
Coastal Management

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/ucmg20

# There Is no I in EAFM Adapting Integrated Ecosystem Assessment for Mid-Atlantic Fisheries Management

**Brandon Muffley, Sarah Gaichas, Geret DePiper, Richard Seagraves & Sean Lucey**

**To cite this article:** Brandon Muffley, Sarah Gaichas, Geret DePiper, Richard Seagraves & Sean Lucey (2021) There Is no I in EAFM Adapting Integrated Ecosystem Assessment for Mid-Atlantic Fisheries Management, Coastal Management, 49:1, 90-106, DOI: 10.1080/08920753.2021.1846156

**To link to this article:** https://doi.org/10.1080/08920753.2021.1846156

COASTAL MANAGEMENT
2021, VOL. 49, NO. 1, 90–106
https://doi.org/10.1080/08920753.2021.1846156



# There Is no I in EAFM Adapting Integrated Ecosystem Assessment for Mid-Atlantic Fisheries Management

Brandon Muffley[a], Sarah Gaichas[b], Geret DePiper[b], Richard Seagraves[a], and Sean Lucey[b]

[a]Mid-Atlantic Fishery Management Council, Dover, DE, USA; [b]NOAA NMFS Northeast Fisheries Science Center, Woods Hole, MA, USA

**ABSTRACT**

Resource managers worldwide are being asked to consider the ecosystem while making management decisions. Integrated Ecosystem Assessment (IEA) provides a flexible framework for addressing ecosystem considerations in decision making. The US Mid-Atlantic Fishery Management Council (Council) adapted the IEA approach and implemented a structured decision framework to address species, fleet, habitat, and climate interactions as part of their Ecosystem Approach to Fisheries Management (EAFM) in 2016. The Council's EAFM decision framework first uses risk assessment to prioritize fishery-ecosystem interactions for consideration. The Council's 2017 EAFM risk assessment identified a range of ecological, social, and management objectives or risk elements. Development of a conceptual model to identify key environmental, ecological, social, economic, and management linkages for a high-priority fishery is the second step in the framework. The Council identified summer flounder (*Paralichthys dentatus*) as a high-risk fishery and finalized an EAFM conceptual model that considers high-risk factors and ecosystem elements in 2019. The Council used the conceptual model to identify three priority summer flounder management questions (recreational data uncertainty, recreational discards, and distribution shifts) to be considered for quantitative management strategy evaluation, the third step in the EAFM framework and set to begin in 2020. Finally, as strategies are implemented, outcomes are monitored and the process is adjusted, and/or other priorities identified in the risk assessment can be addressed. The Council's rapid progress in implementing EAFM resulted from an extensive, positive, and collaborative process between managers, stakeholders, and scientists. Collaboration helps build trust and buy-in from all participants and is essential to IEA and to the success of EAFM.

**KEYWORDS**
conceptual modeling; economic indicators; ecosystem approach; ecosystem indicators; fisheries; integrated ecosystem assessment; management objectives; risk assessment

## Introduction

Integrated Ecosystem Assessment (IEA) is a framework developed to inform ecosystem approaches to management (Levin et al. 2009, 2014). As formally adopted by the National Oceanic and Atmospheric Administration (NOAA) in the US, the IEA

**CONTACT** Brandon Muffley bmuffley@mafmc.org Mid-Atlantic Fishery Management Council Dover, DE, USA.

framework represents a process by which management goals are specified, indicators to track performance against these goals are developed, the indicators are assessed to identify the highest risks to attaining management goals, mitigation strategies are tested through a management strategy evaluation (MSE), and the most effective strategies are implemented by managers (Levin et al. 2008; Harvey, Kelble, and Schwing 2017). The IEA framework is holistic, in that it looks to synthesize information from biogeochemical drivers, biota, human activities, and communities, through to the societal values and objectives which the system is managed for. It is transparent, in that effective stakeholder engagement is foundational to the process, with the ultimate goal of providing timely and relevant scientific advice to managers and informing the general public on the current status of their natural resources. The IEA is designed to be iterative, in that goals, indicators, and analyses are meant to be refined and reviewed through time to capture both scientific progress and shifting priorities. The approach is also scalable and should be tailored to suit both the ecosystem and management issues of interest (Samhouri et al. 2014).

Despite the scientific appeal of the framework, and over a decade of work on IEA science since its first development, management uptake has been slow (Link and Browman 2017; Dickey-Collas 2014; Harvey, Kelble, and Schwing 2017). This slow uptake results from limited dedicated resources, the state of interdisciplinary and transdisciplinary science, and the lack of management authority/bodies in which multijurisdictional issues can be resolved (Dickey-Collas 2014; Harvey, Kelble, and Schwing 2017).

Here we review a successful implementation of the IEA framework within an operational fishery management system and highlight the key features of this implementation contributing to successful management uptake. This success hinged on regional, national, and international collaborations which bolstered capacity to undertake the substantial work entailed and leverage the limited dedicated resources otherwise available to invest in the IEA process. In particular, collaborations included scientists and managers as equal partners. We also identify how the IEA framework was tailored to meet the needs of the Mid-Atlantic Fishery Management Council (Council), with a focus on the most recent processes and approaches implemented by the Council.

## Who is the Council?

The Council is responsible for the conservation and management of fishery resources in federal waters (3–200 nautical miles) off the Mid-Atlantic region from North Carolina through New York (Figure 1). The Council is one of eight regional councils established in 1976 by the Magnuson-Stevens Fishery Conservation and Management Act (MSA), the principal law governing marine fisheries in the US (16 U.S.C. §§1801–1891 d). The law seeks to ensure the conservation and long-term biological and economic sustainability of US fishery resources. Among other things, the MSA explains the role of the regional management councils, including the national standards for management and the mandated contents of fishery management plans (FMPs).

The Council directly manages 14 species,[1] including summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops*), black sea bass (*Centropristis striata*), Atlantic bluefish (*Pomatomus saltatrix*), Atlantic mackerel (*Scomber scrombus*), *Illex* and longfin

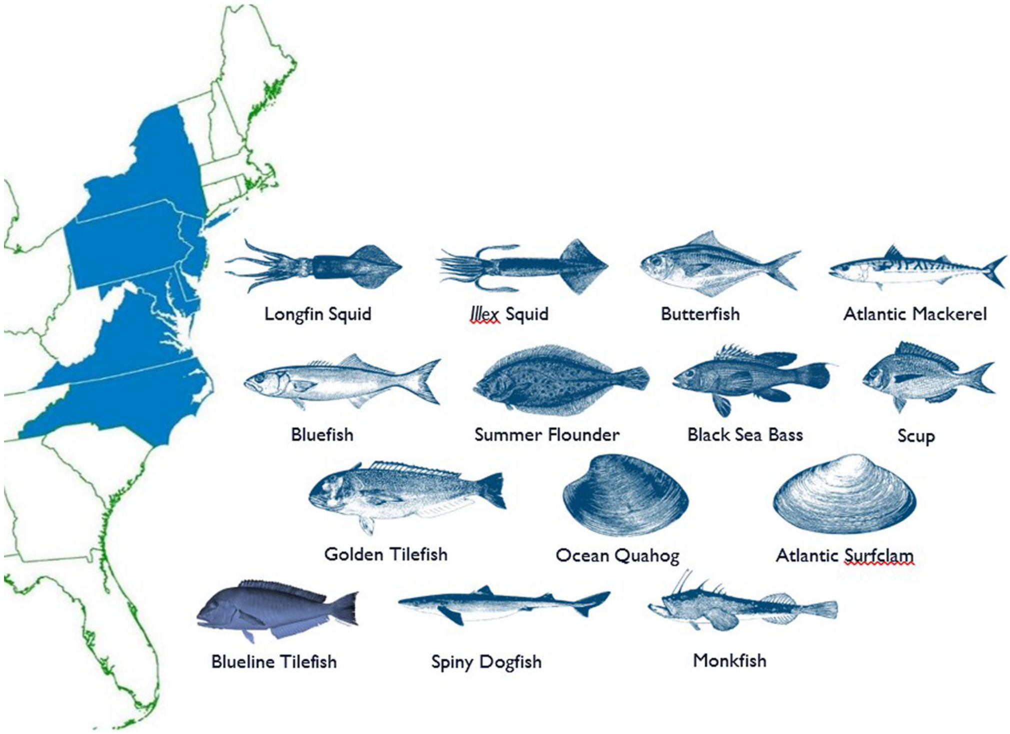



**Figure 1.** The Mid-Atlantic Fishery Management Council area of management jurisdiction (3–200 nautical miles offshore) and the 14 directly managed species covered under 7 different Fishery Management Plans (FMPs). Spiny dogfish and monkfish are jointly managed with the New England Fishery Management Council with the Mid-Atlantic as the lead for spiny dogfish and New England for monkfish.

squids (*Illex illecebrosus* and *Doryteuthis (Amerigo) pealeii*, respectively), butterfish (*Peprilus triacanthus*), Atlantic surfclam (*Spisula solidissima*), ocean quahog (*Arctica islandica*), golden and blueline tilefish (*Lopholatilus chamaelonticeps* and *Caulolatilus microps*, respectively), spiny dogfish (*Squalus acanthias*), and monkfish (*Lophius americanus*), in 7 FMPs (Figure 1). In addition, the Council manages more than 50 forage species as "ecosystem components" in all seven FMPs to prevent the expansion of directed fisheries on these forage species in the Mid-Atlantic.

Council managed fisheries are also fished outside the Mid-Atlantic region and in state waters. Therefore, the Council coordinates management activities closely with other management entities including the New England Fishery Management Council and the Atlantic States Marine Fisheries Commission (ASMFC).

The Council is composed of 25 members, including seven members that represent their states' fish and wildlife agency, 13 citizens from each of the seven Mid-Atlantic states knowledgeable of fisheries and marine issues, and one member from the National Marine Fisheries Service (NMFS). There are also four non-voting members comprised of representatives of the US Fish and Wildlife Service, US Coast Guard, State Department, and the ASMFC. As specified by MSA, the Council is also supported by various stakeholder advisory bodies, including the Scientific and Statistical Committee (SSC)[2] and advisory panels for each fishery.

## Development of the Mid-Atlantic Fishery Management Council Ecosystem Approach (EAFM)

The Council had been considering mechanisms to introduce ecosystem considerations into the fishery management process since the late 1990s (MAFMC 2006). In the fall of 2011, the Council hosted the fourth National Scientific and Statistical Committee Workshop, which was convened to provide an opportunity for the eight regional fishery management councils' SSCs, charged with providing science advice to their respective Council, to discuss incorporation of ecosystem considerations in federal fisheries management (Seagraves and Collins 2012). After a review of the various approaches, the Council agreed to introduce ecosystem considerations into management actions in a stepwise, evolutionary fashion – herein referred to as an ecosystem approach to fisheries management, or EAFM.

Around the same time, the Council also embarked on a Visioning Project in 2011 to chart a course for the future of marine fisheries management in the Mid-Atlantic driven by stakeholder engagement and input. The Council received extensive feedback across all stakeholder groups and a number of common themes and issues emerged from the feedback (for additional detail, see Visioning report, p. 3: http://www.mafmc.org/s/MAFMC-stakeholder-input-report-p7b9.pdf). One unifying theme raised by stakeholders was the need for greater ecosystem and food web considerations in management decisions as fishermen were witnessing the effects of climate change on Mid-Atlantic fisheries first-hand. Stakeholders also wanted a greater role in the management process.

This feedback served as the foundation for the development of the Council's 2014–2018 Strategic Plan, the first-ever strategic plan for a federal fishery management council (see http://www.mafmc.org/strategic-plan). The Strategic Plan established an overarching goal of maintaining sustainable fisheries, ecosystems, and habitats in the Mid-Atlantic through the development of management approaches that minimize adverse ecosystem impacts. Further, the Council identified a specific management objective to advance ecosystem approaches to fisheries management in the Mid-Atlantic to be accomplished, in large part, through the development of an EAFM Guidance Document. The Strategic Plan also identified several objectives and strategies to increase stakeholder participation and engagement in the Council's management process, which were critical to the development and implementation of the EAFM Guidance Document.

To develop the document in a participatory manner, the Council organized four public workshops between 2013 and 2015 which brought together scientists, managers, and stakeholders to discuss four priority ecosystem topics raised during the Visioning Project:

1. Forage/lower-trophic level species considerations;
2. Fisheries habitat;
3. Climate change and variability;
4. Ecosystem-level interactions (species, fleet, habitat, and climate)

Social and economic considerations were integrated throughout the evaluation of each of the four priority topic areas. After completion of the workshops, the Council developed white papers which provide detailed information and in-depth discussion on each of these topics and serve as the foundation of four chapters of the EAFM

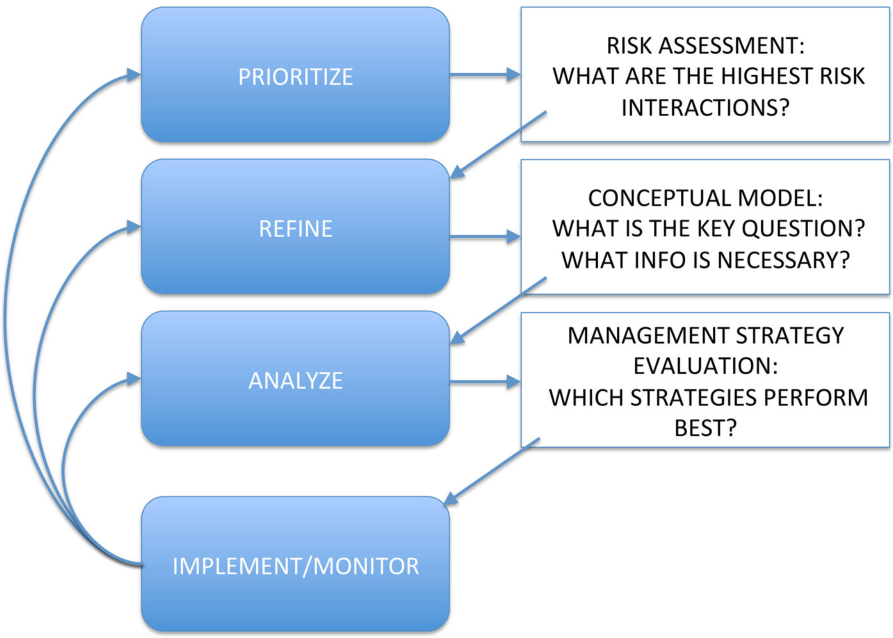



**Figure 2.** The Mid-Atlantic Fishery Management Council's EAFM structured decision framework to incorporate ecosystem considerations into management (from Gaichas et al. 2016).

Guidance Document (workshop materials and white papers are all available at www.mafmc.org/eafm). Approved in 2016, the EAFM Guidance Document is non-regulatory and articulates the Council's ecosystem goals, policies, and recommendations to help transition from single-species management to an approach that considers fisheries within a broader ecosystem context (MAFMC 2016).

Since the EAFM Guidance Document's implementation, the Council has made significant advances in addressing EAFM objectives across all four priority areas. Here, using IEA as a framework, we describe the process developed and outcomes achieved, to date, by the Council to address priority area #4 – integrating ecosystem-level biological, ecological, social, and economic considerations into management decisions.

## Mid-Atlantic Council EAFM structured decision framework: a modified IEA loop

Utilizing the flexible IEA framework, the Council agreed to adopt a structured decision framework approach in order to incorporate species, fleet, habitat, and climate interactions into its science and management programs (Figure 2; MAFMC 2016). Risk assessment is the initial step in the Council's implementation of ecosystem considerations into management (Gaichas et al. 2016). Second, a conceptual model is developed identifying key environmental, ecological, social, economic, and management linkages for a high-priority fishery. Third, quantitative modeling addressing Council-specified questions and based on interactions identified in the conceptual model is applied to evaluate alternative management strategies that best balance management objectives (i.e., a management strategy evaluation, MSE). As strategies are implemented, outcomes are monitored and the process is adjusted, and/or another priority identified in risk assessment can be addressed.

Consistent with the overall EAFM philosophy adopted by the Council, this approach allows the Council to carefully develop a transition strategy, allocate resources, and identify data needs to move from the current single-species focused management system to more of a multi-species/ecosystem-based one. This also allows the Council to meet its current single-species based MSA requirements with respect to the prevention of overfishing and attainment of optimal yield, while beginning to account for interactions at multiple dimensions of the ecosystem, of which humans are inextricably a major component. Importantly, this iterative approach allows for the continued growth, development, and adaptation of EAFM policy at a rate commensurate with the availability of the science necessary to support it. Within each step, the Council recognizes that a broad range of stakeholder interests, involvement, and input is imperative.

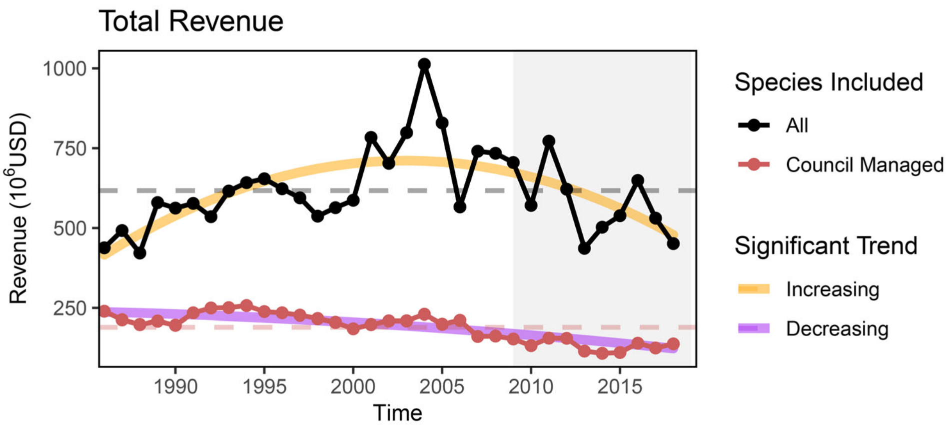
## *Mid-Atlantic EAFM risk assessment*

Given the extensive number of potential fishery ecosystem interactions the Council might want to consider, a risk assessment serves as the first step in the EAFM framework to help identify the highest threats to achieving management goals. Risk assessment provides the Council with a process to monitor a full range of interactions using general information, and to focus its limited analytical resources on interactions of greatest risk or highest priority (Hobday et al. 2011). The process drew on existing scientific efforts, and provided additional management benefits, as detailed below.

The Mid-Atlantic risk assessment was co-created with scientists, managers, and stakeholders in the region, clarifying the list of ecosystem-level management objectives and increasing transparency of the process. Indicators from the Mid-Atlantic State of the Ecosystem (SOE) report, an annual report on ecosystem status and trends developed by NOAA’s Northeast Fisheries Science Center (NEFSC) with support from NOAA’s IEA program, underpin this ecosystem-level risk assessment (Gaichas et al. 2018).

The risk assessment process identified a range of ecological, social, economic, and management objectives or risk elements which were formally adopted by the Council. The International Council for the Exploration of the Sea’s Working Group on the Northwest Atlantic Regional Sea (WGNARS), an international working group aimed at bolstering capacity for ecosystem-based management in Atlantic waters off Canada and US, had invested considerable effort to derive both general goals and operational objectives from US legislation such as the MSA and other regional sources (DePiper et al. 2017). These objectives helped frame the SOE and were used to begin scoping management objectives for the risk assessment with the Council and stakeholders, which expanded on the list.

All objectives/risk elements were evaluated with ecosystem indicators using risk assessment criteria developed within the stakeholder engagement process, and formally adopted by the Council (Figure 3). For example, indicators tracking management performance were developed to assess risks to meeting management objectives (Gaichas et al. 2018). Many of the risk assessment indicators were drawn from the SOE, which itself drew from existing efforts inside and outside the region, including the previously a




b

| Risk Level | Definition |
|---|---|
| Low | No trend and low variability in revenue |
| Low-Moderate | Increasing or high variability in revenue |
| **Moderate-High** | **Significant long term revenue decrease** |
| High | Significant recent decrease in revenue |

**Figure 3.** Example use of ecosystem indicator in the MAFMC EAFM risk assessment: the commercial revenue indicator (a) is evaluated for trend and variability, then risk level is assigned using indicator trend and variability according to Council-established risk criteria; here, moderate-high risk is assigned (b). In panel (a), trend lines are shown when slope is significantly different from 0 at the $p < 0.05$ level. The orange line signifies an overall positive trend, and purple signifies a negative trend. Dashed horizontal lines represent mean values of each time series. The shaded region indicates the most recent ten years. For full results see Gaichas et al. (2018).

published comprehensive Northeast US Ecosystem Status Reports developed as part of the National IEA program (NEFSC 2012), management and economic performance reports (Clay, Kitts, and Pinto da Silva 2014), and social indicators (Colburn and Jepson 2012; Jepson and Colburn 2013; Colburn et al. 2016); the US California Current Ecosystem Status Report (Harvey et al. 2020); and the US Alaska annual Ecosystem Considerations report (Zador et al. 2017). The experience with gathering, documenting, and visualizing indicators across all of these reports was critical to efficient development of our fishery management Council-targeted risk assessment.

Work undertaken to increase transparency, reproducibility, and efficiency in the SOE, including public posting of the document source written in R Markdown (Allaire et al. 2019) and indicator data as an R package[3] (Wickham 2015), along with the details of data sources, extraction, and analysis in the online SOE technical methods,[4] greatly facilitated the development of the risk assessment. The ready-made documentation facilitated communication with both the Council and stakeholders. The SOE automation allows the risk assessment to be updated annually and presented to the Council as part of their EAFM process and implementation, along with the SOE report. This has contributed toward consistency across reports, as well as refinement and responsiveness to address shifting priorities. In particular, since first iteration of the SOE, the Council requested further development of management-oriented indicators such as other ocean uses and regulatory complexity within the risk assessment and SOE. This adaptive approach also allows for improvements to indicator evaluation and analysis and the development of targets and thresholds for different risk elements or indicators.

### Mid-Atlantic EAFM conceptual modeling (toward MSE)

Conceptual model development is the second step in the EAFM structured framework process. This step ensures that key relationships throughout the system are accounted for in further quantitative analysis. Conceptual models are a good communication and engagement tool and are becoming an increasingly common approach used in a variety of systems across a number of regions' ecosystem considerations (Pavao-Zuckerman 2000; Heemskerk, Wilson, and Pavao-Zuckerman 2003; Levin et al. 2016; Breslow et al. 2016). They help organize information, highlight key relationships and allow for managers, stakeholders and scientists to have a common understanding of the system.

Utilizing the results of the risk assessment, the Council agreed to pilot the development of a conceptual model that considered key risk factors affecting summer flounder and its fisheries. As part of the development of the pilot conceptual model, the Council requested information on data availability and needs (i.e., gap analysis), relative importance of risk factors and ecosystem elements, and example management questions that could be answered using the conceptual model and data available. This Council request enhanced the management utility of a potentially academic exercise by having scientists take practical note of data availability and identify possible analytical tools and approaches that could be developed to answer a particular management question.

Collaboration between managers and scientists was built into the conceptual model development process. A multi-disciplinary workgroup comprised of federal, state, and academic scientists, fishery managers, Council and SSC members, and Council staff was formed to work on and address the tasks identified by the Council. The workgroup met over the course of a year to identify system linkages, available data sources, and draft management questions relevant to summer flounder and the associated fisheries. Similar to the approach and process used during the risk assessment (Gaichas et al. 2018), the development of the conceptual model was conducted in a collaborative and iterative process with the Council. All supporting information and documentation were provided to the Council's Ecosystem and Ocean Planning (EOP) Committee for feedback and direction during several in-person and webinar meetings. This process helped identify missing ecosystem risk factors and elements and ensured the conceptual model and potential management questions identified were relevant to the Council.

The initial conceptual model started with the 12 summer flounder high-risk factors identified by the risk assessment (Table 1; Gaichas et al. 2018). The workgroup then identified the critical ecosystem elements that drive or impact the high-risk factor dynamics. Offshore Habitat, Stock Biomass, Stock Assessment, and Offshore Wind were also included by the workgroup and EOP given their overall importance to the summer flounder stock or fleet dynamics, bringing the total to 16 risk factors (Table 1).

The "full model" included all 16 risk factors and the associated summer flounder ecosystem elements and their associated linkages identified by the workgroup and EOP. Linkages, as used in this context, identify relationships associated with each ecosystem

**Table 1.** Summer flounder high-risk ecosystem factors and associated risk definition in terms of the Mid-Atlantic Fishery Management Council (Council) meeting its management objectives, which include achieving optimum yield (OY). The first 12 high-risk factors were identified during the development of the Council's EAFM risk assessment; while the last four factors were identified during the development of the EAFM summer flounder conceptual model.

| High-risk factor | Definition |
|---|---|
| Distribution Shift | Changes in geographic species distribution (= "distribution shifts") can increase risks of ineffective spatial catch allocation; if catch distribution is greatly mismatched with species distribution then OY may not be achieved. |
| Estuarine Habitat | Both nearshore and estuarine (mixed fresh and seawater) water column and bottom features constitute estuarine habitat. Threats to estuarine and nearshore coastal habitat/nursery grounds relate to OY through changes in both fish productivity and distribution change. |
| Allocation | This factor addresses the risk of not achieving OY due to spatial mismatch of stocks and management allocations or because of sub-optimal allocation by sector (commercial/recreational) and/or area (state/region). |
| Commercial Profits | The risk assessment addressed the risk of not maximizing fishery value in terms of commercial profits (although it used revenue as a proxy). |
| Discards | The reduction of discards, particularly regulatory discards, are a high priority in the Council management program given the biological and economic waste. Discards of either the target or non-target species in the fishery are considered. |
| Shoreside Support | This factor ranks the risk of reduced fishery business resilience due to changes in shoreside support infrastructure. |
| Fleet Diversity | This factor ranks the risk to maintaining equity in access to fishery resources. Maintaining diversity can provide the capacity to adapt to change at the ecosystem level for dependent fishing communities and can address objectives related to stability. |
| Management Control | This factor addresses the level of management control in terms of catch estimation and monitoring to prevent overfishing. Adequate management control indicates a low risk of overfishing. Poor management control indicates a higher risk of overfishing and hence not achieving OY. |
| Recreational Value | Providing recreational opportunities is a stated goal of optimal fishery management as part of the definition of benefits to the nation under MSA. Recreational fishing is important in the Mid-Atlantic region with many coastal communities having high recreational dependence. |
| Regulatory Complexity | Constituents have frequently raised concerns about the complexity of fishery regulations and the need to simplify them to improve their efficacy. Complex regulations may lead to noncompliance and/or impact other fisheries. |
| Seafood Production | This factor evaluated optimizing domestic seafood production (e.g., commercial seafood landings) from Council-managed species. |
| Technical Interactions | This element addresses the risk of not achieving OY due to interactions with non-Council managed species including protected species. |
| Offshore Wind | This element addresses the risk of fishery displacement or damage of a fishery resource and/or habitat that supports it because of non-fishing activities in the ocean (specifically wind energy). |
| Summer Flounder Stock Biomass | The risk assessment used biomass levels relative to established reference points from assessments to indicate the level of risk to achieving OY. |
| Stock Assessment | Assessment methods and data quality shape our understanding of stock status and yield. This risk factor addresses risk to achieving OY due to scientific uncertainty based on analytical limitations. |
| Offshore Habitat | Offshore habitat can be defined as a combination of water column and bottom features. Climate and human activities can alter offshore habitat and ultimately affect OY. |

element and their relationship to other elements within a risk factor. Given the complexity of the full model, a series of sub-models were developed for individual risk factors to help highlight key components, identify ecosystem linkages, and build understanding of the full model. Another sub-model evaluating linkages between the 16 different risk factors allowed the relationships between these risk assessment elements to be considered for the first time. This was an additional benefit of the process, which can help advance ecosystem understanding by moving beyond the evaluation of

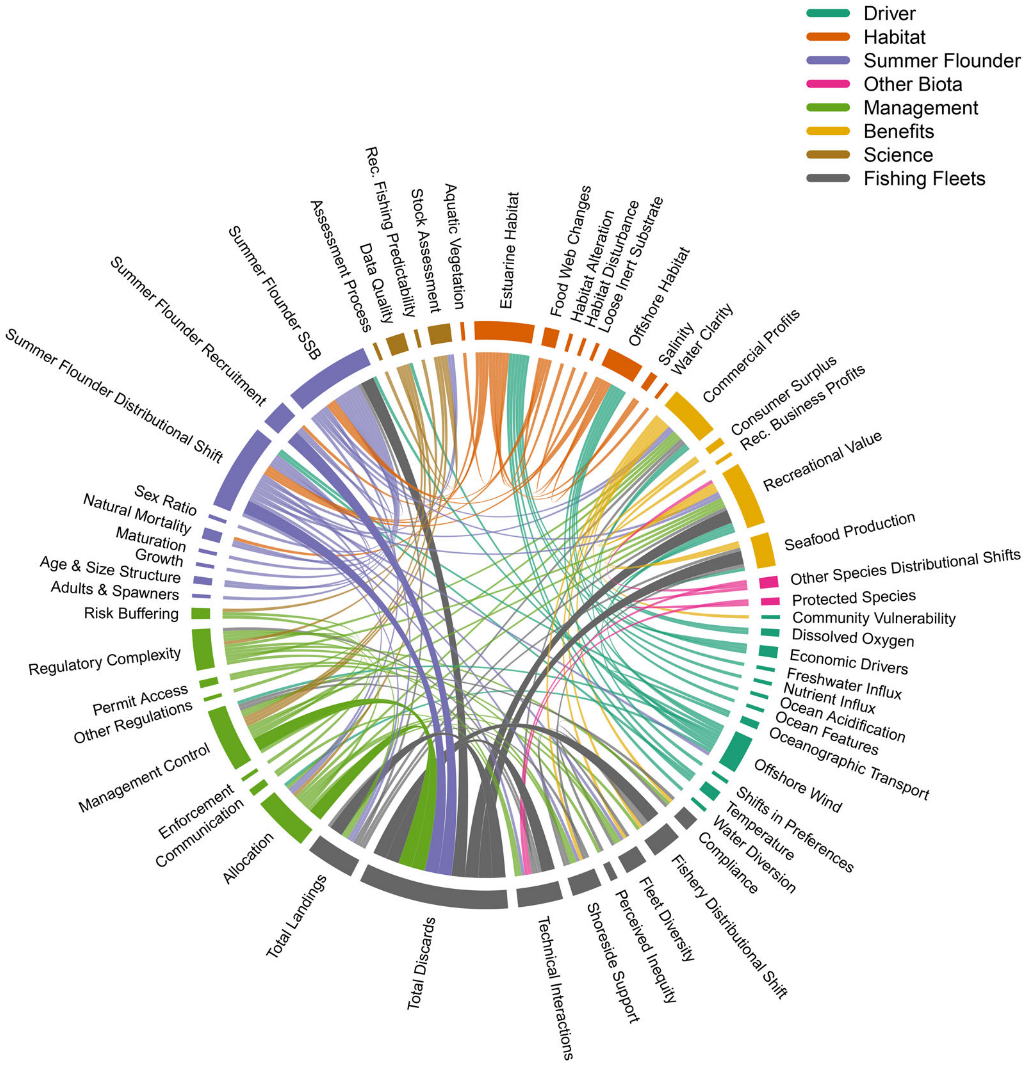



**Figure 4.** Summer flounder conceptual model highlighting ecosystem linkages associated with discards. Recreational discards was the final question selected by the Council for MSE development.

individual risk factors through the identification of relationships and connectivity with other factors.

Given the number of ecosystem elements and overall complexity of the model, a website was developed in order to make all of the models interactive (https://gdepiper.github.io/Summer_Flounder_Conceptual_Models/sfconsmod_riskfactors_subplots.html). This allows a user to highlight and identify the linkages and relationships associated with a specific ecosystem element. An example of this functionality, altered slightly from the original for print reproducibility, can be found in Figure 4. The development of the interactive visualization of the conceptual model was critical in the successful uptake of information by the Council and stakeholders. Workgroup members could select one risk factor, the visualization would highlight the ecosystem elements associated with the risk factor, and then a discussion of these linkages with the Council and stakeholders could ensue.

The conceptual model website provides general background on conceptual models and instructions on how to use and interpret the models. Importantly, the website contains documentation tables for each of the 16 high-risk factors considered to provide details on each of the linkages justification for inclusion, data or information source(s), and spatial considerations. These tables record decisions made by the workgroup, highlight data availability and science gaps, and scope the analytical tools needed for management strategy evaluation. To improve transparency, the EOP had the workgroup add definitions for each of the 16 high-risk factors in terms of risk to the Council meeting its management objectives. A more detailed discussion of the conceptual model development process, along with its linkages to the broader open science movement, can be found in DePiper et al. (In review).

## Management questions for MSE

The initial scoping step in the IEA loop could take many forms (Levin et al. 2009, 2014). In this case, collaborative development of management questions was informed by both risk assessment and the Council's approach to conceptual modeling. Typically, conceptual models are developed around a particular management question to help ensure the appropriate management objectives and factors are addressed. Given the Council's uncertainty about the process, the Council instead tasked the workgroup to develop a conceptual model first and identify management questions that could be addressed with the model and the available data, to better understand the utility of conceptual model development (similar to Levin, Francis, and Taylor 2016). While this approach created some initial challenges for the workgroup, it resulted in a much more comprehensive model, provided the Council with a greater appreciation and understanding of the model, and generated a diverse set of management questions for consideration.

The initial management questions covered ecosystem topics such as distribution shifts, commercial and recreational discards, data quality, commercial profits, recreational satisfaction, habitat change, and changes in stock dynamics. After some additional review and development by the EOP Committee, a final list of three management questions were considered by the Council.

For each question below, the Council explored the rationale, potential issues/outcomes that could be evaluated through an MSE, and how the question tied into the broader ecosystem context and other Council priorities and initiatives.

*1. How does utilizing recreational data sources at scales that may be inappropriate for the data source (e.g., Marine Recreational Information Program (MRIP) data at the state/wave/mode level) affect management variability, uncertainty, and fishery performance? Evaluate the impact of that variability and uncertainty and its use in the current conservation equivalency process on recreational fishery outcomes.*

This question was prioritized given the social and economic importance of the recreational summer flounder fishery, concerns about MRIP data and their use in management, and the potential application to other Council-managed recreational fisheries. The intent would be to understand the biological and management implications associated with the limitations in the current utilization of MRIP data within the recreational management process, rather than a review of the data collection program (a separate, ongoing effort). Evaluating this question can help the Council develop alternative strategies for using these data to help achieve recreational management objectives.

While this question focuses on recreational data and management, the conceptual model illustrated which ecosystem interactions require further analysis. The Data Quality high-risk factor is linked to: Allocation, Regulatory Complexity, Management Control, and the Stock Assessment (Figure 4). Conducting a full evaluation of this question would provide insight and guidance on a number of biological, environmental, social, economic, and management objectives.

*2. What are the mechanisms driving summer flounder distribution shift and/or population range expansion? What are the biological, management, and socioeconomic implications of these changes? Identify potential management and science strategies to help account for the impacts of these changes.*

The Council faces numerous management challenges due to shifting species distributions interacting with spatial allocation schemes. Evaluating this question would provide the Council with improved understanding of what is driving summer flounder population shifts, quantifying and understanding the biological and management implications, and offer different tools and strategies to address these issues to meet the Council's management objectives.

Summer flounder distribution shift was identified as a high-risk factor through risk assessment and is the most linked element within the conceptual model (Figure 4). Eleven other high-risk factors, across all aspects of the summer flounder fishery conceptual model ecosystem, are affected by summer flounder distribution shifts that have implications for not only summer flounder management but other managed fisheries and protected species as well.

*3. Evaluate the biological and economic benefits of minimizing summer flounder discards and converting discards into landings in the recreational sector. Identify management strategies to effectively realize these benefits.*

The Council, stakeholders, and Advisory Panel members devote considerable resources to address and reduce regulatory discards, particularly within the recreational summer flounder fishery where 90% of the catch is released. The Council is currently considering a range of novel management strategies to reduce recreational discards. Given the Council's interest in addressing recreational summer flounder discards in both the EAFM and stock-specific management process, this high priority question presents a unique opportunity to align efforts that were initially separate and distinct.

Summer flounder discards were identified as a high-risk factor through the EAFM risk assessment and is linked to seven additional conceptual model high-risk factors across issues of Management, Summer Flounder Stock, Science, Fishing Fleets, and Benefits derived from the resource (Figure 4).

## Beginning a Mid-Atlantic EAFM MSE

In late 2019, after reviewing the final conceptual model, the Council selected question #3 on summer flounder discards to move forward for further evaluation through an

MSE, the third step in their EAFM structured framework process. MSE would evaluate different management approaches within an ecosystem context to determine which approaches achieve the goals and objectives specified by the Council (Butterworth 2007, Punt et al. 2014, Smith et al. 2007). The Council felt question #3 provided the most tangible benefits to addressing a Council priority, had potential application to other recreational species, and was best fit for an MSE.

Planning for the summer flounder recreational discards MSE is underway. Continuing the collaborative approach used throughout the Council's EAFM process, a steering committee of federal and state scientists, academia, staff, and managers has been formed to develop MSE products, simulation models, stakeholder outreach, and communicating MSE goals and outcomes. A "kick-off" webinar is scheduled for early fall 2020 to introduce participants to the MSE process and expectations and will include a mock stakeholder workshop. The MSE process and modeling efforts will likely occur through 2021 with potential management alternatives and outcomes considered by the Council in early 2022.

## Discussion and conclusions

The Mid-Atlantic Council agreed to a very systematic and strategic EAFM process to incorporate ecosystem considerations into their current management structure that was driven by stakeholder input and guided by science. The process began with stakeholder-centric visioning and strategic planning which helped identify the Council's goals, establish a common understanding, and set the stage to begin the process of implementing EAFM. Science advice, developed in part by the National IEA program, in part by international collaborations within WGNARS, and in part through the Council process itself, helped identify critical ecosystem factors, evaluate risk, and determine management priorities and potential outcomes. Each step in the Council's EAFM structured framework process, modeled after the NOAA IEA loop (Levin et al. 2009, 2014), was then developed through a collaboration between scientists, managers, and stakeholders. While the example provided here is specific to the Mid-Atlantic region and fisheries, this collaborative and deliberative process could be applied to any region and is key to the success of EAFM implementation using IEA as a framework. Below are some key points and lessons learned:

- The Council developed a clear statement of intent for ecosystem management based on broad stakeholder engagement through the Visioning process and strategic planning that set consistent expectations and goals throughout the process;
- The Council proceeded stepwise through a series of distinct but related topics to have concrete discussions about policy options relevant to high priority EAFM topics identified by stakeholders and based on current science availability and future needs;
- The flexible IEA framework was adjusted to meet Council needs and interest, placing risk assessment early on to identify priorities for further analysis within the EAFM process;

- Conceptual models can be an effective tool to identify and communicate complex ecosystem relationships and help scope future comprehensive analyses to address a priority management question of interest;
- IEA provided a process to address ecological, environmental, social, and economic interactions rather than a set of prescriptive rules. The process allowed the Council to "learn by doing";
- Each step of the process was a deliberative, pragmatic approach to help ensure better outcomes and Council application. This also required significant investment and engagement with the Council, scientists, and stakeholders which was crucial in gaining support, trust and buy-in;
- Council resources are finite and other more "traditional" management priorities always arise. Having science, management, and stakeholder champions and regional, national, and international collaborators whose expertise could be drawn upon, is critical to ensure this work remains a priority and resources get allocated and amplified;
- Open-source data and technical documentation was key to developing products on a management timeline, which tends to be extremely short when compared to scientific endeavors such as primary research.

It has been nearly four years since the Council approved the EAFM Guidance Document which outlined the structured decision framework to integrate ecosystem considerations in their management process. While the Council is still working through all of the steps outlined in the framework, we believe this approach is one that can be viewed as a success and serve a model for other regions to consider as they advance ecosystem science and management. While the process was not always easy, and everything did not go as planned or envisioned, each completed step represents incremental progress at advancing and supporting ecosystem management for the Council and its stakeholders.

While scientists can conceive of many possible ecosystem approaches, this example shows that operational IEA involves a significant investment in collaboration with managers, and flexibility in adapting frameworks for practical application (Levin et al. 2009, 2014). Even though the process takes time, it should not be considered a failure or "slow uptake" of ecosystem approaches by managers. As our example shows, extended time yields benefits, ensuring that the science is available, stakeholders remain engaged and trust the process, and the Council can see how each step can inform and enhance the management process. There are always more priorities than a Council can effectively address in a given year. Nevertheless, the Council continues to support the EAFM process and allocate resources to continue progress toward EAFM. It is clear that successful uptake and advancement of ecosystem management requires commitment, resources, and leadership from a large team of science, management, and stakeholder partners engaged at varying degrees, and, therefore, the "no I in EAFM" approach is essential.

## Notes

1. In 2019, the Council approved Amendment 21 to the Mackerel, Squid, and Butterfish FMP that would add chub mackerel (*Scomber colias*) as a managed species under the FMP. At the

time of manuscript development, the National Marine Fisheries Service published a proposed rule to implement Amendment 21 with a final rule anticipated in the summer of 2020.
2. The SSC serves as the Council's primary technical body that provides the Council with science advice for management decisions, including catch limits that cannot be exceeded by the Council.
3. https://noaa-edab.github.io/ecodata/landing_page
4. https://noaa-edab.github.io/tech-doc/

## Acknowledgements

We gratefully acknowledge the members of the Mid-Atlantic Fishery Management Council, in particular the members of the Ecosystem and Ocean Planning Committee. Richard Robins, Jr. (past Council chair), Mike Luisi (current Council chair), and G. Warren Elliott (former chair of the Ecosystem and Ocean Planning Committee) were instrumental in their support of advancing the EAFM structured decision framework. We would also like to thank the members of the Ecosystem and Ocean Planning Advisory Panel, the Summer Flounder Conceptual Model Workgroup, and the International Council for the Exploration of the Seas Working Group on the Northwest Atlantic Regional Sea (ICES WGNARS) for their constructive feedback, thoughtful discussion, and continued support to help develop these various projects. The manuscript was greatly improved by the suggestions of Dr. Chris Harvey and the three peer reviewers.

## References

Allaire, J. J., X. Yihui, J. McPherson, J. Luraschi, K. Ushey, A. Atkins, H. Wickham, J. Cheng, W. Chang, and R. Iannone. 2019. *Rmarkdown: Dynamic Documents for R*. https://CRAN.R-project.org/package=rmarkdown.

Breslow, S. J., B. Sojka, R. Barnea, X. Basurto, C. Carothers, S. Charnley, S. Coulthard, N. Dolšak, J. Donatuto, C. García-Quijano, et al. 2016. Conceptualizing and operationalizing human well-being for ecosystem assessment and management. *Environmental Science & Policy* 66:250–9. 10.1016/j.envsci.2016.06.023.

Butterworth, D. S. 2007. Why a management procedure approach? Some positives and negatives. *ICES Journal of Marine Science* 64 (4):613–7. doi: 10.1093/icesjms/fsm003.

Clay, P. M., A. Kitts, and P. Pinto da Silva. 2014. Measuring the social and economic performance of catch share programs: Definition of metrics and application to the U.S. Northeast Region Groundfish Fishery. *Marine Policy* 44:27–36. 10.1016/j.marpol.2013.08.009.

Colburn, L. L., and M. Jepson. 2012. Social indicators of gentrification pressure in fishing communities: A context for social impact assessment. *Coastal Management* 40 (3):289–300. 10.1080/08920753.2012.677635.

Colburn, L. L., M. Jepson, C. Weng, T. Seara, J. Weiss, and J. A. Hare. 2016. Indicators of climate change and social vulnerability in fishing dependent communities along the Eastern and Gulf Coasts of the United States. *Marine Policy* 74:323–33. 10.1016/j.marpol.2016.04.030.

Dickey-Collas, M. 2014. Why the complex nature of integrated ecosystem assessments requires a flexible and adaptive approach. *ICES Journal of Marine Science* 71 (5):1174–82. 10.1093/icesjms/fsu027.

DePiper, G. S., S. K. Gaichas, S. M. Lucey, P. Pinto da Silva, M. R. Anderson, H. Breeze, A. Bundy, P. M. Clay, G. Fay, R. J. Gamble, et al. 2017. Operationalizing integrated ecosystem assessments within a multidisciplinary team: Lessons learned from a worked example. *ICES Journal of Marine Science* 74 (8):2076–86. 10.1093/icesjms/fsx038.

DePiper, G. S., S. K. Gaichas, B. Muffley, G. Ardini, J. Brust, J. Coakley, K. Dancy, G. W. Elliott, E. Gilbert, D. Lipton, et al. In review. Learning by doing: Collaborative conceptual modeling as a path forward in Ecosystem Based Management. ICES Journal of Marine Science.

Gaichas, S. K., G. S. DePiper, R. J. Seagraves, B. W. Muffley, M. Sabo, L. L. Colburn, and A. L. Loftus. 2018. Implementing ecosystem approaches to fishery management: Risk assessment in the US Mid-Atlantic. *Frontiers in Marine Science* 5(442):1–25. 10.3389/fmars.2018.00442.

Gaichas, S., R. Seagraves, J. Coakley, G. DePiper, V. Guida, J. Hare, P. Rago, and M. Wilberg. 2016. A framework for incorporating species, fleet, habitat, and climate interactions into fishery management. *Frontiers in Marine Science* 3 (105):1–17. 10.3389/fmars.2016.00105.

Harvey, C., T. Garfield, G. Williams, and N. Tolimieri, ed. 2020. California current integrated ecosystem assessment (CCIEA), California current ecosystem status report. A report to the Pacific Fishery Management Council. https://www.pcouncil.org/documents/2020/02/g-1-a-iea-team-report-1.pdf/.

Harvey, C. J., C. R. Kelble, and F. B. Schwing. 2017. Implementing "the IEA": Using integrated ecosystem assessment frameworks, programs, and applications in support of operationalizing ecosystem-based management. *ICES Journal of Marine Science* 74 (1):398–405. 10.1093/icesjms/fsw201.

Heemskerk, M., K. Wilson, and M. Pavao-Zuckerman. 2003. Conceptual models as tools for communication across disciplines. *Conservation Ecology* 7 (3). 10.5751/ES-00554-070308.

Hobday, A. J., A. D. Smith, I. C. Stobutzki, C. Bulman, R. Daley, J. M. Dambacher, R. A. Deng, J. Dowdney, M. Fuller, D. Furlani, et al. 2011. Ecological risk assessment for the effects of fishing. *Fisheries Research* 108 (2-3):372–384. 10.1016/j.fishres.2011.01.013.

Jepson, M., and L. L. Colburn. 2013. Development of social indicators of fishing community vulnerability and resilience in the US Southeast and Northeast Regions. NOAA Technical Memorandum NMFS-F/SPO-129 (US Dept Commerce, 2013). http://www.nmfs.noaa.gov/sfa/management/councils/training/2014/r_h3_fishing_community_vulnerability.pdf.

Levin, P. S., S. J. Breslow, C. J. Harvey, K. C. Norman, M. R. Poe, G. D. Williams, and M. L. Plummer. 2016. Conceptualization of social-ecological systems of the California current: An examination of interdisciplinary science supporting ecosystem-based management. *Coastal Management* 44 (5):397–408. 10.1080/08920753.2016.1208036.

Levin, P. S., M. J. Fogarty, G. C. Matlock, and M. Ernst. 2008. Integrated ecosystem assessments. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-92, 20 p.

Levin, P. S., M. J. Fogarty, S. A. Murawski, and D. Fluharty. 2009. Integrated ecosystem assessments: Developing the scientific basis for ecosystem-based management of the ocean. *PLoS Biology* 7 (1):e1000014. 10.1371/journal.pbio.1000014.

Levin, P. S., T. B. Francis, and N. G. Taylor. 2016. Thirty-two essential questions for understanding the social–ecological system of forage fish: The case of pacific herring. *Ecosystem Health and Sustainability* 2 (4):e01213. 10.1002/ehs2.1213.

Levin, P. S., C. R. Kelble, R. L. Shuford, C. Ainsworth, Y. deReynier, R. Dunsmore, M. J. Fogarty, K. Holsman, E. A. Howell, M. E. Monaco, et al. 2014. Guidance for implementation of integrated ecosystem assessments: A US perspective. *ICES Journal of Marine Science* 71 (5):1198–204. 10.1093/icesjms/fst112.

Link, J. S., and H. I. Browman. 2017. Operationalizing and implementing ecosystem-based management. *ICES Journal of Marine Science* 74 (1):379–81. 10.1093/icesjms/fsw247.

Mid-Atlantic Fishery Management Council (MAFMC). 2006. Evolution towards an ecosystem approach to fisheries (EAF). National Oceanic and Atmospheric Administration Award No. NAO4NMF4410368. http://www.mafmc.org/s/Ecosystem_Report.pdf

Mid-Atlantic Fishery Management Council (MAFMC). 2016. Ecosystem approach to fisheries management guidance document. https://static1.squarespace.com/static/511cdc7fe4b00307a2628ac6/t/589a2b61d2b8575c64fe05ff/1486498674225/EAFM_Guidance+Doc_2017-02-07.pdf

Northeast Fisheries Science Center (NEFSC). 2012. Ecosystem status report for the northeast shelf large marine ecosystem-2011. US Dept Commer, Northeast Fish Sci Cent Ref Doc.12-07. Edited by Ecosystem Assessment Program. Woods Hole, MA: National Marine Fisheries Service. http://www.nefsc.noaa.gov/nefsc/publications/.

Pavao-Zuckerman, M. 2000. The conceptual utility of models in human ecology. *Journal of Ecological Anthropology* 4 (1):31–56. 10.5038/2162-4593.4.1.2.

Punt, A. E., T. A'mar, N. A. Bond, D. S. Butterworth, C. L. de Moor, J. A. A. De Oliveira, M. A. Haltuch, A. B. Hollowed, and C. Szuwalski. 2014. Fisheries management under climate and environmental uncertainty: Control rules and performance simulation. *ICES Journal of Marine Science* 71 (8):2208–20. doi: 10.1093/icesjms/fst057.

Samhouri, J. F., A. J. Haupt, P. S. Levin, J. S. Link, and R. Shuford. 2014. Lessons learned from developing integrated ecosystem assessments to inform marine ecosystem-based management in the USA. *ICES Journal of Marine Science* 71 (5):1205–15.

Seagraves, R. and K. Collins, ed. 2012. Fourth national meeting of the regional fishery management councils scientific and statistical committees. Report of a National SSC Workshop on Scientific Advice on Ecosystem and Social Considerations in US Federal Fisheries Management. Mid-Atlantic Fishery Management Council, Williamsburg, VA.

Smith, A. D., E. J. Fulton, A. J. Hobday, D. C. Smith, and P. Shoulder. 2007. Scientific tools to support the practical implementation of ecosystem-based fisheries management. *ICES Journal of Marine Science* 64 (4):633–9. doi: 10.1093/icesjms/fsm041.

Wickham, H. 2015. *R packages*. 1st ed. Sebastopol, CA: O'Reilly Media.

Zador, S. G., K. K. Holsman, K. Y. Aydin, and S. K. Gaichas. 2017. Ecosystem considerations in Alaska: The value of qualitative assessments. *ICES Journal of Marine Science* 74 (1):421–30. 10.1093/icesjms/fsw144.