

Improving communication: the key to more effective MSE processes¹

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Abstract: The use of management strategy evaluation (MSE) to design and test candidate fisheries management approaches is expanding globally. Participation of managers, scientists, and stakeholders should be an integral component of the MSE process. Open and effective communication among these groups is essential for the success of the MSE and the adoption of the management approach based on it. The highly technical nature of MSE and newness of the approach to many audiences present considerable communication challenges and have, unfortunately, slowed progress in some cases. We draw on diverse experiences with MSE to identify two areas in which the implementation of MSE in multinational fora may be improved: (i) the use of formally constituted “intermediary groups” as a forum for exchange at the management–science interface and (ii) the development of engaging, yet uncomplicated, visual communication tools for conveying key results to different audiences at each stage. While our focus is the MSE processes underway in the regional fisheries management organizations for tunas and tuna-like species, the advice provided is also pertinent for other fisheries, international and domestic alike, pursuing MSE.

Résumé : L'utilisation de l'évaluation des stratégies de gestion (ESG) pour concevoir et valider des approches possibles de gestion des pêches est en croissance à l'échelle planétaire. La participation de gestionnaires, scientifiques et parties prenantes devrait faire partie intégrante du processus d'ESG. Des communications ouvertes et efficaces entre ces groupes sont nécessaires au succès de l'ESG et à l'adoption de l'approche de gestion reposant sur cette dernière. Le caractère très technique de l'ESG et la nouveauté de l'approche pour de nombreux groupes présentent des défis considérables en matière de communication et ont, malheureusement, ralenti les progrès dans certains cas. Nous nous inspirons d'expériences variées d'ESG pour cerner deux domaines dans lesquels la mise en œuvre de cette approche dans des forums multinationaux peut être améliorée, à savoir : (i) l'utilisation de « groupes d'intermédiaires » officiellement constitués comme forum d'échange à l'interface de la gestion et de la science et (ii) l'élaboration d'outils visuels de communication à la fois conviviaux et simples d'utilisation pour transmettre les principaux résultats à différents groupes à chaque étape. Si nous mettons l'accent sur les processus d'ESG en cours dans les organisations régionales de gestion de pêches aux thons et aux espèces apparentées, les avis fournis sont aussi pertinents pour d'autres pêches, internationales ou intérieures, faisant l'objet d'une ESG. [Traduit par la Rédaction]

Introduction

Management strategy evaluation (MSE) is a simulation framework that evaluates the performance of alternative fisheries management approaches against a suite of prespecified management objectives (Sainsbury et al. 2000). The aim is to identify an approach (in an overall process that is also termed MSE) that meets these objectives while being robust to the uncertainties inherent in the system, rather than identifying the optimal approach under the assumption that a particular scenario, or characterization of the system, is true (Punt et al. 2016). MSE is used to design, test, and select management procedures (MPs), also known as harvest strategies (Butterworth 2007). An MP is a pre-agreed management

system that includes well-defined data, together with an algorithm for how those data will be processed to obtain an indicator of stock status, and a decision rule, or harvest control rule (HCR) that determines the management action as a function of the stock status indicator. MPs can increase the transparency, predictability, and effectiveness of fisheries management (Punt et al. 2016). MSE is an essential component of the testing and selection of a fully specified MP.

The five regional fisheries management organizations responsible for management of tunas and tuna-like species (trFMOs) are pursuing MSE-based development of MPs and (or) HCRs. To date only one trFMO has completed an MSE and implemented a fully specified MP. The Commission for the Conservation of Southern

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Table 1. General principles for management strategy evaluation (MSE) communications.

- Build trust by enhancing transparency, credibility, and understanding of the process.
- Target communication efforts at key individuals or groups who are trusted by their colleagues and (or) constituents and can bring others along with their support.
- Less can be more: start with key findings and recommendations and provide additional technical detail only as requested.
- Cull any unrealistic or redundant candidate management procedures and performance statistics within the technical process.
- Strike the right balance between being too technical and too elementary in communications.
- Use analogies that describe MSE aspects in the context of everyday experiences.
- Maintain consistency in the messaging about the MSE process and in the graphic and tabular presentation of results.
- Use two-way communication to understand managers' and stakeholders' interests and achieve the necessary iterative nature of MSE.
- Maintain both formal and informal groups to facilitate different ways to build trust and understanding.
- Dedicate sufficient resources to both the technical and nontechnical aspects of the MSE process, including time, funding, and staff capacity.

Bluefin Tuna (CCSBT) adopted an MP for southern bluefin tuna (*Thunnus maccoyii*) in 2011 (Hillary et al. 2016), which has been used to set the global total allowable catch (TAC) from 2012 to 2020. The CCSBT has recently commenced development of a revised MP (given imminent changes to some of the key sources of input data) to be used for setting the TAC from 2021 (CCSBT 2017a, 2017b). The Indian Ocean Tuna Commission (IOTC) and the International Commission for the Conservation of Atlantic Tunas (ICCAT) have adopted HCRs for skipjack (*Katsuwonus pelamis*) (IOTC 2016a) and northern albacore tuna (*Thunnus alalunga*) (ICCAT 2017) stocks, respectively. The IOTC, ICCAT, and the Western and Central Pacific Fisheries Commission (WCPFC) have agreed to plans to adopt MPs for most key stocks. The fifth tRFMO, the Inter-American Tropical Tuna Commission (IATTC), is at an earlier stage in the process. Despite each of the tRFMOs having particular organizational structures and processes, the challenges associated with MSE development in each are similar. The fact that some of the tRFMOs have over 50 member governments poses additional communication and decision-making challenges, especially when compared with domestic fisheries that may have one centralized decision-making authority. Notwithstanding this additional complexity, we consider the tRFMOs' experiences in MSE to be relevant to other RFMOs and their domestic equivalents since the general approach — both the science and iterative dialogue — is similar regardless of the fishery concerned. If an MSE process can be developed to work effectively in the very complex decision-making environment of the tRFMOs, it can only work better in less complex ones too.

While scientists conduct the technical modeling underpinning the MSE, extensive participation of managers and stakeholders throughout the process is a defining characteristic of MSE. This is because many of the key decisions belong in the management and (or) policy domain, and ultimately those responsible for management of the fishery make the final choice. Stakeholders come in many forms and include not only representatives from the private sector (commercial and recreational industry, processors, and retailers), but also environmental groups and other nongovernmental organizations or civil society organizations. Notably, stakeholders represent key constituencies and are, in many cases, the actual drivers behind MSE development. For example, industry may support development of an MP because they seek certification by the Marine Stewardship Council eco-label, which has an HCR requirement. Environmental groups may advocate for MSE development for establishment of a more sustainable approach to management, instead of the ad hoc and often annual consensus-based negotiations that characterize many RFMOs and can produce unpredictable, varying outcomes (The Pew Charitable Trusts 2016). Both groups seek more stability and transparency in management decisions.

The necessary partnership and common understanding among scientists, managers, and diverse stakeholder groups in MSE processes have proven to be very challenging from a communication perspective. First and foremost, MSE is a highly technical modeling approach that even many fisheries scientists do not com-

pletely understand, particularly those with nonquantitative backgrounds. There is also a pervasive inconsistency in the use of terminology and approaches, with the same terms having different meanings in different bodies or regions and different terms being used for the same construct (e.g., using the term “management procedures” in CCSBT, ICCAT, and IOTC but “harvest strategies” in WCPFC and IATTC). Rademeyer et al. (2007) highlighted alternative uses of MSE-related terms, and the use of conflicting terminology is even more pervasive now. These and other challenges have led to confusion about the process among some key players.

To help address these communication challenges, we convened a group of MSE experts, including fisheries scientists, managers, industry leaders, and conservationists, together with experienced science communicators (see the Acknowledgements for a full list of participants). This manuscript represents the de novo conclusions from that effort, including the consensus expert opinions of the group. Here we propose general principles for planning and implementation of the MSE process and then focus on two critical components: (i) the structure and functioning of the iterative dialogue among scientists, managers, and stakeholders and (ii) the development of visual and interactive communications tools. The success of the MSE process depends upon sound design and implementation of both of these areas, in addition to the overarching prerequisite to dedicate sufficient resources for communications and other aspects of the MSE process, including time, funding, and staff capacity.

General principles for MSE communications

The communications field, particularly the specialized field of science communication, has much to offer regarding techniques for improving communications throughout the MSE process. There are three fundamental steps for a science communication strategy aimed at decision-making (Fischhoff 2013). First, it is important to identify who the audience is, what that audience **already** knows, and what they **need** to know to make a decision. The second step, and purpose of the communication strategy, is then to bridge the audience's gap between what they already know and what they need to know. The final step is to evaluate the adequacy of the communication and go back to step two if necessary. This same basic approach and other general communication tenets should be tailored to and employed in the planning and implementation of MSE exercises (Table 1).

A key to a successful MSE process is trust among scientists, managers, and stakeholders. Therefore, communications should seek to build trust by enhancing transparency, credibility, and understanding of the process, including the roles of the various stakeholders in it (Cash et al. 2003, Heink et al. 2015). Because of high turnover rates in the various audiences at tRFMO meetings, it is necessary to present general information on MSE on a continuing basis to ensure that all participants have reasonable opportunity to understand the process and their roles and responsibilities in it. Realistically, it is unlikely that all parties will

be conversant with the details. In this case, in addition to the regular general briefings, it is prudent to target communication efforts at key individuals or groups who are trusted by their colleagues and (or) constituents and can bring the others along with their support.

As scientists are responsible for the MSE modeling work, they are regularly called upon to present updates on progress and MSE results. Scientists need to appreciate that the best ways of communicating with other scientists are usually **not** the best ways (indeed often the worst) of communicating with others in the process, particularly the senior decision makers (Lynn et al. 2010). Rather than the standard scientific approach of starting at the bottom and justifying all assumptions made in reaching a conclusion, they should start with their (few) key findings and recommendations, explain where these findings fit in the high-level MSE process, and provide additional technical detail only as requested by the audience.

In other words, less can be more in terms of a starting point for most decision makers. When presenting MSE results, scientists should provide only the amount of information that is necessary for the audience to make a decision (e.g., select MP, revise MSE, progress to next stage of MSE). It is important to avoid overloading the audience with “interesting” technical detail that may distract from the decision that needs to be made. While transparency of the technical process is paramount to the credibility of the science and the process, and therefore all of the results should be readily available for those who seek them, it is not the role of decision makers and stakeholders to peer review the entirety, or even a small fraction, of the technical work involved in the MSE. This is the role of the scientific committee and (or) independent experts involved in the technical process.

The number of possible candidate MPs is virtually limitless, which can make the process of design, evaluation, and selection that much more daunting to follow and understand. Therefore, the focus should be on presenting realistic, implementable, and meaningfully different candidate management procedures to keep the process digestible. Any unrealistic or redundant candidate management procedures and variants should be culled within the technical process. The same is true for congruent performance statistics.

It is critical to strike the right balance between being too technical and too elementary, both when describing the MSE process and when presenting results. For example, the use of jargon and acronyms, while useful for efficiency and simplifying communication within technical groups, should be avoided in communicating to managers and stakeholders and replaced with nontechnical language. At the same time, oversimplification of the language and concepts should be avoided so as not, unintentionally, to underplay important uncertainties and caveats that need to be taken into account by decision makers. It is not acceptable to simplify for the sake of improving communication if this results in overly assertive (and misleading) statements. Appendix A lists definitions of common MSE-related terms that aim to strike a balance between technical detail and ease of understanding by an audience of managers and stakeholders. Clear analogies that describe the purpose and process of conducting MSE using everyday experiences can help nontechnical audiences understand the more technical features of MSE. It is also important to avoid simplification to the point that it becomes patronizing, since this can erode trust and willingness to engage. Scientists should not underestimate the ability of the target audience to understand the features of the process when conveyed in appropriate language.

Because the tRFMOs are pursuing MSEs for multiple stocks concurrently, it is important to maintain consistency in the messaging about the MSE process and, in particular, in the presentation of results across different stocks and different presenters, both within individual tRFMOs and ideally among them. Having a consistent format for presenting results in plots and tables reduces

the demands on the audience to adjust to each style of presentation and allows them to focus on the actual results, rather than on interpreting a different form of presentation or statistic. It would also be advantageous to have tRFMOs agree on harmonized diagrams of the MSE process, especially since many governments are members of multiple tRFMOs and are often represented on them by the same people.

Structure and process for dialogue among fishery scientists, managers, and stakeholders

There are generally four groups involved in the MSE process at tRFMOs: the Commissioners, the scientific committee, the technical modeling team, and an intermediary group(s) for dialogue among scientists, managers, and stakeholders (sometimes termed “dialogue groups”; Table 2). As the ultimate decision makers, the Commissioners are responsible for setting the management objectives for the MP and adopting the final MP, but they usually do not need to be closely involved in the development of the technical specifications for the MSE. The scientific committee oversees all the scientific work of the tRFMO and, as such, typically reviews and endorses each major technical step in the MSE development. It would not, however, usually be directly involved in the details of the technical development. The technical modeling team is the small group of fishery scientists that designs the MSE modeling exercise and is fully immersed in the details of the operating models, design of candidate MPs, and interpretation of the MSE results for the fishery on which they are focused. Appendix B lists the issues that this team needs to address.

However, given that MSE is a process that requires active interaction and cooperation between scientists and stakeholders, an intermediary group (or groups) is also essential. The intermediary group(s) serves as the forum for dialogue and guidance among scientists, managers, and stakeholders. In this paper, we focus on the role of the intermediary group(s), since this is where the most complicated and consequential communication often occurs. We provide general guidelines on how to structure intermediary groups to provide fora for capacity building and for iterative discussion en route to a decision. The ideal formulation for each intermediary body is case-specific by RFMO and by stock, but typically both formal and informal meetings are required to achieve the necessary capacity building and iterative discussion.

Intermediary group(s): structure and basic role

The intermediary group(s) seek to bridge the boundary at the science–policy interface and can thus be considered a boundary organization internal to the RFMO (Guston 2001; Jensen-Ryan and German 2018). Boundary organizations have proven useful for facilitating dialogue among scientists and managers on issues ranging from climate change to public health to coastal zone management (Drimie and Quinlan 2011; Koetz et al. 2012; Leith et al. 2016). By facilitating dialogue, these groups create collaborative processes that allow both the science and policy arms to achieve their goals (Gustafsson and Lidskog 2018). Intermediary bodies dedicated to MSE in fisheries function in much the same way.

The group(s) provides the opportunity for iterative dialogue among scientists, managers, and stakeholders. This two-way communication is critical, since managers must provide direction and feedback to scientists throughout the MSE process. The group(s) also provides a forum for resolving communication problems, thus avoiding the MSE process becoming muddled due to misunderstanding. Communication can be challenging in the intermediary group(s) because (i) the technical nature of the key subjects leads to deliberations that are generally heavily cross-disciplinary, and (ii) the individuals involved often have different, even competing, imperatives (e.g., in general, decision makers want an outcome, scientists want to be scientifically “correct”, and stake-

Table 2. Different recommended roles in the MSE process (upper table) and communications needs (lower table) for each of the four groups at

Phase	Commission			Intermediary group		
	Start	Middle	Final decision	Start	Middle	Final decision
MSE process						
Management objectives (MOs)	Propose and prioritize broad MOs	Prioritize MOs	Agree final quantitative MOs and priorities	Review Commission's broad MOs and provide comments	Refine MOs in light of advice from SC and Commission	Propose final MOs and priorities to Commission
Simulation testing with MSE	Review summary of progress from intermediary group and recommend action to SC in broad terms		None	Iterative exchange with SC on operating models (OMs) and priority scenarios		None
Candidate management procedures (CMPs)	Review summary of progress from intermediary group and recommend action to SC in broad terms		Select final MP	Can propose CMPs including design features or just review and comment on candidates from the SC and performance statistic results		Propose final MP candidate(s) to Commission
Information-communication needs						
Introduction to MSE, including work plan	Need comprehensive nontechnical overview of MSE process and requirements	As needed	Based on effective communication, this should result in agreement of long-term financial (and logistical) support for the process	Comprehensive overview, plus solicit insights and (or) needs from managers-stakeholders. Provide advice on operational features. Iterative process	Ongoing information to Commission if needed to update the work plan	None
Projections of catch and (or) effort and abundance	Receive progress reports and provide feedback to intermediary group and SC on level of detail required and presentation		Receive information (e.g., central tendency with probability envelope for recommended MP(s))	Communication will be an iterative process of considering and commenting upon the style and format of preliminary results for all OMs, narrowing range of CMPs, and providing concise progress reports to Commission at an appropriate level of detail. Provide feedback on format of results to SC		Provide final results in sufficient detail and in a suitable format to enable a Commission decision
Explanation of performance statistics (including catch variability, probability of rebuilding, stock status, etc.) and trade-offs	Receive progress reports and provide feedback to intermediary group and SC on level of detail and statistics required		Receive summary of final results from intermediary group and (or) SC	For all OMs and CMPs, receive progress reports and provide feedback to intermediary group and SC on level of detail and statistics required, including format		Provide summary of final results for Commission

holders may desire a specific management outcome). The group(s) can play both general and specific roles; for example, the former includes assisting stakeholders to understand the MSE process, while the latter covers reviewing intermediate results, making suggestions for features of candidate MPs, and evaluating their relative merits based on the MSE results.

As examples of such groups, IOTC and CCSBT have established, respectively, a Technical Committee for Management Procedures (IOTC 2016b) and a Strategy and Fisheries Management Working Group (CCSBT 2010, 2018) to facilitate the dialogue required as part of their MP development processes, including requesting the guidance needed from decision makers on elements of the MSE. The Northwest Atlantic Fisheries Organization established an analogous group, the Working Group on Risk-based Management Strategies (RBFM), in 2013 (NAFO 2013). Comparable organizations

are also found for MSE processes in the non-tuna RFMOs and domestic fisheries environments.

In general, it seems preferable to maintain two separate intermediary groups, one formal (e.g., working groups with a delegation structure) and the other informal (e.g., no official governmental representation and including visits with stakeholders to understand their needs and positions) to provide channels to facilitate different types of communication. The former would tend to focus more on advisory activities and the latter more on educational activities. However, this choice is organization- and resource-specific; for example, NAFO has to date found that a single group has sufficed, probably because of the highly focused tasks their group has pursued and the relatively few government members (11 governments). This illustrates the reason to consider carefully how to establish and structure the intermediary group(s)

the start of the MSE process, during development (middle), and at the end (final decision).

Scientific committee (SC)			Technical MSE modeling group		
Start	Middle	Final decision	Start	Middle	Final decision
Provide advice to intermediary group on quantitative MOs and performance statistics	Select final performance statistics in light of objectives	None	Propose case-specific performance statistics in light of objectives	Refine and prioritize performance statistics in light of advice on objectives	None
Review each step including scenarios to test uncertainty; present results to the intermediary group		Agree final trial structure	Develop final OMs and run MSE; develop final trial specifications; submit results to SC		None
Can propose CMPs and review and refine suggestions from intermediary group		Propose final MP candidate(s) and rationale to intermediary group	Can propose and narrow down list of CMPs		Produce values of key performance statistics for SC
If SC not sufficiently informed on MSE process, it may need an introduction from the technical group explaining SC role. Provide advice as needed to intermediary group and Commission, including explanation of trial structure and key uncertainty tests. Provide advice to the technical group on broad hypotheses to be examined, including species' biology, population dynamics, etc.			As needed (could include providing overview for SC on its role; e.g., in developing conceptual hypotheses)	Provide explanation of proposed OMs for consideration in MSE	None
Provide feedback on proposed assumptions and format by the technical group	Review preliminary results and agree format (e.g., central tendency with probability envelope, plus trade-offs)	Agree on format and present results for final set of CMPs	Develop proposed format	Provide preliminary results after incorporating feedback including on format	Provide results for all OMs, in appropriate formats. Archive results
NA	Review preliminary results for all CMPs, culling CMPs that fail	Provide summary of final results for intermediary group	Develop proposed formats for presentation of performance statistics	Provide results for all OMs and CMPs, highlighting key features	Provide final results for all CMPs in formats suitable for each group, highlighting key features

to reflect the needs of the governing body. The formation of each group needs to acknowledge the limitations of what the group can do and how it can operate within the structure of the specific RFMO or domestic fisheries management system. Naturally, it is also possible for a single group to operate in a more formal mode at some times and more informal at others. IOTC provided an example in 2018 in which the Technical Committee for Management Procedures operated in an informal, capacity-building mode during the first day and a more formal, decision-making mode on the second day. In our experience, it is useful to provide an informal space for uncompromised, off-the-record discussions where no commitments are sought and potentially sensitive ideas can be explored openly without fear of backlash.

Timeline and resource-specific focus

When a Commission decides to initiate MSE for a specific resource, an intermediary group should first develop an agreed

work plan with clearly defined roles, tasks, and timing, and this should be agreed upon by the Commission to ensure that the group has a clear mandate to implement this work plan. As a general guide, an MSE process in a tRFMO would reasonably be expected to take 2 to 4 years, depending on the complexity of the specific case and the maturity of the current monitoring, stock assessment, and management arrangements in place. In the International Whaling Commission, which has the most experience with such exercises, the process has been refined so as to be able to be accomplished in 2 years.

To operate successfully such a timeline, we recommend that the intermediary group(s) be dedicated entirely to an MSE for the resource in question, rather than constitute a more general scientists-managers dialogue group. These intermediary bodies' focus on a single MSE enables appropriate membership and allows the group's work plan to concentrate exclusively on tasks pertinent to

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the specific MSE, thus expediting the process. For example, by dedicating the work of its RBFM group to Greenland halibut (*Reinhardtius hippoglossoides*) only, NAFO was able to conduct a full MSE and adopt an MP in less than 1 year (NAFO 2017). This contrasts with the process in ICCAT where there is a Standing Working Group on Dialogue between Fisheries Scientists and Managers that covers a broader scope, including, for example, ecosystem-based fisheries management, and which therefore has less time to dedicate to MSE-related discussions (ICCAT 2013).

Contributions by scientists and managers to the intermediary group(s)

At each stage of the iterative MSE process when scientists present results, they should emphasize the specific issues that require resolution and the implications of different decisions (e.g., limits on interannual variability in catch, probabilities of achieving targets, desired recovery timeframe). Managers should provide the necessary guidance on these issues so that the scientists can advance the MSE development. Separate iterative meetings of the Commission or scientific committee (or their domestic equivalents) cannot play this role, since managers and scientists need to sit together at the same table to allow for ample discussion, collaboration, and building of trust. This interdisciplinary partnership is critical to success, as MSE requires inputs from both managers and scientists, in concert with stakeholders.

Formal intermediary groups

The main reason that formal sessions or groups are needed is that such are typically required for any decision-making based on RFMO rules of procedure, where a quorum of governments must come to consensus. This includes when providing requests or guidance to the scientific committee on the MSE and when making recommendations to the Commission.

(1) Structure and membership

Clearly, any intermediary group must include participants drawn from all of the Commission, the scientific committee, and the technical modeling team.

Ideally, a representative from the Commission and a representative from the scientific committee should serve as joint Chairs of an intermediary group, thereby conveying the joint ownership and vested commitment to the mandate of the group. The science Chair would be responsible for liaising with the scientific committee, so the Chair of the scientific committee might be the most appropriate person. Depending on the strengths of the joint Chairs, and in particular their familiarity and ability to communicate MSE concepts to different audiences, an independent facilitator (with knowledge and experience of the MSE process) may be desirable.

It is preferable for each member nation to be represented by at least one scientist and one manager on this group, as well as by key stakeholders. Accordingly, if tRFMOs are able to provide funding for developing country participation, they should support both a manager and scientist from such countries.

(2) Key elements

There are four key elements that are essential to structuring effective formal intermediary groups. First, any formal intermediary group must be formally constituted with terms of reference set by the Commission. Second, to ensure timely progress, the group should be established as a stand-alone subsidiary body, rather than adding the responsibility to an existing subsidiary body of the RFMO. As mentioned above, because NAFO's RBFM group was dedicated entirely to the Greenland halibut MSE, it was able to progress from start to MP adoption in just 7 months (NAFO 2017). Third, this intermediary body should report directly to the Commission, but should also have the ability to report to — and receive feedback from — the RFMO's scientific committee. This

structure allows for the group to operate at the science–management interface. Finally, this group should also have the authority to offer broad direction to the scientific committee and technical modelling team as appropriate (e.g., giving guidance on how to assess trade-offs in the achievement of management objectives or suggestions for new candidate MPs to evaluate), as well as the power to make recommendations on MPs to the Commission. This last process should narrow down the candidate MPs to perhaps one or two options only, based on a more thorough review of the MSE results, than can, or should, be expected at the Commission level.

(3) Meeting frequency

The timing and frequency of formal intermediary group meetings should be driven by the requirements of the particular MSE process rather than following an annual cycle. In some years, this group might meet multiple times, yet in others it might not meet at all, depending on the MSE work plan and availability of results. To maximize the participation of the appropriate audience, it may be preferable to schedule meetings as close as possible to other meetings of the Commission.

However, at some stages of the MSE process, a meeting may need to be scheduled with a sufficient interval before a Commission meeting (especially when it is time to make a final decision). This is to prepare the output from the formal intermediary group for presentation to the Commission and to provide sufficient time for member nations to consider the results before the Commission meeting itself. The scientific experts from the technical modeling team need to be available at multiple times intersessionally each year, especially in the early stages, to ensure timely information flow to and from the formal intermediary group and also ensure continued progress outside the formal meeting cycle. While it may be challenging for tRFMOs to schedule time and dedicate resources for additional intersessional meetings, it is necessary to ensure a timely and successful process.

(4) Effective operation

For the formal intermediary group, which will focus increasingly on discussing the results of the MSE process and making decisions or recommendations for refinement as the process advances, presentations should include a small number of standard tables and plots for the resource under consideration, which aim to facilitate the understanding by the less technical audience. This package of standard plots and tables needs to be properly documented in a readily available location (e.g., the RFMO website). Appendix C provides examples of graphics that could be considered as part of this package.

Informal intermediary groups

Informal intermediary group meetings are not just acceptable; they are desirable and should be considered an integral part of the process for the greater understanding and ownership that they can generate. Many of the comments made above concerning formal intermediary groups also obviously apply to informal ones, so that the sections below do not repeat these, but focus rather on differences and additions.

Meetings of informal intermediary groups (with no official governmental representation) play a different role and are beneficial as they provide a venue for more open discussion, with scientists, managers, and stakeholders speaking without the constraints of formal delegations. This allows participants more latitude to speak to their area of individual expertise or interest and to ask questions, which is particularly valuable at certain points of the process, including at the beginning when the most capacity building is necessary. Relaxing the formality of the meeting (without government representatives speaking from behind their flag) helps to minimize posturing. Being less encumbered by national positions, participants are able to delve further into particular

Table 3. General advice for informal intermediary groups.

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- Agree that there will be no attribution to individuals outside the meeting so as to increase speakers' openness.
 - Adopt a casual dress code to make the process more informal.
 - Employ a more circular room layout with group tables to help to break down established, or default, groupings among participants.
 - Plant people at the tables to lead lateral, small group discussions that can then be shared with the larger group.
 - Use hands-on and facilitated activities rather than traditional lecture-style presentations with questions to ensure a genuine dialogue among all participants.
 - Bring in managers and stakeholders with experience in other MSE processes to share their perspectives, rather than having all presentations made by scientists early in the capacity-building process.
-

steps in the process — both the underlying science and management implications — to determine how to proceed.

(1) Structure and membership

Membership is important to the success of the informal intermediary group, which will progress faster if kept smaller in numbers. For tRFMOs with many members, however, it may be difficult to keep the group small enough to enable a true dialogue to take place and to accomplish necessary tasks. This is especially true when each nation should in principle be represented by at least one scientist and manager, as well as key stakeholders, and it is preferable to allow each to speak as individuals to maximize engagement. While member governments might be urged to bring only their essential staff, tRFMOs typically do not exclude interested participants. Smaller groups may be better suited to getting into the details of the MSE, but again the political reality of the tRFMO must be taken into account; whether informal or formal, the group must be large enough and representative enough to maximize ownership of the process and the outcome and to minimize the risk that there is no acceptable MP to adopt at the conclusion of the process. This is also why it remains important for the Commission, as the ultimate decision maker, to approve each major stage of the process, regardless of the membership and efficacy of any intermediary group.

(2) Key elements

The first three elements that applied to the formal intermediary group again apply here. However, it is unlikely that the informal group would need to provide direction to the scientific committee and technical modelling group, and it certainly would not make recommendations on MP selection to the Commission.

(3) Meeting frequency

Broadly the same considerations apply as for the formal group.

(4) Effective operation

Informal intermediary groups need to be engaging and committed to genuine dialogue among all participants (see Table 3 for suggestions). Independent facilitators with good communication skills and MSE understanding (though there are unfortunately few) may be particularly helpful to assist in clarifying concepts and identifying misunderstandings. The meeting format, however, should be a wide-ranging discussion among participants, where exploratory questions are encouraged, in contrast with a structured discussion interpreted through the facilitator, to the extent that is possible within the context of a multilateral forum, such as a tRFMO.

When developing the agenda for informal meetings, there are some important considerations. First and foremost, although some introductory material on MSE and MPs should be presented at certain times in the process (especially because the composition of national delegations can change regularly), it is important to get beyond the big picture and to provide the specific details and results for the particular case relevant to the group (i.e., what are the implications of the MP and MSE for them and their fishery). More specifically, once initial results become available from

the technical modelling team, what are the quantitative trade-offs among the performance statistics for the various objectives (e.g., across the broad categories of stock status, catch, and catch rates for major fleets) for the different candidate MPs?

(5) Language difficulties

One particular challenge for informal intermediary groups is that there are often language barriers, particularly in the case of technical discussions. Meetings with simultaneous interpretation often err toward the more formal, but this can be overcome (e.g., through small breakout group meetings with multilingual participants on hand to translate as needed). Furthermore, because of language barriers, together with the large number of nations involved in the tRFMOs and the expense of travelling to one central location, convening regional workshops can be valuable to allow for smaller meetings in the regional language that also relieve the pressure common to larger group meetings where there is a requirement to make a decision. Capacity-building workshops organized by the FAO Common Oceans/ABNJ Tuna Project in the context of IATTC (in Spanish) in 2015 and in ICCAT (in French) in 2018 are examples.

Recommendations for communication tools

Well-designed communications tools, developed in concert with experts in communications and graphics, can be tailored to present the appropriate level of detail to the four groups, from the technical MSE development group up to the Commission, and to facilitate the necessary level of understanding within each group. However, it can be difficult to determine how to define “appropriate” for each group. It is clear where to start (i.e., voluminous level of detail at the technical subgroup level, commonly running to hundreds of pages) and where to end (i.e., a very condensed version for Commissioners, running to less than 10 pages, with an executive summary of less than a page), but the middle is case-specific. To determine the appropriate level of detail for the intermediary group(s) and scientific committee, scientists must work with managers and stakeholders to understand the range of knowledge levels, information needs, and decision-making responsibilities within each group (Hart 1996; Fischhoff 2013).

Scientists involved in MSE need an overall package of visuals to present both preliminary and final MSE results in a consistent manner. Detailed suggestions are provided in the Stage 3 section of Appendix B, with some graphical examples and explanatory text in Appendix C. The most important of these metrics can also be presented in simple tabular form (e.g., see Table C1). Recall that audience matters — only the technical subgroup conducting the actual MSE needs this entire package. Table 2 presents a matrix of which of these tools should be used for each group and how they should be tailored to meet that group's specific needs.

Developing effective and comprehensible communication tools can be challenging given the complexity of MSE. For example, the suite of results will typically include multiple candidate management procedures, multiple performance statistics, and multiple operating models. Most audiences will therefore likely have difficulty comprehending a matrix of the complete results. For deci-

sion makers and stakeholders, it is usually sufficient to display the trade-offs in performance for the principal management objectives (e.g., population size versus catch, as seen in Fig. C1) and an overview of uncertainty (e.g., using probability envelopes and error bars). Time series trajectories (sometimes called worm plots; Figs. C4 and C5) are also beneficial in that they illustrate not just the start and end points but also the extent of variability in population size and catch over time. Spider plots are useful for simultaneously visualizing the performance of multiple candidate management procedures against multiple performance statistics (Fig. C3) and were the primary graphic used by ICCAT for the northern albacore MSE results (ICCAT 2018).

Since most MSE processes produce similar types of results, it is possible to produce standardized communications tools that could be used across stocks within RFMOs and even among RFMOs and for domestic fisheries. This is particularly valuable to facilitate understanding among managers and other stakeholders who are viewing MSE results for many different fisheries in multiple fora. For example, IOTC is developing a suite of graphics to be used for the presentation of MSE results for all of its stocks (IOTC 2018). Templates for slide presentations of results would also help to streamline what information scientists share with stakeholders and to provide a consistent and familiar structure for the audience. Since the overall MSE process is new to many groups and quite complex, it is also critical to develop overview materials, including multimedia tools, to describe the purpose, steps, and outcomes (both at the model output stage and on the water once put in practice). Together, these communication tools for the process and results could be housed together on dedicated webpages (e.g., hosted by each RFMO) to make them easily accessible.

There are basic tips that should be considered when developing any visuals (see also Appendix C). The ultimate goal is to give the Commissioners what they need to make a decision. Simpler (but not oversimplified) messages are more likely to be understood, remembered, and accurately repeated to others. As long as all of the results are readily available for those with the need, or interest, to access them, they do not all need to be presented. When developing visuals to communicate MSE results, consider these basic tips:

- Tell a story, with one main point per graphic. Captions should tell this story clearly, completely, and **concisely**.
- Realize that people bring their own (common) biases to presentations (e.g., green is good, things at the top are better).
- Minimize redundancy (e.g., do not present results for similar performance statistics), and advise the audience when a subset of results is presented.
- Communicate why the audience can have confidence in the science (e.g., stress the wide types and extent of uncertainty under which the proposed MP will work reliably).
- Emphasize the central tendency (means or medians) of projections for a very few performance statistics, as this will often provide sufficient core information for Commissioners.
- Be careful when choosing a scale for axes because scaling can inadvertently make a minor difference look appreciable and vice versa. Take the time to explain the axes on a graph before discussing its implications.
- When possible, use interactive interfaces where users can enter various management options and see their performance to build understanding of dynamics, uncertainty, and interactions of elements of the management system. An example of such an interface is available from <https://puntapps.shinyapps.io/tunamse/>.
- When giving oral presentations, control the flow of information so that the audience focuses on only one point at a time. For example, stagger the appearance of text and build the components of diagrams and plots, rather than displaying the complete slide content at once.

Once draft tools are developed, it is wise to request feedback from managers and stakeholders, even if they are from other fisheries, as well as communication experts, for their advice on how to refine the tools to meet the needs of the various audiences. Adherence to these suggestions can help to improve MSE communications tools and thereby MSE communication more broadly.

Conclusions

In this paper we have highlighted two related and necessary areas of communication in MSE: (1) an intermediary group or groups to facilitate effective dialogue among scientists, managers, and stakeholders and (2) production of effective and engaging visual and interactive tools. Taken together and implemented effectively as part of a carefully designed MSE process, these practices have the potential to increase the likelihood of adoption of a widely supported and transparent MP.

The MSE development process is iterative, requiring multiple rounds of exchange among scientists, managers, and stakeholders. As such, listening and genuine dialogue, in contrast with technical lecturing, are critical to a successful process. It is inevitable that some participants will never understand all of the details. This is not a barrier as long as they trust those who do, understand their role in the MSE process, and have the information required to weigh the benefits and risks associated with different MPs and to advise on, or make, the decisions for which they are responsible.

At present there are no scientific communications staff at the tRFMOs, and although coaching and training can be provided, strategic communication and graphic design experts can help catalyze the dialogue and lead to better understanding of the process and its potential benefits. As MSE use expands in tuna RFMOs, and for other international and domestic fisheries, there is an opportunity to develop a consistent, multidisciplinary, multimedia approach to communication that promotes understanding and supports the development of MSE-tested MPs as a fisheries management approach.

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Appendix A. Glossary of MSE concepts

Harvest control rule (HCR): A rule that describes how the harvest is to be managed (e.g., catch- or effort-related limits) based on the state of a specified indicator(s) of stock status. Also known as a decision rule.

Management objectives (MOs): Formally adopted goals for a stock and fishery. These include high-level objectives often expressed in legislation, conventions, or similar documents. As the process progresses, they should also include operational biological and socio-economic objectives that are specific and measurable and possibly also associated timelines and minimum required probabilities that can be achieved.

Management procedure (MP): A pre-agreed framework for recommending or making fisheries management decisions, such as setting catch limits, that is designed to achieve specific management objectives. A fully developed MP specifies which monitoring data will be collected, how the data will be analyzed, and what harvest control rule(s) will be applied and has been simulation-tested to determine likely performance across a range of uncertainties (e.g., via MSE). Also known as a harvest strategy.

Management strategy evaluation (MSE): A simulation-based, analytical framework used to evaluate the performance of multiple candidate management procedures relative to the prespecified management objectives. The expression is also used to describe the process of implementing this framework to lead to the eventual adoption of an MP.

Operating model (OM): The part of the MSE that represents the “true” underlying status and dynamics of the population, fishery, and monitoring regime. There will be a number of OMs considered so as to capture the full range of uncertainties applying to the resource and fishery. Often two sets of OMs are used: a “reference set” of the most plausible scenarios or hypotheses with the greatest impact on outcomes and a “robustness set” of unlikely but still possible scenarios or hypotheses.

Performance statistic: A quantitative expression of a management objective. Performance statistics compare the value of an indicator or variable (e.g., biomass, depletion) at a given point in time (or over a period of time, such as average catch over the next 20 years) to the stated objective for this indicator, so as to evaluate how well the objective is expected to be achieved under the MP being evaluated. Also known as performance metrics or performance measures.

Reference point: A benchmark against which to compare indicators of stock abundance, fishing mortality, or socio-economic outcomes to evaluate status. Target reference points refer to desirable states, while limit reference points are boundaries that define states to be avoided.

Appendix B. Issues to be addressed by MSE technical modeling groups

General considerations

- The main duties of an MSE technical modelling group are to
 - specify and implement the MSE operating models;
 - conduct the projections;
 - summarize the results for presentation to the scientific committee; and
 - winnow the set of candidate management procedures passed on the scientific committee to a manageable number.
- The work of the MSE technical modelling group could be conducted by the group's members or contracted out.
- The work of the MSE technical modelling group needs to be peer-reviewed through an appropriate process (e.g., the scientific committee).
- The management procedures to be evaluated need to be endorsed by the scientific committee and subsequently by the intermediary group(s).

- The Group will work iteratively, making use of feedback provided from time to time by the scientific committee, the intermediary group(s), and the Commission.
- Ensure that code and results are archived throughout the process; there are software packages and online shareable repositories available that can assist with this (e.g., GitHub).

Stage 1 — designing the MSE

- Given the management objectives that have been decided by the Commission, develop relevant performance statistics, including the time frame over which they are calculated (some of these may be based on the Dynamic B_0 concept to allow for nonstationarity in the processes governing the dynamics; e.g., Punt et al. 2014). Some of these performance statistics may readily allow comparisons with standard reference points.
- Identify the data that could be used
 - as input to candidate management procedures; and
 - for conditioning the operating model (i.e., fitting the operating model to the data).
- Identify plausible hypotheses and determine the structure of the associated operating models, thus taking model uncertainty into account. The types of uncertainties that should be considered for possible inclusion in any MSE include
 - stock structure, including movement and dispersal;
 - nonstationarity of parameters (in particular for the stock-recruitment relationship);
 - productivity;
 - implementation error (including allocation of TACs among fleets and future fleet behavior);
 - observation error associated with future data and sources of process error (e.g., deviations in recruitment, catchability, selectivity) to be sampled in projection replicates; and
 - the values for parameters (such as natural mortality, steepness) that are prespecified.
- Develop a specifications document for the operating models and associated trials, including the process for generating the data used by the candidate management procedures.
- Assign the trials to a reference set (the more plausible and influential uncertainties) of operating models, with the rest assigned to the robustness trials. Typically, the number of uncertainty types included in the reference set should not exceed five without compelling reason, for each of which usually at most three levels will be sufficient. Individual operating models will consist of unique combinations of each uncertainty type or level.
- Develop a “code validation” process (focused on any code that has not been validated previously) — this includes checking that the generated data reflect the actual statistical properties of errors (i.e., residuals) in assessments.

Stage 2 — conditioning and management procedure specifications

- Conduct the conditioning (i.e., estimate the operating model parameters by fitting to the data available).
- Develop and implement a process for evaluating the adequacy of the conditioning (i.e., does the model fit the data).
- Suggest a relative plausibility for each trial (which needs to be agreed or refined by the scientific committee).
- Using a small set of management procedures, identify and then eliminate correlated performance statistics (keep the simpler ones). In the final selection process, it will typically be difficult to take more than about five performance statistics into close account.

- Identify candidate management procedures, including any “design features”, such as agreed limits (maximum and minimum) on TAC or effort changes (note that candidate management procedures may be specified by members of the MSE technical modelling group or by other participants in the process).
- Specify proposed “exceptional circumstances” protocols and the basis for their implementation, taking account of issues raised at and suggestions made by the scientific committee, the intermediary group(s), and the Commission.
- Develop a way to tune the management procedures to facilitate fair comparisons, a process that should be endorsed by the scientific committee. Such tuning might be to a standard reference point (e.g., one related to population size) for a specified trial.

Stage 3 — plots and summaries

- Run the trials for each candidate management procedure put forward.
- Compute the plots and tables; an essential list (see also Appendix C) includes
 - projections for catch and (or) effort and (some measure of) abundance;
 - both central tendency and some probability envelope;
 - a measure of interannual catch variability;
 - some output to make clear that a central tendency (e.g., median) projection does not reflect the behavior to be expected in practice (e.g., worm plots);
 - results for the reference case or an average over a reference set of OMs; and
 - trade-off plots and Zeh plots (box plots of statistics for multiple management procedures for one operating model or for one management procedure for multiple operating models).
- Attempt to reduce the number of candidate management procedures and trials for which results are reported:
 - eliminate any management procedures that fail to achieve performance standards agreed by the scientific committee (e.g., a maximum probability for falling below a certain population size might be specified by that committee, though that would need to have taken account of discussions about trade-offs against other performance statistics, such as the size and variability of catches, in the intermediary group(s) and possibly the Commission);
 - eliminate variants of the same management procedure when they achieve near-identical results; and
 - eliminate reporting of outcomes from trials that show near-identical results from those finally included in the reference set.

Reference

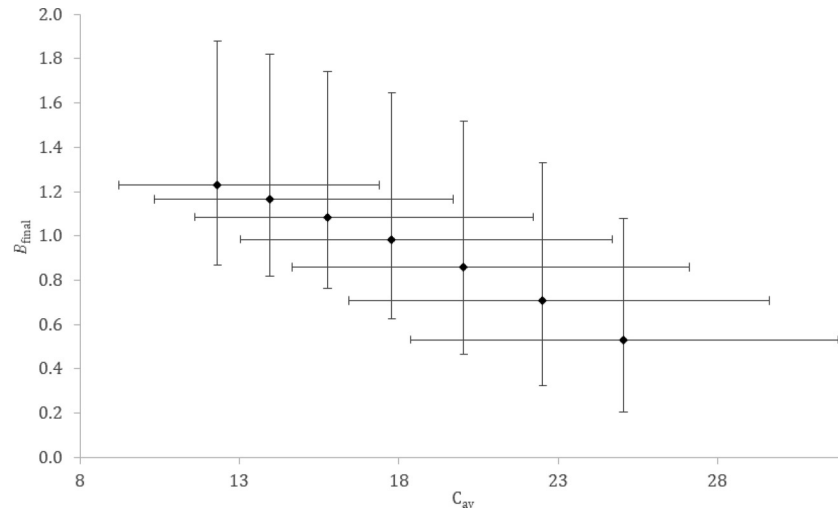
Punt, A.E., A'mar, T., Bond, N.A., Butterworth, D.S., de Moor, C.L., De Oliveira, J.A.A., Haltuch, M.A., Hollowed, A.B., and Szuwalski, C. 2014. Fisheries management under climate and environmental uncertainty: control rules and performance simulation. *ICES J. Mar. Sci.* 71: 2208–2220. doi: 10.1093/icesjms/fst057.

Appendix C. Examples of plots frequently used to summarize key MP performance statistics

MSE exercises produce a considerable quantity of output material, and it is essential to summarize this in a manner that allows for ready interpretation in relation to the most important performance statistics.

The examples that follow are from an application of the MSE approach to a real resource (NAFO 2017). Generally, results from an MSE need to reflect expectations for the future for (at least) catches, resource conservation, and fishery stability. The examples are in terms of performance statistics that are frequently chosen to summarize such results (see the captions of Figs. C1 and

Fig. C1. Trade-off in performance between average annual catch over the projection period (C_{av}) and biomass relative to its value at MSY at the end of a 20-year projection period (B_{final}) for different tunings of a candidate MP for a particular operating model. Median values are plotted, with the error bars indicating 90% probability interval.



C2 for their definitions) and reflect results for replicates of 20-year projections. These examples cover a minimum set of what will need to be presented in most cases. The format might be amended but should always respect good practice guidelines by keeping all axes in the same direction for low-to-high values and avoiding comparison of more than some three to four options to maintain clarity. Given the importance of plots in particular for effective communication in the overall MSE process, advice from science graphic designers may be valuable to better ensure that the key messages of such plots are conveyed to decision makers in a clear, compelling, and easily understood manner.

Figure C1 shows how results may be illustrated for what is typically the most important trade-off selection to be made between conflicting objectives — whether to aim for more resource recovery or for greater catches in the short-to-medium term. Note that the biomass (B_{final}) shown here might reflect either the total biomass of the population or some component thereof, such as exploitable or spawning biomass, with the last being the most frequent choice.

Typically one or a few choices for this trade-off are made early in the process, and subsequent candidate MPs are “tuned” to such selection(s) to facilitate comparisons of their performances. Thus, subsequent results shown here are for candidate MPs that were all tuned to achieve B_{MSY} in median terms after 20 years (i.e., here $B = 1$ as biomass in the plots is shown relative to B_{MSY}). The plots that follow contrast performances for three candidate MPs all tuned in this way for a (baseline in this case) operating model. As is customary, results for the case of zero future catches ($C = 0$) are also shown, as these indicate the bound for the largest extent of recovery of which the resource is capable within the projection period.

The next two figures (Figs. C2 and C3) illustrate two different ways (Zeh and spider plots, respectively) of integrating results to show trade-offs and thereby aid the choice among candidate MPs based on their differences in performance. They allow the results for different candidate MPs to be shown together, typically accompanied by those for the $C = 0$ scenario. Because of the tuning to the same final median biomass after 20 years, usually median average annual catches for such MP candidates do not differ much, but other performance statistics may show rather larger differences, as the average annual catch variability statistic (AAV) does in this case.

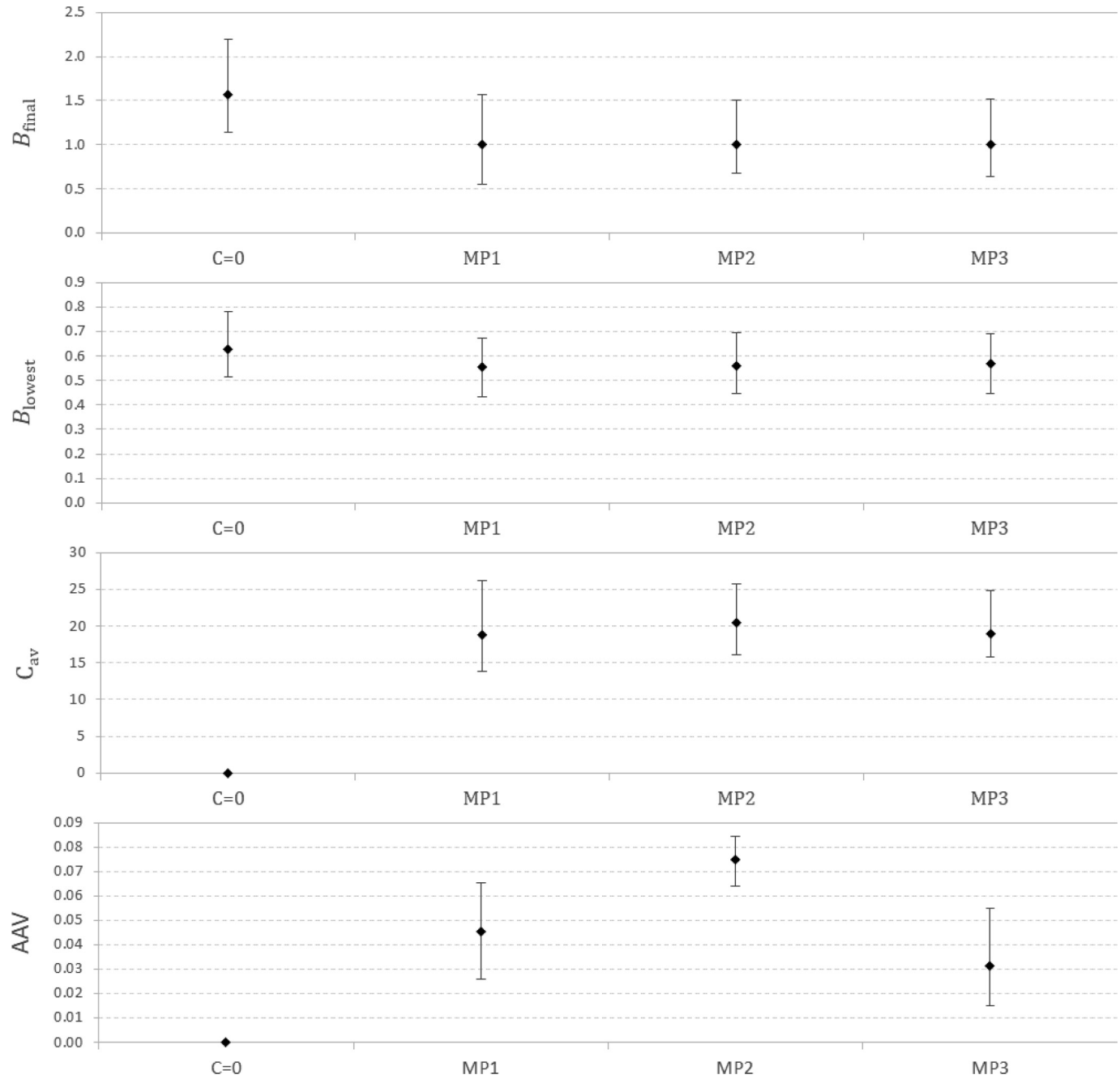
The subsequent two figures add important further information about the way in which various measures (generally involving annual catch and biomass) are expected to change over time in the future. Figure C4 contrasts the three MPs (and the $C = 0$ scenario) in terms of the median and lower tenth percentiles of the distributions arising from the projection replicates (the lower percentile provides a measure of risk). Figure C5 shows “worm” plots for one of the MPs; these show a number of individual replicate trajectories and provide important insights, as they often show variability characteristics that are not evident from the plots in Fig. C4.

These are followed by Table C1, which lists the values of the performance statistics shown in Figs. C2 and C3, which would typically be reported in tabular form as well.

Reference

NAFO. 2017. Report of the Commission and its Subsidiary Bodies (STACTIC and STACFAD), 39th Annual Meeting of NAFO, 18–22 September 2017, NAFO/COM Doc. 17-29 (Revised) [online]. Northwest Atlantic Fisheries Organization. Available from <https://www.nafo.int/Portals/0/PDFs/com/2017/comdoc17-29.pdf>.

Fig. C2. An example of a “Zeh plot” used to compare trade-offs in performance statistics among different candidate MPs (MP1, MP2, MP3, as well as zero future catches, $C = 0$). The symbols show projected median and 80% confidence intervals. The performance statistics shown are as follows (from top to bottom): exploitable biomass relative to its value at MSY at the end of the projection period (B_{final}), which reflects resource status; the lowest value of the projected exploitable biomass during this projection period (B_{lowest}), which relates to resource conservation (higher values reflect keeping risk low and hence safety high); the average annual catch over the projection period (C_{av}); and the average interannual proportional change in catch (AAV), which needs to be low if the fishery is to be stable.



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Fig. C3. An example of a “spider” plot, which provides a simple basis to compare multiple performance statistics among different candidate MPs. Shown here are the same three MPs and the $C = 0$ scenario as in Fig. C2, together with the medians of the same performance statistics. Notation in this and the figures following (Figs. C4–C5) is explained in the introductory text for Appendix C.

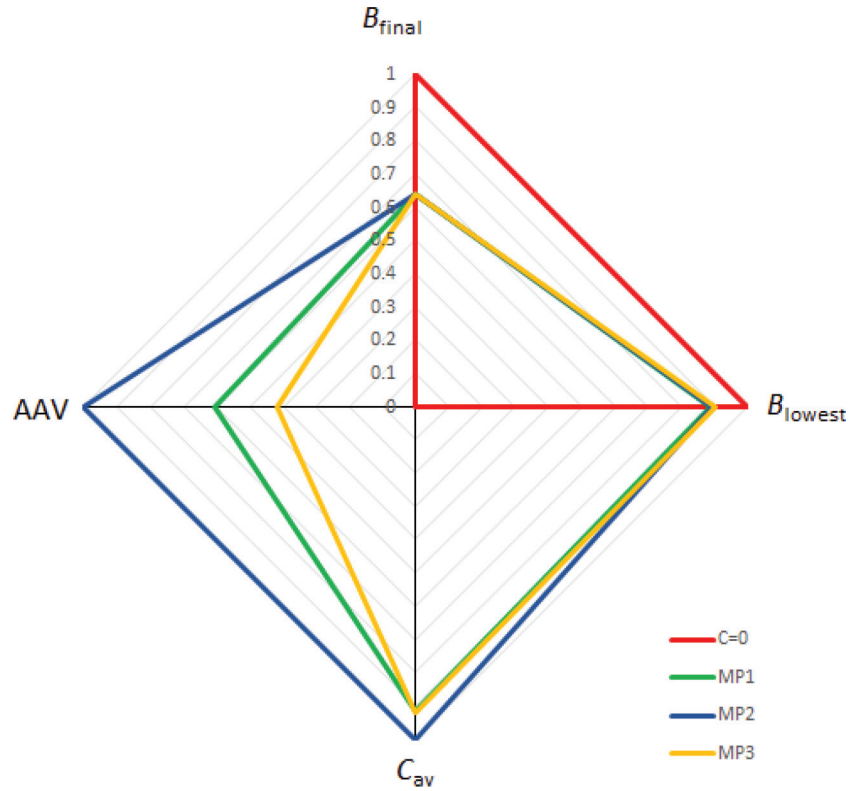
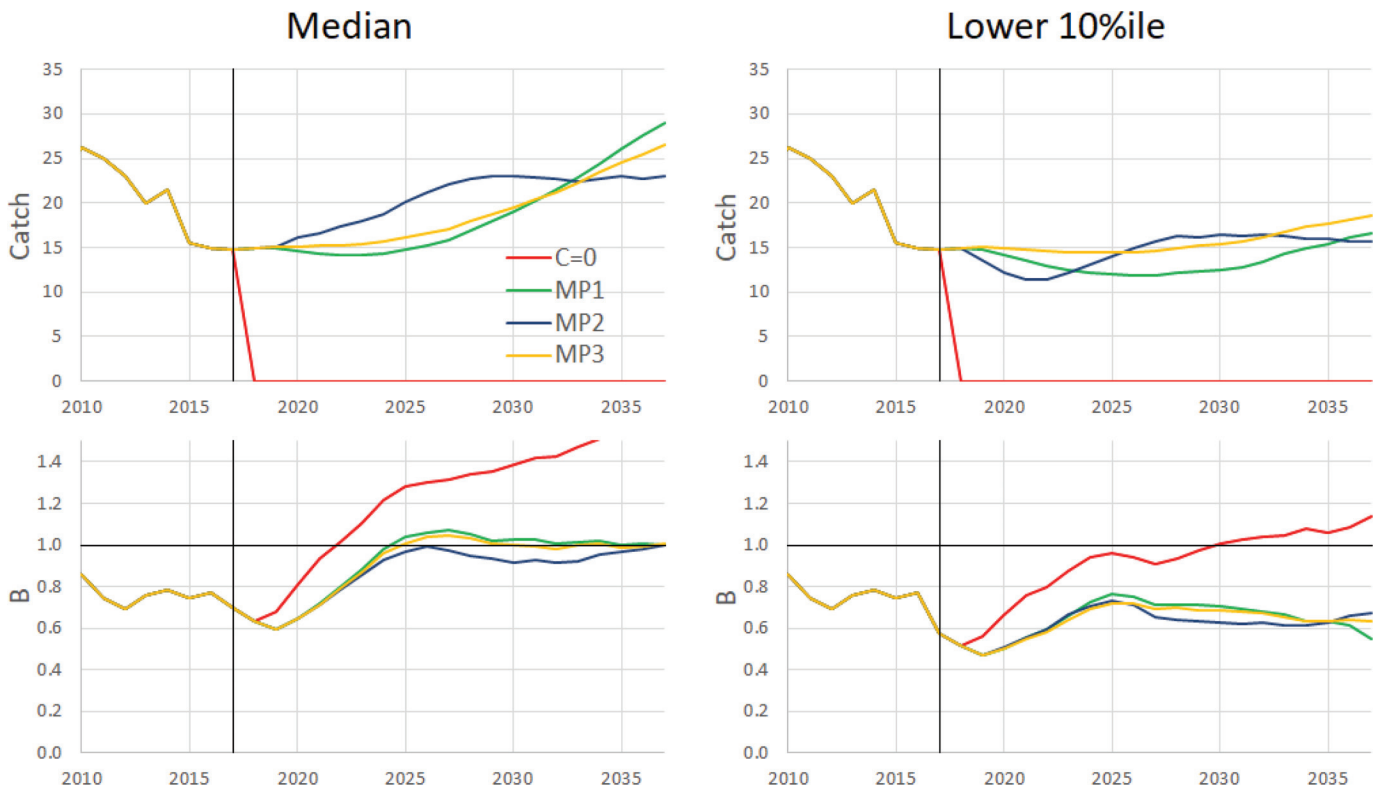


Fig. C4. Projected 20-year median and lower 10th percentiles for catch (C) and biomass (B) (relative to B_{MSY}) for three candidate MPs: MP1, MP2, and MP3, as well as for $C = 0$ for a particular operating model.



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Fig. C5. “Worm” plots showing individual trajectories as well as the 80% probability envelopes (grey shading) for catch and spawning biomass B^{SP} (relative to B_{MSY}) for MP3 under a particular operating model.

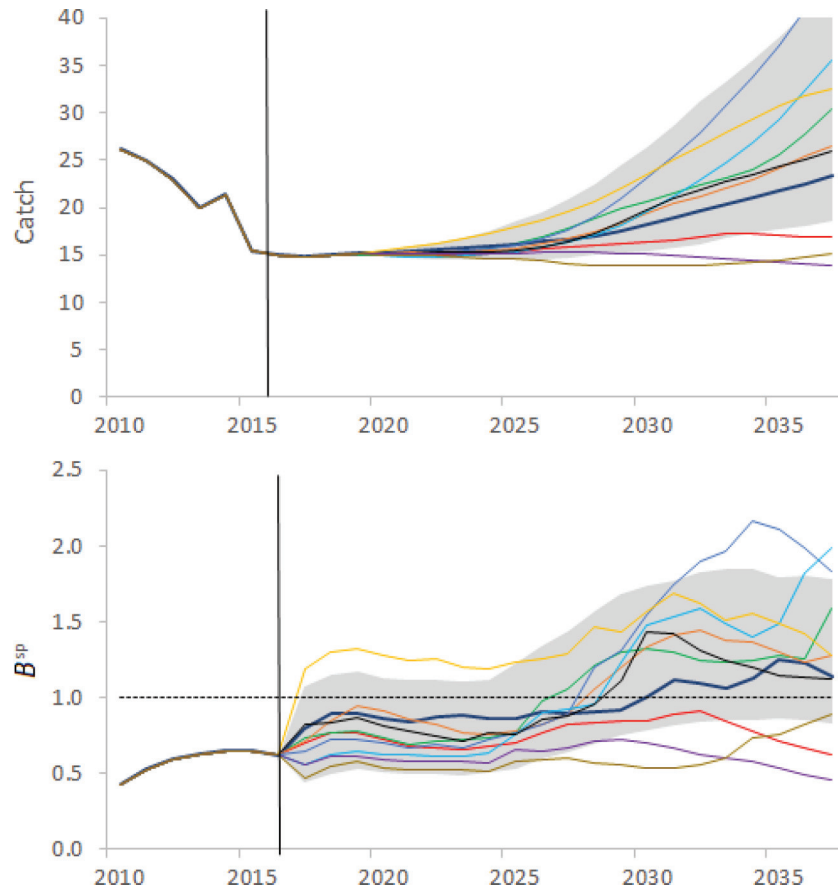


Table C1. Performance statistics, medians with 80% probability intervals in parentheses.

	B_{final}	B_{lowest}	C_{av}	AAV
$C = 0$	1.57 (1.14; 2.19)	0.63 (0.51; 0.78)	0.00 (0.00; 0.00)	0.00 (0.00; 0.00)
MP1	1.00 (0.55; 1.56)	0.56 (0.43; 0.67)	18.80 (13.82; 26.13)	0.05 (0.03; 0.07)
MP2	1.00 (0.67; 1.51)	0.56 (0.45; 0.70)	20.53 (16.15; 25.68)	0.07 (0.06; 0.08)
MP3	1.00 (0.64; 1.52)	0.57 (0.44; 0.69)	18.89 (15.77; 24.81)	0.03 (0.01; 0.05)

Note: B , biomass; C , catch; AAV, average annual catch variability; MP1–MP3, alternative management procedures.

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