/08 (IOTC, 2025b). Dr Charles Edwards presented a scoping study that found the current stock assessment model suitable as a basis for MSE OMs and suggested that length-frequency data may be more reliable than catch rates for informing CMPs. The study also posed the utility of management measures that limit blue shark fishing mortality without significantly reducing overall fleet effort given the economic importance of target species (e.g. swordfish, tunas). It was suggested that TACs for blue shark may be undesirable because they could constrain fishing opportunities for these target species. Instead, measures such as minimum size limits could help protect juvenile sharks and prevent growth overfishing, with catch rates monitored for any indication of population decline. However, considering

that blue shark is also captured as a target species, output control measures (i.e. catch limits or TAC) were also considered desirable for this stock. The group considered that a mixed approach including catch and size limits would be preferable. Since the status of most blue shark stocks falls in the green quadrant of the Kobe plot, indicating a healthy stock status under current management, the group noted that a constant-effort MP may be an appropriate management option for blue shark.

3.2 CONSIDERATIONS FOR FUTURE MSE EFFORTS

Roles and responsibilities

Group discussions stressed the need to define and agree on roles at the outset of the MSE process, ideally during the initial science-management dialogue meetings. Participants noted that it was essential that managers are involved from the very beginning of the process to agree on MOs, types of control measures, and other key components of the MSE framework. Moreover, it was considered important that managers and stakeholders share a common understanding of and vision for the overall MSE framework from early in the process (e.g. if the MP will have catch or effort control). Establishing these foundations early helps ensure that MSE results are more readily accepted at later stages.

One key role of managers in the MSE process, for example, is setting MOs for the stock, which typically include reference points (RPs), as well as pre-defined performance indicators (PIs) for quantifying MP performance in relation to the MOs. Fishery MOs most commonly fall into one of four categories: status (e.g. maintaining the stock at a healthy level, such as the target reference point [TRP]), safety (e.g. avoiding dangerously low stock levels, such as the limit reference point [LRP]), yield (e.g. maximizing catch rates), and stability (e.g. minimizing the change in catches between management cycles). A presentation by Dr Rebecca Scott on *Management Objectives for Blue Shark* noted that no RFMO has formally adopted reference points (either LRPs or TRPs) for shark species. However, it was noted that IOTC Resolution 15/10 provides guidance for setting reference points for IOTC-managed stocks, and that most recent stock assessments (IOTC, 2015) – except for the North Pacific – have used MSY-based reference points to evaluate status. Some commonalities in MOs and RPs across RFMOs were also noted, including typical LRP ranges of 40–50 percent B_{MSY} at ICCAT and IOTC, and 14–20 percent of spawning stock

biomass at unfished conditions (SSB_0) at WCPFC and IATTC; safety MOs requiring an 80–90 percent probability of staying above the LRP (or a lower value for more conservative LRPs); and status MOs that require a minimum of 60 percent probability of the stock being in the green quadrant of the Kobe matrix.

The group briefly discussed asppropriate considerations for MOs, RPs and PIs for shark species. Given their high productivity relative to other shark species, participants noted that blue shark MPs could potentially use similar probabilities and reference points when defining MOs (e.g. for status and safety MOs) as for tuna or swordfish stocks. Since operating models already capture blue sharks' lower productivity compared to some tuna species (e.g. skipjack), there would be no need to make MOs more conservative. While there are no existing mandates for beginning blue shark MSE efforts at the Pacific RFMOs (WCPFC, IATTC), the group noted that running blue shark MSE efforts in parallel with future swordfish MSEs could be valuable given their frequent co-occurrence in landings. The group noted that a standardized set of MOs, RPs and PIs across stocks within an RFMO could streamline MSE efforts.

Ecosystem-based objectives – such as juvenile protections or MPAs – were also discussed, though the extensive range of blue sharks might require very large protected areas to be effective. For evaluating MP performance, the group noted that a 30-year horizon commonly used to assess long-term MP performance in other pelagic MSEs may be too long given the longevity of blue shark, and that a 20-year timeframe may be more appropriate in some cases. Participants also noted that a yield-based objective should be defined for blue shark given the economic importance of the fishery. While these discussions were a useful brainstorming exercise, the group emphasized that final decisions on MOs, RPs and PIs ultimately rest with managers.

Whereas managers must set the MOs, RPs and PIs, a key role of scientists in the MSE process is the creation of operating models, which form the foundation of the MSE framework. Each OM represents a hypothesis about the "true" state of the stock and fishery by capturing a range of plausible values for factors such as stock biology (e.g. productivity, natural mortality) and fishery dynamics (e.g. levels of illegal fishing).

In their presentation on *Specifying Operating Models*, Dr Nathan Taylor and Dr Joel Rice noted that OMs for MSEs can be built by importing stock assessment model files, or OMs can be conditioned using modelling approaches such as openMSE's RCM (Blue Matter Science, 2023). They also pointed out that uncertainty in life history parameters (e.g. growth, natural mortality, steepness) can be represented in OM grids, or by using Monte Carlo sampling of parameters and using the results as priors for RCM-based OMs. Whereas the reference set of MSE OMs reflects best available science for biological parameters and other (e.g. structural) assumptions, and is used for baseline performance evaluation, the robustness set of OMs incorporates alternative assumptions and error structures to test how well MPs hold up under structural uncertainty and non-stationarity.

The MSE roadmap

It was noted that the major time constraint for MSE efforts at RFMOs isn't typically the technical modelling work, but the complex international negotiations required. There is limited capacity for scheduling multiple meetings throughout the year and limited meeting time at each meeting. It was also noted that there can be very long discussions around OM development followed by relatively very short discussions on MPs and MP development, when it should be the opposite; operating models should sufficiently capture key uncertainties and system dynamics, but increasing their complexity to replicate reality is time consuming and may provide diminishing returns. MPs are what guide real decisions; MP development should test a wide range of CMPs to thoroughly explore the strategy space and find the MP that best performs under uncertainty and balances trade-offs. The group acknowledged that the time required to develop an MSE will continue to shorten as the RFMOs become more familiar with the process.

Another way to streamline and ensure success of MSE efforts is to have a clearly defined and organized timeline, or roadmap, for MSE efforts. An example of an MSE roadmap (Carruthers, 2024b), a 1-page schematic detailing all MSE processes, was presented by Dr Tom Carruthers (see Appendix 4). Features of the roadmap include:

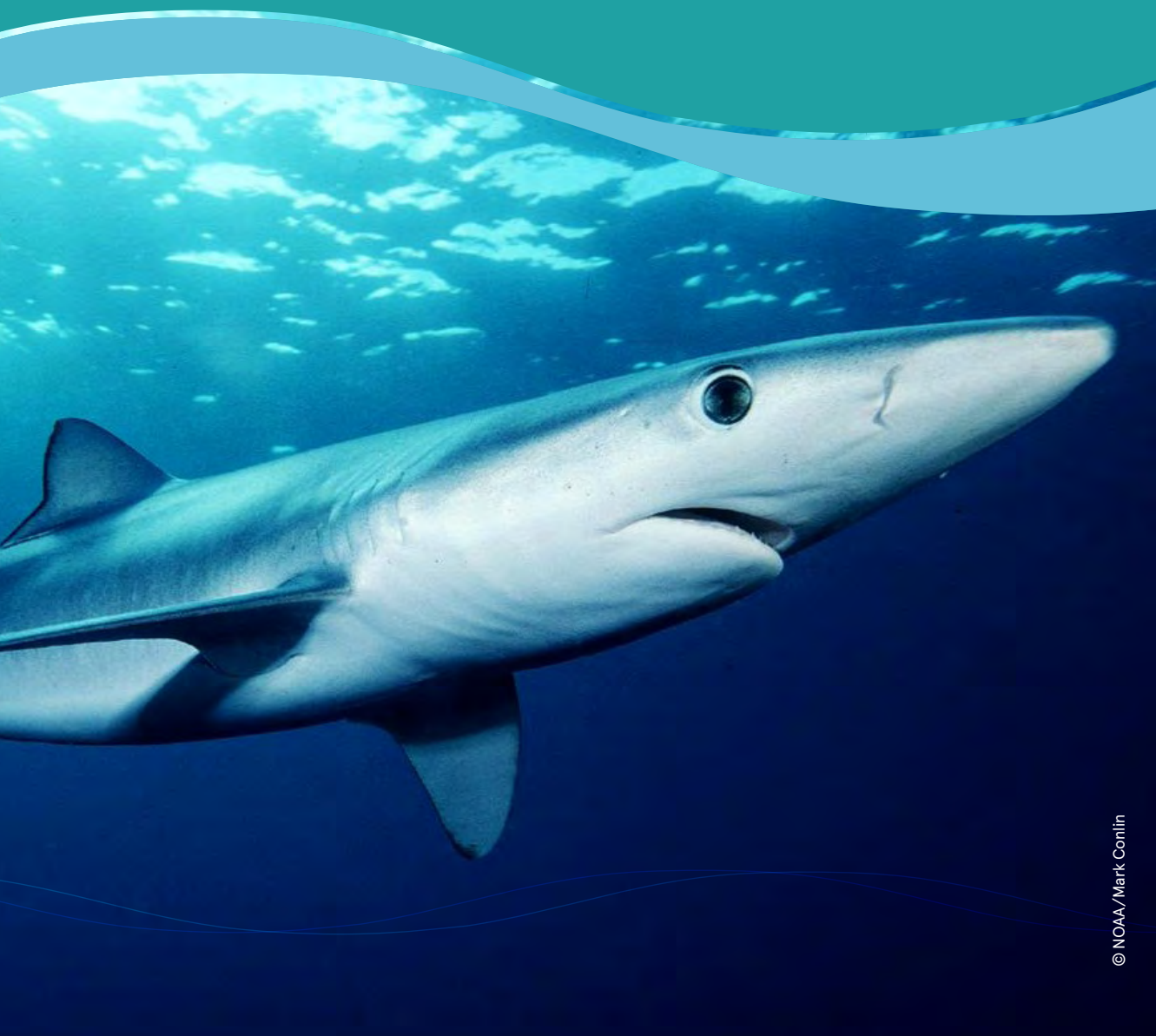
- Processes (boxes) are nested within Tasks, which are nested within Phases.
- Responsibilities are identified up front and processes assigned to each group or member are colour-coded.
- Consideration of situations where MSE is not familiar to managers and stakeholders.
- Inclusion of data guillotines, or hard stops on incorporation of new data, to maintain discipline in moving forward with MSE development.

This roadmap can be repurposed by any individual or group looking to streamline or organize an MSE process and was provided to workshop attendees to support structured development of future blue shark MSE efforts at their respective RFMOs (Carruthers, 2024b).

SECTION 4

HANDS-ON TECHNICAL SESSIONS

Working in regional breakout groups, participants used real world data from global BSH stocks to step through the MSE modeling process in guided technical sessions.



The final two days of the workshop were devoted to guided, hands-on technical sessions using the openMSE software framework, an open-source modelling tool that has been used in multiple RFMO MSE efforts (Blue Matter Science, 2023).

Dr Tom Carruthers and Dr Adrian Hordyk of Blue Matter Science, the developers of openMSE, guided workshop participants through the entire MSE process within openMSE and provided attendees with existing R scripts for use in breakout sessions to streamline the process. Participants also received the necessary software prerequisites (Appendix 5) to have installed on their laptops before arriving at the workshop to save meeting time.

The main goal of the hands-on sessions was for workshop attendees to learn how to modify the three main MSE axes within openMSE: operating models, MPs and performance indicators. Participants were able to work with real world data, as stock assessment model files for five blue shark stocks (North and South Atlantic, North and Southwest Pacific, Indian Ocean) were made available by tuna RFMOs in advance of the meeting. Participants were divided into three regional breakout groups based on their ocean basin of interest and/or expertise (Atlantic, Pacific or Indian Ocean). Over several multi-hour coding sessions, attendees built suites of operating models to represent key uncertainties in their regions, experimented with designing CMPs tailored to blue shark management needs, and coded custom performance indicators to evaluate the effectiveness of their hypothetical MPs to achieve MOs via the MSE feedback loop.

A presentation by Shana Miller highlighted the suite of plots commonly used to visualize MSE results, including time series plots, Kobe time plots, trade-off plots, quilt tables, and others. The group discussed ways to more effectively communicate MSE results to stakeholders and managers, emphasizing the need to harmonize figures within an RFMO to avoid confusion among stakeholders and for analysts to be deliberate in selecting which outputs to present to avoid overwhelming decision-makers. While all MSE results should be made available in some format (e.g. a Shiny app), communication should focus on a clear, concise set of key plots. Participants noted that the IOTC already uses an approved suite of standard plots for conveying MSE outcomes (IOTC, 2019) and suggested that

broader agreement on a similar standardized set across RFMOs would be valuable. They also stressed that managers should be included in these discussions to ensure that the final set of plots meets their needs as the primary audience for MSE results.

Dr Adrian Hordyk provided a demonstration on the Slick Shiny app, which is used to visualize MSE results via "objects" from openMSE model outputs (Blue Matter Science, 2025). Breakout groups created their own Slick visuals using the modelling work they completed during the workshop, and incorporated these into final group presentations. While the Slick interface may be too technical for some audiences, it's a valuable tool for use within MSE working groups, enabling members to explore and better understand model results and to produce clear visuals for communicating with managers.

Breakout groups successfully specified and tested multiple hypothetical CMPs for each of the five represented blue shark stocks, exploring both model-based and empirical approaches. Examples included MPs that relied on different subsets of CPUE indices, constant harvest rates, and size-based strategies. Each group also developed multiple operating models for each stock, most commonly incorporating alternative values for natural mortality and catch levels to address uncertainties in biological parameters and catch data, respectively. In addition to the technical work, each group commented on the appropriate processes and channels for advancing blue shark MSE efforts within their respective RFMOs. It is important to note that all products developed during the workshop were considered strictly hypothetical and preliminary training examples, none of which have been presented or endorsed through formal RFMO procedures. Workshop products could nevertheless be used as tools and/or starting points for formal MSEs, if further developed, presented and discussed within formal RFMOs MSE processes. The Indian Ocean group's work, for example, was shared at the IOTC Working Party on Methods meeting in late October 2025 as preliminary input for the Commission's requested blue shark MSE and to obtain feedback and guidance (IOTC, 2025c). Workshop products, including R code, openMSE modelling products and summary presentations from regional breakout groups, can be accessed on the workshop's GitHub page: https://github.com/rl-scott/Workshop-on-Global-Blue-Shark-MSE-2025.

NEXT STEPS AND IMPLICATIONS

The 2025 Workshop on Global Blue Shark MSE represented a milestone in the collective effort toward sustainable blue shark management, bringing together experts from across the globe to share knowledge, examine the current state of global blue shark management, and advance efforts toward developing MSE-tested MPs for these stocks. Participants left with strengthened cross-regional connections, a deeper understanding of the MSE process – including the openMSE framework and Slick Shiny app – and a set of preliminary products to inspire or support ongoing blue shark MSE initiatives. The insights and preliminary products generated will support ongoing and future MSE efforts at ICCAT and IOTC where blue shark MSE efforts are already underway. Although Pacific RFMOs do not yet have formal directives for blue shark MSE, this workshop provided a forum for early discussions on feasibility, key modelling considerations, and potential first steps towards developing a stock assessment for Southeast Pacific Ocean stock and testing MPs for the other Pacific blue shark stocks. Together, these achievements mark meaningful progress toward the global long-term sustainability of this economically and ecologically valuable species.

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APPENDICES

This section includes supplementary material, parts of which can be downloaded as separate files. To download an appendix, just click on the link of the document that you're interested in.

→ *Blue shark (Prionace glauca), Faial-Pico Channel, Azores Islands, Portugal*

APPENDIX 1
AGENDA

HOSTED BY THE OCEAN FOUNDATION & THE PEW CHARITABLE TRUSTS

With funding from Oceankind, Paul M. Angell Family Foundation and the FAO Common Oceans Program
Location: Mia Room Mate Collection - Via Capo d'Africa, 54, 00184 Roma RM, Italy

Date: 14–16 October 2025

DAY ONE

09.00–09.30	**Welcome/Introduction** → Introductions → Review agenda → Workshop goals (incl. participants')	Grant Galland Shana Miller Joe Zelasney
09.30–09.45	**Management context** → Communication opportunities for workshop outcomes/products	Shuya Nakatsuka
09.45–10.30	**Regional summaries on BSH science/management** → Atlantic → North Pacific	Rodrigo Sant'Ana Shuya Nakatsuka (for Michael Kinney)
10.30–10.45	**COFFEE BREAK**	
10.45–11.30	**Regional summaries on BSH science/management** → South Pacific → Indian	Phil Neubauer Dan Fu
11.30–11.45	**MSE concepts and common language**	Nathan Taylor Tom Carruthers
11.45–12.45	**Why MSE for blue sharks?** → MSE vs stock assessment → MSE success stories → Challenges for blue shark assessments/ management	Hilario Murua Joel Rice
12.45–14.15	**LUNCH**	
14.15–15.30	**Preliminary BSH MSE work** → North Atlantic → Indian Ocean	Nathan Taylor Charlie Edwards
15.30–15.45	**COFFEE BREAK**	

15.45–17.00	**BSH operating models** → Identifying BSH biological parameters and other uncertainties → Specifying operating models • Importing assessments • Conditioning OMs • Reference vs Robustness OMs	Joel Rice Nathan Taylor
17.00–17.15	**Wrap-up discussion**	Shana Miller
17.30–19.30	**COCKTAIL RECEPTION** - Mia Room Mate Collection Rooftop Terrace	

DAY 2

09.00–09.15	**Opening/Overview** → Day 1 reflections → Day 2 overview	Grant Galland
09.15–10.30	**Management objectives for BSH, including:** → Reference points → Performance indicators	Becky Scott
10.30–10.45	**COFFEE BREAK**	
10.45–11.45	**Designing candidate MPs (CMPs) for BSH** → Empirical CMP options → Using simplified estimation models for model-based CMP options	Nathan Taylor
11.45–12.45	**openMSE walkthrough using BSH data** openMSE proof-of-concept OM specification Designing and tuning candidate MPs	Tom Carruthers Adrian Hordyk
12.45–14.15	**LUNCH**	
14.15–15.00	**openMSE walkthrough (cont.)** → Overflow from morning → Running closed-loop simulations → Calculating performance metrics → Summarizing results	Tom Carruthers Adrian Hordyk

15.00–15.45	**openMSE breakout session (by region)** → Using regional data: • N/S Pacific, N/S Atlantic, Indian Ocean	Tom Carruthers Adrian Hordyk Nathan Taylor
15.45–16.00	**COFFEE BREAK**	
16.00–17.15	**openMSE breakout session (cont.)**	Tom Carruthers Adrian Hordyk Nathan Taylor
17.15–17.30	**Wrap-up discussion**	Tom Carruthers Adrian Hordyk Shana Miller
20.00	**GROUP DINNER** - Al Pompiere Restaurant Piazza delle Cinque Scole, 28	

DAY 3

09.00–09.15	**Opening/Overview** → Day 2 reflections → Day 3 overview	Grant Galland
09.15–09.45	**Presenting results for BSH MSEs** → Recommendations for standard visualization tools → Shiny App options, including Slick tutorial	Shana Miller Adrian Hordyk
09.45–10.30	**Slick breakout session (by region)**	Tom Carruthers Adrian Hordyk Nathan Taylor
10.30–10.45	**COFFEE BREAK**	
10.45–11.30	**Slick breakout session (cont.)**	Tom Carruthers Adrian Hordyk Nathan Taylor

11.30–12.15	**Template BSH MSE Workplans** → Develop RFMO-specific workplans	Tom Carruthers Rui Coelho
12.15–13.45	**LUNCH**	
13.45–14.30	**Template BSH MSE Workplans** → Regional breakout sessions to map potential paths forward	Tom Carruthers Adrian Hordyk Nathan Taylor
14.30–15.30	**Regional report-outs: breakout session results** → Presentation of regional MSE, Slick, and workplan products	Becky Scott
15.30–15.45	**COFFEE BREAK**	
15.45–16.15	**Regional report-outs (cont.): breakout session results**	Becky Scott
16.15–17.00	**Wrap-up Discussion** → Barriers to timely, successful development & implementation of BSH MSE, plus strategies/tools to overcome them	Grant Galland Shana Miller

APPENDIX 2
LIST OF PARTICIPANTS

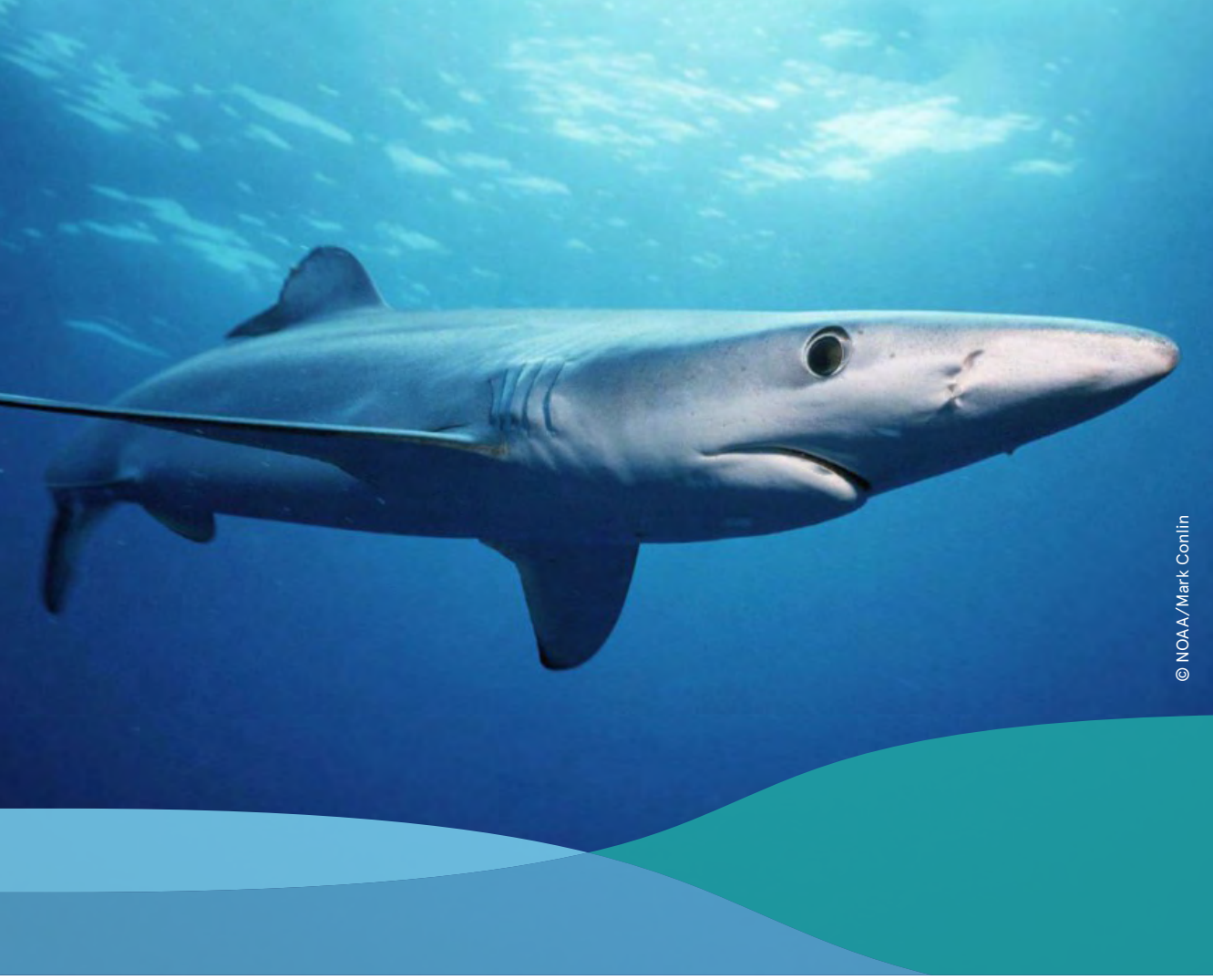
NAME	AFFILIATION
Don Bromhead (virtual)	AFMA
Tom Carruthers	Blue Matter Science
Rui Coelho	IMPA
Maria DiMarino	FAO
Charlie Edwards	CEscape Consultancy Services
Carmen Fernandez	Instituto Español de Oceanografía
Rodrigo Forselledo (virtual)	Dirección Nacional de Recursos Acuáticos
Dan Fu	IOTC-FAO
Grant Galland	The Pew Charitable Trusts
Adrian Hordyk	Blue Matter Science
Gonzalo Liniers Terry	Instituto Español de Oceanografía
Shana Miller	The Ocean Foundation
Carolina Minte-Vera	IATTC
Hilario Murua	ISSF
Shuya Nakatsuka	FRA/WCPFC
Philipp Neubauer	Dragonfly
Toby Patterson	CSIRO
Ann Preece (virtual)	CSIRO
Joel Rice	Rice Marine Analytics
Rodrigo Sant'Ana	Universidade do Vale do Itajaí
Rebecca Scott	The Ocean Foundation
Ghada Souilah	FAO
Nathan Taylor	ICCAT
Joe Zelasney	FAO

APPENDICES TO DOWNLOAD

Appendix 3 → Global Literature Review of Blue Shark *Prionace glauca* Biological Parameters

Appendix 4 → Roadmap for MSE Development

Appendix 5 → Required workshop software and installation instructions



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COMMON OCEANS | Tuna project

Fisheries and Aquaculture Division (NFI)

Food and Agriculture Organization of the United Nations (FAO) Rome, Italy

www.fao.org/in-action/common-oceans | common-oceans@fao.org

The Common Oceans Tuna project brings together a global partnership dedicated to sustainable tuna fisheries aiming to advance responsible tuna fisheries management and biodiversity conservation in areas beyond national jurisdiction (ABNJ). Funded by the Global Environment Facility (GEF) and led by the United Nations Food and Agriculture Organisation (FAO), it works in collaboration with five regional tuna fisheries management organizations, national agencies and intergovernmental organizations and initiatives, the private sector, civil society and academia.

IN COLLABORATION WITH: Commission for the Conservation of Southern Bluefin Tuna (CCSBT), Inter-American Tropical Tuna Commission (IATTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Indian Ocean Tuna Commission (IOTC), Western and Central Pacific Fisheries Commission (WCPFC), Agreement on the Conservation of Albatrosses and Petrels (ACAP), BirdLife International (BLI), Conservation International (CI), INFOPESCA, International MCS Network (IMCSN), International Pole and Line Foundation (IPNLF), International Seafood Sustainability Association (ISSA), International Seafood Sustainability Foundation (ISSF), International Whaling Commission (IWC), Marine Stewardship Council (MSC), Mercator Ocean international (MOI), Pacific Community (SPC), Pacific Islands Forum Fisheries Agency (FFA), Secretariat of the Pacific Regional Environment Programme (SPREP), The Nature Conservancy (TNC), The Ocean Foundation (TOF), The PEW Charitable Trusts, US National Oceanic and Atmospheric Administration (NOAA), World Wide Fund for Nature (WWF).

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