ARTICLE

Integrating management strategy evaluation into fisheries management: advancing best practices for stakeholder inclusion based on an MSE for Northeast US Atlantic herring[1,2]

R.G. Feeney, D.V. Boelke, J.J. Deroba, S. Gaichas, B.J. Irwin, and M. Lee

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

Résumé : Le New England Fishery Management Council a utilisé l'évaluation des stratégies de gestion (ESG) pour évaluer des règles possibles de contrôle des prises pour le hareng de l'Atlantique (*Clupea harengus*), dans la première ESG aux États-Unis et possiblement dans le monde à employer des ateliers publics ouverts à tous pour obtenir des renseignements. Si l'inclusion des parties prenantes peut rendre plus réaliste et probable l'utilisation par les gestionnaires, l'atteinte de l'inclusivité n'est pas chose facile. Les participants volontaires présentaient des antécédents variés et différents degrés d'intérêt et de préparation. Nous décrivons certains défis que pose l'intégration directe du grand public à l'ESG et offrons des suggestions plus larges pour en arriver à une participation publique efficace durant un processus décisionnel. La réalisation d'une ESG ouverte cadre bien avec une gestion axée sur l'apport du grand public, mais nécessite des objectifs et une communication clairs. Le recours à des organisateurs efficaces, des facilitateurs impartiaux et des analystes bien informés peut améliorer la communication et la compréhension de l'ESG, pour une meilleure gestion des pêches. Nous visons à pousser plus loin les pratiques exemplaires d'ESG en matière d'intégration des parties prenantes et espérons que les leçons que nous avons tirées sur la communication, la participation et l'intégration des ESG dans les pratiques de gestion existantes seront utiles pour d'autres intervenants. [Traduit par la Rédaction]

Introduction

Management strategy evaluation (MSE) generally involves defining a decision problem, specifying objectives, and simulating the managed system to help evaluate uncertainties, risks, and trade-offs of management alternatives. The MSE approach was first developed through the International Whaling Commission (IWC) in the 1980s (Punt and Donovan 2007), though the South African hake fishery (*Merluccius* spp.) was perhaps the first case where an MSE was integrated into management decisions, in the early 1990s (Geromont et al. 1999; Holland 2010). Application of MSE has become more common globally over the past 30 years (De Oliveira et al. 2008; Punt et al. 2016), primarily for quota-managed fisheries, though the approach remains a departure from the status quo for many fisheries. In the US, the National

Marine Fisheries Service (NMFS) is now expanding capacity to broaden the use of MSE (USRFMC 2018).

Stakeholders have been involved in MSEs to varying degrees. On one end of the spectrum is a process in which scientists identify parameters and conduct modeling largely separate from the management arena (e.g., Deroba 2014; Taylor et al. 2014). On the other end, stakeholders participate throughout the MSE (e.g., Jones et al. 2016). It appears that stakeholder integration typically involves working with small groups of selected representatives. In the cases of South African hake and New Zealand rock lobsters (*Jasus edwardsii*), MSE stakeholder participants were quota holders and their industry associations, which have legal rights to participate in management processes on behalf of the industry (Holland 2010). Smith et al. (1999) detail the early Australian Fisheries Man-

R.G. Feeney and D.V. Boelke. New England Fishery Management Council, 50 Water St., Newburyport, MA 01950, USA.
J.J. Deroba, S. Gaichas, and M. Lee. Northeast Fisheries Science Center National Marine Fisheries Service, 166 Water St., Woods Hole, MA 02543, USA.
B.J. Irwin. US Geological Survey, Georgia Cooperative Fish and Wildlife Research Unit, University of Georgia, 180 E. Green St., Athens, GA 30602, USA.
Corresponding author: Rachel Gallant Feeney (email: rfeeney@nefmc.org).

agement Authority (AFMA) process, in which about seven representatives from state or territory governments, quota holders, and the conservation community were invited to collaborate with MSE analysts in closed session to develop recommendations for the AFMA. We 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 (hereinafter Council) and the US NMFS, using MSE to develop a management strategy for Atlantic herring (*Clupea harengus*) 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. 2019). 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. 2019), 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 adoption of the HCR, but the assessment model and data input into the model-based HCR (e.g., Butterworth 2007).

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

Public interest in the Atlantic herring resource is heightened by its role as forage to multiple predators in the ecosystem (e.g., groundfish, tuna, whales), which support commercial fisheries, recreational fisheries, and ecotourism. The objectives and preferences of stakeholders from these industries are frequently in direct conflict with the objectives and preferences of the herring industry. For example, in 2000, participants in the whale watching industry claimed that commercial herring harvests negatively impact ecotourism, thus urging managers to consider the dietary needs of marine mammals when setting catch limits (65 Federal Register 77460). Similar concerns were raised in 2006, 2007, and 2013 for other predators (70 Federal Register 21973; 72 Federal Register 11258; 78 Federal Register 61832). Stakeholders are concerned about the level of harvest relative to biomass and the spatial and temporal distribution of harvest, under the hypothesis that intense harvest causes localized depletion of the herring re-

source and is associated with poor outcomes in other human uses. Thus, management of this fishery has been 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 US 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 US federal fisheries and the degree of public contention drove many of our decisions for an open process.

Deroba et al. (2019) 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 HCR to set the acceptable biological catch (ABC), which is 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 explore concurrently 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 available for predators in the ecosystem may be less than estimated. Managers recognized this concern and the potential influence of other uncertainties.

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

For its first MSE, managers carefully considered the degree of stakeholder participation in the process. One option was to invite invested stakeholders to engage, an approach that can effectively build momentum and reduce time spent introducing concepts (e.g., Lake Erie walleye (*Sander vitreus*); Jones et al. 2016). However, how would participants be selected? Most MSEs to date had been for fisheries managed with catch shares (e.g., Australian eastern gemfish (*Rexea solandri*); Smith et al. 1999); in those cases, identifying interested parties was relatively straightforward (Holland 2010). The directed Atlantic herring fishery is limited access with about 35 active vessels managed with fishery-wide quotas. Given the importance of Atlantic herring to the ecosystem, its management attracts hundreds of interested parties (e.g., commercial and recreational fisheries, ecotourism, conservation community). It

Table 1. Workshop evaluation questions and responses.

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 trade-offs that need to be made when managing the herring resource and how uncertainty influences the management options.	Not asked	3.7

Note: Average responses are provided in this table, using the following codes: 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.

would have been very difficult to overcome public skepticism over introducing a new process and the specific membership of a closed group. 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, personal communication, 2016). Importantly, to comply with US 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 (composed of herring fishermen and other stakeholders) and subcommittee 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 2-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., inter-annual 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 nonprofit 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 5 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. 2019). 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 2-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 trade-offs and how the number of HCRs simulated could be narrowed (from 5460 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 sub-

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

Phase 4 — peer review (January–March 2017)

Given the regional novelty of MSE and degree of controversy, managers had the MSE peer-reviewed (in March 2017). To prepare, the MSE analysts refined simulations and reporting based on public input. The 3-day review by four MSE experts was public and included public comment. The panel concluded that the MSE represented the current best available science for evaluating the anticipated performance of Atlantic herring control rules and their potential impact on key predators and that the methods for identifying objectives, performance metrics, and control rules for testing generally followed MSE best practices (NEFMC 2018a). The peer review helped this MSE gain acceptance among the public and managers and reduced some controversy over model assumptions and data limitations.

Phase 5 — incorporation into fishery management action (January–December 2017)

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

Managers unanimously approved a final range of ten ABC HCRs in April 2017, and staff spent the next several months incorporating the MSE results (e.g., outcomes for all 14 performance metrics identified at the first stakeholder workshop) into the environmental impact analysis — 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 trade-offs 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 im-

Table 2. Steps towards improving stakeholder engagement in MSE.

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
  - 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

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

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

A challenge with inclusivity is balancing time allotted for education versus achieving other workshop goals efficiently. Knowledge levels about MSE and herring biology and management varied widely among the participants. Though background materials were provided in advance, there was no guarantee that they

would be read and understood. Likewise, participants were not obligated to attend both workshops, and stakeholder turnover necessitated that time be spent 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 (*Sardinops sagax caerulea*) 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 trade-offs 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, for example, 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 (1 mile = 1.609 km) 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 state publicly 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).

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

Graphic type	Pros	Cons
Boxplot	Show range among all options Displays effect of operating models succinctly	Inability to track one option among boxplots–metrics Inability to display trade-offs
Scatterplot	Displays trade-offs Can display many alternatives	Displaying uncertainty difficult Limited to two dimensions
Bag plot	Displays uncertainty Displays trade-offs	Only effective for small number of options Limited to two dimensions
Radar or spider plot	Displays trade-offs High dimensionality	Displaying uncertainty difficult Only effective for small number of options
Bar plot decision table	Displays effect of operating models succinctly Combine visuals with quantitative information	Difficult to examine trade-offs Displaying uncertainty difficult

Terminology misunderstandings between participants and MSE experts need to be overcome. For example, the term "fishery closure" is commonly thought of in the Northeast US as when a catch limit is reached mid-year, prohibiting the directed fishery for the remainder of the year. For an 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 major 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 per maximum sustainable yield), 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 maximum sustainable yield). 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. 2019), 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 analogies. To explain that models do not have the capacity to replicate reality fully, but are still useful, true ecosystem dynamics were likened to a stealth bomber and operating models were likened to a simple prop plane. To explain the data and model constraints, our MSE was likened to a horse and buggy, rather than a sports car. When setting up discussion about performance trade-offs, participants were first encouraged to consider their decision process when making airline reservations. How are trade-offs weighed among flight departure and arrival times, trip duration, and price? This eased the consideration of the trade-offs demonstrated by the MSE (e.g., yield versus variation in yield). Use of analogies could be broadly beneficial in MSE and stakeholder engagement processes and supplement existing best practice recommendations.

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

To help ensure that an MSE is used in management, an MSE implementation team may need to include experts in modeling, management process, meeting facilitation, and communications. In 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., 1–3 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

Fig. 1. Example graphics used in this MSE; the radar plots and bar plot decision tables proved most useful for end users. [Colour online.]
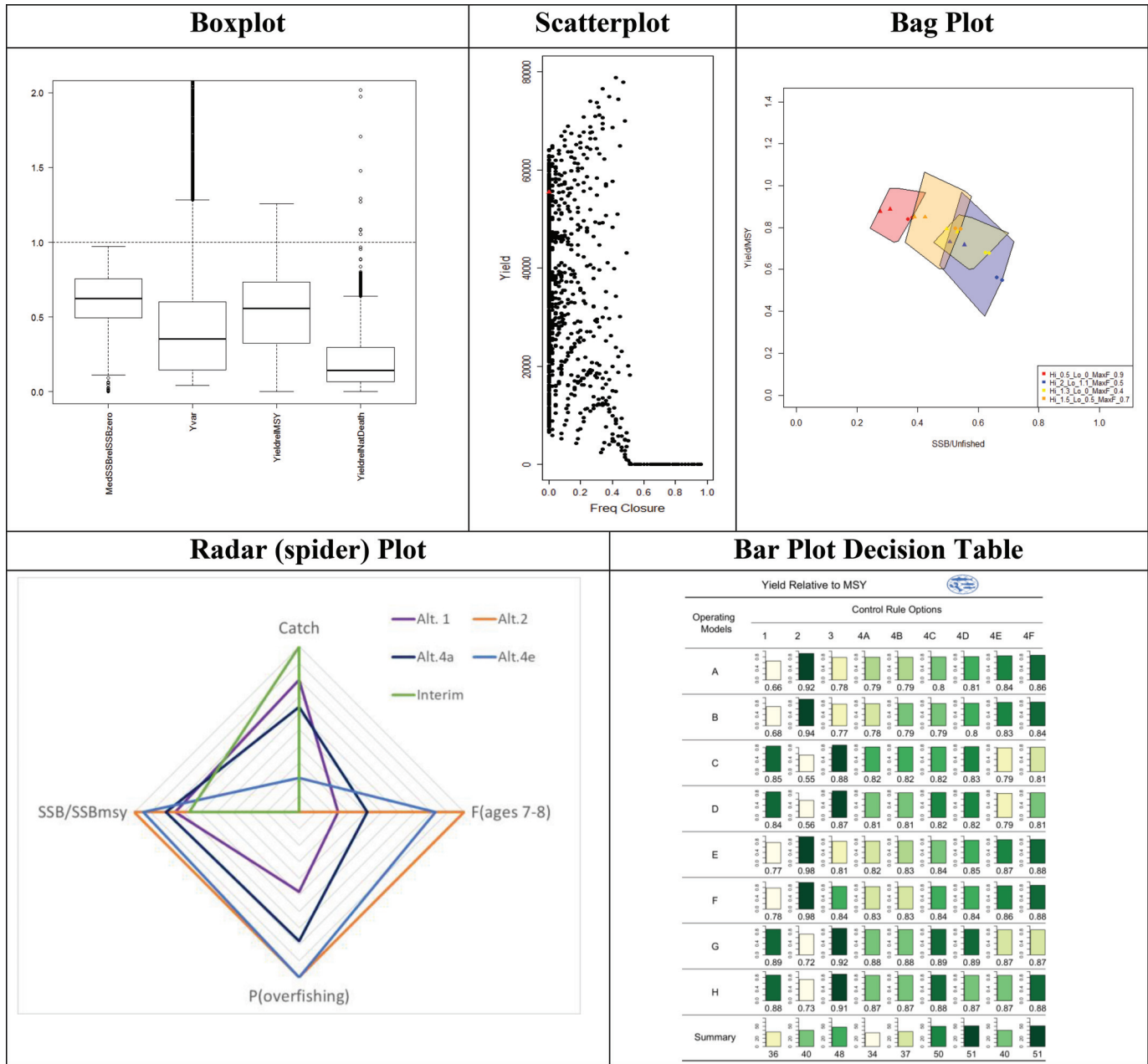
rigid framework can be addressed by allowing a "block quota" that applies to a range of years but allotted within the range of years in a relatively flexible way. Similarly, if catch in a year is less than the ABC, then a portion of the unused ABC might be allotted to a future year (i.e., a "rollover"), 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, 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 as follows: (1) be inclusive — participant input is important for both technical and process aspects of the MSE; (2) manage expectations — constraints may affect participation, modeling, and decision-making; (3) clearly articulate scale considerations — disconnects occur on both spatial and temporal scales; (4) retool communications products until they are understood — simple examples, analogies, and graphics can help convey complex topics; (5) build capacity — provide MSE training opportunities; and (6) be open to mid-course improvements — look for ways to gain information and refine the MSE. When viewing MSE as a participatory process, we concur with Reed (2008) that success depends on having clear goals, impartial facilitation, and effective communication.

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

This MSE was an effort to move away from fishery management decisions based on short-term approaches that do not always consider multiple objectives or long-term consequences. It remains infeasible to use MSE for all actions, and managers may need to be selective when determining which questions merit MSE. We do not necessarily recommend an entirely open stakeholder process for all MSEs moving forward. It proved to be a valid approach in this case, in which MSE was being introduced to an established fishery management system and stakeholder community where a high degree of controversy exists. This level of participant involve-

ment may be unnecessary in more straightforward applications. Before management 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.

Acknowledgements

References

APA. 1946. Administrative Procedures Act. In 5 USC 500, USA.

ASMFC. 2018. Addendum 26 to amendment 3 to the American lobster fishery management plan; draft addendum 3 to the Jonah crab fishery management plan for public comment. Atlantic States Marine Fisheries Commission, Arlington, Va.

Butterworth, D.S. 2007. Why a management procedure approach? Some positives and negatives. ICES J. Mar. Sci. 64: 613–617. doi:10.1093/icesjms/fsm003.

De Oliveira, J.A.A., Kell, L.T., Punt, A.E., Roel, B.A., and Butterworth, D.S. 2008. Managing without best predictions: the management strategy evaluation framework. In Advances in Fisheries Science. 50 Years on from Beverton and Holt. Edited by A. Payne, J. Cotter, and T. Potter. Blackwell Publishing, Ltd., Oxford. pp. 104–134.

Deroba, J.J. 2014. Evaluating the consequences of adjusting fish stock assessment estimates of biomass for retrospective patterns using Mohn's Rho. N. Am. J. Fish. Manage. 34(2): 380–390. doi:10.1080/02755947.2014.882452.

Deroba, J.J. 2015. Atlantic herring operational assessment report. NEFSC Reference Document 15–16, Woods Hole, Mass.

Deroba, J.J., and Bence, J.R. 2012. Evaluating harvest control rules for lake whitefish in the Great Lakes: accounting for variable life-history traits. Fish. Res. 121–122: 88–103. doi:10.1016/j.fishres.2012.01.015.

Deroba, J.J., Gaichas, S.K., Lee, M.-Y., Feeney, R.G., Boelke, D.V., and Irwin, B.J. 2019. The dream and the reality: meeting decision-making time frames while incorporating ecosystem and economic models into management strategy evaluation. Can. J. Fish. Aquat. Sci. [This issue.] doi:10.1139/cjfas-2018-0128.

Dixit, A.K., and Nalebuff, B. 2008. The art of strategy: a game theorist's guide to success in business and life. W.W. Norton and Company, New York.

FACA. 1972. Federal Advisory Committee Act. In 86 USC 770.

Freeman, R.E. 1984. Strategic management. Pitman Publishing, Inc., Marshfield, Mass.

Geromont, H.F., De Oliveira, J.A.A., Johnston, S.J., and Cunningham, C.L. 1999. Development and application of management procedures for fisheries in southern Africa. ICES J. Mar. Sci. 56(6): 952–966. doi:10.1006/jmsc.1999.0536.

Hanna, S.S. 1999. Strengthening governance of ocean fishery resources. Ecol. Econ. 31(2): 275–286. doi:10.1016/S0921-8009(99)00084-1.

Holland, D.S. 2010. Management strategy evaluation and management procedures: tools for rebuilding and sustaining fisheries. OECD Food, Agriculture and Fisheries Working Papers.

Ihde, T.F., Wilberg, M.J., Secor, D.H., and Miller, T.J. 2011. FishSmart: harnessing the knowledge of stakeholders to enhance U.S. marine recreational fisheries with application to the Atlantic king mackerel fishery. Am. Fish. Soc. Symp. 73: 75–93.

Jones, M.L., Catalano, M.J., Peterson, L.K., and Berger, A.M. 2016. Stakeholder-centered development of a harvest control rule for Lake Erie walleye *Sander vitreus*. *In* Management science in fisheries. *Edited by* C.T.T. Edwards and D.J. Dankel. Routledge, Oxford and New York. pp. 163–183.

Mohn, R. 1999. The retrospective problem in sequential population analysis: an investigation using cod fishery and simulated data. ICES J. Mar. Sci. **56**(4): 473–488. doi:10.1006/jmsc.1999.0481.

Myerson, R.B. 1979. Incentive compatibility and the bargaining problem. Econometrica, **47**(1): 61–73. doi:10.2307/1912346.

NEFMC. 2018*a*. Amendment 8 [online]. Available from https://www.nefmc.org/library/amendment-8-2 [accessed 29 June 2018].

NEFMC. 2018*b*. Draft amendment 8 to the Atlantic herring fishery management plan. Newburyport, Mass.

NEFMC. 2018*c*. New England Fishery Management Council home page [online]. Available from www.nefmc.org [accessed 28 March 2018].

NEFSC. 2018. 65th northeast regional stock assessment workshop (65th SAW) assessment summary report. NEFSC Reference Document 18-08, Woods Hole, Mass.

Newton, A., and Elliott, M. 2016. A typology of stakeholders and guidelines for engagement in transdisciplinary, participatory processes. Front. Mar. Sci. **3**: 230. doi:10.3389/fmars.2016.00230.

Ostrom, E. 1990. Governing the commons. Cambridge University Press, Cambridge, UK.

Pastoors, M.A., Poos, J.J., Kraak, S.B.M., and Machiels, M.A.M. 2007. Validating management simulation models and implications for communicating results to stakeholders. ICES J. Mar. Sci. **64**(4): 818–824. doi:10.1093/icesjms/fsm051.

PFMC. 2013. Draft report of the Pacific sardine harvest parameters workshop. Portland, Ore.

Pikitch, E.K., Boersma, P.D., Boyd, I.L., Conover, D.O., Cury, P.M., Essington, T.E., Heppell, S.S., Houde, E.D., Mangel, M., Pauly, D., Plagányi, É.E., Sainsbury, K.J., and Steneck, R.S. 2012. Little fish, big impact: managing a crucial link in ocean food webs. Lenfest Oceans Program, Washington, D.C.

Punt, A.E., and Donovan, G.P. 2007. Developing management procedures that are robust to uncertainty: lessons from the International Whaling Commission. ICES J. Mar. Sci. **64**(4): 603–612. doi:10.1093/icesjms/fsm035.

Punt, A.E., Butterworth, D.S., de Moor, C.L., De Oliveira, J.A.A., and Haddon, M. 2016. Management strategy evaluation: best practices. Fish Fish. **17**: 303–334. doi:10.1111/faf.12104.

Reed, M.S. 2008. Stakeholder participation for environmental management: a literature review. Biol. Conserv. **141**: 2417–2431. doi:10.1016/j.biocon.2008.07.014.

Riley, S.J., Decker, D.J., Carpenter, L.H., Organ, J., Seiemer, W.F., Mattfeld, G.F., and Parsons, G. 2002. The essence of wildlife management. Wildl. Soc. Bull. **30**(2): 585–593.

Rochet, M.-J., and Rice, J.C. 2009. Simulation-based management strategy evaluation: ignorance disguised as mathematics? ICES J. Mar. Sci. **66**(4): 754–762. doi:10.1093/icesjms/fsp023.

Seidl, R., Eastaugh, C.S., Kramer, K., Maroschek, M., Reyer, C., Socha, J., Vacchiano, G., Zlatanov, T., and Hasenauer, H. 2013. Scaling issues in forest ecosystem management and how to address them with models. Eur. J. For. Res. **132**(5): 653–666. doi:10.1007/s10342-013-0725-y.

Smith, A.D.M., Sainsbury, K.J., and Stevens, R.A. 1999. Implementing effective fisheries-management systems — management strategy evaluation and the Australian partnership approach. ICES J. Mar. Sci. **56**(6): 967–979. doi:10.1006/jmsc.1999.0540.

Smylie, M. 2004. Herring: a history of the silver darlings. Tempus Publishing Limited, Gloucestershire, UK.

Taylor, N., Hicks, A.C., Taylor, I.G., Grandin, C., and Cox, S.P. 2014. Status of the Pacific hake (whiting) stock in U.S. and Canadian waters in 2014 with a management strategy evaluation. International Pacific Hake Joint Technical Committee.

USRFMC. 2018. Sixth National SCS Workshop 2018 [online]. Available from http://www.fisherycouncils.org/ssc-workshops/sixth-national-ssc-workshop-2018 [accessed 3 July 2018].

Wiedenmann, J., Wilberg, M.J., and Miller, T.J. 2013. An evaluation of harvest control rules for data-poor fisheries. N. Am. J. Fish. Manage. **33**(4): 845–860. doi:10.1080/02755947.2013.811128.