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Integrating information from semi-structured interviews into management strategy evaluation: A case study for Southeast United States marine fisheries

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Management strategy evaluation (MSE) has become a more common tool for engaging stakeholders in fisheries management, and stakeholder participation in MSE is increasingly recognized as a vital component of the process. The participation of stakeholders, specifically fishers, in MSE is of particular importance because they often possess intimate knowledge of the socio-ecological management system that MSE seeks to model. When the resources to conduct a "full" MSE with direct fisher involvement are unavailable, MSEs are sometimes conducted by desk-based analysts with no fisher engagement. We propose an intermediate framework in which information collected from semi-structured interviews is used to inform a "desk-based" MSE. We demonstrate that semi-structured interviews with commercial and recreational fishers can elicit some of the same kinds of information that fishers provide during direct participation in MSE. We conducted 30 semi-structured interviews with commercial and recreational fishers from the Southeast United States participating in either Atlantic cobia (*Rachycentron canadum*) or black sea bass (*Centropristis striata*) fisheries. We collected primarily qualitative and some quantitative information about preferred conceptual objectives and management measures, and how their fishing behavior has changed in response to past management action. Commercial fishers generally preferred conceptual objectives and management measures that align with traditional MSY-based fisheries management, while recreational fishers' responses were substantially more heterogeneous, indicating a more diverse range of desired objectives and preferred management measures. We synthesized this information to develop a suite of management procedures that employ a range of fishing mortality-based constant-catch harvest control rules and size-based management measures for simulation testing against preferred

objectives by sector. We demonstrate that integrating information from semi-structured interviews with MSE in this way offers a cost-effective alternative intermediate approach to fisher participation in MSE when direct participation is not possible.

KEYWORDS

marine resource management, fishers' knowledge, management strategy evaluation, experiential knowledge, ecosystem approach management

Introduction

Management strategy evaluation (MSE) is an increasingly common tool for engaging stakeholders in fisheries management (Deith et al., 2021). MSE is a closed-loop simulation framework that seeks to model entire management scenarios. MSE typically includes an operating model (OM) to simulate population and fishery dynamics, an estimation model to determine stock status, i.e., an assessment or some simplification of the process, and an implementation model in which a management procedure is applied. Then the effects are projected forward in time (Punt et al., 2016; Ono et al., 2017). The primary goal of MSE is to identify management procedures that will achieve objectives in the long-term and are robust to uncertainty (Butterworth and Punt, 1999; Butterworth, 2007).

One of the key advantages of MSE is the ability to directly involve stakeholders in the development of management scenarios (Bunnefeld et al., 2011). Stakeholder participation in MSE is widely recognized as a vital component of the process (Bunnefeld et al., 2011; Feeney et al., 2019; Goethel et al., 2019; Deith et al., 2021). The degree of stakeholder participation is dependent on the timetable for completing the MSE and the format. MSEs can be conducted over multiple years as an iterative process in which stakeholders participate as part of a dedicated MSE group. Over several years, the group identifies conceptual objectives and uncertainties in the management system, works with scientists to operationalize those objectives, selects candidate management procedures for simulating testing, and engages in participatory modeling exercises to identify risks and tradeoffs by evaluating management procedures against objectives and over a range of uncertainties (Punt et al., 2016; Feeney et al., 2019; Goethel et al., 2019). We refer to these as "full MSEs" with "full" stakeholder participation. Examples include the OysterFutures workgroup who met nine times over two years for a Maryland eastern oyster (*Crassostrea virginica*) MSE (Goethel et al., 2019; Goelz et al., 2020), and the Management Strategy Advisory Board of the International Pacific Halibut commission who met twice a year during 2013-2020 to participate in MSE for pacific halibut (*Hippoglossus stenolepis*) (Branch, 2020). Full MSEs can also be conducted under truncated timetables in which stakeholder involvement in the MSE can be facilitated through a series of workshops designed to expedite the process, e.g., the Atlantic herring (*Clupea harengus*) MSE, which was conducted in just one year (Deroba et al., 2019). Stakeholder participation is a central aspect of what makes MSE effective (Dickey-Collas, 2014; Goethel et al., 2019). The participation of fishers is of particular importance because they often possess intimate knowledge related to uncertainties in the socio-ecological management system that MSE attempts to model, e.g., fishery operations, social and political dynamics, biology, ecology, and fine-scale spatial and seasonal processes (Neis et al., 1999; Crona, 2006; Wilson, 2006; Murray et al., 2006; Paterson, 2010).

However, MSE is a time and resource-intensive process, therefore many MSE tools or simulation frameworks for assessing tradeoffs are developed by analysts without fishers' involvement. These are colloquially referred to as "desk-based" MSEs. Semi-structured interviews are a common tool for eliciting qualitative and quantitative fishers' knowledge (Hind, 2015), and information obtained from semi-structured interviews has been used to inform, complement, improve, or directly integrate fishers' knowledge with stock assessment (Neis, 1992; Carruthers and Neis, 2011; Tesfamichael et al., 2014; Duplisea, 2017). This study began with the idea that there could be a 'middle ground' between full and desk-based MSEs in which semi-structured interviews are conducted during a desk-based MSE with stakeholders, specifically fishers, to address knowledge gaps related to conceptual management objectives, candidate management measures, fishing behavior, and other observations related to the management system when resource limitations preclude direct stakeholder participation.

In this paper, we present a case study in which we applied this intermediate MSE approach to two marine fisheries in the Southeast United States: the Southeast black sea bass (*Centropristis striata*) and Atlantic cobia (*Rachycentron canadum*) fisheries. Although commercial fishing remains the dominant source of global removals, regionally, recreational fishing can rival or exceed commercial removals (Coleman

et al., 2004; Arlinghaus et al., 2019). In the Southeast United States (SE US), recreational fishing is the dominant source of fishing mortality (Shertzer et al., 2019). We chose these two fisheries for our case study to compare interview results and integration with MSE across fisheries with different degrees of recreational use. The overarching goal of the article is to describe how information obtained from semi-structured interviews conducted with commercial and recreational fishers was used to inform a MSE tool designed to evaluate tradeoffs between potentially competing commercial and recreational fishing objectives. We present results from interviews with commercial fishermen and recreational anglers in each fishery and discuss how information obtained from interviews was used to set up management scenarios for future testing of the MSE tool.

Methods

Case study background

Currently, both fisheries' recreational component is made up of private recreational anglers and the for-hire recreational fleet, i.e., private charter vessels and headboats, and there exists at least one commercial fishery (SEDAR, 2018; SEDAR, 2020). The management procedure used to set total allowable catch (TAC) for both black sea bass and cobia fisheries is a constant catch harvest control rule (HCR) based on a fishing mortality (F) reference point and is regulated using management tools such as minimum size limits, vessel/trip limits, bag limits and seasonal closures (SEDAR, 2018; SEDAR, 2020). Southeast black sea bass fisheries are managed using an 11-inch size limit and vessel limits in the commercial sector, and a 13-inch size limit and combination of bag limits and vessel trip limits for the recreational sector, respectively (SEDAR, 2018). The TAC for black sea bass is allocated nearly equally (50-50) between commercial and recreational sectors, but in recent years, commercial fisheries have not attained their allocation, recreational fishing, primarily from private angling, has become the dominant source of mortality and the magnitude of dead discarded fish from the recreational sectors has greatly increased (Rudershausen et al., 2014; SEDAR, 2018). The Southeast Atlantic cobia commercial fishery, an incidental bycatch fishery, is managed using a 36-inch size limit and vessel limits, while the recreational fishery is also managed using a 36-inch size limit and bag limit (SEDAR, 2020). As of the 2019 stock assessment, the commercial fleet is allocated less than 10% of the TAC, and the recreational fleets over 90% (SEDAR, 2020). During the past 10 years however, the recreational fleets have landed more than 95% of the cobia TAC (SEDAR, 2020).

Research design

We conducted interviews with commercial and recreational fishers from the Southeast US to learn what they valued about the fishery they participated in, their desired fishery objectives, preference for future management actions, and how past management actions had affected their fishing behavior. Interviews were conducted using a semi-structured interview instrument (Appendix I), meaning that interviewees could introduce other topics, including suggesting alternative goals and management actions not included in the instrument (Patton, 1990; Murray et al., 2010; Carruthers and Neis, 2011). The goal of the interviews was to obtain information related to the values driving broad-scale conceptual fishery objectives (Andrews et al., 2021), learn fishers' preferred management measures, and collect information on fisher behavior that could inform the development of the MSE tool. We designed the interview instrument to include questions salient to the history of management in each fishery and described in the case study background.

We conducted a total of 30 interviews between May and August of 2020 in two phases due to a difference in sampling methods. During the first phase, 14 interviews were conducted during May with five commercial fishers who fished for black sea bass in the commercial pot fishery, one commercial fisher who caught cobia in seasonal commercial bycatch fisheries, six recreational fishers for black sea bass, of whom five identified as private anglers and one as a private charter, two recreational fishers for cobia, of whom one identified as a private angler and the other a private charter and headboat captain (Table 1). We selected initial interview participants based on the number of years of participation in each fishery with preference for those who had fished for 10 or more years, and additional participants were identified using snowball sampling by asking interviewees to recommend other commercial fishermen or recreational

TABLE 1 Interview participation by sector (recreational or commercial) and species (black sea bass or cobia) by phase (1 or 2).

Phase I Participants	Number of Phase I participants	Phase II Participants	Number of Phase II participants
Recreational black sea bass	6	Recreational black sea bass	10
Recreational cobia	2	Recreational cobia	6
Commercial black sea bass	5	Commercial black sea bass	
Commercial cobia	1	Commercial cobia	

anglers (Murray et al., 2006). The second phase occurred during June-August, in which an additional 16 interviews were conducted with 16 recreational fishers, all of whom identified as private anglers: ten who fished for black sea bass and six who fished for cobia (Table 1). Participants during the second phase were selected from the National Oceanic and Atmospheric Administration's (NOAA) Marine Recreational Information Program (MRIP) database using a combination of stratified random sampling (by state within the Southeast US) and systematic random sampling of license holders who had renewed their license for 10 or more years.

Interviews

Our study occurred during the height of the COVID-19 pandemic, therefore all participants were contacted and interviewed *via* telephone. Once contacted, fishers were read a script that described the purpose of the study and how information collected during interviews would be used (Appendix II). For those who declined to participate, we thanked them for their time and ended the call. For those who chose to participate, we assigned them a code referring to the species they fished for, i.e., "BSB" for black sea bass or "COB" for cobia, the sector they fished in, i.e., "CO" for commercial and "RE" for recreational (includes private and for-hire sectors), and their number in the order of interviews conducted. Detailed notes, including participant quotes, were made during each call. We attempted to call from university-owned computers using Cisco Jabber to call from a North Carolina State University (NCSU) number and record calls. However, calls were flagged as spam on cell phones, therefore all calls were made using personal phones and were not recorded. As such, we made transcriptions whenever possible during calls, and kept detailed notes. Interviews ranged from approximately 20 minutes to 1.5 hours. All participants were anonymously referred to in terms of their target species and sector in our results. All data collection and analyses involving human subjects were conducted in compliance with NCSU's Human Subjects Independent Review Board.

Integration with MSE

We synthesized the information obtained from the semi-structured interviews to be integrated with an MSE tool. The MSE tool consists of an OM connected with an assessment model, and an implementation/projection model. The OM was conditioned to reflect the estimates of population and fishery dynamics from the most recent black sea bass and cobia stock assessments (SEDAR, 2018; SEDAR, 2020), and written in R statistical software (R Core Team, 2022). The assessment model is an integrated statistical catch-at-length model developed by Cao et al. (2017) for the Gulf of Maine Northern Shrimp (*Pandalus borealis*) population in AD Model Builder (Fournier et al., 2012); it is a forward-projecting assessment that applies a growth transition matrix to the fish (or shellfish) population dynamics to model the probability of fish transitioning from one length bin to the next (Chen et al., 2003). The implementation/projection model is an extension of the OM that simulates the population forward in time three years, then a stock assessment is conducted to model the real-world assessment process, then implementation/projection model applies reference points estimated from the assessment to the population to simulate the implementation of management procedures, and the process is repeated. This forms the complete MSE simulation loop that models the entire management scenario. We chose a size-structured framework because most marine stocks in the Southeast US are managed using regulations that are size-based and avoids the need for age-length conversion which introduces additional uncertainty into assessment model estimates (Quinn and Deriso, 1999; Cao et al., 2017).

We emphasize that the purpose of this study is not to present the MSE model in full or its results, but rather to demonstrate the ways that semi-structured interviews can be integrated with the framework itself. Integration with the framework described above was accomplished by synthesizing the interview results to determine the conceptual objectives of commercial and recreational fishers in black sea bass and cobia fisheries against which management procedures are evaluated and determine the management procedures for simulation testing. We used interview responses related to changes in fishing behavior to determine what kind of HCR was necessary to capture the functional response of the commercial and recreational fleets to changes in the population dynamics within the implementation/projection model. We determined management procedures for implementation and simulation testing by reconciling the HCR with preferred management measures, i.e., finer-scale tools such as sector allocation and minimum size limits. We also used responses to determine performance metrics: the measurements that are required to determine whether objectives were met by the management procedure (Plagányi et al., 2014; Grüss et al., 2016).

Results

Responses to interview questions

Results are organized in the following order: summaries of responses from general recreational fishers (if applicable), followed by summaries specific to recreational black sea bass and cobia fishers, followed by general commercial fishers (if applicable), followed by summaries specific to commercial black sea bass and cobia fishers.

In response to Question 1, which asked what was most important to participants about the fishery, most recreational fishers voiced that sustainability/conservation and the ability to keep fishing seasons open were of utmost importance to them (Table 2). Some recreational fishers discussed their concerns: those who fished for cobia specifically cited a reduction in the availability of legal-sized fish and importance of larger fish to the fishery (Table 2). Recreational black sea bass fishers also identified catching larger fish as being of great importance (Table 2), and identified maintaining clean water, fishery sustainability, availability, and equitable harvest between recreational and commercial sectors as features important to them (Table 2). Commercial both black sea bass and cobia fishers described fishing as a business and necessity for their livelihood. In this sense, they summarized what they valued about the fishery in terms of how it fit into their business portfolio. However, some commercial black sea bass fishers expressed enthusiasm for eating black sea bass, and the sustainability of the fishery (Table 2).

Question 2 asked participants to choose three conceptual objectives from a list of six that we provided: A) "Catching the greatest number of pounds," B) "Catching the greatest number of fish," C) "Catching the largest size fish," D) "Maximizing the length of the season," E) "Conservation of the resource," and E) "Increased access or opportunity within the fishery," and rank each as their first, second and third most-preferred. All participants were encouraged to provide any other objectives they thought were missing and rank them if desired. Responses to Question 2 provided quantitative summaries of objective prioritization for commercial and recreational fisheries by species (Figure 1). We note that not all participants chose to rank objectives, providing qualitative answers instead. Recreational black sea bass fishers ranked "catching the largest fish," and "maximizing the length of the season" second and most frequently, each with n = 4, and "conservation of the resource" and "increased access or opportunity [within the fishery]" third, each with n = 4; another also suggested reducing recreational black sea bass discards as an objective but did not rank it. The recreational black sea bass fisher who identified as a charter captain explicitly suggested the sustainability and optimization of yield as their top-ranked objective. Recreational cobia fishers ranked "maximizing the length of the season" first with n = 5, and also second with n = 4, and "catching the greatest number of fish" third and most frequently with n = 6; the fisher who identified as a charter and headboat captain suggested "consistency of success" as an equally top-ranked objective to "maximize length of the season," referring to a combination of having enough days to fish and enough fish available to be caught. Commercial black sea bass fishers consistently ranked "catching the greatest number of pounds" first (n = 3), followed by "catching the greatest number of fish" and "increased access or opportunity [within the fishery]" (n = 2), and nearly all options excluding "catching the largest fish" were ranked third by at least one participant (n = 1). One commercial black sea bass fisher suggested that one objective should be reducing mortality from recreational discarding of black sea bass. The commercial cobia fisher ranked "increased access or opportunity [within the fishery]" first, "maximizing the length of the season" second, and "catching the greatest number of pounds" third. At least one recreational black sea bass fisher ranked each objective first, but "catching the greatest number of pounds" received the highest rank (n = 3).

Question 3 asked participants to choose three management measures from a list of six that we provided: A) "Changing the vessel/trip or bag limits," B) "Changing the size limits," C) "Changing the size limits to a slot limit," D) "Seasonal closures," E) "In-season adjustments to vessel/trip or bag limits," and E) "Changing catch limit allocation among sectors," and rank them as their first, second, and third most-preferred. Interviewers encouraged participants to list any additional management measures they preferred and rank them as desired. Question 3 provided quantitative summaries of management measures preference for commercial and recreational fisheries by species (Figure 2). Recreational black sea bass fishers ranked "change size limits" first and most frequently (n = 6), "change size limit to a slot

TABLE 2 Responses to interview Question 1 by sector (recreational or commercial) and species (black sea bass or cobia).

Recreational Black Sea Bass	Recreational Cobia	Commercial Black Sea Bass	Commercial Cobia
Enjoyment/being able to get outdoors/ Food	Having year-round availability of legal fish	Sustainability/keeping it open	Important seasonal bycatch, supplement to other fisheries
Availability during cooler months	Uniqueness of the fish and availability	Important winter fishery	
Regularly catch fish/large individuals	Maintaining healthy stock of larger fish	Added source of income/family business	
Maintain clear water		Enjoy eating them	
Sustainability/legitimate season (keep it open)			
Equitable harvest			

Question 1 asks fishers to tell the interviewer what they value most about the fishery.

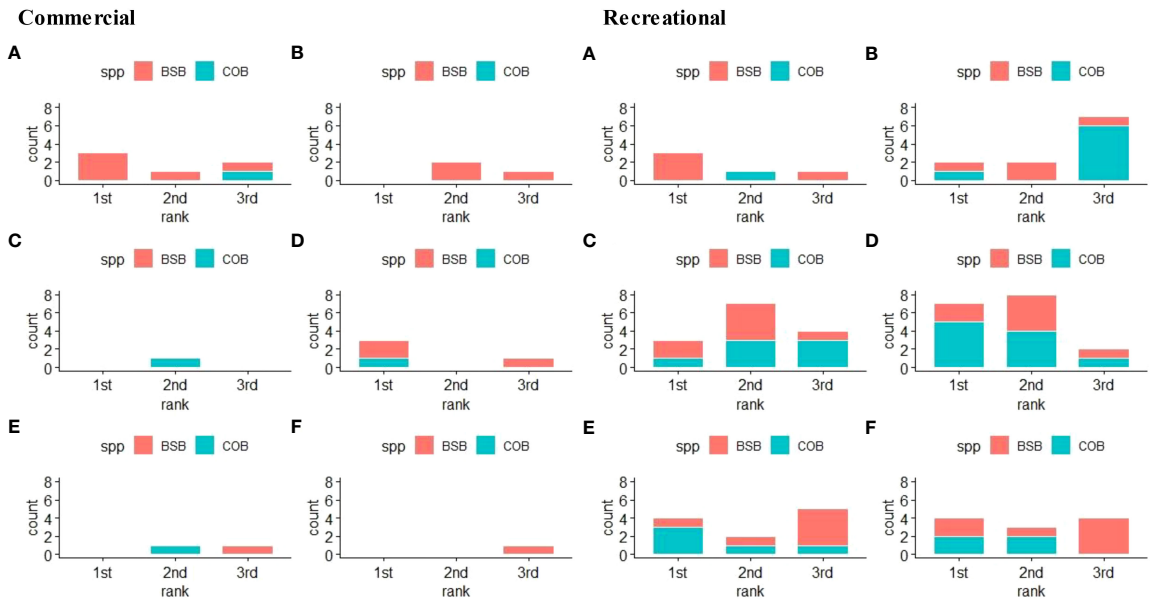

FIGURE 1
Tallied responses to Interview Question 2 which asks fishers to identify their top three conceptual objectives from a list provided by the interviewer. Conceptual objectives were ranked 1st, 2nd, or 3rd by commercial fishers (left) and recreational fishers (right) for black sea bass (red) and cobia (blue). Options for ranking were **(A)** "Catching the greatest number of pounds," **(B)** "Catching the greatest number of fish," **(C)** "Catching the largest size fish," **(D)** "Maximizing the length of the season," **(E)** "Conservation of the resource," and **(F)** "Increased access or opportunity within the fishery.".

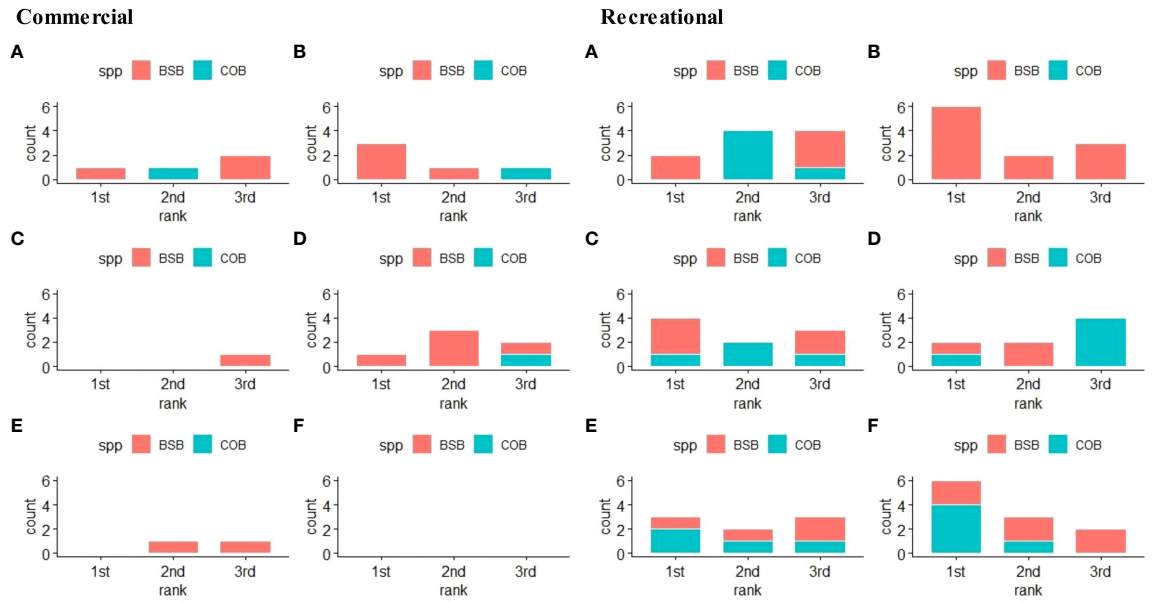

FIGURE 2
Tallied responses to Interview Question 3 which asks fishers to identify their top three management measures from a list provided by the interviewer. Management measures were ranked 1st, 2nd, or 3rd by commercial fishers (left) and recreational fishers (right) for black sea bass (red) and cobia (blue). Options for ranking were **(A)** "Changing the vessel/trip or bag limits," **(B)** "Changing the size limits," **(C)** "Changing the size limits to a slot limit," **(D)** "Seasonal closures," **(E)** "In-season adjustments to vessel/trip or bag limits," and **(F)** "Changing catch limit allocation among sectors.".

limit" second (n = 5), and "change vessel/trip/bag limits," "change size limits," and "seasonal closures" third, each with n = 3. Recreational cobia fishers generally ranked "change allocation among sectors" first (n = 4), "change vessel/trip/bag limits" second (n = 4), "change vessel/trip/bag limits," "change size limit to a slot limit," and "in-season adjustments to limits" third, each with n = 1. Commercial fishers consistently ranked "changing the size limits" first (n = 3), "seasonal closures" second (n = 3), and "changing vessel/trip/bag limits" third (n = 2). The commercial cobia fisher did not choose to rank any of the six measures first, ranked "changing vessel/trip/bag limits" second, and both "changing size limits" and "seasonal closures" third. No additional management measures were proposed.

Question 4 asked participants to describe any changes in their fishing behavior in response to past vessel or trip limits, depending on whether they were a commercial or recreational fisher. Some recreational fishers expressed hesitation when answering this question. They often answered that they followed the regulations, threw small fish back, or did not fish during a closure. Other recreational fishers reported that they fished less, targeted other species, or promoted more catch and release when trip limits were reduced. Some also expressed that this caused them to fish less offshore. A recreational cobia fisher reported that, "I will not run offshore and justify the fishing if I can't come home with enough fish." Most recreational fishers however stated that it caused no change to their behavior, that they followed the regulations, and kept fewer fish. Commercial fishers generally cited switching up gear, fishing new areas, or targeting different species when past changes to vessel limits were implemented. Commercial black sea bass and cobia fishers reported having to change some aspect of their business operations when vessel limits were reduced; for example, the commercial cobia fisher described changing the business model to focus on fewer catches of higher quality meat, stating that "you need to be able to make it on less and be smart about how to go about it, " and one commercial black sea bass fisher shared that they, "had to work to maximize profits. Used to have two guys working on the boat, now we have only one. I've cut corners on everything I can. Learned to maximize bait and groceries. Pay less a percent to the crew that I used to. Been taking off things off expenses, taking tackle out of expenses." Another commercial black sea bass fisher commented on their frustration with past changes to trip limits, "We've gone through changes and every year we go through a different change. The problem with trip limits is they're not very enforceable. Can tell you from the commercial aspect, if commercial boats were required to carry VMS (vessel monitoring system), if they were required to have that, then it would be more enforceable … all they can do is look at your fish box, might catch a red snapper violation, but can only gauge trip limit when catch is offloaded."

Question 5 asked participants to describe any changes in their fishing behavior in response to past changes to size limits in their respective sector. Recreational fisher responses varied. Some expressed that the greater size limits caused them to fish more to catch their limit, and others stated that they, "just didn't focus on black sea bass as much. But if I'm catching 9/10 under size, I could be going after something else, I know I can catch." Some recreational fishers expressed concern about handling more fish and increased discard mortality. One cobia angler stated that they "gotta handle more fish, so there's more opportunity for injury to fish and angler." A recreational cobia fisher said that the changes in size limits were confusing, especially near state lines, or that they were disappointed and did not understand the rationale behind differing size limits among sectors. Slot limits, which were suggested as a potential management measure in Question 3, came up in discussions with both commercial and recreational fishers in response to this question. Most commercial fishers were against a slot limit because it would forgo yield. Recreational fishers were generally more receptive to slot limits. Some stated that they thought it would enable them to focus on retaining larger fish (within the legal range), with one angler stating that "if the science supports, I support it". Others took the opportunity to say, "no slot limits." Commercial fishers generally reported that they let more fish go, changed gear to accommodate the new size limits, or had no change. One commercial black sea bass fisher had repeatedly expressed that more restrictions would have negative effects for commercial fishermen; they said, "fight them [size limit changes] when they come up and they're proposed. Fight them and try to stop them. No size limit when I started."

Question 6 asked participants to describe any changes in their fishing behavior in response to past seasonal closures. Recreational and commercial fishers for both black sea bass and cobia cited fishing less, targeting other species, or not fishing at all. Some recreational fishers stated that they were disappointed when closures occurred but noted that their livelihood was not at stake; others responded by saying they simply followed the regulations. However, one recreational cobia fisher reported that, "If I catch a cobia and it's out of season, he goes in the box." One commercial black sea bass fisher described how they switched fisheries entirely in response to closures: "I gill netted instead of black sea bass fishing. Now I can black sea bass fish all year. I luckily can fish here in the wintertime for black sea bass now though since closures have not happened in a while." Commercial black sea bass fishers also expressed strong opposition to seasonal closures, stating that they wanted to avoid them at all costs.

Synthesis of interview results for integration with MSE

Several responses to Question 1 overlapped with ranked conceptual objectives listed in Question 2, therefore we synthesized responses to Questions 1 and 2 to identify a

preliminary set of conceptual objectives and performance metrics for evaluation in the MSEs (Table 3). Additionally, for responses to Questions 2 and 3, we prioritized objectives and management measures by the number of times they were selected (highest n) regardless of rank. For recreational black sea bass fishers, "catching the most pounds" was the number-one ranked objective in Question 2, however, "catching the largest fish" and "maximize the length of the season" were the most frequent responses. Given that recreational black sea bass fisher responses to Question 1 included "regularly catch large individuals/fish," "availability during cooler months," and "sustainability/legitimate season (keep it open)" (Table 2) suggest that the number-two ranked objectives may be of greater importance. Consequently, we chose all three as recreational fishing objectives for evaluation. For performance metrics, we chose to measure changes in the median of recreational catch, the proportion of legal-sized fish in the estimated population, and the exploitation rate as a proxy for season length (Bohaboy et al., 2022). Reducing discards was an additional objective that both a commercial and recreational fisher cited but did not rank in response to Question 2. Given the recent increase in discard mortality in the most recent assessment for black sea bass (SEDAR, 2018), we included this as an additional conceptual objective for both sectors and chose to measure the magnitude of discards as a performance metric. For commercial black sea bass fishers, "catching the greatest number of pounds" was the most common and number one-ranked conceptual objective in response to Question 2, and responses to Question 1 included "added source of income/family business;" therefore we selected "catching the greatest number of pounds" as the primary commercial fishing objective for the black sea bass MSE. However, commercial catches of black sea bass have consistently been lower than the proportion of the total allowable catch allocated to the sector (SEDAR, 2018), suggesting that attaining the TAC may not be a sufficiently realistic performance metric, therefore we chose to examine changes in the median of commercial catch. For the commercial and recreational cobia fishers, "maximize length of the season" was the number one-ranked objective in Question 2, therefore this was selected as the primary commercial and recreational fishing objective for the cobia MSE. Additionally, we selected "catching the largest fish," recreational cobia anglers' number two-ranked objective, as an additional recreational fishing objective. We used the same performance metrics identified for use in the black sea bass MSE. We chose exploitation rates as a performance metric for both commercial and recreational season length, and the proportion of legal-sized fish in the population, respectively. Conservation of the resource was not the number one-ranked objective in responses to Question 2 for any fishery or sector, however, recreational black sea bass fishers consistently ranked it second (Figure 2), and recreational fishers' responses to Question 1 suggested it was a high priority, e.g., "maintaining healthy stock of larger fish," "sustainability/keeping it open," and "sustainability/legitimate season (keep it open)" (Table 2). We interpreted these responses to mean that conservation, in the sense of keeping the fishery open in the long-term, was an important objective regardless of fishery and sector, therefore, we translated this into a conceptual objective designed to avoid fishery closures (SEDAR, 2018; SEDAR, 2020): maintain spawning stock biomass above the minimum stock size threshold (Table 3).

We synthesized responses from all questions to determine what HCR and management measures should comprise management procedures for implementation and simulation testing. In response to Question 3, "changing the size limit" was the highest ranked management measure among commercial fishermen and recreational anglers for black sea bass in response to Question 2 (Figure 2), and the reduction of discards was cited as a concern by both a commercial fisherman and recreational angler in response to Question 2. Additionally, "equitable harvest" was mentioned in response to Question 1 by recreational anglers for black sea bass (Table 2). Therefore, due to concerns over discards and the inequity in size limits across sectors, we chose to explore an 11-inch minimum size limit in both commercial and recreational fisheries, and a decrease in

TABLE 3 Conceptual objectives and performance metrics derived from participants' responses to interview questions.

Type of Objective	Species	Conceptual Objective	Performance Metric
Commercial Fishing	Black sea bass	Catch the greatest number of pounds	Changes in median of average catch
Recreational	Black sea bass	Catch the greatest number of pounds	Changes in the median of average catch
Recreational	Black sea bass	Catch the largest fish	Proportion of legal-sized fish in the population
Recreational	Black sea bass	Maximize the length of the season	Changes in exploitation rates as a proxy for season length
Recreational and Commercial Fishing	Black sea bass	Reduce discards	Magnitude of discards
Commercial Fishing	Cobia	Maximize the length of the season	Changes in exploitation rates as a proxy for season length
Recreational Fishing	Cobia	Maximize the length of the season	Changes in exploitation rates as a proxy for season length
Recreational Fishing	Cobia	Catch the largest fish	Proportion of legal-sized fish in the population
Conservation	Black sea bass/Cobia	Maintain SSB above MSST	% of simulations in which SSB remains above MSST

dead recreational discards by half (Table 3). Recreational cobia fishers ranked "changing allocation among sectors" as their most preferred management measure (Figure 2). We chose not to explore any management measures that would change the allocation further in favor of the recreational sector given the magnitude of the TAC landed by the recreational fleets. In responses to Questions 1 and 4, commercial fishermen for both black sea bass and cobia spoke of the value of the fishery in terms of economic importance and changing their business model or operations to maximize profits in response to management action (Table 2). This information is aligned with the prioritization of yield-based conceptual fishery objectives and is consistent with the aim of traditional maximum sustainable yield (MSY)-based management (Kell and Fromentin, 2007). Therefore, we selected a range of status quo HCRs that are explored in current stock assessments, specifically variations of the *F*-based reference point that will achieve MSY, e.g., F_{MSY} and fractions of F_{MSY}, including those with a P^* management buffer, for testing in both MSEs. Additionally, because the majority of participants cited no change to fishing behavior in response to changes to vessel/trip and bag limits, changes to minimum size limits, or seasonal closures, we only included the constant catch HCR in the implementation/projection model, as opposed to an HCR that includes a functional response in fishing to stock status (Berger et al., 2012).

We reconciled *F*-based constant catch HCRs with preferred management measures to develop a list of management procedures for implementation (Table 4). For black sea bass, the management procedures included a constant catch at F_{MSY} with no changes to minimum size limits or allocation by sector, 75% F_{MSY} with no changes to minimum size limits or allocation by sector, F_{MSY} with $P^* = 0.4$ with no changes to minimum size limits or allocation by sector, F_{MSY} with $P^* = 0.38$ with no changes to minimum size limits or allocation by sector, F_{MSY} with $P^* = 0.4$ with no changes to minimum size limits, but 50% less catch allocated to discard to simulate improved discard practices ergo higher black sea bass discard survival, and F_{MSY} with $P^* = 0.4$ with 11-inch minimum size limits for both recreational and commercial sectors and no change to allocation by sector (Table 4). F_{MSY} with $P^* = 0.38$ was included in the last two because it was the preferred alternative implemented for managing Southeast black sea bass in 2018 (Chip Collier, SAFMC, personal communication). For cobia, we chose to test the same four black sea bass management procedures without changes to size limits or allocation (Table 4). We chose F_{MSY}, 75% F_{MSY} and F_{MSY} with $P^* = 0.4$ because these are all management procedures used for projections in the most recent stock assessments (SEDAR, 2018; SEDAR, 2020).

Discussion

Using information obtained from semi-structured interviews with stakeholders, we were able to identify conceptual objectives and preferred management measures, and develop candidate management procedures for implementation and simulation testing; these constitute several elements of the MSE participatory modeling framework outlined by Goethel et al. (2019), and represent several key features of stakeholder engagement in MSE regardless of timetable (Punt

TABLE 4 Management procedures by species: black sea bass (BSB) and cobia (COB).

Management procedure	Species	Description/notes
F_{msy}	Black sea bass	Constant catch, no change to status quo minimum size limits
75%F_{msy}	Black sea bass	Constant catch, no change to status quo minimum size limits
F_{msy} with P* = 0.4	Black sea bass	Constant catch, P* = 0.4 is approx. 92% F_{msy}
F_{msy} with P* = 0.38	Black sea bas	Constant catch, 13-inch size limit (rec), 11-inch size limit (comm) P* = 0.38 is approx. 94% F_{msy}; currently applied
F_{msy} with P* = 0.38 and 50% reduction in discard F	Black sea bass	Same as above with discard mortality reduced by 50% simulating improved discard practice
F_{msy} with P* = 0.38 and 11-inch recreational minimum size limit	Black sea bass	Constant catch with selectivity changed to reflect 11-inch minimum size limit in recreational fishery
F_{msy}	Cobia	Constant catch, 36-inch size limit; currently applied
75%F_{msy}	Cobia	Constant catch, no change to status quo minimum size limits
F_{msy} with P* = 0.4	Cobia	Constant catch, P* = 0.4 is approx. 92% F_{msy}, no change to size limit
F_{msy} with P* = 0.38	Cobia	Constant catch, P* = 0.38 is approx. 94% F_{msy}; currently applied

P* is a management buffer; P* = 0.40 is approximately 92%F_{msy} and 0.38 is approximately 94%F_{msy}. Those management procedures that are currently applied are noted as such in the description/notes.

et al., 2016; Deroba et al., 2019; Feeney et al., 2019). Our study demonstrates that conducting semi-structured interviews with stakeholders, specifically commercial fishermen and recreational anglers, in tandem with MSE tool development is a viable intermediate approach to a full MSE when direct stakeholder participation in MSE is not feasible.

Our study was not without some shortcomings. Without iterative stakeholder participation and feedback, we had to translate information obtained from interview responses into information that could be used in the MSE tool. The compartmentalization and distillation of information obtained from fishers is an ongoing concern in resource management (Holm, 2003) and who is doing the translating, and how the information is put to use by resource managers and scientists matters, therefore we must look critically at the translation process (Murray et al., 2005). Our participants chosen during the first phase was largely based on snowball sampling, however, most participants were recreational fishers who were chosen using a statistical sampling framework during Phase II. Most landings in Southeast marine fisheries come from recreational fishing (Shertzer et al., 2019), therefore we believe our approach was equitable. Another challenge in integrating experiential knowledge with quantitative frameworks is that it requires a process designed to receive it (Nadasdy, 1999; Stephenson et al. 2016; Steins et al., 2020); the design of our MSE tool and initial testing precluded the exploration of certain management scenarios that could have been developed from interview responses. For example, recreational black sea bass anglers ranked "changing the size limit to a slot limit" as their second most-preferred management procedure in Question 3 (Figure 2), and slot limits were the subject of much discussion in response to Question 5 (see Results). During initial testing of the MSE tool, we modified fishery selectivity in the OMs and implementation/projection model to reflect the implementation of a slot limit but could not obtain convergent model results. Similarly, although "seasonal closures" was the third most-preferred management procedure for both recreational black sea bass and cobia anglers (Figure 2), this conflicted with our goal of conditioning the OMs to reflect the most recent stock assessment estimates for black sea bass and cobia, which used non-seasonal models (SEDAR, 2018; SEDAR, 2020). We also acknowledge some sampling bias. In choosing fishers who have participated in the black sea bass and cobia fisheries for 10 or more years, we exclude those who may have exited either fishery due to past management actions. By selecting participants with long histories of fishing however, we may avoid the 'shifting baseline syndrome' sometimes associated with newer entrants to the fishery whose experience with fisheries management may be limited (Murray et al., 2010). We also acknowledge a heavy skew toward private anglers in terms of recreational fisher participation in interviews. Charter and headboat operations are an important component of recreational fishing economies in the Southeast US, and the captains, crew and clients are likely to have different motivations and perspectives concerning each fishery. Moreover, for black sea bass, private angling comprises the greatest proportion of landings and fishing mortality (SEDAR, 2018). For cobia, landings data and fishing mortality are aggregated by general commercial and recreational fleets (SEDAR, 2020), but MRIP catch estimates suggest that private angling and charter boats are equally responsible for the majority of fishing mortality in the Southeast US (National Marine Fisheries Service Fisheries Statistics Division, personal communication). Additionally, we focused on fishermen participating in the commercial pot fishery for black sea bass because it is the dominant source of fishing mortality in the commercial sector (SEDAR, 2018). This introduces a bias toward views of the commercial black sea bass pot fishery in commercial black sea bass responses. However, few fishers attended SEDAR, 2018, and those that did were participants in the commercial pot fishery.

One of the key features of MSE is the ability to identify tradeoffs associated with each management procedure (Bunnefeld et al., 2011; Punt et al., 2016). Many of the management procedures chosen for simulation testing based on the interview results were MSY-based, which have often failed to meet recreational objectives (Miller et al., 2010; Ihde et al., 2011). Recreational fisheries remain the dominant source of fishing mortality in the Southeast US (Shertzer et al., 2019), therefore, it is vital to engage with fishery stakeholders, specifically those from recreational sectors, to determine where those tradeoffs may occur. New intermediate approaches to engaging stakeholders and utilizing their data in MSE are being pioneered to determine whether management strategies meet recreational objectives (Bellquist et al., 2022). Although labor-intensive, our study represents a cost-effective alternative intermediate framework for stakeholder engagement in MSE. We anticipate that these approaches will become increasingly necessary as recreational fisheries outgrow commercial fisheries (Arlinghaus et al., 2019) and the cost of government implementation of MSE remains high (Aranda & Motos, 2006).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by North Carolina State University Independent

Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

MD is the first author for this work. JC is the senior author. All other authors shared an equal contribution as second authors. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2022.1063260/full#supplementary-material

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