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# Evaluating the theoretical and practical linkages between ecosystem-based fisheries management and fisheries co-management

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ABSTRACT

Ecosystem-based fisheries management (EBFM) is increasingly recognized as the future of fisheries conservation and stewardship, appearing prominently in policy documents internationally. Although considerable progress has been made to translate EBFM from theory to practice, limited attention has been given to assessing the theoretical and practical linkages between EBFM and fisheries co-management. While EBFM and fisheries co-management are not new ideas, growing interest in both compels reflection on the interplay of these concepts, even though they have traditionally been viewed as disparate approaches. We report on the results of a literature review that explored the extent to which EBFM and fisheries co-management are linked. We describe the fundamental drivers, attributes, and desired outcomes commonly used to characterize these management concepts and quantify the degree of overlap in the literature. To illustrate how EBFM and co-management are integrated in practice, we present three examples. These examples highlight that these concepts exist on a continuum, with elements of co-management regularly appearing in conventional management regimes and elements of EBFM appearing in fisheries co-management initiatives.

## 1. Introduction

A central objective of fisheries management is to maintain sustainable marine resources long term. Ecosystem-based fisheries management (EBFM) is regarded as the future of fisheries conservation and stewardship, appearing prominently in an array of high-level policy documents both in the United States and internationally (e.g., [1–5]). EBFM differs from traditional single-species approaches to management by considering multiple species, habitat issues, bycatch, and overall system resilience [6]. Around the world, including in the United States, there are many ongoing efforts to incorporate ecosystem-based approaches to fisheries management. For example, in 2016, the U.S. Department of Commerce's NOAA Fisheries released an EBFM Policy and subsequent roadmap that outlined a series of guiding principles to maintain resilient marine ecosystems through holistic management and concurrently directed the Regional Fisheries Management Councils to develop Fisheries Ecosystem Plans (FEPs) [7,8]. This shift towards an ecosystem-based approach to fisheries management parallels the rise in coastal and marine spatial planning, as well as a growing recognition that single-species based approaches often fail to account for the complexity of marine systems that is necessary to maintain resilient marine ecosystems long term [1,2].

Despite continued interest in moving EBFM from theory to practice, limited attention has been devoted to assessing EBFM's linkages with other management approaches. The focus of this paper is on the relationship between EBFM and fisheries co-management. EBFM and fisheries co-management are often thought of as independent approaches, though some scholars have noted parallels between these concepts in the literature (e.g., [9–14]). Continued interest in both EBFM and fisheries co-management compels further study regarding if, how, and to what degree they are interconnected.

In this paper, we report on the results of a content analysis-based literature review that identifies the synergies and tensions between these two concepts. First, we provide a review of the stated drivers, attributes, and desired outcomes of EBFM and fisheries co-management, based on a detailed review of the literature. Next, we quantitatively assess the degree of overlap that exists between these management approaches, based on themes derived from the literature review. Finally, we present three marine resource management examples from the U.S. that illustrate the varying degrees that EBFM and fisheries co-management are integrated in practice. We conclude with an overview of the relationship between EBFM and fisheries co-management, and

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suggest how a deeper understanding of the interplay between these key approaches in ocean management and conservation may help bring clarity to their use and application.

## 2. Research methodology

### 2.1. Content analysis

Content analysis is a research method for interpreting text through the classification process of coding and identifying themes in the text data [15]. The purpose of content analysis as a research methodology is to attain a broad description of a phenomenon [16,17]. Content analysis allows for replicable and valid inferences to be made from text data through a systematic, rule-guided process of analysis in order to provide knowledge and novel insights [18]. In order to assess how EBFM and fisheries co-management are described in the literature, we employed a mixed-methods approach to content analysis, incorporating both qualitative and quantitative strategies so as to create a more complete picture of the research topic and systematically explore the relationship between the two management approaches [19].

### 2.2. Literature review: data collection, preparation, and database management

A literature search was conducted via Web of Science, an indexing service that provides a comprehensive search of the scientific literature. To ensure a wide breadth of results, searches were 'topic searches', which search for keywords, titles, and titles of cited articles (after Johnson et al., [20]). Search terms included in the topic search were '*ecosystem-based fisheries management*,' and '*fisheries co-management*.' The search terms did not include ecosystem management, ecosystem-based management, or co-management more broadly, as we were specifically interested in the fisheries management context.

From an initial search of these terms, a total of 361 unique articles were identified for EBFM and 115 articles were identified for fisheries co-management. Only peer-reviewed articles were included in the review. The remaining papers were analyzed in detail to ensure that they include an explicit definition of either EBFM or co-management. Articles containing the search term without a definition or description of the management type were excluded from further analysis. Following this process, the analysis was conducted on 146 peer-reviewed journal articles: 93 focused on EBFM and 53 focused on fisheries co-management. Journal articles that were selected for the content analysis literature review were published between 1993 and 2018 and spanned over 50 peer-reviewed journals (Appendices A and B) (Fig. 1).

### 2.3. Coding schema

Content analysis as a methodology is a systematic, replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding [21–23]. Two approaches to content analysis can be distinguished: inductive and deductive analysis [24]. An inductive approach involves themes emerging from the raw data through repeated examination of the text [25]. A deductive approach involves developing predetermined coding schemes that are applied to the text [26]. The choice of approach is determined by the main purpose of the study. Deductive content analysis is recommended when the purpose of the study is to test theory [21]. Inductive analysis is used when there are no previous studies that deal with the phenomenon or when former knowledge is fragmented [17]. Here, we employed inductive and deductive approaches simultaneously. This combined approach allowed us to collect information on predetermined coding categories for each article, while also allowing for themes and new insights to emerge from the coding process [27].

Four coding categories were predetermined before analysis and collected for each article (Fig. 2A). These include: *definition* (how EBFM and co-management are being defined in the article) *drivers* (why the management approaches are being championed) *attributes* (characteristics of the management approach) and desired *outcomes* (what they seek to accomplish). Transparency and replicability of the research

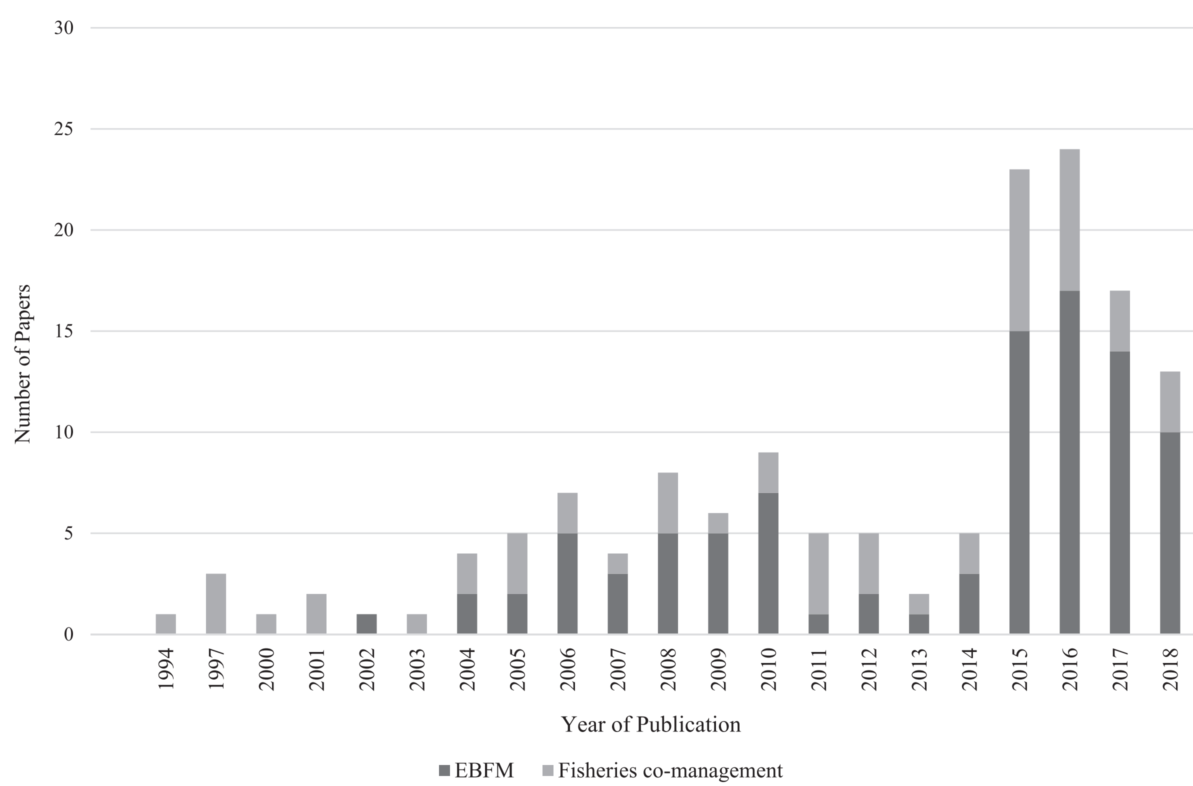


**Fig. 1.** Publication years of literature analyzed in the literature review of EBFM (n = 93) and fisheries co-management (n = 53) journal articles.

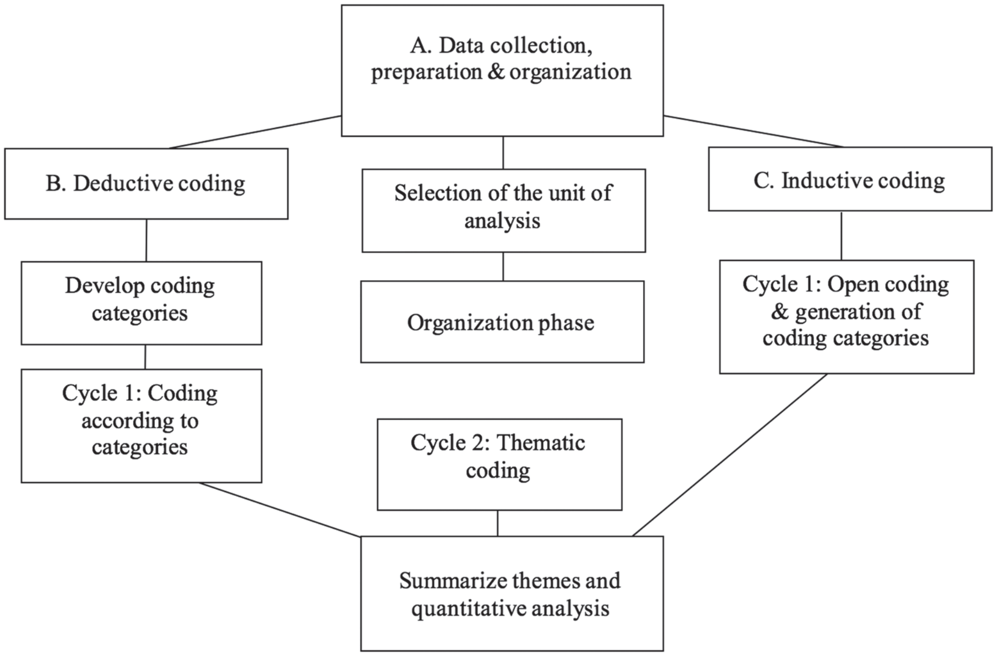


**Fig. 2.** Conceptual model of the content-analysis based literature review process using both and inductive and deductive coding approaches. Adapted from Elo et al. (2014) [26].

design are key component of content analysis and were ensured by careful documentation of the entire research process ([21,28]).

A model of the coding process for the literature review is illustrated in Fig. 2. Following the preparation/organization phase and the deductive coding generation (Fig. 2B), the first cycle of open coding was conducted to organize data into meaningful categories through thematic analysis. Thematic analysis is a search for themes that emerge as being important to the description of the phenomenon [29]. The process involves the identification of themes through careful reading and re-reading of the data [30]. It is a form of pattern recognition, where emerging themes in the text become the categories for analysis [31]. These codes were identified as prominent themes throughout the process of reviewing the literature [31] (Fig. 2C). A comprehensive list of inductive and deductive coding categories identified in the coding cycles as well as example text for each management type are listed in Appendix B.

Once the literature was initially analyzed and inductive and deductive coding categories were generated, we conducted a second cycle of coding [31]. The second cycle of coding involved creating sub-categories of themes generated from the initial coding categories [29]. The second-cycle codes were generated through the process of sub-coding, where meta-codes are developed that identify similarly coded data by grouping them into themes [31]. After qualitative coding was complete and major themes were identified, the quantitative analysis phase consisted of our summarizing the total number of papers that identified each major theme derived from the qualitative coding. The major themes that we identified from the content analysis review of drivers, attributes, and desired outcomes of EBFM and co-management literature are depicted in Table 1.

We analyzed the articles using the qualitative data analysis software NVivo (version 11.4.2). Descriptors such as title, author, year and journal published were recorded for each article in addition to the scale and scope of the research and if the article was written from a developed or developing country context (Appendix A).

## 3. Results

### 3.1. Drivers, attributes and desired outcomes

We identified a variety of similarities and differences through our analysis of descriptions of EBFM and fisheries co-management in the scientific literature. Both EBFM and co-management are driven by a common recognition that marine systems are dynamic and necessitate a holistic approach to manage for such complexity ([10,32,33]). As alternative approaches to conventional management, both EBFM and co-management literature cite that traditional approaches to management do not account for this complexity and often are critical of their ability to maintain resilient fish stocks and marine ecosystems long-term ([34–37]). Bottom-up efforts were exclusively cited as drivers in co-management papers in addition to a need for equitable management. The need for management change and policy directives calling for an ecosystem approach were the two most prominent drivers of EBFM efforts identified in the literature. Preservation of ecosystem health was the most commonly cited driver shared by both management approaches.

The content analysis review revealed numerous shared attributes between EBFM and co-management. Both EBFM and co-management are characterized as adaptive, flexible forms of management ([38,39]). Both have long-term, continual goals for system health and sustainability of ecosystems ([40–42]). EBFM and co-management are described as being place-based; however, the scale of this implementation typically differs. Co-management often occurs at the local level, while EBFM is envisioned at a larger spatial scale and spans multiple jurisdictions ([43,44]). EBFM efforts typically focus on multiple species and species interactions, whereas fisheries co-management tends to focus on single species resource management ([45]). The fisheries co-management literature heavily emphasized community outcomes such as social learning, power-sharing, trust, and focuses more specifically on stakeholder engagement. The EBFM literature also incorporates social outcomes, but more explicitly focuses on broader ecological outcomes such as conservation of fish stocks, preserving fish habitat, and the development of ecological metrics and indicators of ecosystem health to inform decision-making ([34,41,46–49]). More

**Table 1**
A summary of key drivers, attributes, and desired outcomes commonly described in defining ecosystem-based fisheries management and co-management as described in the literature.

| | EBFM | Co-Management | Key Similarities |
|---|---|---|---|
| Driver | • Management failure | • Management failure | o Shared driver |
| | • Recognition of complexity | • Recognition of complexity | |
| | • Changing environmental conditions | • Marginalization | |
| | • Trend towards ocean and coastal planning | • Constrained budget environment | |
| Attribute | • Adaptive | • Adaptive/flexible | |
| | • Systematic | • Collaborative | |
| | • Geographically based (large-scale, spans multiple disciplines, ecosystem boundaries) | • Geographically based (smaller scale, local level) | o Shared attribute, however the scale of implementation differs |
| | • Multi-scaled | • Involves power sharing and decentralization | |
| | • Fisheries-focused | • Enables shared learning (experimental/experiential) | |
| | • Attentive to system interactions | • Inclusive of multiple sources of knowledge | |
| | • Holistic (human/natural connections) | • Facilitates feedback of information | o Potential synergy (feedback in a complex adaptive system can enable attentiveness to system interactions at a fine scale) |
| | • Long-term | • Long-term/ continual | o Shared attribute |
| | • Tends towards multi-species focus | • Tends towards single species focus | |
| Desired outcome | • Sustained ecosystem services | • Sustained ecosystem services | o Shared outcome |
| | • Increased system-level resilience | • Increased and balanced accountability | |
| | • Sustained system function | • Empowered communities | |
| | • Optimized benefits/tradeoffs | • Produces collective goods | |

Note: Examples of overlap and interplay as described in the literature are noted.

recent literature, including NOAA's implementation of EBFM, however, has focused more on human dimensions and social outcomes [49–52].

Similarities among attributes are also prevalent in descriptions of EBFM and fisheries co-management. For example, feedback loops of information are often described as key attributes of co-management whereas a focus on holistic human-natural connections is described as an important characteristic of EBFM ([43,45,53]). These characteristics are potentially related; tight feedback loops of information created through co-management efforts can provide fine-scale knowledge to inform holistic human-natural connections at larger scales appropriate for EBFM.

Desired outcomes identified for both EBFM and co-management include enhanced decision support, productive and sustainable fisheries, and socioeconomic benefits. The co-management literature additionally cited unintentional and negative outcomes of management arrangements, such as conflict or corruption, and focused more on societal and community outcomes overall. The EBFM literature emphasized meeting multiple objectives, whereas co-management papers heavily referenced specific outcomes of fishing area closures and moratoriums. Both management arrangements cited outcomes related to greater collaboration and interaction between management organizations, as well as fostering resilient social-ecological systems. Major themes of drivers, attributes, and outcomes derived from the EBFM and co-management literature are quantified in Fig. 3 with key similarities summarized in Table 1.

### 3.2. Inhibiting factors

We also identified inhibiting factors that prevent the progression of EBFM and co-management efforts. A reoccurring theme cited as an impediment to successful management efforts included unrealistic outcomes and objectives ([54–58]). Similarly, ambiguous or conflated management objectives were identified as a cause of confusion in both EBFM and co-management efforts ([55,59]). This uncertainty in outcomes makes it difficult for managers and stakeholders to measure and evaluate progress and achievement of goals ([54,59]).

The need to understand the effectiveness of the management arrangement was cited as crucial for identifying needs and barriers to successful management for both EBFM and co-management efforts ([42,54]). A lack of indicators to serve as reference points for key thresholds in the management arrangements was also referenced as a barrier to implementation [60]. These performance indicators can help to identify key targets that are vital to effective management and can identify if the management approach is achieving results, what threats are impacting the goals, and what strategies are necessary to meet those goals.

Limited data and scientific knowledge to understand critical pieces of the fisheries ecosystems were two additional factors identified as inhibiting factors ([46–48]). Funding challenges to acquire this information or to support management implementation was identified as a major barrier to the progression of EBFM and fisheries co-management efforts as well ([61–63]). Inhibiting factors and exemplary text are identified in Appendix C.

### 3.3. Critiques

Numerous critiques of EBFM and fisheries co-management emerged from the literature review. These critiques were distinct to EBFM or co-management, with little overlap. Fisheries co-management was critiqued for often being based on a definition of "local resource user" that is too limited. For example, Barratt notes that co-management has relied on the assumption that communities are homogenous, which can exclude important stakeholders from engaging in decision-making processes [41]. Additionally, fisheries co-management was critiqued for being viewed as a panacea to all fisheries management problems. As noted by Levine et al., fisheries co-management may not be the most practical or feasible option in all contexts [45]. Kuperan et al. emphasize that fisheries co-management should be viewed as an adaptive process that evolves over time, adjusting to incorporate aspects of power sharing and social empowerment [64]. Lopes et al. add that unless co-management is followed by adaptive management and increased participation from resource users and diversification of economic sources, it does little to enhance community resilience [58]. Finally, fisheries co-management was cited as being prone to the 'free-rider' or 'fox in the henhouse' problem, where user organizations with a formal position in the management system will be tempted to abuse the trust they have been permitted as guardians of the resource [65].

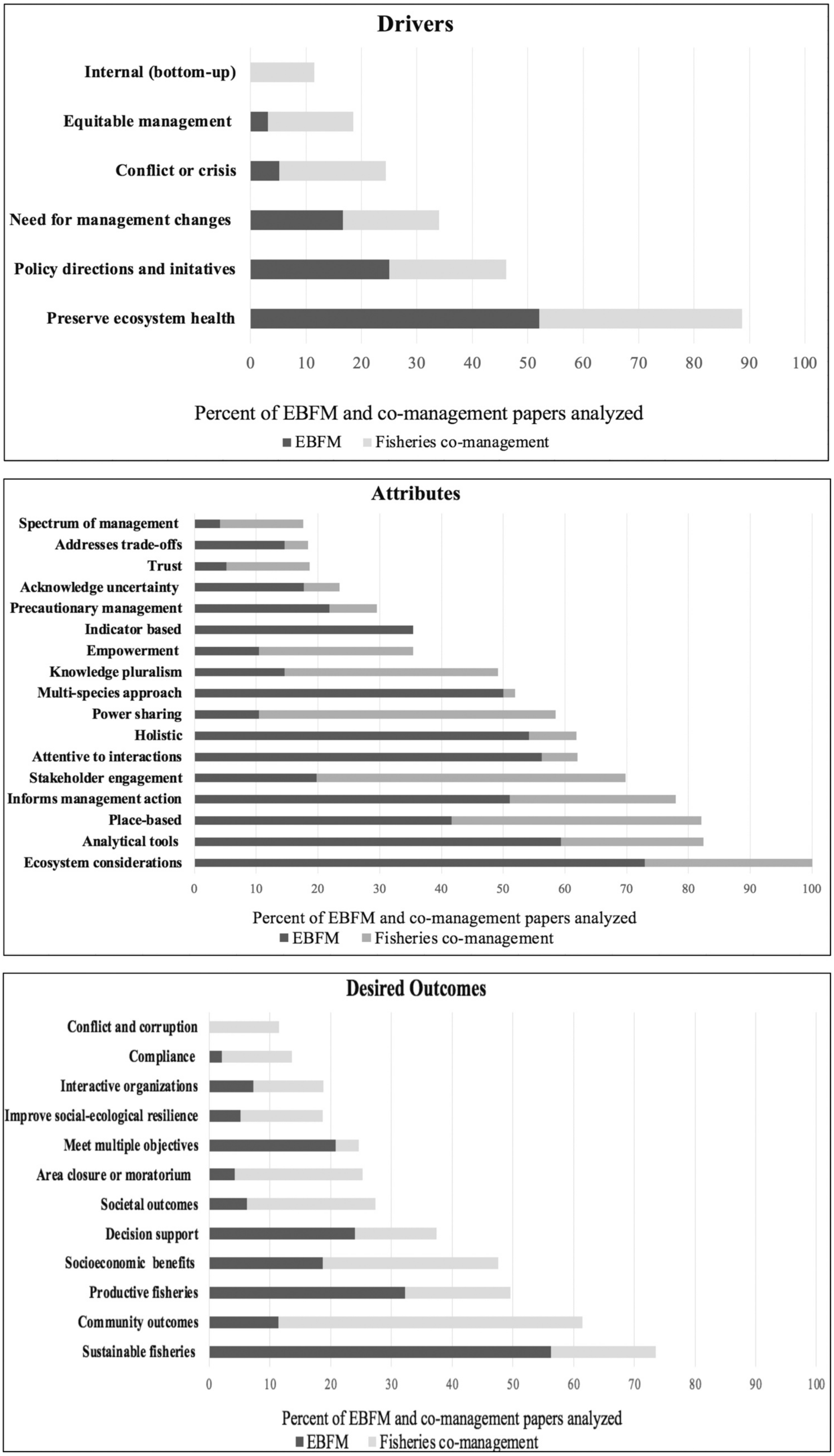


**Fig. 3.** Major themes identified from a content analysis-based review of drivers, attributes, and outcomes of the literature on EBFM and co-management. Colored bars depict the percent of papers within the management type that were coded for a specific theme.

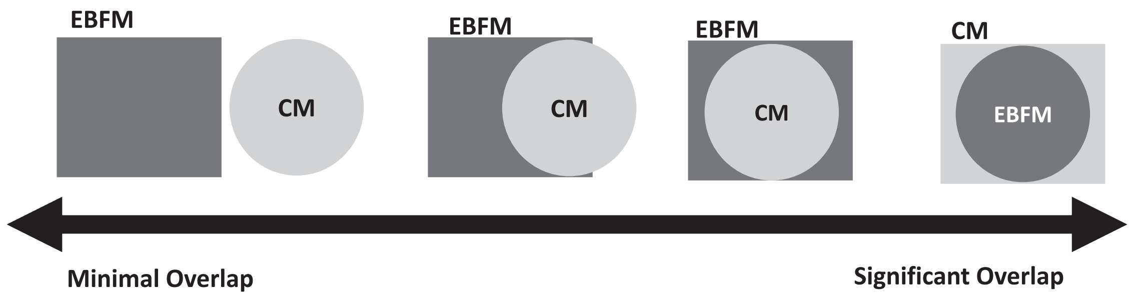


**Fig. 4.** Conceptual overlap between ecosystem-based fisheries management (EBFM) and fisheries co-management (CM). On one side of the continuum, EBFM and fisheries co-management are separate concepts and little overlap exists between these management approaches. Towards the middle of the continuum, elements of EBFM and co-management are integrated and some overlap is present. Towards the opposite side of the continuum, EBFM and co-management are highly integrated, with EBFM as a critical part of fisheries co-management and fisheries co-management as a critical part of EBFM.

EBFM is criticized for emphasizing language that supports unrealistic management goals. As noted by Gilman et al., terms like "integrity" and "health" that are used to describe the ecosystem imply that there is a target state of an ecosystem that management should strive to ultimately achieve [66]. They argue that this state is unrealistic in the face of expanding anthropogenic impacts on natural systems ([10,66]). Numerous papers noted that the theory of EBFM is well developed, while practical application of this approach on the ground lags behind ([10, 41]); this point is also highlighted in other more recent papers outside of this review [67,68]. This gap between theory and practice is emphasized by Arkema and colleagues, who note that scientists characterize EBFM differently than mangers who implement it. Finally, uncertainty about the operationalization of EBFM contributes to critiques of EBFM as an approach to sustainable fisheries management ([35,55]).

## 4. Discussion

### *4.1. Concepts on a continuum*

A significant catalyst for this work was our observation that many individuals hold different views about the relationship between EBFM and co-management. Perceptions of these concepts appear to be deeply subjective, despite the existence of formal definitions. In practice, drastically dissimilar efforts can be labeled as either EBFM or co-management. Thus, it can be argued that very traditional approaches to management have elements of EBFM and co-management, while seemingly strong cases of EBFM or co-management can be seen as poor examples of the concepts [69]. This definitional ambiguity impedes our ability to rigorously evaluate the theoretical and applied connections between these management approaches.

In reality, fisheries management approaches do not exist in isolation, but along a gradient, with elements of co-management regularly appearing in conventional management regimes and vice versa [83]. Both EBFM and co-management have been described as flexible management approaches that exist along a spectrum (e.g., see [10,34,50, 57]). We propose the continuum approach as an alternative to singular definitions of EBFM and fisheries co-management (Fig. 4). The continuum eliminates ambiguity by presenting a range of options for the relationship between EBFM and fisheries co-management [35]. The array of management strategies present in the continuum reflects the complexity of fisheries management in practice. This approach also may eliminate the need for creating new definitions for these concepts in the future.

## 5. Integration of EBFM and co-management integration in practice

To illustrate how EBFM and co-management are linked in practice, we provide a brief review of three initiatives in marine resource management: rebuilding Maine's inshore scallop fishery, NOAA's EBFM implementation, and cetacean mortality reduction efforts in the North Atlantic. Each effort is concisely described, to highlight how elements of EBFM and co-management are integrated in the decision-making process. Each example is situated on the conceptual continuum illustrated in Fig. 4, based on how elements of EBFM and co-management are incorporated. It is important to note, however, that the review of these case studies is meant to broadly illustrate the continuum of EBFM and co-management approaches applied by management initiatives on the ground and is not intended to exhaustively capture the complexities of each initiative. We invite the reader to examine other case studies and situate them on this same continuum.

### *5.1. Rebuilding Maine's inshore scallop fishery*

Restoration of Maine's inshore winter scallop fishery is an example of a strong fisheries co-management effort that integrates fishermen's knowledge into management practice. Inshore landings of Atlantic sea scallops in Maine have steadily declined since the 1990s, reaching their lowest level in 35 years in 2005 [70]. In 2009, the Maine Department of Marine Resources issued a moratorium on new licenses entering in the fishery. Twenty percent of state waters were subsequently closed to scallop fishing for a three-year period in an attempt to rebuild the scallop stocks [71].

In 2010, the Maine Department of Marine Resources asked the Maine Center for Coastal Fisheries, a regional non-profit community development organization, to convene scallop fishermen to propose potential management suggestions for reopening and managing the previously closed inshore scallop fishery. To achieve this, the Maine Center for Coastal Fisheries engaged in the process of community fisheries action roundtables (C-FAR). They held over 100 meetings statewide and heard from roughly half of Maine's scallop fishermen over nearly two years. The goal of the C-FAR process was to engage resource harvesters in conversations about their vision for the future of the fishery and provide a platform for them to share their values and knowledge [72]. Meetings were organized around specific concerns identified by fishermen and the process involved facilitated sessions where harvesters collaborated with scientists and regulators to share their knowledge and express concerns [73].

Through the C-FAR process, fishermen identified ecologically and socio-economically distinct scalloping areas along the Maine coast. In 2012, they submitted a proposal to the Maine Department of Marine Resources that suggested separate management approaches for three distinct areas identified. Following the proposal, the State agreed to manage the regions as three separate management areas, as suggested by fishers. In the years that followed, a significant rebounding of the scallop fishery was observed, and, in 2017, the fishery exceeded expectations for abundance and profitability [70]. In-season information sharing, timely closures, and ongoing collaborations between fishers and scientists to further improve monitoring of the resource additionally have contributed to the restoration of the scallop fishery. The communication and trust built between industry, scientists, and managers filled a critical knowledge gap and fostered a collaborative decision-making process that led to area-based scallop management [73].

This initiative represents a cooperative management effort between fishermen, scientists, and managers to develop place-based management informed by fishers' local ecological knowledge [73]. The rebuilding of Maine's inshore scallop fishery illustrates the importance of stakeholder engagement and the benefits of flexible and adaptive management. In assessing how management decisions were made, this initiative is situated at one end of the theoretical continuum, where EBFM and co-management are not integrated (Fig. 4). This case study exemplifies traditional co-management efforts; decisions were made at hyper-local scale, and disassociated from the larger ecosystem as it focused on managing a single resource. For the inshore scallop fishery to integrate EBFM, a broader recognition of the ecosystem, as well as increased management consideration beyond the local scale, would be necessary.

### 5.2. NOAA fisheries' approach to ecosystem-based fisheries management

In 2016, NOAA Fisheries released an agency-wide EBFM policy to direct continued progress towards the national implementation of an EBFM approach. The EBFM policy directed the Regional Fisheries Management Councils to develop fisheries ecosystem plans as a mechanism for incorporating ecosystem principles, goals, and policies into current fishery management structures. Fisheries ecosystem plans provide councils with direction on how the physical, biological, and human/institutional context of ecosystems within which fisheries are managed guides the development and implementation of fisheries management options. The agency's adoption of EBFM policies is intended to facilitate sustainable management of the nation's living marine resources.

The EBFM road map, released in 2016, builds upon the Policy and identifies actions to address each of the Policy's six Guiding Principles to maintain resilient marine ecosystems through EBFM [7]. NOAA's EBFM road map advances the broader implementation of a big-picture approach that considers habitat, predator-prey interactions, and the impacts of changing ocean conditions in fisheries management. The systematic approach is intended to enable the facilitation of tradeoffs between priorities and establishes a framework to enhance and accelerate the implementation of EBFM within the National Marine Fisheries Service. The road map describes operational EBFM from a national perspective while allowing for flexibility in the regional application. In this way, it is meant to provide a menu of options to Regional Fishery Management Councils; it is not a prescriptive process. The road map calls for the development of regional implementation plans to leverage ongoing work, encourages active partnership with Councils and engagement with external stakeholders, and internal coordination among science and management institution, in addition to focusing on regionally specific priorities [8].

A central objective of the NOAA EBFM road map is to ensure that its various efforts are well coordinated among NOAA Fisheries Science Centers, Regions, Headquarters Offices, Regional Fishery Management Councils, states, and key stakeholders. As outlined in NOAA's EBFM Policy Statement, the agency strongly supports implementation of EBFM to better enable decisions regarding trade-offs among and between fisheries. In NOAA's EBFM implementation, the Regional Fisheries Management Councils are accountable for developing fisheries ecosystem plans to describe and integrate ecosystem goals, objectives, and priorities across multiple fisheries and the effects of various pressures on fisheries within an ecosystem [8].

The Regional Fisheries Management Councils system can arguably be viewed as a form of co-management, as management councils include a diverse group of fisheries stakeholders. Established by the Magnuson-Stevens Fisheries Management and Conservation Act, each of the nine councils are comprised of state and federal officials along with industry representatives and environmental interest groups [74]. Although the agency calls for increased coordination with councils and other partners through the EBM policy and road map, implementation and decision-making of EBFM is ultimately a top-down approach. Input from councils and stakeholders, particularly in the development of fishery ecosystem plans, provides a platform for operationalizing EBFM [50]. Elements of both EBFM and co-management are present in NOAA's EBFM implementation. Thus this example is situated in the middle of the conceptual continuum (Fig. 5).

### 5.3. Cetacean mortality reduction in the Atlantic

The Marine Mammal Protection Act (MMPA) of 1972 requires NOAA's National Marine Fisheries Service (NMFS) to develop and implement Take Reduction Plans to prevent the depletion and assess the recovery of certain marine mammal stocks that are seriously injured or killed incidentally in commercial fisheries [50,75]. In 1996, the Atlantic Large Whale Take Reduction Team was established to develop a take reduction plan for reducing the incidental take of right whales, humpback whales, fin whales, and minke whales in commercial trap/pot and gillnet gear in U.S. waters from Maine to Florida. The Take Reduction Team is composed of a variety of stakeholders including fishermen, scientists, conservationists, as well as state and federal officials. The plan is dynamic in nature and evolves as NOAA learns more about why whales become entangled and how fishing practices might be modified to reduce the risk of entanglement [76].

Numerous challenges in decision-making exist in the case of marine mammal mortality reduction such as data paucity, a variety of conflicting stakeholder perspectives, and the complex life history of cetaceans. To account for these challenges, NMFS implements working groups by area, fishery, or topic to promote focused discussions that then inform the work of the larger team. Discussions with the smaller subgroups have allowed NMFS to identify where improvements can be made to the larger take reduction process. The Plan has several components, including gear restrictions and modifications, outreach, and a disentanglement program [77].

Research relating to whale populations, behavior, prey distribution, as well as fishing gear interactions and modifications contribute to filling critical knowledge gaps to inform management. In the northeast sub-group, the fishing community is engaged in field testing modifications to fishing gear in order to advance mortality reduction strategies for the protection of critically endangered North Atlantic right whales. This includes testing alternative color, strength, and shape of fishing rope to reduce bycatch, while also meeting the needs of the fishing industry. Alternative forms of fishing, such as rope-less fishing methods, also are being explored [78].

The Take Reduction Team approaches the complexity of whale entanglement as a coupled social-ecological systems problem as the Plan incorporates both the social and ecological elements of this complex cetacean conservation issue (after Ostrom 2009) [79]. Management of marine mammals through the Take Reduction Plan exhibits components of both co-management and ecosystem-based management [77]. Although the Plan is federally mandated, bottom-up support is cultivated within the top-down mandate. Regional working groups work closely with industry to fill knowledge gaps and engage fishers and other stakeholders in actions that contribute to cetacean mortality reduction in the region. The integration of co-management and EBFM exhibited in the Take Reduction Team leads us to place this example closer to one side of the continuum where EBFM and co-management are strongly integrated (Fig. 5).

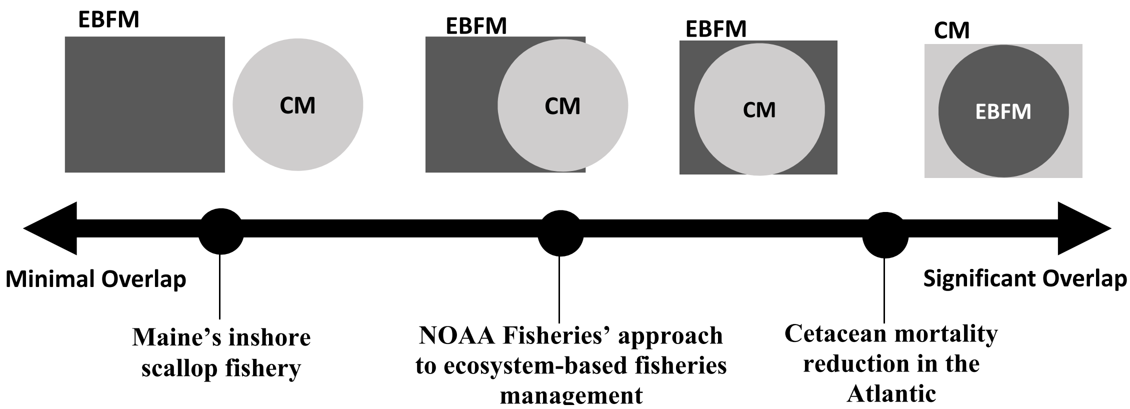


**Fig. 5.** A simplified model illustrating where each example management initiative falls on the conceptual continuum demonstrating the overlap between EBFM and co-management in Fig. 4.

## 6. Conclusions

Fisheries are highly complex social-ecological systems [80,81]. Growing recognition that traditional single-species based fisheries management approaches do not account for this complexity has prompted an interest in alternative management practices. EBFM and fisheries co-management have gained recognition as alternatives to traditional fisheries management and have been highly promoted as the future of fisheries conservation [82]. These approaches have largely been viewed as distinct, though some scholars have acknowledged their similarities (e.g. see [9–14]). In this paper, we employed a content analysis-based review of the literature to evaluate the extent to which these concepts are related and the similarities among their drivers, attributes, and desired outcomes.

We found that similar drivers, attributes, and outcomes characterize EBFM and fisheries co-management in the published literature and also are illustrated by resource management in the water, as detailed in the examples above (Fig. 5). The scallop co-management case study demonstrates that enriched management outcomes can be achieved with enhanced participation from resource harvesters. Local fishers embedded in the management process resulted in increased participation, communication, labor, trust, and shared information between the fishing community and decision-makers. At the federal level, NOAA's EBFM implementation represents a top-down approach that includes some key elements of co-management. The EBFM integration process encourages coordination with the Regional Councils and presents a range of options for councils to operationalize EBFM on a regional scale. The NOAA Take Reduction planning effort revealed that stakeholder engagement early in the decision-making process greatly contributes to improved outcomes. At-sea testing in sub-groups of the Take Reduction Team fills critical knowledge gaps that informs regional management to protect cetaceans. It is important to note that although these examples highlight state-led co-management efforts and top-down federal efforts, we do not suggest that state and federal efforts characteristically fall on opposite sides of the continuum.

Fisheries management has broadened in recent decades to include target fisheries within the context of a complex biophysical and social environment, including fishers as part of coastal communities that have dynamic social, economic, and political environments [80]. Each of the examples that we presented highlight that fishers can directly contribute to an ecosystem approach to fisheries. Engaging fishers in the management process improved outcomes, due to increased participation, communication, labor, trust, and resource-sharing. Similarly, an ecosystem-based approach helps inform fisheries co-management arrangements. Bringing EBFM and co-management together effectively will require a deeper engagement by and with stakeholders.

We propose that EBFM and co-management exist on a conceptual continuum rather than as distinct management approaches. Differences in perceptions of the relationship between these concepts can largely be attributed to the definitional ambiguity surrounding these terms. The continuum approach captures the diversity of management practices associated with EBFM and co-management, and potentially will prevent the need to develop alternative concepts in the future.

Managers who focus on marine system dynamics require fine-scale knowledge, like that produced though co-management, as well as holistic, whole system knowledge, like that which is essential for an EBFM approach. Co-management generates high-resolution, continuous, and place-based information that is necessary to understand the physical, biological, economic, and social interactions of fisheries systems [34]. These management requirements bring these two concepts closer together, in instances where EBFM and co-management are highly integrated.

The varied scales and goals of EBFM and co-management remain key challenges to implementation, and attention must be paid to the information and institutional structures needed to effectively manage a system in an integrated, ecosystem-based manner as well as what is required to collect, maintain, interpret, and use this information in decision-making. A deeper understanding of the interplay between these two approaches to ocean management and conservation will help clarify their use and application.

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## CRediT authorship contribution statement

**Marina Cucuzza:** Conceptualization, Methodology, Data curation, Writing - original draft preparation. **Joshua S. Stoll**: Conceptualization, Supervision, Writing - review & editing. **Heather M. Leslie:** Conceptualization, Supervision, Writing - review & editing.

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*Declaration of competing interest*

None.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.marpol.2020.104390.

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