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Food for Thought

Ten lessons from the frontlines of science in support of fisheries management

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After 20+ years as a research scientist, I recently made a career change to a scientific administrator in NOAA Fisheries. Part of the NOAA Fisheries mission is to provide scientific advice for fisheries using ecosystem based approaches to management. Where I used to see fisheries science as a relatively straightforward discipline, I now recognize fisheries as a complex socio-ecological system that spans natural and social sciences. With this recognition has come an appreciation for the concept of wicked problems and for the incremental approach to policy-making. Here I describe my perspectives before and after this recognition and present 10 lessons for myself as a guide to providing science in support of fisheries management.

Keywords: complex socio-ecological systems, ecosystem approaches to management, fisheries management, fisheries science, human dimensions.

Introduction

As a research scientist shifting into a scientific administrator role in marine fisheries, I am often asked: "what is your biggest challenge?". My answer is simple: *small-p-politics*. I use *small-p* to indicate that my challenge is not ideological nor political. Rather my challenge comes from the recognition that marine fisheries management focuses on a public natural resource, which is managed through debate, conflict, and resolution, and involves a number of stakeholders (Underlined words are defined in the terminology section.), each with their own goals, values, needs, and objectives. In this sense, my challenge reflects a shift in my definition of fisheries science from a technical, relatively narrow natural science to a transdisciplinary science associated with the complex socio-ecological system that is marine fisheries (*sensu* Ostrom, 2009).

I was a research scientist for 20+ years, a fisheries oceanographer, a disciple that focuses on the interaction between fisheries and the ocean ecosystem. After graduate school, I took a job with the National Oceanic and Atmospheric Administration (NOAA, a US government agency), where I have worked since. My early research focused on inter-annual variability in recruitment and transitioned to studying the effect of climate change on fisheries dynamics. I started as a postdoc in a research group and worked my way up to a leader of a group of researchers. As my career developed, the research topics and issues became more complex and I learned to appreciate collaboration and multiple perspectives. Throughout my career, I have justified my research as being applicable to fisheries management and I have gained a better understanding of the role of science in fisheries management. I have grown to appreciate the value and limitations of single-species management and have supported a shift towards ecosystem-based fisheries management (EBFM) that includes consideration of climate change, habitat, species interactions, and economic and social dimensions, and that envisions more integrated ecosystem-based management (EBM).

In October 2016, I was selected to serve as director of the NOAA Fisheries Northeast Fisheries Science Center, a part of NOAA responsible for providing scientific advice in support of the management of >50 marine fishery stocks in the Northeast United States (from Maine to North Carolina). The Center also works on protected species, aquaculture, and marine ecosystem topics ranging from physical sciences to biological sciences to social sciences. Most of our science is based around single-species fishery management, but Center scientists have long been involved in marine ecosystem science. One of my goals as a director is to support more integrated management, recognizing the value of a continuum of approaches from single species to ecosystem-based fisheries management to ecosystem-based management depending on the specific circumstances (see Dolan *et al.*, 2016).

According to my training, the idealized scientific process is to constrain a problem such that hypothesis testing, deductive reasoning, and validated models can provide results with a known degree of certainty. Results and conclusions are then based on a rational interpretation of the weight of evidence. I brought this perspective with me to my administrator role; scientific advice should be provided by scientists, uncertainty in that advice should be quantified, and fisheries management decisions should be based upon this advice and uncertainty.

The premise of this essay is that most of our fisheries science institutions were developed to serve one model of fisheries management—single-species management—and one model of policy-making—the rational-comprehensive model. My career as a scientist and as an administrator is embedded within the cultures developed around these models of management and policy. To be successful in fisheries science and management, I now believe that we need to adapt lessons from an incremental policy approach and from ecosystem approaches to management at both an individual level and an institutional level. In short, my change in perspective recognizes fisheries as a complex socio-ecological system and fisheries management as a wicked, problematic problem.

What follows is an exploration of the basis for my new perspective, a description of the challenges that have caused me to question the rational-comprehensive model under which I was trained, and ten lessons that I am going to take forward in applying an incremental approach to science in support of fisheries management, be it single-species or ecosystem-based.

My perspective is United States centric, but I believe that my experiences and lessons are applicable in other countries. Evaluations of "how we do fisheries management" are occurring in Canada (e.g. Soomai, 2017), Europe (Linke and Bruckmeier, 2015; Sampedro *et al.*, 2017), and Australia (Nursey-Bray *et al.*, 2018). Furthermore, "how we do fisheries management" is changing with the shift from single-species management to ecosystem-based fisheries management (Ramirez-Monsalve *et al.*, 2016; Marshall *et al.*, 2019). I believe that part of this shift should include an explicit examination of the policy model under which science is developed and provided in support of management.

Two perspectives on policy-making

Rational-comprehensive approach

The expectation for rational decision-making is at the heart of policy formulation that has developed over the past 70 years (Lasswell, 1951; Hoppe, 1999). The rational-comprehensive approach is envisioned as a five-step process: problem definition, analysis of potential solutions (or options), decision-making, implementation, and evaluation. Institutions and trained professionals oversee and conduct the required comprehensive planning and decision-making, and much of the natural resource management in the United States is based on this "command-and-control" model (Holling and Meffe, 1996). From my perspective, it is important to recognize that "how we do fisheries management" in the United States and throughout the ICES community, has roots in this model of policy.

Incrementalism

In the policy-formulation discipline, the counter to a rational-comprehensive approach is termed incrementalism, which recognizes that many problems are too complex for full understanding, let alone allowing clearly defined steps and comprehensive decision-making to develop and implement solutions (Lindblom, 1959; Hoppe, 1999). Incrementalism suggests that each stakeholder (including scientists) has a different perspective of the issues and that decision-making represents a compromise among these different perspectives. The approach provides for continued work on a problem and implements decisions stepwise with the full participation of all stakeholders (Howlett and Migone, 2011).

Fisheries management

Commercial fishing has occurred across the North Atlantic for centuries, and fisheries management has been in place for almost as long (e.g. Hoffmann, 2005; Poulsen, 2008; Bolster, 2012; Waldman, 2013). Overtime, fisheries science and management have become more institution based, with government and intergovernmental organizations largely responsible for developing science in support of fisheries management and national and international laws defining the processes for fisheries management (Farside, 2005; Lado, 2016).

The generation of knowledge (the science) for fisheries management largely uses a rational-comprehensive approach. Scientists refine the problem definition, collect data, perform assessments, and then convey the results and the uncertainty—as advice—to managers. Managers then make decisions regarding catch levels, effort controls, fishing areas, gear restrictions, and allocations.

Fisheries management, however, combines aspects of both policy-making perspectives. In the United States, decisions are made through Fishery Management Councils and Marine Fisheries Commissions, with the different stakeholder groups formally represented on the decision-making bodies. These management decisions are then implemented by representatives of the federal and state governments. Within legal constraints, problems, potential solutions (or options), and processes are debated and agreements are negotiated—sometimes there are compromises and sometimes not. Legal challenges to fishery management decisions and actions are frequent, as are calls for changing the legislative framework for fisheries management. Some stakeholders have more to gain or lose than others, and some are more influential than others. These differences reflect the power issues inherent in the fisheries management process. It is the *small-p-politics* of this process that I find most challenging.

In other countries, fishery stakeholders have less involvement in decision-making processes and decisions are made by government representatives (e.g. Canada, countries that are part of the European Union). The balance between the two policy-making perspectives (rational comprehensive and incremental) differs from country to country, but *small-p-politics* is part of fisheries management in most, if not all countries.

From my background as a scientist, I believed (past tense) that keeping the science of knowledge generation independent from the *small-p-politics* of management was paramount (Figure 1). In the scientific process, debate, conflict, and agreement by scientists

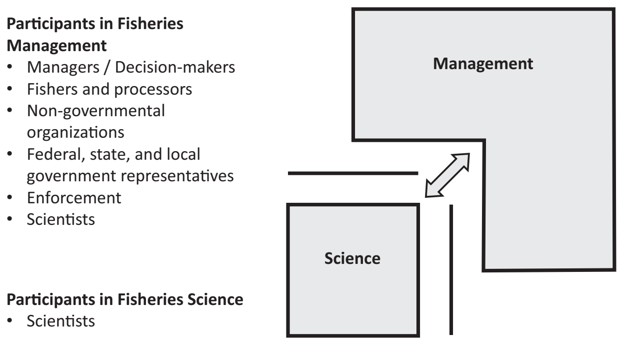

Figure 1. Conceptualization of my prior belief regarding the relationship between science and management.

occur within the culture of science. There is little to no room for non-science stakeholders to be involved in science. In fact, the connections between science and management are controlled to limit the influence of management and *small-p-politics* on the generation of knowledge (science).

As I become more involved in the fisheries management process, I find myself in an uncertain landscape, both from a scientific and policy-formulation standpoint. As an example, take the general goal of "sustainable fishing". From a science perspective, the problem, process, and solution are straightforward. The goal is to maintain "sustainable" marine fisheries. The problem is setting the harvest rates necessary to achieve optimum yield. The process to address the problem is to collect data, model the fish stock, conduct a stock assessment, peer-review the data collection and assessment results, and provide results to managers. The policy solution is then based on scientific results; managers implement regulations to set required harvest rates and ensure the sustainability of the fishery.

However, the problem, process, and solution for achieving sustainable fisheries are influenced by a range of other "problems" including: how one defines sustainability; the definition and calculation of optimum yield; definition of fish stocks; concerns regarding fishery-dependent and fishery-independent data collection; the impact of climate change on fisheries; accounting for species interactions and fishery interactions; defining who is involved in the scientific process; market and social changes affecting fisheries; changes in fishing effort and practices; changes in allocations to different vessels, fleets and regions; incentives and disincentives throughout the process; and the social and economic consequences fishery management decisions. I could continue, but the point is I find myself in an uncertain landscape where the problem, process, and solution are not as clear as they first appeared.

In this uncertain landscape, I find one of the major strengths of the fisheries management system in the United States is that stakeholders are directly involved in decisions and the science and management are iterative. Scientists assess the status of fisheries and provide scientific advice to managers. Managers, which represent a range of stakeholders, use this advice in decision-making related to fisheries including catch and effort limits, allocations, closed areas, and gear restrictions. Stock assessments and tactical management (e.g. catch limits, effort controls) are iterated generally every 1–5 years depending on the fishery. Other management issues (e.g. allocations, closed areas, gear restrictions) are addressed as needed in a participatory public process, which provides for transparency and accountability. In this sense, one of the major strengths of the marine fisheries management process in the United States is that it has many elements of the incremental policy-formulation approach.

Wickedness and problematicity

The problems I am experiencing in providing rational and comprehensive science in support of incremental fisheries management are not new. Fisheries management, and environmental management in general, have been described as "wicked problems" for more than a decade (Jentoft and Chuenpagdee, 2009). Wicked problems were formally described by Rittel and Webber (1973). These are problems that are difficult to define, are symptoms and causes of other problems, have a large number of interactions, involve a large number of stakeholders, have complex governance, and so on.

The wicked problem concept has recently been reviewed and reframed as problematicity (Turnbull and Hoppe, 2019). Wickedness and problematicity recognize a continuum of complexity. Characteristics (or dimensions) of wicked, highly problematic, and complex problems faced in fisheries management include: long history, large number of stakeholders, large cultural differences among stakeholders, complex governance, large economic impacts of decisions, large social impacts of decisions, large ecological impacts of decisions, high scientific uncertainty, and multiple potential solutions (i.e. options).

The elements of a wicked or problematic problem as defined by Turnbull and Hoppe (2019) are as follows (see Figure 2):

(i) *Problem field*: Every problem occurs in the context of natural and human components. In the case of fisheries management, natural components include species, habitats, climate, ecological processes, and interactions. Human components include laws, regulations, institutions, power, knowledge, norms, and biases, as well as economics, livelihoods, fishing approaches, communities, and cultural values.

(ii) *Dimensions of a problem*: Three dimensions have been defined: definition of the problem, identification of potential solutions (i.e. options), and the process by which problems are defined and solutions are proposed and decided.

(iii) *Stakeholders' perspectives*: Every stakeholder, be they a group or an individual, a fisher or a scientist, has a different perspective or frame-of-reference of a problem: different motivations, objectives, goals, and ideas on definition, solution, and process. Every group, including scientists, also has their own culture (norms, knowledge, experience) from which they engage with the problem and with other stakeholder groups. Stakeholders also have different reliance on aspects of the system and different amounts of power to influence the system.

(iv) *Distances among stakeholders*: Distance refers to the differences in the perspectives of different stakeholders. If all stakeholders are in agreement over problem definition, solutions to consider, and the process for decision-making, the distances among stakeholders are small and the problem is less wicked, less problematic, and less complex.

(v) *Path dependency*: Every problem has a history. The current problem field, stakeholder perspectives, and stakeholder distances are based in part on past efforts to address the

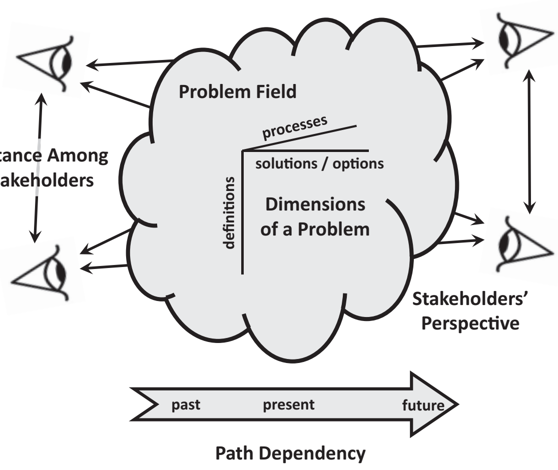

Figure 2. Conceptualization of the components of a problem as outlined in Turnbull and Hoppe (2019).

> problem or related problems. Conflicts, disagreements, and unsuccessful definitions, processes, and solutions in the past make the present problem more problematic. Emerging factors (e.g. invasive species) and baseline shifts (e.g. change in assessment results, changing climate) can also make a problem more problematic as solutions seem more distant and new problems come forward without resolution of current problems.

Two "traps" have been described for wicked, problematic problems (DeFries and Nagendra, 2017). The first trap is that problems are oversimplified to constrain the definition, process, and solutions to something that can be addressed. Oversimplification can contribute to the problem itself; for example by excluding some stakeholders, creating processes that constrain defining the problem, starting with narrow-set of potential solutions, and ignoring past inequities. In the conceptual frame above, oversimplification can increase the distance among stakeholders, making agreement less likely. One could argue that this is the current trap for science in support of marine fisheries management: continuing with single-species fisheries management in light of evidence of the importance of species interactions, habitat effects, impacts of climate change, and importance of economic-, social-, and community-level factors. The second trap is that problems are perceived as overly complicated and thus impossible to address. The result is no action, and by default, the *status quo* continues. One could argue that this trap has limited the progress towards ecosystem-based fisheries management in that ecosystem approaches appear overly complicated and intractable (Marshall *et al.*, 2019).

These traps are also related to the rational-comprehensive policy approach, which is based on a model of comprehensive planning and decision-making. Under this model, fisheries management has been defined as single species and has simplified the inclusion of ecosystem interactions. Thus, the rational-comprehensive policy approach has contributed to the oversimplification of the problem and has made ecosystem approaches appear overly complicated. If progress towards ecosystem-based fisheries management is limited by the rationale-comprehensive approach, how should we move forward? How does this "realization" of wickedness and problematicity help?

Ways forward

Fisheries management is scientifically and socially complex and political—hardly a revelation (e.g. McCay, 1981; Ludwig *et al.*, 1993). There are also numerous examples of the human and social aspects of science related to fisheries (e.g. Johnson and McCay, 2012; Spijkers and Boonstra, 2017; Olson and Pinto da Silva, 2019) and of the social and economic aspects of common property resources in general (e.g. Ostrom, 2009; Berkes and Ross, 2013).

For me, recognizing fisheries management as a "wicked problem", with fisheries science and management embedded within a highly problematic problem field, leads to a well-documented public policy and sustainability literature that provides insights into improving how science advice can be developed and provided in support of fisheries management, be it single species or ecosystem based. This past work supports the concept of incrementalism and provides guidance as to how to avoid the traps of oversimplification and overcomplication. Based on this literature and my experience as a scientist engaged in the fisheries management process, I will take ten lessons forward with me.

Ten lessons

(i) *Accept that fisheries are* <u>*complex socio-ecological systems*</u> *(explicitly acknowledging humans are part of ecosystems).* The divide between natural and social sciences in terms of fisheries is artificial. Humans are an important component of the ecological systems within which fisheries occur, and thus, fisheries are a complex socio-ecological system and need to be evaluated as such (see Ostrom, 2009).

(ii) *Strengthen existing* <u>*adaptive management*</u> *processes and institutions.* The fishery management council and commission model in the United States is already incremental and adaptive by design. There are examples in the Northeast region of the fishery management councils explicitly addressing fisheries management as complex socio-ecological systems (Gaichas *et al.*, 2016) and international examples of developing Integrated Ecosystem Assessments (ICES, 2019). Building upon these and other similar efforts will be critical to strengthen adaptive management.

(iii) *Encourage and engage in participatory science (*<u>*co-learning*</u>*).* <u>Collaborative science</u> involves stakeholders throughout the scientific process, and there are many examples (e.g. Mackinson, 2001; Guenther *et al.*, 2015; Turner *et al.*, 2017). Too often these efforts have fallen short in authentically engaging, collaborating, and co-learning with fishermen and other relevant stakeholders. The purpose should be to increase the ability to understand the problem jointly and develop solutions together, effectively decreasing the distances among stakeholders. In my opinion, this is a cornerstone to developing science in support of ecosystem approaches to fisheries management and ecosystem-based fisheries management (*sensu* Dolan *et al.*, 2016).

(iv) *Question inertia.* It is important to understand the history of fisheries science and management related to a specific problem (the path dependency of a problem). However, the path dependency of a problem should inform—but not determine—future problem definition, process, and solution.

(v) *Respect all perspectives.* Science is one perspective of the marine fisheries management problem; it is a powerful discipline that can inform the management process. It is important to recognize that there are multiple perspectives within science: disciplinary, philosophical, and personal differences. This means that there can be multiple scientific perspectives of a problem. In addition, other stakeholders bring different perspectives and different types of knowledge and expertise: managers, fishers, fishery processors and dealers, and environmental groups, among others. There is value in all the perspectives of a problem, and these perspectives should be explored and discussed, respectfully. Furthermore, it is important to recognize that science has a lot of authority and power in fisheries management, but this does not equate to *de facto* legitimacy. Legitimacy comes from respectful involvement in a process that values the perspective of all stakeholders.

(vi) *Recognize fishers as knowledge experts.* Fishers make a living based on their experience and knowledge of fisheries. In many ways, fishers are scientists, using their mental model of marine ecosystems to predict where fishing will be successful and then testing these predictions and adjusting their mental model (Kohut *et al.*, 2012). There is tremendous value in including their knowledge and expertise in the scientific process and in the creation of scientific advice. Acting on this recognition will strengthen fisheries science, adjust power structures, and likely decrease the distances among stakeholders (see Hartley and Robertson, 2008).

(vii) *Always consider the scale of the problem.* Scale is always an issue in complex problems. Working at too large a scale can result in oversimplification. Working at too small a scale can result in overcomplication. Working for the short term can negate options for addressing problems in the long-term. Working in the long-term can ignore short-term realities. The balance between small scale–large scale and short term–long term is situationally dependent and needs to be explicitly evaluated and re-evaluated. Incremental steps (small scale; short term) are needed to work towards improvement in a problem while recognizing the large scale and long term of the problem field and problem dimensions.

(viii) *Be open to changing your mind and adjusting your perspective.* This is the hallmark of the scientific process: curiosity and evidence-based decision-making. As scientists, we need to be willing to question and adjust our perspective based on different types of knowledge and different types of expertise. More broadly, all stakeholders should be willing to adjust their perspectives on a problem.

(ix) *Read, listen, and discuss broadly.* Part of the incremental approach is to consider the problem from many different perspectives and to learn about new perspectives. Reading, listening, and discussing are essential to learning, particularly co-learning (Wiber *et al.*, 2009). This lesson is very similar to lesson number one for fisheries scientists from Campana (2018) Food for Thought article: *Read, read, read.*

(x) *Publish and communicate results of science and management.* This lesson is also very similar to a lesson from Campana (2018): *Write, write, write.* The scientific process provides the opportunity to document progress in addressing a problem. Publishing leaves markers to establish where you have been and what you were doing (e.g. documenting the path). Using the scientific process of communication and peer review ensures that publications are adding to the knowledge base that constitutes science. It is important to recognize that publishing is not enough; one must work to communicate results with all stakeholders involved in fisheries management not just those reading the peer-reviewed scientific literature.

In terms of actions, I will take these lessons with me as I work in the fisheries management problem field and more broadly in the environmental management problem field (i.e. fisheries, protected species, aquaculture, habitats). I recognize that the application of these lessons will be situationally dependent. To be clear, I am not advocating for the capitulation of the scientific approach to *small-p-politics* in decision-making. I am arguing for participatory fisheries science to contribute to participatory fisheries management. Furthermore, I am defining fisheries science broadly as providing knowledge to inform decision-making in a socio-ecologically complex system (*sensu* Ostrom, 2009). Our goal as scientists should be to represent an evidence-based perspective as part of an incremental, participatory process.

Cautions

I am not as naive as to the challenges of an incremental approach to fisheries science and management. To be successful, the incremental approach requires sincerity, intentionality, attention, respect, and expertise from all stakeholders, including scientists. The approach also assumes that stakeholders are allowed to participate, are willing to seek agreements and settlements, and can change their perspectives, and their perspectives and frames of reference can be partially reconciled. Finally, the approach relies on trial-and-error co-learning: stakeholders are willing to learn slowly together rather than scientists generating and presenting solutions.

Based on these requirements, an incremental approach to fisheries science and management faces obstacles. There can be a great deal of mistrust among stakeholders (i.e. very large distances among stakeholders) (e.g. Johnson and McCay, 2012). Science-based advice has a lot of influence, and uncertainty in science is used by certain stakeholders to advance their goals (Spijkers and Boonstra, 2017). Institutional structures attempt to constrain the dimensions of the problem but can also limit participation, the ability for adaptive management, and the opportunities for co-learning (Olson and Pinto da Silva, 2019).

Another caution—raised during the review of this essay—is whether we have run out of time for the incremental approach. Is transformative change by governments and institutions needed to address global problems such as climate change, loss of biodiversity, and environmental quality and can the incremental approach support the magnitude of change required? This is a very good question. As a scientific administrator, I would argue that we have not used the incremental approach to the degree necessary nor embraced the lessons of problematicity (Figure 2); we need to work to decrease the distance among stakeholders and iterate faster on problem definition, processes, and solutions.

Closing thoughts

I indicated at the beginning of this essay that *small-p-politics* were my greatest challenge. That said, *small-p-politics* are inherent to complex socio-ecological systems and contribute to the wickedness and problematicity of fisheries management. Thus, *small-p-politics* cannot be eliminated nor ignored. Over the next several years, I will use the ten lessons as a guide in providing science in support of fisheries management be it single-species or ecosystem-based.

I fully recognize that the ideas expressed here are not new (Ludwig *et al.*, 1993; Holling and Meffe, 1996; Acheson *et al.*, 2000). However, my appreciation for the need of an incremental approach is new, as is my belief that our science and management cultures have limited our ability to apply the incremental approach. I also know that momentum is growing for a more ecosystem-based approach to fisheries management; this essay is meant to lend my weight to this momentum. In the ICES community, the Strategic Initiative on the Human Dimension aims to develop strategies to support the integration of social and economic science into marine science and management. The NOAA Fisheries Ecosystem-Based Fisheries Management Roadmap explicitly recognizes that humans are part of marine ecosystems (NMFS, 2018) and ecosystem approaches are being used to build the context, framework, and format to understand fisheries management challenges (DePiper *et al.*, 2017). Also, scenario planning and management strategy evaluation are developing approaches for formally including stakeholder perspectives in defining a management problem and identifying potential solutions that are consistent with explicit objectives (Smith *et al.*, 1999; Sainsbury *et al.*, 2000; Deroba *et al.*, 2018; Feeney *et al.*, 2018; Borggaard *et al.*, 2019). All of these approaches strengthen the incremental approach to fisheries management and embrace the concept of ecosystem approaches to management.

I also recognize that my perspective is United States centric and marine fisheries management differs from country to country. That said, there is value in considering the wicked-problematicity concept (Turnbull and Hoppe, 2019) in fishery management systems throughout ICES community and globally. In this consideration, current science and management structures should be evaluated for where incremental ecosystem approaches are being applied and can be applied. The concept of wicked problems also has been discussed in the context of environmental management (Balint *et al.*, 2011), climate policy (Grundmann, 2016), species protection (Redford *et al.*, 2013), and Ecosystem-Based Management (DeFries and Nagendra, 2017). More broadly, sustainability science has integrated these elements for more than a decade (Ostrom, 2007, 2009). The lessons presented here are more broadly applicable than just fisheries management.

Terminology

Adaptive management: It is an approach for simultaneously managing and learning about natural resources (Williams, 2011).

Co-learning: Individuals from two or more stakeholder groups attempt to learn together.

Collaborative science: It involves scientific activities that require the resources (i.e. expertise, knowledge, technology, equipment, funding) of more than one individual or one organization (Shrum *et al.*, 2007). Here, I am particularly referring to collaborations between individuals or organizations representing different stakeholder groups.

Complex socio-ecological systems: Social-ecological systems are linked systems of people and nature, emphasizing that humans must be seen as a part of nature (Berkes and Folke, 1998).

Ecosystem-based fisheries management: There are multiple definitions but one used in the United States is a systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals (Dolan *et al.*, 2016; NMFS, 2018).

EBM: EBM is an integrated management approach that recognizes the full array of interactions within an ecosystem, including humans, rather than considering single issues, species, or ecosystem services in isolation (Dolan *et al.*, 2016; NMFS, 2018).

Fish stock: It is a group of fish that can be treated as a unit for the purposes of conservation and management and that are identified on the basis of geographic, scientific, technical, recreational, or economic characteristics, or method of catch.

Optimum yield: Optimum yield is the amount of fish that: (i) will provide the greatest overall benefit to the nation, particularly with respect to food production and recreational opportunities, and takes into account the protection of marine ecosystems; (ii) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and (iii) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.

Stakeholder: Stakeholders are those who have an interest in or are affected by the fisheries management process or more broadly any policy or management process (https://coast.noaa.gov/digitalcoast/training/stakeholder.html).

Stock assessment: Stock assessment is a process of collecting and analysing biological and statistical information to determine the changes in the abundance of fishery stocks in response to fishing and, to the extent possible, to predict future trends of stock abundance. Stock assessments may be based on resource surveys; knowledge of the habitat requirements, life history, and behaviour of the species; the use of environmental indices to determine impacts on stocks; and catch statistics. Stock assessments are used as a basis to "assess and specify the present and probable future condition of a fishery".

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