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Title: Integrating Management Strategy Evaluation into fisheries management: advancing best practices for stakeholder inclusion based on an MSE for Northeast U.S. Atlantic herring

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20 ***ABSTRACT***

21 The New England Fishery Management Council used Management Strategy Evaluation (MSE)
22 to evaluate possible harvest control rules for Atlantic herring, the first MSE in the U.S. and
23 perhaps globally to use open-invitation, public workshops for input. Stakeholder inclusion can
24 increase both realism and likelihood of use by managers, but inclusivity is not achieved easily.
25 Here, self-selected participants had diverse backgrounds and differing levels of interest and
26 preparedness. We describe some challenges with directly engaging the public in MSE and offer
27 broader insights for obtaining effective public participation during a decision-making process.
28 Conducting an open MSE aligns well with publicly-driven management but requires clear goals
29 and communication. Investment in effective organizers, impartial facilitators, and knowledgeable
30 analysts can improve communication and understanding of MSE, to the betterment of fisheries
31 management. We aim to further MSE best practices on integrating stakeholders and hope that
32 our lessons learned on communication, engagement, and integration of MSE into an existing
33 management arena will be useful to other practitioners.

34 **INTRODUCTION**

35 Management Strategy Evaluation (MSE) generally involves defining a decision problem,
36 specifying objectives, and simulating the managed system to help evaluate uncertainties, risks
37 and trade-offs of management alternatives. The MSE approach was first developed through the
38 International Whaling Commission (IWC) in the 1980s (Punt and Donovan 2007), though the
39 South African hake fishery was perhaps the first case where an MSE was integrated into
40 management decisions, in the early 1990s (Geromont et al. 1999; Holland 2010). Application of
41 MSE has become more common globally over the past 30 years (De Oliveira et al. 2008; Punt et
42 al. 2016), primarily for quota-managed fisheries, though the approach remains a departure from
43 the status quo for many fisheries. In the U.S., the National Marine Fisheries Service (NMFS) is
44 now expanding capacity to broaden the use of MSE (USRFMC 2018).

45 Stakeholders have been involved in MSEs to varying degrees. On one end of the spectrum is a
46 process in which scientists identify parameters and conduct modeling largely separate from the
47 management arena (e.g., Deroba 2014; Taylor et al. 2014). On the other end, stakeholders
48 participate throughout the MSE (e.g., Jones et al. 2016). It appears that stakeholder integration
49 typically involves working with small groups of selected representatives. In the cases of South
50 African hake and New Zealand rock lobsters, MSE stakeholder participants were quota holders
51 and their industry associations which have legal rights to participate in management processes on
52 behalf of the industry (Holland 2010). Smith et al. (1999) detail the early Australian Fisheries
53 Management Authority (AFMA) process, in which about seven representatives from state or
54 territory governments, quota holders, and the conservation community were invited to
55 collaborate with MSE analysts in closed session to develop recommendations for the AFMA. We
56 agree with Rochet and Rice (2009), however, that the MSE literature has largely focused on

modeling aspects, with less emphasis on the degree of stakeholder engagement, how accessible the MSE process was to the public, and how MSE outputs informed management decisions. We believe that stakeholder engagement should not be at the periphery of MSE scholarship for at least two reasons. First, early and frequent involvement of stakeholders in knowledge acquisition and policy making can reduce the likelihood of problem misidentification or that the wrong tool is developed to solve it (Freeman 1984). Higher levels of stakeholder engagement can improve governance and increase regulatory legitimacy (Ostrom 1990; Hanna 1999). Second, while participatory approaches (e.g., workshops) involving both decision-makers and a spectrum of stakeholders is now considered MSE best practice (Punt et al. 2016), engaging stakeholders remains time-consuming and challenging. Who are the “right” stakeholders? How can involvement of people with diverse backgrounds, interests and experiences be effective and efficient? We address these questions using experience from a close collaboration between the New England Fishery Management Council (Council) and the U.S. NMFS, using MSE to develop a management strategy for Atlantic herring that accounts for its role as forage in the ecosystem (NEFMC 2018a). This management strategy was, however, only the harvest control rule (HCR; a formulaic approach to setting catch limits) and did not include the stock assessment model (Deroba et al. 2018). Not including the stock assessment model may result in selection of an HCR that does not meet fishery objectives or perform as anticipated. Including the stock assessment model is considered best practice and this could be explored in future MSE revisions (Deroba et al. 2018), similar to a process used by the IWC. The initial IWC New Management Procedure led to developing the Revised Management Procedure which included not only the

79 adoption of the HCR, but the assessment model and data input into the model-based HCR (e.g.,
80 Butterworth 2007).

81 Atlantic herring management, led by the Council since 1999, is at a nexus of competing interests,
82 challenged to sustain both a directed fishery and ecosystem benefits (NEFMC 2018c). The
83 directed fishery for Atlantic herring has been integral to the maritime economy and culture of
84 New England since at least the 1700s. First used as bait for the cod fishery, the canned market
85 burgeoned in the late 1800s, fueling over 60 canneries (Smylie 2004, p. 76-84) though they have
86 all closed due to a decrease in domestic demand for canned herring. The Atlantic herring fishery
87 now supplies bait for the American lobster fishery, one of the largest fisheries on the United
88 States Atlantic coast (\$670M in ex-vessel revenue in 2016; ASMFC 2018).

89 Public interest in the Atlantic herring resource is heightened by its role as forage to multiple
90 predators in the ecosystem (e.g., groundfish, tuna, whales), which support commercial fisheries,
91 recreational fisheries, and ecotourism. The objectives and preferences of stakeholders from these
92 industries are frequently in direct conflict with the objectives and preferences of the herring
93 industry. For example, in 2000, participants in the whale watching industry claimed that
94 commercial herring harvests negatively impact ecotourism, thus urging managers to consider the
95 dietary needs of marine mammals when setting catch limits (65 *Federal Register* 77460). Similar
96 concerns were raised in 2006, 2007, and 2013 for other predators (70 *Federal Register* 21973; 72
97 *Federal Register* 11258; 78 *Federal Register* 61832). Stakeholders are concerned about the level
98 of harvest relative to biomass and the spatial and temporal distribution of harvest, under the
99 hypothesis that intense harvest causes localized depletion of the herring resource and is
100 associated with poor outcomes in other human uses. Thus, management of this fishery has been
101 quite contentious.

This was the first application of the MSE approach by the Council, and the level of stakeholder participation in this MSE appears to be rare, if not unique, at least for U.S. fisheries. Open-invitation, public workshops were used to increase awareness of MSE, identify value-based objectives and new data sources, discuss known or hypothesized ecological conditions, inform development of the analytical components of the MSE, present simulation results to the public, and generate recommendations to managers. The legal constraints of U.S. federal fisheries and the degree of public contention drove many of our decisions for an open process.

Deroba et al. (2018) report on our MSE simulation modeling. Here, we describe efforts to engage the public and highlight lessons learned from fully involving a diverse group of self-selected participants. We aim to further MSE best practices as they relate to integrating stakeholders, anticipating increased calls for more transparent and participatory decision making, and hope that our lessons learned on communication, engagement, and integrating MSE into an existing management arena will be useful to other practitioners.

TO MSE OR NOT TO MSE?

Atlantic herring has been managed since 2007 with a harvest control rule to set the Acceptable Biological Catch (ABC), the overall catch limit. This HCR was subject to change each time ABCs were specified (typically every 3 years). In 2015, managers began work on a longer-term HCR, one that would account for the role of Atlantic herring in the ecosystem and stabilize the fishery at a level designed to achieve optimum yield (NEFMC 2018b). Later in 2015, managers also chose to concurrently explore policy solutions to localized depletion concerns. At that time, the Atlantic herring stock was considered to be near carrying capacity (Deroba 2015). However, the latest assessment had diagnostic problems (*sensu* Mohn 1999), which suggested biomass could be overestimated. Some stakeholders were concerned that the actual amount of herring

125 available for predators in the ecosystem may be less than estimated. Managers recognized this
126 concern and the potential influence of other uncertainties.

127 Instead of developing HCR alternatives immediately after public scoping, the potential impacts
128 of which would be later evaluated, managers diverged from this typical approach by opting to
129 conduct their first MSE to support decision making. It was hoped that the MSE models could be
130 designed to help consider the robustness of predicted outcomes to assumptions and uncertainties,
131 such as assessment bias. This commitment to greater, upfront discussion of fishery objectives
132 and simulation of potential alternatives was also influenced by: 1) recommendations from
133 scientific advisors, MSE experts within NMFS, and staff; 2) preliminary evaluation of six control
134 rules; and 3) an acknowledgement that MSE is becoming more widely accepted as central to the
135 scientific basis for fisheries management, though novel in New England.

136 For its first MSE, managers carefully considered the degree of stakeholder participation in the
137 process. One option was to invite invested stakeholders to engage, an approach that can
138 effectively build momentum and reduce time spent introducing concepts (e.g., Lake Erie
139 walleye, Jones et al. 2016). However, how would participants be selected? Most MSEs to date
140 had been for fisheries managed with catch shares (e.g., Australian eastern gemfish, Smith et al.
141 1999); in those cases, identifying interested parties was relatively straightforward (Holland
142 2010). The directed Atlantic herring fishery is limited access with about 35 active vessels
143 managed with fishery-wide quotas. Given the importance of Atlantic herring to the ecosystem,
144 its management attracts hundreds of interested parties (e.g., commercial and recreational
145 fisheries, ecotourism, conservation community). It would have been very difficult to overcome
146 public skepticism over introducing a new process and the specific membership of a closed group.
147 A second option was to have no managers at the table, but outcomes of MSEs conducted with

that approach (e.g., Ihde et al. 2011) can struggle to gain traction in decision-making (M. Wilberg, pers. comm., 2016). Importantly, to comply with U.S. federal law, Council-organized meetings must be public (APA, 1946). Although accepting public comment at its meetings is optional (FACA, 1972), the Council rarely disallows public comment.

Managers opted to allow all points of input to be open to the public, diverging from typical MSE stakeholder processes, primarily due to the diversity of interests and degree of controversy. This MSE was designed to mirror the existing, open management process as much as possible, while recognizing that engaging in MSE would be novel to managers and participants alike.

The MSE implementation team (managers, staff, MSE modeling team), recommended how best to integrate the MSE into the existing fishery management process. Plans were vetted through an existing advisory panel (comprised of herring fishermen and other stakeholders) and sub-committee of managers and ultimately approved by the full Council, all at public meetings. Regular check-ins with managers to formally review and approve each MSE step, while time-consuming, were essential to keep the MSE transparent and tailored to management needs. The MSE proceeded in the following distinct phases.

ATLANTIC HERRING MSE PHASES

Phase 1 – Developing initial input (January-June 2016)

The first two-day workshop (in May 2016) aimed to identify a range of potential objectives, how progress towards these objectives may be measured (i.e., associated performance metrics; e.g., interannual catch variation), and the range of control rules to test. Substantial agenda time was devoted to explaining the purpose and pathway of MSE approaches, establishing expectations for what could be addressed with an HCR, and fostering dialogue across stakeholder groups.

Workshop preregistration was encouraged, and outreach was conducted through normal channels for public notice (*Federal Register*, website, email, postal mail, trade publications). Registrants were tracked, and outreach was targeted towards achieving a broad spectrum of interested parties.

To help navigate contentious, unfamiliar waters, independent facilitators were used to lend neutrality to the process and ensure fairness to diverse interests. The lead facilitator was deliberately selected from outside of New England. Four small-group discussion facilitators provided additional assistance; they had knowledge about regional fisheries and management issues but little prior MSE experience.

The first workshop drew diverse participation of 64 individuals, including: herring fishermen and industry representatives; lobstermen; commercial, party/charter and private angler fishermen of tuna, groundfish, and striped bass, fishing community and environmental non-profit organization staff; scientists; whale-watch businesses; federal and state agencies; herring advisors, and managers. Of those 64, 58% attended for both days. Three MSE analysts and several support staff were present. Importantly, managers were asked to be in “listen-only mode” to allow the public to be central to the discussions. Reaching consensus at the workshop was deemphasized and recommendations were not prioritized, so managers could consider the full range of input. Attendees were encouraged to submit voluntary workshop evaluation forms, which the MSE implementation team used to make mid-course improvements (Table 1).

Upon review of the workshop recommendations and additional input from technical and advisory bodies, managers approved by consensus the objectives, performance metrics, and initial range of ABC control rule alternatives identified at the first workshop.

Phase 2 – Simulation testing (July-November 2016)

Over five months up until the second workshop, the MSE analysts identified, refined, or developed models of Atlantic herring, predators, and fishery economics and tested HCR performance relative to the performance metrics (Deroba et al. 2018). To support the legitimacy of the MSE as a public process, results were prepared for all metrics approved by managers, even those that the scientists expected to be less informative (e.g., uninfluenced by model parameters or control rules). This was different than some MSE processes where candidate objectives and models are exclusively designed by analysts (e.g., Wiedenmann et al. 2013).

Phase 3 – Second iteration of input (December 2016)

The second two-day workshop (in December 2016) aimed to review MSE outputs and generate input for finalizing the MSE. Participants were asked to identify acceptable ranges of performance for the metrics to help managers consider tradeoffs, and how the number of HCRs simulated could be narrowed (from 5,460 evaluated) into a more reasonable number of alternatives for further consideration.

This workshop was advertised similarly as the first and drew a similar number of individuals (n=65) and stakeholder types. Of these, 51% attended for both days and 51% had attended the first workshop. To increase public access, most of the workshop was broadcast via webinar (in listen-only mode); about 12 people observed this way. Though there was substantial attendee turnover, the participation of managers was consistent across workshops, and they were again primarily in “listen-only” mode. Attendees submitted evaluation forms at the close of this workshop as well (Table 1).

While there was much constructive input, there proved to be insufficient time to pare down the thousands of potential control rules into a reasonable range of alternatives. Management

215 deadlines precluded holding a third stakeholder workshop, which would have been beneficial to
216 meet this goal.

217 Phase 4 – Peer review (January - March 2017)

218 Given the regional novelty of MSE and degree of controversy, managers had the MSE peer
219 reviewed (in March 2017). To prepare, the MSE analysts refined simulations and reporting based
220 on public input. The three-day review by four MSE experts was public and included public
221 comment. The panel concluded that the MSE represented the current best available science for
222 evaluating the anticipated performance of Atlantic herring control rules and their potential
223 impact on key predators, and that the methods for identifying objectives, performance metrics,
224 and control rules for testing generally followed MSE best practices (NEFMC 2018a). The peer
225 review helped this MSE gain acceptance among the public and managers and reduced some
226 controversy over model assumptions and data limitations.

227 Phase 5 - Incorporation into fishery management action (January-December 2017)

228 Simultaneous to Phase 4, managers developed the range of ABC control rule alternatives for
229 further consideration, with input through public meetings of their technical and advisory bodies.
230 Rather than take the typical approach of identifying a range of management options prior to
231 analysis, integrating the MSE approach emphasized first identifying desired performance relative
232 to objectives and then using simulation results to winnow thousands of potential HCRs down to a
233 reasonable range for decision-making.

234 Managers unanimously approved a final range of ten ABC HCRs in April 2017, and staff spent
235 the next several months incorporating the MSE results (e.g., outcomes for all 14 performance
236 metrics identified at the first stakeholder workshop) into the environmental impact analysis -
237 another step in integrating the MSE with more standard management. In September 2017,

managers formally approved the work, but did not identify a preliminary preferred alternative, not wanting to influence public opinion during the subsequent comment period in spring 2018. Ultimately, the Council recommended a final HCR in September 2018 by considering the MSE results, near term catch projections following an assessment that showed herring biomass in decline (NEFSC 2018), public comment, and legal constraints. It was clear at the final meeting that some stakeholders and managers had used the MSE results when comparing the HCR alternatives considered. The final HCR recommendation is a slight variation on one of the ten previously analyzed, balances many objectives, and accounts for uncertainty. The MSE better enabled decision makers and the public to more fully appreciate the tradeoffs of HCR strategies on various elements of the ecosystem. The next step is for NMFS to review and potentially approve the recommendation. If approved, implementation of the HCR is expected mid-2019.

LESSONS LEARNED

An MSE that includes major stakeholder engagement can be challenging for scientists, managers, and stakeholders. We highlight a few lessons from our open-process MSE and note where they confirm established best practices or forward a different perspective (Table 2).

Wield the double-edged sword of inclusivity

Within MSE, stakeholder engagement is generally expected to produce benefits in terms of increased realism and improved implementation. However, stakeholders have unique experiences, interests, objectives, and approaches to engaging with managers, so an inclusive process can be time-consuming and untidy. Punt et al. (2016) offers as a best practice the need to engage stakeholders through “inclusive workshops” representative of the range of interests in the questions at hand. However, who and how many are the “right” stakeholders? Where stakeholder

260 engagement is described in MSE literature, participants have largely (perhaps exclusively) been
261 selected in advance, though who is doing the selecting has varied (MSE analysts, managers,
262 undescribed). We suggest that an MSE with a completely open process can be a viable option
263 when the legal constraints and/or degree of controversy demand a high level of public
264 engagement. Allowing for stakeholders to self-identify and participate throughout helped cut
265 through the veil of mystery surrounding MSE. Even so, complications were introduced.

266 A benefit of inclusivity was that our bounds expanded on who an Atlantic herring stakeholder is.
267 We had approached this MSE with a broad concept of “stakeholders” as forwarded by Newton
268 and Elliott (2016), as “...a person, organisation or group with an interest (professional or
269 societal) or an influence on the marine environment or who is influenced directly or indirectly by
270 activities and management decisions.” Even so, several workshop participants were entirely new
271 to the fisheries management arena, and we probably would not have thought to invite them under
272 a closed-group scenario. Unexpectedly, newcomers contributed novel insights and data. For
273 example, scientists from another federal agency contributed much expertise and data on the
274 reliance of seabirds on Atlantic herring (e.g., common tern fledgling success), filling a gap
275 within the MSE analytical team and the NMFS more broadly. This collaboration may not have
276 occurred without the open process.

277 A challenge with inclusivity is balancing time allotted for education versus achieving other
278 workshop goals efficiently. Knowledge levels about MSE and herring biology and management
279 varied widely among the participants. Though background materials were provided in advance,
280 there was no guarantee that they would be read and understood. Likewise, participants were not
281 obligated to attend both workshops, and stakeholder turnover necessitated that time be spent
282 retracing completed steps so that the group had enough baseline understanding. However, given

the regional novelty of MSE, repeating introductory material was probably quite useful to most participants.

As a best practice, we offer that MSE workshops be conducted by external facilitators. Ours served as a calming presence and helped reassure stakeholders of an independent and fair process. Ahead of the first workshop, staff apprised the facilitator of the interests and parties involved, which improved workshop productivity. If time had allowed, having the facilitator observe several management meetings in advance would have been beneficial as well.

We also recommend having several external stock assessment scientists or fishery biologists present to help field stakeholder questions. This would help foster a broader sense of ownership in the MSE process and reduce the potential for a perception that a few individuals are acting as arbiters. Rather, we relied on just a few Atlantic herring experts to help explain control rule concepts and MSE results; having others more removed from the fishery may have been even more useful.

Some workshop participants may have been hired by a stakeholder group to attend and engage in the short-term, rather than have a long-term, direct “stake” in the managed system. Thus, an open MSE may be vulnerable to perceived or real issues related to more experienced or resourceful stakeholders being able to “stack the deck.” Even when a diverse group shares a common interest, the assembled individuals may have widely different expectations regarding group dynamics and focus. These differences may affect how readily participants support the progress of the process. Reed (2008) notes that participatory processes do not exist within a power vacuum and that power inequalities within a group can be a barrier to effective engagement. We did not require consensus, in part, to avoid these problems.

Punt et al. (2016) suggests having a small number of performance statistics so they can be easily reported on, perhaps based on experience with the Pacific sardine MSE, where managers narrowed and refined the performance metrics proposed by stakeholders (PFMC 2013; Punt et al. 2016). For transparency, we found it important to analyze all objectives and performance metrics recommended by the public, despite known data and model limitations. These constraints were discussed at both workshops, and in the end, some of these metrics had very little response to the control rules. Although the MSE analysts could have argued that some metrics would be uninformative, it was important that the public see the results of the entire suite. It was, however very difficult to communicate the performance of all metrics in a digestible manner, and some of the less salient ones got relegated to report appendices. We suggest careful consideration of potential negative outcomes of narrowing stakeholder recommendations prior to analysis.

We also offer as a best practice evaluating specific control rules that stakeholders bring to the table if possible. Many of our MSE stakeholders entered the process with a strong preference for a particular piecewise-linear “forage” HCR described by Pikitch et al. (2012). Without prior analysis of this control rule for Atlantic herring, this preference was likely driven by assumed performance. Preconceived preferences for alternative(s) are probably common in natural resource management. In these instances, explicitly describing the relative performance of alternatives can be helpful so that the associated tradeoffs become clearer as the MSE progresses. Doing so may not alter personal preferences, but assumptions are formally tested, and the process is more inclusive.

Manage expectations

No matter the degree of inclusivity, we agree with the best practice of clearly setting expectations for participants and managers about the potential scope of a given MSE: its

timeframe, modeling capacity and data (Punt et al. 2016). In this MSE, additional proactive efforts in advance of the first workshop may have helped convey the technical limitations (e.g., available data), which then may have led to more consistent expectations and more focused discussions.

We had challenges related to both spatial and temporal scales. Issues of scale continue to complicate natural resource management; disconnects between the scales impacted by management actions versus those experienced by stakeholders (Riley et al. 2002; Seidl et al. 2013). Some of our participants vocalized concerns over localized depletion, that fish removals from a ‘small’ area (a few square miles or less) are not replenished in a ‘short’ time (days to weeks), resulting in temporarily poor conditions for predators and their human users (e.g., tuna fishery, ecotourism). Directly addressing local effects of fishing using a stock-wide (covering an area from Maine to New Jersey), annual ABC was not possible during this initial iteration of this MSE, but it was very difficult to help the public understand this. At the time, the herring and predator models were not sufficiently developed to represent finer spatial scales, and in most cases, spatial and temporal resolutions of available ecological data were also insufficient. Simultaneous to, but separate from, this MSE, managers were addressing concerns about the potential for localized depletion and related user conflicts and were developing alternatives for time and area closures for the herring fishery. Regardless, several participants wanted a control rule that would be responsive to ecosystem needs at finer scales than the stock area. Several participants left partway through the first workshop, when they realized that their expectations did not match the focus of the workshop. In total, issues of scale and the associated constraints quickly contributed to communication challenges within this MSE.

Many stakeholders appeared to approach MSE as a bargaining process as opposed to a collaboration to create an evaluation tool. When bargaining, eliciting true preferences is difficult, because stating true preferences may not be incentive-compatible (Myerson 1979; Dixit and Nalebuff 2008). Knowing that their input would be used for policy, and that other stakeholders hold directly opposing views, some stakeholders may have had an incentive to behave strategically. A bargaining perception created some initial problems in soliciting stakeholder preferences for the performance of a control rule (i.e., what value for performance metrics was desirable to the stakeholders). Several stakeholders were reluctant to publicly state their preference, while others claimed exaggerated preferences relative to their actual preference. However, once participants realized that the intention was to provide control rules that met their criteria, they were more eager to share their preferences. We suggest outreach prior to stakeholder workshops to clarify the method and purpose of MSE to reduce bargaining style approaches. Explicitly demonstrating how stated preference will be used to develop possible management alternatives would also clarify the MSE process. Nevertheless, it may simply take some time and recurring interactions among participants to build or rebuild trust in the process.

Communicate simply

The challenge of communicating MSE results to the public, and even to seasoned managers, was recognized throughout the workshops and subsequent meetings. MSE output is generally very technical and does not always translate well to an unfamiliar audience. We offer a few examples of how to implement the MSE best practice of clear communication identified by Smith et al. (1999) and Punt et al. (2016).

Terminology misunderstandings between participants and MSE experts need to be overcome. For example, the term “fishery closure” is commonly thought of in the Northeast U.S. as when a

catch limit is reached mid-year, prohibiting the directed fishery for the remainder of the year. For a HCR MSE, however, that term means when the ABC is set at zero, precluding fishing for the entire year. When asked, “What should the probability be of a fishery closure?”, the herring fishermen in attendance first said that they had a high tolerance for fishery closures, because in-season closures occur regularly. Alarm bells went off though when the fishermen realized that the MSE analyst was asking about their tolerance for setting ABC equal to zero.

Misunderstandings were not a significant setback in this application, but care is nonetheless needed to encourage communication among diverse individuals. Patience and attention on the part of MSE facilitators and analysts are required to identify and resolve instances of miscommunication. Failure to identify such instances may lead to confusion, frustration, or hinder the transparency that stakeholder processes are intended to create.

Most participants struggled to interpret results when presented in relative units (e.g., yield/MSY), which are generally not as understandable as absolute units (e.g., yield in metric tons), the everyday currency of fishermen (i.e., fishermen measure harvest in tons and not fractions of MSY). Metrics recorded in relative units, however, are generally more robust to uncertainties that are represented by differences among operating models than metrics in absolute units (e.g., Deroba and Bence 2012; Deroba et al. 2018), which make relative units appealing analytically. We agree with Pastoors et al. (2007) that focusing exclusively on absolute units, however, can be distracting and hinder scientifically informed decision-making, and so the appropriate units may be case specific.

During the first workshop, it was clear that participants were mostly unfamiliar with MSE concepts in general and had differing expectations for what was feasible in the current MSE. For the second workshop, MSE analysts decided to communicate some MSE concepts using

396 analogies. To explain that models do not have the capacity to fully replicate reality, but are still
397 useful, true ecosystem dynamics were likened to a stealth bomber and operating models were
398 likened to a simple prop plane. To explain the data and model constraints, our MSE was likened
399 to a horse and buggy, rather than a sports car. When setting up discussion about performance
400 tradeoffs, participants were first encouraged to consider their decision process when making
401 airline reservations. How are tradeoffs weighed between flight departure and arrival times, trip
402 duration, and price? This eased the consideration of the tradeoffs demonstrated by the MSE (e.g.,
403 yield versus variation in yield). Use of analogies could be broadly beneficial in MSE and
404 stakeholder engagement processes, and supplement existing best practice recommendations.

405 Improvements in public understanding (and in efforts to communicate) continued past the
406 dedicated workshops through the remainder of the amendment process. Efforts to improve
407 communication products were made at each step; boxplots, scatterplots, bag plots, and radar
408 (spider) plots were provided, but each type has pros and cons for communicating MSE outputs
409 (Table 3, Figure 1). During the summer of 2017, experts in MSE communications joined the
410 team to help translate outputs into more user-friendly formats. Their bar plot decision tables,
411 which compare control rule alternatives for a given metric across the operating models (potential
412 resource conditions) were novel to our management arena, but easy for end users to visualize
413 MSE results. In the end, these tables combined with more traditional radar plots, comparing the
414 performance of alternatives across metrics, were the most useful visualization tools for
415 managers. Gaining familiarity with these tools may yield dividends in future MSEs in the region.

416 To help ensure that an MSE is used in management, an MSE implementation team may need to
417 include experts in modeling, management process, meeting facilitation, and communications. In
418 our case, the communications expertise was brought in rather late, during Phase 5. It may have

been worthwhile to have had it from the start. Also, it was very helpful to have the MSE experts stay engaged throughout to integrate their work into the more traditional decision-making process.

Stand at a new vantage point

Introducing MSE into an established management system challenges managers and the public to think from a different vantage point. Smith et al. (1999) describe reactions of the main players in the AFMA to MSE as it was being introduced, indicating that the transition may have been easier, because the fisheries were managed with individual quotas. Although the Atlantic herring fishery is managed differently, the fishermen still have vested interests in the long-term prosperity of the fishery, but perhaps not to the same degree as the AFMA fisheries. People accustomed to the traditional Council process tend to be most concerned with potential impacts occurring in the near-term (i.e., one to three-years); however, MSEs often measure performance across a longer term (i.e., multiple generations). Here, public calls for seeing how the HCR alternatives would impact short-term fishery yields eventually pushed managers to direct staff to include generic projections that demonstrated the short-term consequences of the alternatives considered. However, as managers have yet to take final action, it is still to be determined how much weight will be given to short- versus long-term impacts.

Consistent with Smith et al. (1999), some managers and industry members have been cautious about implementing a control rule, feeling like there would be less scope for stakeholder engagement down the road, taking the management out of managing. Butterworth (2007) argues that the concern that MSE is an overly rigid framework can be addressed by allowing a “block quota” that applies to a range of years but allotted within the range of years in a relatively flexible way. Similarly, if catch in a year is less than the ABC, then a portion of the unused ABC

might be allotted to a future year (i.e., a “rollover”), which is an option currently available in the case of Atlantic herring. Butterworth (2007) also recommends scheduled reviews of MSEs to ensure that the system has not shifted outside of the range considered during the MSE, potentially requiring a change to the MSE modeling and preferred performance for various objectives or metrics. We support such scheduled reviews and encourage MSE practitioners to evaluate flexible management strategies when possible, being careful not to create so much flexibility as to lose the advantages of the MSE approach. The flexibility available in an MSE, albeit perhaps less than traditional processes, may also need to be conveyed to stakeholders to not undermine the possible advantages.

Unfortunately, time constraints on this MSE did not permit more than two formal stakeholder workshops, which was likely insufficient for most participants to fully comprehend and buy into the MSE approach. This challenge was partially overcome by stakeholders contacting subject matter experts from within management and scientific arenas through informal channels (e.g., phone and email), which generally bolstered the positive relationships developed at the formal workshops. Such interactions may be beneficial in other MSEs. Having repeated presentations of the same results at subsequent management meetings also improved mutual understanding.

Build capacity

In general, scientists, facilitators and the public alike need more education about MSE to expand the capacity for conducting MSEs, garner the full benefits of participatory involvement, and facilitate consideration of longer-term time horizons. Such educational opportunities should ideally be provided outside of and prior to undertaking a specific MSE, or with time explicitly allotted within the MSE, so that general education is separated more from opportunities for

providing input. Lack of MSE analysts in some regions of the world may also be a “bottleneck” for increasing use of more stakeholder driven MSE approaches.

Evaluate the evaluation

To the literature on MSE best practices, we add the importance of evaluating the stakeholder engagement process, apart from evaluating the MSE as a scientific endeavor through peer review. At the close of both workshops, about 25% of participants submitted voluntary evaluation forms with feedback on a series of closed- and open-ended questions (Table 1). On average, respondents from both workshops generally agreed that they were well informed about the workshop, had enough background materials, and that the presenters and facilitators were well prepared and clear. They also agreed that there was enough opportunity for input. Participant evaluation of the first workshop influenced managers to keep the MSE an open-invitation process, to continue general education on MSE, and to use simple terms and data displays. Specific feedback (e.g., on herring fishery economics) improved subsequent modeling and impact analysis. During the spring 2018 public comment period, the Council received about 15 comments (3%) on the MSE. Most commended the Council for the endeavor and used the MSE results in their rationale for support of specific alternatives. Some were concerned about potential shortfalls in our current ability to model Atlantic herring in the ecosystem. At the end of the management process, we expect to solicit stakeholder reflections to inform managers about how to move forward with future MSEs.

SUMMARY

There are several lessons learned from stakeholder engagement in the Atlantic herring MSE (Table 2), largely that it is possible to have a successful MSE using open, public meetings for input. The most salient from our process are: 1) be inclusive – participant input is important for

487 both technical and process aspects of the MSE; 2) manage expectations – constraints may affect
488 participation, modeling, and decision making; 3) clearly articulate scale considerations –
489 disconnects occur on both spatial and temporal scales; 4) retool communications products until
490 they are understood – simple examples, analogies, and graphics can help convey complex topics;
491 5) build capacity – provide MSE training opportunities; and 6) be open to mid-course
492 improvements – look for ways to gain information and refine the MSE. When viewing MSE as a
493 participatory process, we concur with Reed (2008) that success depends on having clear goals,
494 impartial facilitation, and effective communication.

495 Fully integrating a public MSE into the management arena has more effectively included public
496 input throughout the amendment process and is better equipping interested parties with
497 quantitative ways to evaluate tradeoffs and balance multiple objectives, particularly if longer-
498 term performance of potential actions is considered. Although this MSE was perhaps more rapid
499 than some, it has resulted in a more thorough and integrated analysis than similar actions by this
500 Council.

501 This MSE was an effort to move away from fishery management decisions based on short-term
502 approaches that do not always consider multiple objectives or long-term consequences. It
503 remains infeasible to use MSE for all actions, and managers may need to be selective when
504 determining which questions merit MSE. We do not necessarily recommend an entirely open
505 stakeholder process for all MSEs moving forward. It proved to be a valid approach in this case,
506 in which MSE was being introduced to an established fishery management system and
507 stakeholder community where a high degree of controversy exists. This level of participant
508 involvement may be unnecessary in more straightforward applications. Before management
509 bodies invests in MSEs, they could reflect carefully on the expected benefits and costs associated

with MSE. The clearest signal of the benefits of an MSE approach would be if managers or stakeholders request this type of analysis for future management actions that also require difficult choices. In fact, the Council is considering an MSE to support development of a Georges Bank fishery ecosystem plan.

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625 **TABLES**

Question	Workshop #1 N=15 (23%)	Workshop #2 N=19 (29%)
1. I was well informed about the workshop and its goals/objectives.	4.1	3.9
2. The background material provided was sufficient to feel prepared for the workshop.	3.9	3.8
3. The facilitators and presenters were well prepared.	4.0	4.2
4. The presentations were clear and made technical information understandable.	4.1	4.1
5. I had sufficient opportunity to provide input.	4.1	4.5
6. The workshop's goals/objectives have been accomplished.	3.3	3.2
7. The workshop lived up to my expectations.	3.5	3.4
8. A follow-up workshop after the simulations would be helpful.	4.6	Not asked
9. In general, a workshop is an effective forum to give input in the Council process.	4.0	4.1
10. The workshop helped me learn what is/isn't well understood about herring in the ecosystem.	Not asked	3.7
11. I have a better appreciation for the tradeoffs that need to be made when managing the herring resource and how uncertainty influences the management options.	Not asked	3.7

Note: average responses provided here, using codes:

1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree

626 **Table 1. Workshop evaluation questions and responses**

Wielding the double-edged sword of inclusivity

- Consider an open-process MSE when legal constraints and/or degree of controversy demand a high level of public engagement.
- Use external facilitators for MSE public workshops.
- Have several scientists on-hand to help field stakeholder questions.
- Carefully consider potential negative outcomes of narrowing stakeholder recommendations prior to analysis.
- For inclusivity, evaluate specific control rules that stakeholders contribute.

Manage expectations

- In advance of the first workshop:
 - Make constraints on timelines, data, and modeling clear in advance of the first workshop.
 - Clarify the method and purpose of the MSE to reduce bargaining approaches.

Communicate simply

- Ensure common understanding of MSE concepts and terms
- Use relatable analogies
- Present results in units understandable to the end user
- Retool communications products until they are understood

Stand at a new vantage point

- Encourage a shift towards long-term thinking.

Build capacity

- Have general education on MSE precede workshops.
-

Evaluate the evaluation

- Evaluate the stakeholder engagement process in addition to technical work

628 **Table 2. Steps towards improving stakeholder engagement in MSE**

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Graphic Type	Pros	Cons
Boxplot	<ul style="list-style-type: none">• Show range among all options• Displays effect of operating models succinctly	<ul style="list-style-type: none">• Inability to track one option among boxplots/metrics• Inability to display tradeoffs
Scatterplot	<ul style="list-style-type: none">• Displays tradeoffs• Can display many alternatives	<ul style="list-style-type: none">• Displaying uncertainty difficult• Limited to 2 dimensions
Bag Plot	<ul style="list-style-type: none">• Displays uncertainty• Displays tradeoffs	<ul style="list-style-type: none">• Only effective for small number of options• Limited to 2 dimensions
Radar or Spider Plot	<ul style="list-style-type: none">• Displays tradeoffs• High dimensionality	<ul style="list-style-type: none">• Displaying uncertainty difficult• Only effective for small number of options
Bar Plot Decision Table	<ul style="list-style-type: none">• Displays effect of operating models succinctly• Combine visuals with quantitative information	<ul style="list-style-type: none">• Difficult to examine tradeoffs• Displaying uncertainty difficult

630 **Table 3. Some advantages and limitations encountered when using various graphics to**
631 **summarize performance of alternative control rules within an MSE.**

FIGURES

Figure 1. Example graphics used in this MSE; the radar plots and bar plot decision tables proved most useful for end users.