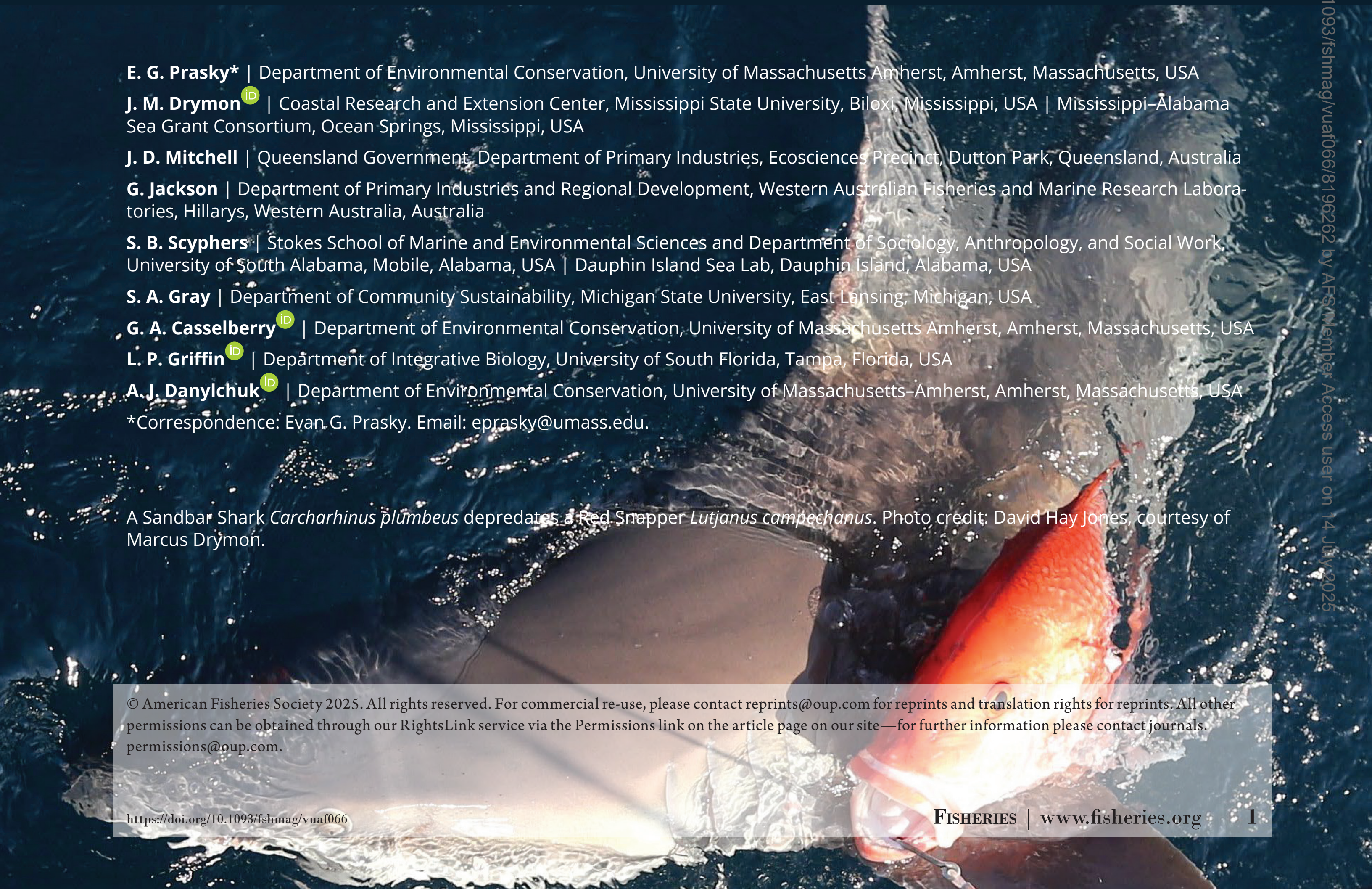
FEATURE

A framework for fuzzy cognitive mapping workshops: Shark depredation as a case study



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A Sandbar Shark *Carcharhinus plumbeus* depredates a Red Snapper *Lutjanus campechanus*. Photo credit: David Hay Jones, courtesy of Marcus Drymon.

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ABSTRACT

Recreational fisheries are dynamic and complex social–ecological systems with many actors and threats, both real and perceived. Challenges related to the management of recreational fisheries may be attributed to tensions and misunderstandings among anglers and agencies charged with regulation and enforcement. Fuzzy cognitive mapping (FCM) is a semiquantitative way to capture and share the perceptions of different stakeholders and can be a useful tool for revealing issues and tensions in recreational fisheries. Our paper aims to use our experience with FCM workshops focused on shark depredation to reveal the benefits and challenges behind this process. Specifically, we held two in-person workshops that included FCM-building exercises to gain perspectives on beliefs and perceptions about depredation, one with anglers to capture their on-water local ecological knowledge and the other with fisheries managers and scientists. We implemented two different FCM methodologies to capture perceptions among stakeholder groups to understand potential barriers to mitigating shark depredation. Although FCM can uncover subtleties within complex systems and build trust between managers and stakeholders, its use, adoption, and implementation are potentially hampered by its seemingly complex approach and subjectivity. Coproducing FCMs for shark depredation showcased the benefits of shared learning opportunities among stakeholders, managers, and scientists. Collectively, we hope that our experiences with FCM and the process we reveal can act as a catalyst for other opportunities where such methods can be used to establish a shared understanding of the complexities of recreational fisheries and highlight paths to hone outreach and management.

INTRODUCTION

Recreational fisheries are dynamic and complex social–ecological systems (SES) with many actors and threats (Arlinghaus et al., 2015). Challenges related to the management of recreational fisheries may be attributed to tensions and misunderstandings between recreational anglers and management agencies in charge of regulation and enforcement. Understanding these challenges is crucial for both parties, as it provides unique insights and opportunities for effective management. Fisheries managers are tasked with managing fish stocks to balance human exploitation with resources sustainably. This often leads to a disconnect between fisheries managers and recreational anglers who may distrust the scientific process behind regulatory decisions for management and conservation needs (Gray, Shwom, et al., 2013).

Fuzzy cognitive mapping (FCM) is one tool for capturing and quantifying the perceptions and complexities of SES, including recreational fisheries. Fuzzy cognitive mapping is a semiquantitative way to capture and share the perceptions of different stakeholders and is useful for revealing issues and tensions within complex systems (S. A. Gray et al., 2013). First described in 1986 by Bart Kosko, FCMs were proposed to create qualitative maps (Jetter & Kok, 2014; Kosko, 1986). Fuzzy Cognitive Models are built by extracting a system's current knowledge and experiences (Papageorgiou & Salmeron, 2013). This is done using stakeholders as experts to build and develop a SES model based on their behavior and perceptions when interacting within a SES (Özesmi & Özesmi, 2004). When developing FCMs, they can be created by individual stakeholders, by distinct stakeholder groups, or collaboratively by groups creating shared models (S. A. Gray et al., 2014).

In FCMs, concepts are variables that can positively or negatively influence other variables and are depicted as nodes (S. A. Gray et al., 2013). The connections between nodes are shown as edges (lines connecting nodes) with weights reflecting the positive or negative strength of one concept's influence on another (Figure 1; S. A. Gray et al., 2013). The term "fuzzy" pertains to the capability of the methodology to capture subtleties and levels of influence rather than just binary connections (S. A. Gray et al., 2014), as well as uncover subtleties between groups or individuals building the models (S. A. Gray et al., 2014). The inclusion of resource users in model development is key, as it allows decisionmakers to bridge knowledge gaps in the environmental systems they manage (S. A. Gray et al., 2013). The process of creating FCMs with stakeholders can foster trust and uncover information that might not be part of scientific assessments conducted by scientific experts alone (S. A. Gray et al., 2013).

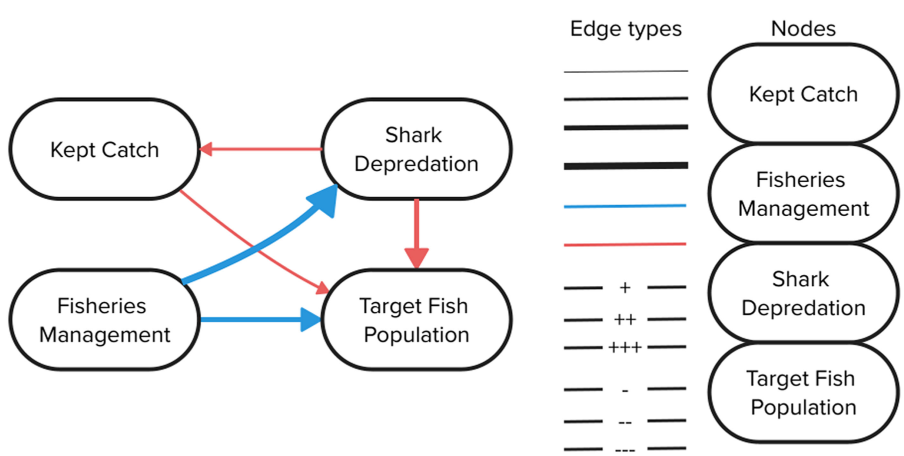

Figure 1. A visual example of nodes and different edge types. The fuzzy cognitive mapping example is a snapshot of four nodes with the edges drawn from Figure 2C. Edge weights can be determined in various ways, such as line thickness, color, where blue is positive and red is negative, or marking the line with a corresponding weight. In the example provided, edges are determined by color and line thickness.

Using FCM, we hosted two workshops to capture local ecological knowledge (LEK) and perceptions among stakeholder groups to understand potential barriers to implementing mitigation methods for reducing shark depredation within recreational fisheries. Shark depredation, where a shark partially or wholly consumes an angler's catch before it is landed (Mitchell et al., 2023), can lead to competition and conflict between fishers and sharks (Casselberry et al., 2024; Holder et al., 2020; Robinson et al., 2022) and is a widespread issue in many countries worldwide (Mitchell et al., 2023). Anglers in regions with progressive shark management frameworks, such as the United States and Australia, have reported increased shark depredation levels for over a decade (Mitchell et al., 2018, 2023). The perception of marked increases in shark depredation has led to a rise in negative angler attitudes toward sharks (Casselberry et al., 2022; Prasky et al., 2023). Prasky et al. (2023) revealed that 61% of surveyed anglers blame fisheries management success in restoring select shark populations as the cause for increases in shark depredation. However, other factors have influenced increases in depredation, including learned shark behavior, increases in recreational angler effort, environmental changes, and possibly reduced prey populations for sharks (Mitchell et al., 2018, 2023; Prasky, 2023). The interplay between shark depredation and these additional factors makes it an inherently complex problem. Recreational anglers' perception of shark overabundance may threaten efforts to restore historically depleted shark populations (Simpfendorfer et al., 2021) as it intersects with anglers' perceived satisfaction while fishing (Drymon & Scyphers, 2017; Robinson et al., 2022).

The purpose of our paper is to illustrate the utility of FCM for engaging stakeholders in complex recreational fisheries management issues. To do this, we present the use of FCM in two different contexts and formats to understand perceptions around the complex social–ecological interactions of shark depredation among recreational anglers, fisheries managers, and scientists. We specifically focus on the facilitation process, including the selection of participants and the modes of engagement to foster stakeholder interactions and discussion. We use our experience to describe how FCM can build trust, engage participants in challenging conversations, and facilitate the transfer of ideas and experiential information. Through these methodologies, we provide specifics of the development and insights into conducting an FCM workshop.

APPROACH 1: METHODS OF CAPTURING LOCAL ECOLOGICAL KNOWLEDGE

Process

One method to create a FCM is using hand-drawn models on a noteboard or whiteboard and then adding concepts on either sticky notes or by drawing them (Knox et al., 2024). Nodes can then be connected via a color or scale-connected line or "edge" (S. A. Gray et al., 2013). We adopted this approach when conducting a workshop to characterize perceptions held by recreational anglers in the Gulf of Mexico (GoM).

Perceived increases in depredation escalate frustrations in the recreational GoM reef fish fishery due to increased angler effort and overall mortality for target fish species (Casselberry et al., 2022; Prasky et al., 2023). For those within the charter-for-hire industry, negative emotions experienced by customers due to depredation events may lower customers' likelihood of booking a return trip (Casselberry et al., 2022). Depredation has become a prominent topic of discussion during the Gulf of Mexico Fishery Management Council (GMFMC) meetings. The GMFMC is the management agency responsible for managing fisheries in federal waters (greater than three nautical miles offshore). Anglers are actively seeking solutions to reduce depredation, but a comprehensive characterization of how they perceive the issue is lacking. Therefore, we set out to identify common themes, trends, and differences among charter-for-hire captains in the GoM reef fish fishery (Drymon et al., 2022).

We held an in-person workshop in April 2022 at Gulf State Park in Gulf Shores, Alabama, to address rising concerns about depredation in the recreational angling community. The timing and location of this workshop were planned in accordance with a GMFMC meeting, thereby increasing attendance without significantly increasing costs for participants to attend. To prepare for the workshop, we reviewed existing depredation data sets from the National Marine Fisheries Service Reef Fish Observer Program. This acted as a literature review for facilitators and allowed deeper conversations between facilitators and participants about the complexities they experienced with depredation.

The structure of the one-day modeling workshop was divided into six sessions that included the following:

1. A welcome session, which included introductions of all the scientists and charter-for-hire captains;
2. an overview of the purpose of the modeling exercise and the workshop goals;
3. a group session focused on building mental models;
4. a discussion on extrapolating the models and how the data can be applied;
5. a presentation of results and concluding thoughts; and
6. exit surveys.

After introductions, the second session began by listening to the anglers as they voiced their frustrations and shared their experiences about depredation encounters. This discussion allowed us, the facilitators, to develop rapport with the anglers, transition into the workshop's goals, and describe our modeling exercise. In the third session, anglers ($n = 22$) were assigned to regional breakout groups: Eastern GoM (i.e., Florida, $n = 12$), Central GoM (i.e., Alabama, Mississippi, and Louisiana, $n = 6$), and Western GoM (i.e., Texas, $n = 4$). To develop FCMs focused on regional depredation (Drymon et al., 2022), each breakout group included several facilitators who fostered discussions and assisted in the collaborative model-building process. Each FCM was built on a large notepad using sticky notes to label the components and, depending on the relationship (i.e., positive or negative), weighted lines to connect the components (Figure 2B). The weight between the components was determined by adding one to three plus or minus signs next to the intended connector line. Facilitators assisted in this process by preparing each notepad with four predetermined key concepts: angler satisfaction, depredation, reef fish populations, and fisheries management effectiveness, which were specifically chosen to see how they interact within regional models.

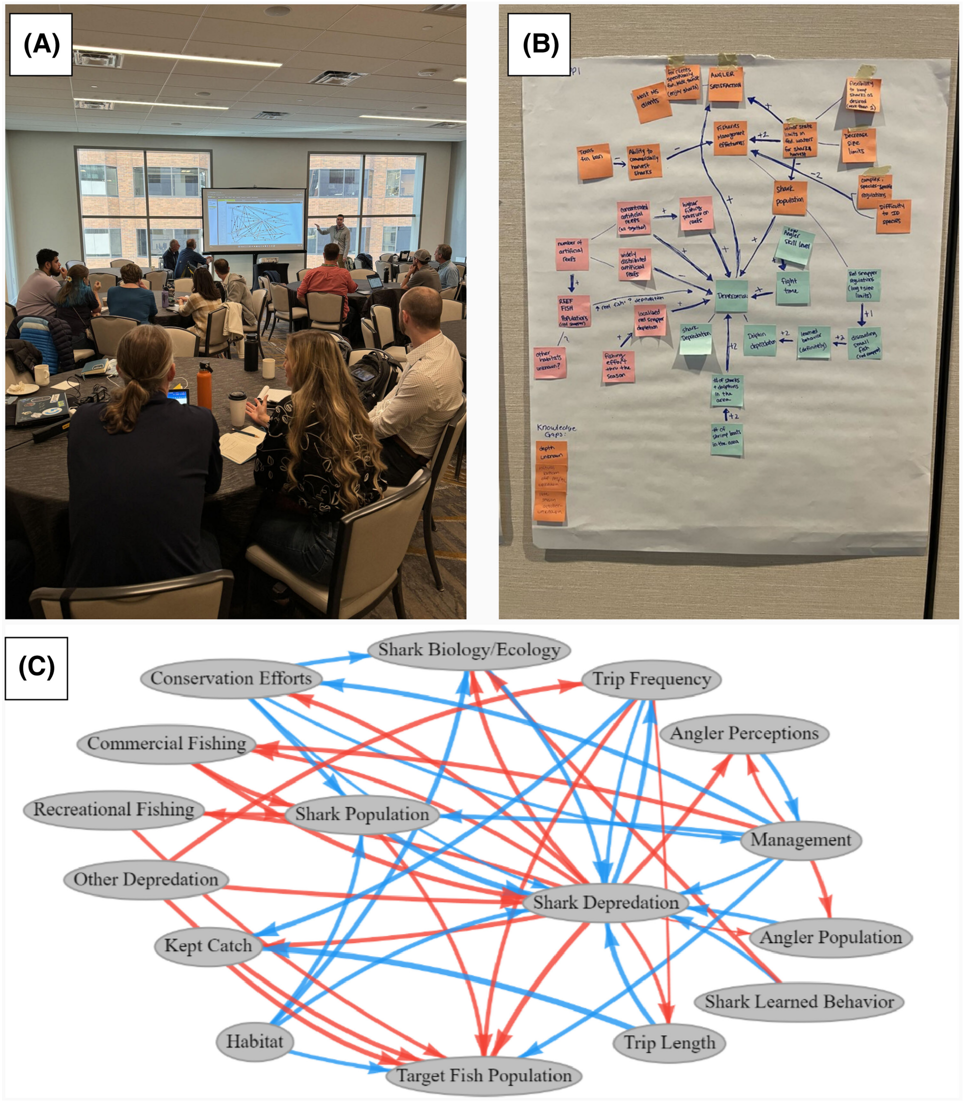

Figure 2. (A) Images of a workshop being conducted. (B) A completed concept map using an oversized notepad and sticky notes with connections drawn between the concepts. (C) A completed model from the second workshop where participants used only the modeling software.

The workshop and model-building process were semi-structured, with the above four predetermined concepts used as the starting point for the model-building process. Twenty additional concepts (Figure S1) were printed and displayed for all participants to see and use if desired. Participants were also encouraged to generate their own concepts. Additional concepts were informed by responses to the survey question: "In two words or less, what do you see as the single greatest cause of depredation?" (Prasky et al., 2023). Facilitated discussions within each group were conducted by asking the participants guided questions to extrapolate details of their unique perspectives. Early in the process, we encountered challenges because of differences of opinion among the Mississippi and Louisiana members of the Central GoM group regarding the impact of depredation on varying habitat types. Participants in each group were firm about how depredation impacted them within their specific region. As such, we reorganized the three regional groups into five state-specific groups to better capture the fine-scale differences across the GoM. This approach ensured that the views of participants were reflected appropriately.

After regional zones were split up, we had the following number of charter-for-hire representatives from each state: Florida $n=8$, Alabama $n=4$, Mississippi $n=4$, Louisiana $n=2$, and Texas $n=4$. There were trade-offs for splitting the groups. Smaller groups allowed for a more conversational interaction between facilitators and participants. However, the smaller groups reduced the diversity of opinions, and this may have led to model-building conversations being dominated by fewer voices. Overall, the decision to split the groups was made to reduce conflict and proceed with the workshop. To assign weights, facilitators would ask how the newly added component interacted with each previously identified component placed on the notepad. For example, when shark populations were added, participants discussed how it influenced depredation, fisheries management effectiveness, angler satisfaction, and reef fish populations. Weights would only be added if they were agreed upon by all group members (Özesmi & Özesmi, 2004). If stakeholders agreed on whether there was a positive or negative impact but disagreed on the extent, they could average the weights between the components. If they disagreed on whether the impact was positive or negative, they could split the components into multiple, more precisely defined components to make sense of the connections in question. This ensured agreement between all participants, which helped build a model representative of the participants' views.

The fourth session began after participants had finished making their models. The hand-drawn models were then converted into a digital format using Mental Modeler (https://www.mentalmodeler.com; S. A. Gray et al., 2013). The models were transcribed by mapping one concept at a time and then adding connections individually to the newly transcribed components. Facilitators undertook data analysis by running the scenario analysis tool. The scenario analysis tool quantifies each component's relationship to the rest of the model. The tool can define the number of indegrees (the number of connections flowing into a component), outdegrees (the number of connections flowing out of a component), and centrality (the total number of connections) of a component. We used these metrics to identify participant perceptions of the leading drivers of depredation within each community. We used the scenario analysis tool to manipulate the most significant drivers of depredation and to visualize the impact that changing the strength of these drivers had on the rest of the model.

We began the fifth session by showing the digitized models to the anglers in their breakout groups. This allowed the facilitators to review the model with the anglers, discuss the scenario analysis tool, and ensure that the connections were transcribed correctly. Next, we asked one angler from each breakout group to present their model to all the other anglers in the modeling session. Doing so provided anglers with a sense of increased ownership of their model and facilitated angler-to-angler dialogue. The sixth and final session was an exit survey, which focused on gathering feedback on the effectiveness and design of the model-building exercise. These surveys were used to improve this process and receive honest, anonymous feedback from the anglers involved.

Outcomes

A key finding from our first approach was that charter-for-hire captains acknowledged and agreed that depredation rates had increased. Despite changes in abundance in select shark populations, reported shark depredation rates from recreational anglers outpace a logical correlation (Drymon et al., 2024). However, they could not agree that shark populations or fisheries management were the drivers (Drymon et al., 2022). During our scenario analysis, we explored the impacts of adjusting the relative change in shark populations and fisheries management, which had different results for every state model. Charter-for-hire captains' perceptions of depredation are likely influenced by their region and habitat (i.e., inshore or offshore) and other variables, such as the frequency of depredation encounters, personal views and beliefs of fisheries management, and exposure to others encountering depredation. Additionally, changes in perception due to social media pages, blogs, or news stories may be driving the dialogue that shark depredation is increasing.

We found that there was a threshold for depredation encounters where low encounter rates had the potential to increase business through social media promotions, which is also in line with the findings of Casselberry et al. (2022). Captains explained that posting pictures of depredated fish or pictures of sharks would increase short-term bookings. However, above a certain threshold, depredation became a nuisance, and if captains were hired to target sharks, they were apprehensive, as they were met with extreme pushback on social media. Similarly, Prasky et al. (2023) found that depredation becomes problematic for anglers in the Gulf of Mexico when it occurs in more than 1 out of every 10 fish caught.

Considerations

At the conclusion of the workshop, we collected the exit surveys from the participants. Several participants expressed gratitude for being invited to join and participate in the model-building exercise and optimism about their voices being heard. Overall, feedback was positive, and the data collected led to several technical publications (Drymon et al., 2022; Gervasi et al., 2023) where the LEK collected was used to help inform fisheries management. Negative feedback was focused on group dynamics, where differences of opinion stalled the model-building process. This is common in model-building exercises where dynamic values can take time and increase tensions between group members if they cannot agree on an acceptable outcome (Furman et al., 2021). Solutions to this problem include splitting the concept that cannot be agreed upon into multiple concepts or, if that cannot be done without agreement, dividing groups further, which we did. Ultimately, drastic differences in participants' views can slow down the model-building process and derail the group involved in this discussion. Knowing how to address these issues as they arise will reduce conflict and increase the time spent building models.

Our FCM workshop was successful in many ways, but it also had its limitations and shortcomings. Preparing it required a team of nine people and necessitated travel for facilitators and participants, which was resource-intensive and expensive. Expenses included renting the conference room for 2 d, which cost approximately US$600, and flights for five participants, totaling around $2,500. Lodging and food accommodations were provided for all facilitators, which cost about $3,000. Charter-for-hire captains were also compensated for their time to make up for missing time out on the water. Together, a rough estimate for this workshop is approximately $10,000. Allocating funds and finding an appropriate time and location that works for everyone may make workshops like this one challenging.

APPROACH 2: METHODS OF CAPTURING EXPERT ECOLOGICAL KNOWLEDGE

Process

Another method for FCM is using software rather than paper to build the initial models (S. A. Gray et al., 2013). An added advantage of building the models on a digital canvas is the potential for the real-time ability to run hypothetical scenarios, allowing participants to explore how changing one or more concepts in the model can influence the weighting of relationships

(S. A. Gray, Chan, et al., 2012). With that in mind, we adapted our process and used Mental Modeler (S. A. Gray et al., 2013) to have the participants build the models. This allowed users to develop a simple qualitative FCM on a digital canvas without requiring facilitators to translate the hand-drawn models (S. A. Gray et al., 2013).

For this workshop, we focused on scientists and fisheries managers who have been studying shark depredation over the past 10 years (Mitchell et al., 2018, 2023; Prasky, 2023). Following a special session on shark depredation at the 2023 World Recreational Fisheries Congress in Melbourne, Australia, a shark depredation working group was formed to build collaboration between scientists and fisheries managers from a range of countries with similar goals (Mitchell et al., 2023). We then held an FCM workshop at the ninth World Fisheries Congress in Seattle, in March 2024.

Drawing from our initial workshop experience, we adapted the structure of the second workshop to fit a shorter timeframe and a smaller facilitation team, while still engaging a comparable number of participants ($n = 21$). We modified the structure and plan based on lessons learned from our first approach. By balancing the benefits of co-learning in a group setting with the participants' worldwide individual perspectives, we could tailor the FCM-building process to utilize its strengths and generate collaborative, diverse models, where group discussions primarily drove model building. The facilitators were more of a guide to help build the models rather than extract the knowledge. Diverse knowledge exchanges between participants occurred while building the models, and secondarily, they happened when the models were completed and presented to the facilitators and other groups. The trade-off for this approach was that it may have minimized softer voices or not entirely captured regional perspectives if they were in contrast to the entire group. Additionally, disagreements within groups when taking this approach can stall the model-building process, as a lengthy discussion slows progress and leaves participants losing focus.

The workshop structure was divided into six sessions:

1. Recruitment to ensure enough participants with diverse backgrounds attended the workshop;
2. introductions and an overview of our goals for the workshop;
3. presentation of what FCM is and an instructional guide on how to use the Mental Modeler software;
4. building mental models in groups;
5. discussing the results and scenario analysis; and
6. group feedback.

The first session focused on maximizing the involvement of scientists and fisheries managers by ensuring they were informed about the workshop and invited to participate. Recruitment began shortly after arriving at the conference by extending email invitations to all symposium speakers and verbal invitations to fellow attendees.

The second session began with facilitator introductions. The participants sat in self-assigned groups based on their work experiences (e.g., scientists sat with scientists, managers sat with managers). In total, there were four groups and 21 participants: Group One (fisheries scientists, $n = 6$), Group Two (fisheries scientists and managers, $n = 4$), Group Three (fisheries managers, $n = 6$), and Group Four (fisheries scientists, $n = 5$). For the third session, we presented an example of a mental model using a topic unrelated to depredation (e.g., climate change, emissions, laws and regulations, and human population) to show participants how to make connections between components and how to use the modeling software. Guidelines were shared with participants who were expected to build models directly with the modeling software. This was in contrast to the first workshop, where groups built paper-based models, and the facilitators transferred them to the modeling software.

In the fourth session, one participant from each group built their model using the modeling software on their own computer (Figure 2C). We used the same semi-structured approach as we did in the first workshop: 20 concepts (Figure S1) were displayed for all participants to see and use as necessary (Drymon et al., 2022; Prasky et al., 2023). Participants were also encouraged to generate their own concepts. If groups could not reach a consensus, participants were given the same set of instructions as the first FCM workshop: either average the weight between the components in question or split the components into multiple components to make sense of the connections in question. Two of the groups progressed to utilizing the scenario analysis tool, which runs multiple analyses and provides instant feedback regarding model integrity. Once models exceeded 15–17 connected components, groups were instructed on how to use the tool. The scenario analysis tool was used to ensure connections were properly weighted and their impact was measured correctly. Once all models were received, the facilitator ran all four models through the scenario analysis tool and displayed each model in front of all participants (Figure 2A). The scenario analysis included manipulating multiple variables, such as shark populations, which were a primary driver for each group model. Similar to the first workshop, we asked one participant from each group to present their model and discuss the model-building process. The sixth session occurred after the conclusion of the in-person portion of the workshop, by emailing all participants and asking for feedback on how to improve future workshops. The email thanked participants for attending the session and asked if they could provide a couple of sentences detailing what worked during the workshop and what did not.

Outcomes

In general, fisheries scientists and managers in the USA and Australia acknowledge signs of recovery in some shark populations (e.g., Tiger Shark *Galeocerdo cuvier*, Scalloped Hammerhead *Sphyrna lewini*, Great Hammerhead *S. mokarran*, Bonnethead *S. tiburo*, and Smooth Dogfish *Mustelus canis*; Braccini et al., 2020; Pacoureau et al., 2023), following the implementation of management of shark fisheries to rebuild shark stocks following a period of overfishing in the 1970s to the 1990s. Additionally, species like the Bull Shark *Carcharhinus leucas* continue to increase in some of these regions (Mullins et al., 2024) and are frequently associated with depredation. However, changes in shark population abundance alone do not explain the reported increases in shark depredation rates. It is likely that growing shark populations, in combination with an increasing angler base and shark-learned behavior, explain the perceived rapid increases in shark depredation rates (Mitchell et al., 2020). Environmental changes, such as shifts in shark species' distributions related to climate change and altered food web dynamics affecting shark prey availability, may also be influencing the perceived increase in shark depredation rates. During the scenario analysis, we investigated the impacts of adjusting the relative change in shark populations as well as other factors that participants wanted to explore. We found many other variables, such as the angler population, discards, and shark learning behavior, all independently increased the perceived relative increase in shark depredation.

A key finding from this approach was how fisheries scientists and managers used the model-building process as a discussion to brainstorm ideas among participants from diverse backgrounds. Developing a shared understanding of shark depredation fostered new ideas and different perspectives from Australia, the United States, and South Africa. Although the preparation and planning of the second approach vastly differed from the first, the workshop was ultimately deemed a success due to the completion, presentation, and discussion of the models built primarily using a digital canvas. This approach has the potential to be tailored further to build models in the field with the appropriate equipment and design. Currently, the limiting barrier is the software's ability to be used exclusively on a computer.

Considerations

The feedback we received from scientists and fisheries managers was overwhelmingly positive. However, the complexities of hosting a workshop during a conference may have hindered participant turnout. First, attendance may have been hindered due to concurrent conference presentations or other conference commitments that superseded our workshop. Second, some at the conference believed the workshop to be a private event, which may have reduced overall participation. Third, the target attendance of the workshop may be considered biased as it was only made available for people who attended the conference.

Feedback from participants also suggested that more time and/or additional facilitators would be helpful for some groups to improve the completeness of the models created. Some participants noted that complex group dynamics unnecessarily prolonged the determination of connections, causing frustration within their group, which also occurred in our first workshop. The time constraint of only half a day was a challenge, and more time would have allowed the models built during the workshop to be more developed. However, this was also an issue during the first workshop, and additional facilitators may allow every group to create highly developed models when building directly in the modeling software. Having a dedicated facilitator for each group would also allow participants to stay on track and be more productive, as it can be easy for one participant to derail the model-building process. In the future, a standardized feedback survey would help compare the approaches.

DISCUSSION

The process of using FCM has great potential for assessing ecological knowledge of diverse stakeholder groups through facilitated workshops (Knox et al., 2024; Özesmi & Özesmi, 2004). Complex human–wildlife conflicts, such as shark depredation, present unique challenges for fisheries management and addressing these challenges through facilitated FCM workshops can help promote a shared understanding of the issues and foster stakeholder participation, potentially establishing trust (Gray, Shwom, et al., 2012). Coproduction via FCM could also help reduce frustrations between resource users and managers while uncovering new understandings of the intricate processes that drive these wicked problems (Jentoft & Chuenpagdee, 2009) and even understanding how to build resilience in SES (S. A. Gray et al., 2015).

The approaches we used in our workshops go beyond the typical use of FCM, which is usually employed to model complex human systems like human governance (Knox et al., 2024). To assist in future work involving FCM workshops, we created a framework to showcase the steps we took in both workshops to extract LEK effectively from resource users, fisheries managers, and scientists (Figure 3). Both workshops relied on a comprehensive understanding of the topic (i.e., shark depredation) we were trying to model, which was informed by the facilitators conducting a literature review and analyzing results from a survey (Prasky et al., 2023) and the extensive knowledge that the participants brought with them. The methods for building the models differed. Our first workshop built models manually with notepads, requiring closer facilitation. The second workshop relied on the participants to input their knowledge directly to a digital canvas, and the facilitators merely acted as guides when a problem arose. The presentation of data back to the entire workshop was similar between workshops and yielded similar feedback responses from participants.

Identifying the appropriate modeling workshop approach will depend on several factors, including funding, capacity to attend, familiarity with the software, the number of facilitators, the number of participants, and how comfortable participants are with using a software-based approach. Determining which approach to use will likely depend on the demographic whose knowledge you are trying to extract. Moreover, a software-based approach made more sense when paired with the ability to operate with fewer facilitators. Nevertheless, the software model-based approach would require at least one computer per group to be connected to the internet, which may not be possible in some venues and/or locations.

Our workshops highlighted the strengths of FCM and showcased its ability to generate descriptions of data-poor environments efficiently. These results can inform scientists and resource managers in their decision making, including in situations where stakeholder perceptions may differ. It should be noted that FCM is most effective when both facilitators and participants are actively engaged and fully committed to the process. When conducting workshops, gaining a wide range of diverse voices is essential to ensure the modeling does not produce false narratives or misunderstandings, which can be a downside when using FCMs (Knox et al., 2024). Also, these workshops can help understand complex systems at a deeper level and build models that can be used for further data exploration (S. R. J. Gray et al., 2019).

The time and effort required to conduct effective FCM workshops are far outweighed by the positive results and trust earned from the participants involved. The process of shared

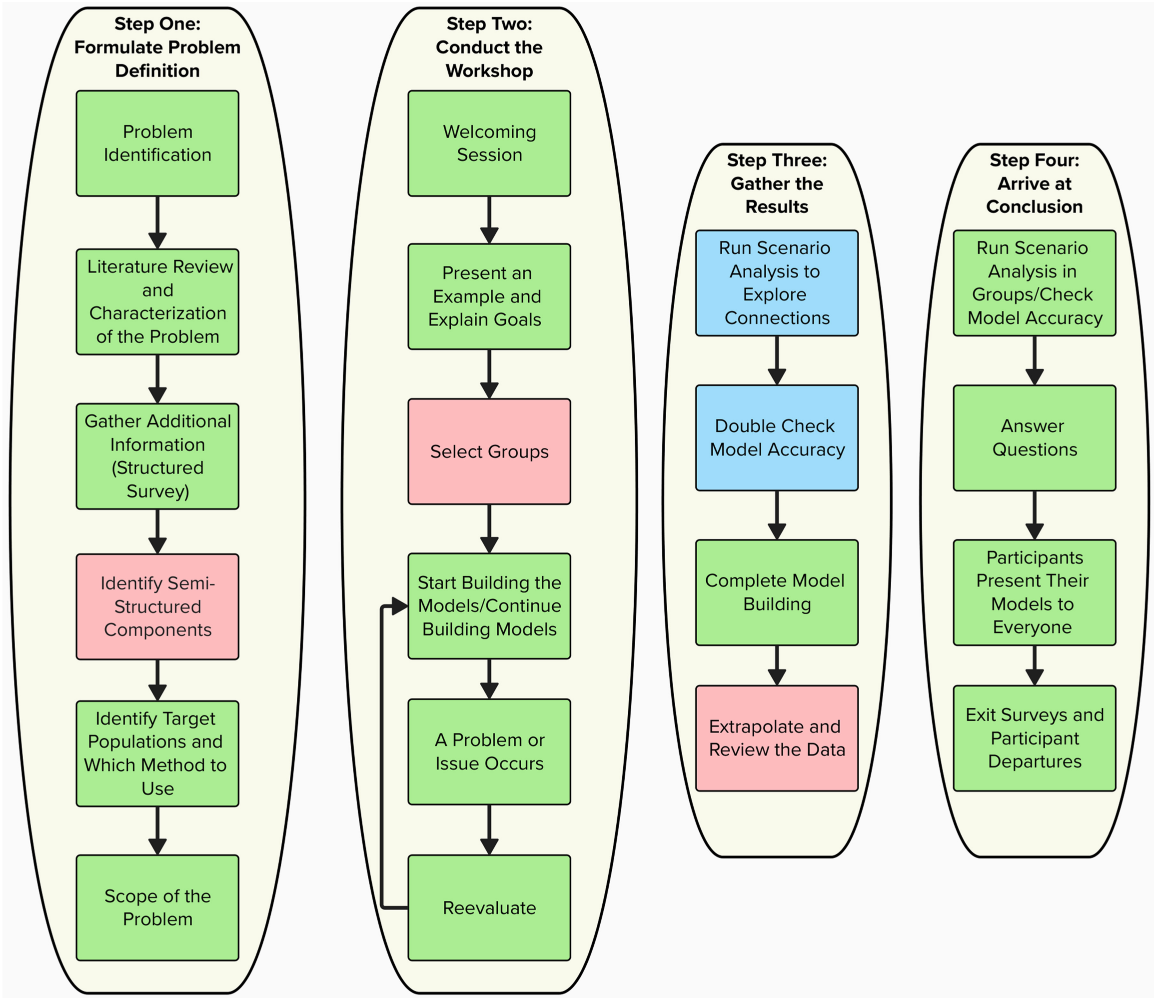

Figure 3. Framework of the process used for conducting a fuzzy cognitive mapping workshop. Starting from left to right are the four steps for conducting an effective workshop and the sequences of actions within each step. Green boxes indicate steps taken in both workshops, red boxes indicate steps only done in the first workshop, and blue boxes indicate steps only done in the second workshop.

learning went beyond the facilitator–stakeholder relationship. Feedback from participants allowed us to hone our skills and try different methods as we moved from one workshop to the next. While these methods were not entirely new (Knox et al., 2024), they are not widely applied in an ecological context. Both workshops resulted in participants building completed models and sharing their perspectives with other workshop participants and the facilitators, which gave everyone a greater understanding of group perspectives. We feel that the success of our workshops was primarily due to the facilitation team having a clear understanding of the workshop goals as well as each individual team member being aware of their roles. It was important to have team members experienced in FCM and broader facilitation skills. We were also fortunate to have willing participants at both workshops who were keen to give their time and attention; this may not always be the case as some participants might lack the motivation to participate in responding to research requests despite the potentially positive benefits (Eayrs & Pol, 2018).

Efforts looking to incorporate FCM should focus on standardizing the process from one workshop to the next to compare workshops if that is an intended goal. This can be done by aligning similar concepts in the workshop design and having participants start the model-building process by using more predetermined concepts. From there, overlapping concepts could be directly compared, and a greater understanding of the gaps in knowledge and perceptions could be quantified. Workshops for FMC could further dissect points of conflict and understand the disconnect between management and resource users. Some examples where this process might be helpful are understanding responses to management decisions, such as how recreational anglers perceive the implementation of new size, bag limits, and season closures. Ultimately, FCMs add to a growing set of tools that can be useful for addressing the complexity of SES in recreational fisheries, and for resource management in general.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Fisheries* online.

DATA AVAILABILITY

Data available upon request.

ETHICS STATEMENT

Northeastern University's Institutional Review Board approved the first workshop in Gulf Shores (Approval #13-07-16). The studies were conducted in accordance with local legislation and institutional requirements. The participants provided their digital informed consent to participate in this study.

FUNDING

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CONFLICTS OF INTEREST

None declared.

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