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SUPPORTING SCIENCE AND COMMUNICATING RESULTS.

BUILDING EFFECTIVE FISHERY ECOSYSTEM PLANS

A REPORT FROM THE LENFEST FISHERY ECOSYSTEM TASK FORCE

CONTENTS

Implementation Volume, Appendixes, and, Task Force photos and biographies: Available at www.lenfestocean.org/EBFM

PREFACE

PREFACE

Connections matter. That is the unifying principle of ecosystem-based fisheries management (EBFM). Ecological connections matter because fishing affects target species, predators, prey, competitors, bycatch species, and habitat. Economic connections matter because management affects fishermen, wholesalers, retailers, and recreational fishing guides. And social connections matter because fishing supports families and communities.

U.S. fisheries management has made tremendous strides under the current management framework, which centers on single stocks or stock complexes rather than ecosystems. Since reforms in 1996, the number of overfished stocks has declined dramatically, from 86 to 38, and the number of stocks subject to overfishing has plunged from 72 to 28. In addition, fishermen, managers, and many others have cooperated to reduce bycatch, conserve habitats, and improve the equity and safety of fisheries.

However, conventional management has certain limitations. It generally focuses on one fishing sector at a time, which may unexpectedly lead to worse outcomes in another sector. It often considers a narrow range of issues, potentially overlooking other factors that shape fishery systems, such as loss of habitat and the behavior of people and markets. And fundamentally, the current system is atomized into individual fishery management plans (FMPs), often leaving little opportunity to consider overarching management goals or the trade-offs across fisheries that attend almost every decision.

EBFM provides mechanisms to address these issues and many others. Yet despite this, and despite many other reports and studies that have made the case for EBFM, it has not been widely adopted. We believe a major reason is that there is no clear way to put its principles into practice.

The purpose of this report is to offer a blueprint for Fishery Ecosystem Plans (FEPs) as a means to translate EBFM into action. FEPs have been proposed for this purpose before, and most U.S. Regional Fishery Management Councils have since either started or completed an FEP. But these plans often focus on system description rather than management action.

We are proposing a next generation of FEPs that focus on action. We envision FEPs as a structured planning process that uses adaptive management to operationalize EBFM. This process starts by identifying the key factors that shape a fishery system and considering them simultaneously, as a coherent whole. It then helps managers and stakeholders delineate their overarching goals for the system and refine them into specific, realistic projects. And it charts a course forward with a set of management actions that work in concert to achieve the highest-priority objectives.

This report contains no new science or policy innovations. This is because we have found – through deliberation, document review, and conversations with managers and stakeholders – that EBFM is feasible today using existing science tools, policy instruments, and management structures. Not only that, nearly all of the steps in our process are already being carried out by U.S. fishery managers.

A key element of our approach is the inclusion of humans as part of the ecosystem. This is simply a practical recognition that fisheries management is about managing people for purposes that are defined by people. In our view, EBFM is not about putting nature before humans, any more than conventional management is about putting humans before nature. Rather, EBFM offers a framework for the deliberate, transparent consideration of all relevant scientific evidence and stakeholder goals.

OUR MISSION

The Lenfest Fishery Ecosystem Task Force, convened with support from the Lenfest Ocean Program, consists of 14 researchers pre-eminent in the sciences that support fisheries management. The purpose of the Task Force was to provide a blueprint for FEPs, with the goal of providing guidance to managers on implementing EBFM. The Task Force charge focused on answering three questions: (1) What are the key principles of EBFM that should be included in an FEP, and what is the current status of fisheries ecosystem planning that incorporate these principles? (2) What are the gaps between scientific knowledge and planning? and (3) What are new approaches that can be used to fill these gaps?

TASK FORCE PROCESS

Because the goal of our process was to develop guidance for managers that would be used to influence future decisions about EBFM, it was imperative to the Task Force process that we hear directly from diverse viewpoints on experiences with EBFM. We engaged with stakeholders, managers, and other decision-makers through regional workshops and by convening an advisory panel to help guide our efforts.

Workshops

We convened workshops around the U.S. to hear regional perspectives on EBFM from scientists, managers, and representatives from commercial and industrial fisheries and environmental NGOs. We met in Seattle; New Orleans; Portland, Maine; and Baltimore. At each meeting we invited individuals to share their experiences with EBFM in their region and had candid discussions about EBFM progress, hurdles, and potential next steps. These conversations were invaluable in shaping our perspective of what is possible and in developing our recommendations of what is necessary to move EBFM forward in U.S. fisheries management.

Advisory Panel

The Task Force is advised by a panel of current and former Council members, as well as participants from state agencies and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries). Because the goal of the Task Force was to provide guidance for managers, we believed that a panel of practitioners would provide grounding to our advice and ensure that our recommendations were realistic. We therefore engaged with the advisory panel throughout our process, and it has been instrumental in developing our findings and recommendations.

HOW THIS REPORT SHOULD BE USED

The first six chapters of this report are intended for an audience with knowledge of and interest in fisheries. We have sought clarity at every juncture, but we also assume some familiarity with basic concepts of fisheries science and management. We hope that novice and non-U.S. readers will still find the general points useful, even if they are unfamiliar with some of the details, especially with regard to the workings of the U.S. Council system and the laws governing fisheries.

Chapter 1 provides our definition and scope of EBFM, reviews progress toward EBFM in the U.S., and describes the key next steps in operationalizing EBFM. Chapter 2 gives reasons to develop next-generation FEPs, describes how we envision FEPs and FMPs can work together to improve management, outlines the nature and purpose of next-generation FEPs, and describes how next-generation FEPs can help overcome many of the perceived barriers to implementing EBFM. Chapter 3 gives the blueprint itself, a structured planning process for FEPs as described above. Chapter 4 provides three key considerations for developing FEPs. Chapter 5 supports the feasibility of the blueprint by providing examples from case studies that illustrate each step of the process. Chapter 6 summarizes our key findings and recommendations that are laid out in Chapters 1-5.

The report also includes an Implementation Volume and three Appendices, which are intended mainly for a narrower audience of managers, Council staff, Council advisers, and other managers and technical professionals. The Implementation Volume provides detailed guidance on a range of scientific tools and policy instruments to carry out this process. It is not our intention to prescribe specific tools or approaches. Instead, we want to provide a menu of options from which Councils could pick and choose what is most appropriate for their system. Appendix A provides an overview of the principles of EBFM and fisheries as systems. Appendix B is a table of challenges to EBFM identified from the scientific literature, with suggestions for how a new generation of FEPs can overcome them. Appendix C provides narratives of the case studies used in Chapter 5. The Implementation Volume and all Appendices can be accessed at www.lenfestocean.org/EBFM. Kristin Marshall and Laura Koehn provided invaluable contributions to this report.

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CHAPTER 1

EBFM AND FEPS: WHERE ARE WE NOW?

BACKGROUND

Fishing is critical to food security and the well-being of individuals and communities around the world (Cisneros-Montemayor and Sumaila, 2010; FAO, 2014). It is also a globally significant industry, contributing more than US$140 billion to world economies (Food and Agriculture Organization, 2014). The conventional approach to managing people's use of fisheries resources sets regulations by focusing on one species (or group of similar species) and its fisheries at a time to sustain the delivery of food, employment, economies, and social benefits. Where applied, this approach can succeed at avoiding overfishing and rebuilding depleted target stocks (Melnychuk et al., 2012; Melnychuk et al., 2013; Neubauer et al., 2013; NOAA Fisheries, 2015). However, conventional management generally does not focus on the ecological, economic, and social systems that fisheries are part of.

This leads to certain limitations. First, because species and fishing participants do not exist in isolation, regulations focused solely on one fishing sector may unexpectedly lead to worse outcomes in another. Second, because the conventional approach often considers a narrow range of management levers, it may overlook other options. For example, conventional rebuilding plans often focus on reducing fishing mortality of the target species, with less consideration given to other factors slowing recovery, such as loss of habitat. Third, the focus of conventional management makes it difficult to consider the full range of trade-offs that attend many decisions. Management decisions made for one fishery rarely consider broad trade-offs across all fisheries in a region, for instance across jurisdictional boundaries.

The importance of a broader, ecosystem-based approach has been recognized for more than a century (Baird, 1873) and over the past two decades has been increasingly promoted as a more effective framework for fisheries management to meet societal needs (Foley et al., 2013; Francis et al., 2007; Link, 2002; McLeod et al., 2005; Pikitch et al., 2004). For example, several international organizations and agreements have adopted ecosystem-based management frameworks (Bianchi and Skjoldal, 2008; Pikitch et al., 2004) and the U.N. Food and Agriculture Organization (FAO) has provided guidance to implement an ecosystem approach to fisheries (Ecosystem Approach to Fisheries, FAO, 2003). In the European Union, one of the goals of the reformed Common Fisheries Policy is to develop ecosystem-based fisheries management (EBFM), and the broader Marine Strategy Framework Directive (EU COM, 2008) has the goal of "clean, healthy, and productive" oceans ("Good Environmental Status") by 2020. And Australia has a notable track record of implementing ecosystem approaches to fisheries management (Fletcher et al., 2010; Smith et al., 2007), which has contributed to improved sustainability of stocks (Smith et al., 2007).

In the U.S., there has also been progress (which we outline below), but EBFM has not been widely or systematically adopted at the federal level. In this chapter, we further describe the concept of EBFM, review the status of its implementation in the U.S., and introduce what we believe is the critical next step in operationalizing it.

WHAT IS EBFM?

Our definition of EBFM synthesizes multiple existing definitions (Fogarty, 2014; Garcia et al., 2003; Larkin, 1996; Link, 2010; McLeod et al., 2005; Pikitch et al., 2004).

> **EBFM IS A HOLISTIC, PLACE-BASED FRAMEWORK THAT SEEKS TO SUSTAIN FISHERIES AND OTHER SERVICES THAT HUMANS WANT AND NEED BY MAINTAINING HEALTHY, PRODUCTIVE, AND RESILIENT FISHERY SYSTEMS.**

This contrasts with a conventional fisheries management focus, which is more narrowly pointed on the *direct* consequences of management actions on targeted stocks, and protected nontarget species.

Fundamental to EBFM is the conceptualization of fisheries as systems. Fishery systems consist of linked biophysical and human subsystems with interacting ecological, economic, social, and cultural components (Charles, 2014, 2001). A system is made up of its components (e.g., targeted fish stock, interacting species, habitats, people employed by fishing), and the linkages among them (e.g., predator-prey interactions, fishermen who shift from one fishery to another). These linkages can span regulatory units and jurisdictions that are common in conventional management. Management actions that do not account for these linkages can therefore produce unintended indirect effects (Bianchi and Skjoldal, 2008; Ecosystems Principles Advisory Panel, 1999; Garcia et al., 2003). See Appendix A for a fuller description of the Task Force's key principles for understanding fisheries as systems and consequences of these principles for fisheries management.

The goal of EBFM is to improve decision-making by providing a means for managers to transparently consider all components of a fishery system: ecological, social, and economic across all fisheries prosecuted in the system. This triad is also known as the "triple bottom line" (Elkington, 1997; Halpern et al., 2013). Conventional management can take the triple bottom line into account within a single fishery, but EBFM does this more comprehensively by looking across species, fisheries, and jurisdictions. That is, it considers the system as a whole. In an EBFM approach, managers can make decisions that explicitly take into consideration how different components of the fishery system and the linkages among them affect the benefits people receive from fisheries. A holistic view of systems can help managers better identify a fuller suite of threats to fisheries and provide a more coherent framework to account for the dynamics of systems. EBFM can identify elements that confer resilience, helping managers avoid exceeding limits that may lead to rapid and irreversible system change. Finally, EBFM can improve the ability to reach the goals of conventional management by explicitly incorporating environmental and ecological information in science advice used to access stocks.

Several pressing needs in fisheries management can be more effectively addressed with EBFM, including:

- prepare for and respond to rapid environmental change, including by formulating management strategies to sustain fishing-dependent communities;
- assess and respond to cumulative effects from multiple fisheries and from nonfishery stressors, such as land-based pollution and environmental change;
- minimize the risks of system reorganization into new, undesired states;
- modify biological reference points to account for interactions among targeted species, habitats, and environmental conditions.

STATUS OF EBFM IN THE UNITED STATES

Many Regional Fishery Management Councils – the bodies that manage U.S. federal fisheries along with NOAA – have been expanding the scope of conventional management in a stepwise fashion over the past several decades to address such linkages. For example, they have protected important benthic habitats from negative impacts associated with fishing gear by designating Essential Fish Habitat and restricting fishing in certain areas (Murawski et al., 2000). They have also reduced bycatch using several methods, such as catch shares (Little et al., 2014), spatial management (Dunn et al., 2011), and technical management (Melvin et al., 2014). And they have enacted precautionary measures such as biomass buffers to protect forage fish, which serve as important prey to other species (Pikitch et al., 2012, e.g., pp. 41, 47).

Stock assessment models have also advanced to reflect the stepwise expansion of conventional management. For instance, some stock assessments link recruitment to environmental conditions, track changes in mortality due to predators, or use information on habitats to better standardize abundance indices. In fact, our review of 207 quantitative stock assessments found that roughly 45 included explicit habitat or oceanographic conditions and three explicitly included predation (an additional 23 assessments included data on predation in the report for context). This progress demonstrates both the capacity to improve stock assessments by including ecosystem information and the tremendous opportunity to expand the application of EBFM in stock assessments.

Similarly, conventional management has advanced to address social and economic goals of fisheries. For instance, the Alaskan halibut and sablefish individual transferable quota fishery enacted constraints on permit trading and limitations on ownership in 1995 to avoid overconsolidation of quota into a small number of owners, which would lead to few active participants (Kroetz et al., 2015). This has resulted in more fishermen and vessels being active than would have been without these restrictions (Kroetz et al., 2015). Also, groundfish fisheries have implemented Community Quota and Community Development Quota Programs in Alaska (Carothers, 2011; Ginter, 1995) to encourage greater participation by local Alaska communities. Quota leasing through the Community Development Quota program has provided revenue to these communities and produced a nearly fiftyfold increase in asset value (Carothers, 2011; Ginter, 1995). These advances are laudable, but because they have been limited to social and economic goals *within* fisheries (and do not address similar issues that span multiple management jurisdictions or management plans) there are opportunities to expand how fisheries management considers social and cultural outcomes.

Concurrent with Councils' stepwise expansion of the scope of conventional management, an effort to establish a more overarching version of EBFM in the U.S. began two decades ago. In 1999, this Ecosystem Principles Advisory Panel (EPAP) concluded that while conventional fishery planning approaches included provisions to address ecosystem principles, they were not sufficient to implement EBFM because of their inherently narrow focus (Ecosystem Principles Advisory Panel, 1999). **Instead, a new tool was needed: Fishery Ecosystem Plans (FEPs).** The report included recommendations for the development of FEPs, with three objectives in mind:

- provide Council members with a clear description and understanding of the fundamental physical, biological, and human/institutional context of ecosystems within which fisheries are managed;
- direct how that information should be used in the context of Fishery Management Plans (FMPs); and
- set policies by which management options would be developed and implemented.

Over subsequent years, eight FEPs have been developed (others are currently in development), covering four Council regions. The scope of these FEPs varies widely (Table 1.1), but one notable and consistent pattern is that FEPs generally do not include direct links to management actions. This point is also noted in a recent review of FEPs in relation to the recommendations in the EPAP Report (Wilkinson and Abrams, 2015), which found that several of the EPAP recommendations had not been implemented. The review also identified three key elements not included in the original EPAP Report that should be central to the development of future FEPs:

1. establishment of ecosystem goals and objectives;
2. use of ecosystem indicators to monitor progress in achieving goals; and
3. analysis of trade-offs across objectives.

Table 1.1

KEY ASPECTS OF THE FEPS DEVELOPED IN 4 COUNCIL REGIONS

OBJECTIVES AND STRATEGIES	ALEUTIAN ISLANDS (NPFMC)	SOUTH ATLANTIC (SAFMC)	CALIFORNIA CURRENT (PFMC)	MULTIPLE ECOSYSTEMS (PIFMC)
OBJECTIVES				
Integrate and provide information for Council decision-making	✓	✓	✓	✓
Provide indicators to inform health of fishery system	✓			
Build toward ecosystem assessment			✓	
Coordinate conservation and management measures				✓
Set management objectives				✓
Establish structure to provide management advice				
STRATEGIES				
Overview of the fishery system	✓	✓	✓	✓
Indicator development	✓			
Qualitative risk assessment	✓			
Amendments for habitat protection		✓		
Initiatives that can be taken up at the Council's discretion			✓	
Replaces FMPs				✓
Direct links to required action	No	No	No	Yes*

* The FEPs for the Western Pacific Regional Fishery Management Council reorganized existing FMPs but did not revise them.

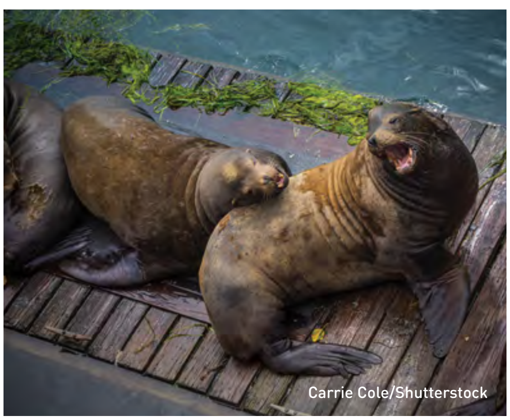
NEXT STEPS: OPERATIONALIZING EBFM

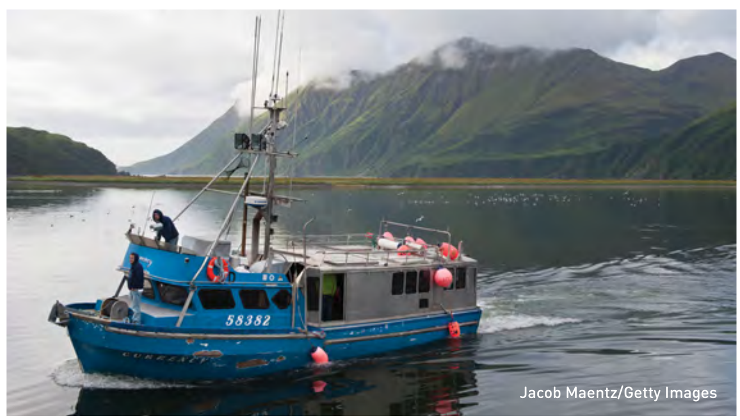
The Task Force believes that operationalizing EBFM – putting principles into practice - requires a systematic framework. A framework creates a scaffold on which to hang our knowledge of a fishery system. A framework illustrates the pathways through which managers can identify a coherent set of actions to increase and sustain the multiple benefits people derive from fisheries.

The Task Force believes that one reason for the limited application of EBFM is the lack of a structured, deliberate, transparent process for doing so. We further believe that adopting such a process is a necessary next step in operationalizing EBFM. The Task Force therefore proposes that a new generation of FEPs should be used as a tool for operationalizing EBFM.

The rest of this report outlines our vision for these FEPs, how managers can integrate them into existing management (Chapter 2), and our five-step process for creating next-generation FEPs (Chapter 3). Subsequent chapters provide further detail and examples. This process could accomplish critical tasks that are needed to operationalize EBFM such as:

- set and prioritize overarching goals for the fishery system based on a transparent, stakeholder-driven process;
- set performance measures, consider a wide range of alternative actions, and explicitly confront the trade-offs inherent in selecting an alternative;
- specify an internally consistent set of policies that achieve fishery system goals across multiple fisheries; and
- adopt adaptive management, an approach for making decisions under uncertainty and systematically adjusting course based on new information.





Male sea lions in Newport, Oregon, at the Historic Newport Docks (left). A small longline commercial fishing vessel in Kodiak Island, Alaska (right).

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CHAPTER 2

THE NATURE AND PURPOSE OF NEXT-GENERATION FISHERY ECOSYSTEM PLANS

INTRODUCTION

Chapter 1 described how ecosystem-based fisheries management (EBFM) can lead to improved decision-making by taking a more holistic view of fishery systems. It argued that one reason EBFM has not been widely adopted in the U.S. is the lack of a structured, deliberate, transparent process for doing so. The Lenfest Fishery Ecosystem Task Force proposes a new generation of Fishery Ecosystem Plans (FEPs) as a tool to carry out that process and translate the principles of EBFM into action.

Here we explain why we believe Regional Fishery Management Councils should develop FEPs and how FEPs can be used in concert with Fishery Management Plans (FMPs) to achieve EBFM, and we describe the overall nature of next-generation FEPs.

WHY DEVELOP AN FEP?

The overall purpose of an FEP is to foster improved decision-making by incorporating the principles of EBFM. By applying a broad suite of considerations and scientific tools, managers can better achieve sustainability goals for fishery systems.

The Task Force recognizes that there are substantial upfront costs to developing and implementing an FEP, while the benefits will follow over the long term. We nevertheless believe that next-generation FEPs warrant Councils' serious consideration because of the following four key benefits.

1. FEPs provide a structured process for translating goals and principles into action.

The main recommendation of this report is that next-generation FEPs be used to create a structured process for establishing goals and translating them into action. This process can help Councils prioritize among the many systemic issues and management goals they face and select which goals and objectives to pursue during the life of the current iteration of the plan. This is important because Councils will not have the resources to pursue all management issues simultaneously. The inability to consider all issues need not prevent them from moving forward on some. While risk and uncertainty will always exist, a triage approach can highlight high risks across the fishery system and thereby identify issues where management action is most urgent and most likely to improve outcomes (Fletcher, 2005; Levin et al., 2014).

2. FEPs provide a coordinated way to simultaneously consider ecological, economical, and social goals.

Our vision for next-generation FEPs to support EBFM includes considerations of food web dynamics, climate forcing, bycatch, and habitat protection (Ecosystem Principles Advisory Panel, 1999). But it equally focuses on human well-being, including equity, and economic considerations in decision-making (see recent review by Long et al., 2015). Therefore, FEPs that focus on fishery systems can demonstrate how fishery managers could assess, and potentially improve, outcomes across these dimensions. This "triple bottom line" offers an opportunity to build a broader, engaged community of stakeholders, scientists, and managers to improve fisheries management (Elkington, 1997).

3. FEPs create a process of identifying and transparently addressing trade-offs.

Next-generation FEPs will explicitly assess trade-offs, particularly across multiple fisheries operating in a Council region. In many cases, decision-makers already weigh multiple objectives implicitly and allocate resources accordingly. However, FEPs could provide a way to reveal and document the full spectrum of expected costs and benefits, monetary and nonmonetary, to all parties of fishery management actions (including but not limited to single-species catch limits). Tools for examining trade-offs within and among economic and ecological objectives are common, and methods to incorporate social and cultural dimensions are emerging. By exploring alternative policy measures in an attempt to root out trade-offs, decision-makers will have a more complete picture of consequences of alternative management actions and so can make better-informed decisions. This can foster an inclusive, transparent process of decision-making, since it makes clear the implications of each decision.

4. **FEPs provide a framework to consider cumulative impacts.**

Fishery systems are increasingly subjected to stressors that are external to fisheries and outside the control of management. Next-generation FEPs can help managers account for these external forces, including land-based pollution, climate forcing, climate change, and shifting global markets. An FEP can also serve as a venue for strategic recommendations on changes in institutional structure to support EBFM—for example, organizing science divisions to promote interaction among various fields (e.g., protected species, habitats, population assessment, social sciences, oceanography).

FISHERY ECOSYSTEM PLANS: A STAGE UPON WHICH FISHERY MANAGEMENT PLANS ACT

As context for the Task Force's vision of next-generation FEPs, this section describes the main ways fisheries regulations are made in the U.S. using FMPs, indicates how FEPs and FMPs can jointly be used to advance EBFM, and highlights the similarities and differences between next-generation FEPs and FMPs.

What are Fishery Management Plans?

In the U.S., fisheries management is operationalized by FMPs. The Magnuson-Stevens Fishery Conservation and Management Act (MSA) encourages integrated management of stocks via FMPs, and thus FMPs often consist of many functionally similar stocks (e.g., groundfish, coastal pelagic species, highly migratory species). The MSA stipulates that FMPs must prevent overfishing; rebuild overfished stocks; and protect, restore, and promote the sustainability of fish stocks. Therefore, FMPs must specify maximum sustainable yield and Optimum Yield[1] (OY), include overfishing definitions, establish a mechanism for specifying Annual Catch Limits, and minimize bycatch. The MSA also requires FMPs to allocate harvest restrictions equitably among sectors, and to describe essential fish habitat (EFH), and minimize to the extent practicable adverse impacts to EFH. In addition to these required components, FMPs also may, at the discretion of a Council, include time/area management requirements, gear requirements, limited access regimes, harvest incentives for reduced bycatch, requirements for fishery observers, and conservation of target and nontarget species and habitats.

FMPs are principally driven by objectives centered on individual species or stocks. The requirement to prevent overfishing and rebuild overfished stocks is the driving policy underlying the MSA and thus FMPs. Therefore, individual FMPs are not designed to lead to a consistent overall framework for the management of interacting species and fishing participants distributed among many FMPs, among species managed by multiple jurisdictions (e.g., federal vs. state), or legal authorities (e.g., MSA and the Endangered Species Act) (Fogarty and Rose, 2013).

1 National Standard 1 of the MSA defines OY as the amount of fish that will provide the greatest overall benefit to the nation based "on maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor."

How are FEPs and FMPs used to operationalize EBFM?

The Task Force envisions that next-generation FEPs will be similar to FMPs in certain ways. FEPs, like FMPs, will have the generic elements of a good plan. These include goals and objectives, strategies and actions to achieve objectives, performance evaluation and review, mechanisms for prioritization, and mechanisms for evaluating trade-offs in selecting between alternative strategies and actions.

Next-generation FEPs are distinct from FMPs, however, and the unique features of FEPs might make them preferable for addressing certain issues. FEPs have a different purpose, a different legal mandate, and different scope:

Purpose: The purpose of FMPs is to achieve management goals set for particular species, species groups, or fisheries, while the purpose of FEPs is to achieve the broader goals of EBFM for the fishery system.

Legal mandate: FMPs are statutorily required, legally binding instruments that stem directly from MSA and seek to meet the act's National Standards, whereas FEPs are discretionary and not legally binding. This creates both limitations and opportunities. One potential limitation is difficulty making FEPs "actionable" given that they have no legal basis. However, FEPs can specifically articulate how management plans will be implemented through FMP amendment processes should regulatory changes be needed. One benefit is that the FEP process may be especially helpful for planning and aspirational thinking because an FEP does not trigger mandatory action. This encourages "outside the box" thinking that can inspire novel solutions to complex problems. Management actions that follow from FEPs can be applied on a temporary basis to learn how the system responds and to determine whether expected benefits are produced.

Scope: The spatial focus of FMPs is often defined by the stock structure of key commercial and recreational species. In contrast, the scale of an FEP is defined by the spatial structure of the fishery system. Because boundaries in fishery systems tend to be porous, FEPs may need to acknowledge known biophysical and socio-economic exchanges. Further, the boundaries of FEPs should recognize the scale of human institutions and governance, including the regional distribution of fishing sectors, fishing effort, stakeholder commitments, and international/tribal treaties.

The scope of possible objectives of an FEP is also broader than a FMP. FEPs specify a Council's vision for economic, ecological, and social sustainability of the whole fishery system. FEPs are the means to consider conflicts or inconsistencies among FMPs, and between fisheries and other ecological and socio-economic objectives. FEPs also provide a platform to examine cumulative impacts of all human activities in the system.

The broad scope of FEPs means that they can also more appropriately address the human dimensions throughout entire fishery systems, such as those highlighted in several places in the MSA. For example, the degree to which allocation of resources to fishermen is fair and equitable (National Standard 4) and the ability for management to take into account the importance of fishery resources to fishing communities[2] (National Standard 8) may be best addressed at the scale of the entire fishery system so that all fisheries (state and federal) can be explicitly considered in their totality.

2 The MSA defines fishery community as a community that is substantially dependent on or substantially engaged in the harvest or processing of fishery resources. Fishing communities include members that reside in a specific location and share a common dependency on fishing or on directly related fisheries-dependent services and industries. (MSA Section 3; and 50 CFR 600.345(b)(3), National Standard 8)

Perhaps more importantly, FEPs can be used to inform OY (Patrick and Link, 2015). While OY is determined for single species, the amount of catch from all fisheries that yields the greatest benefit to the nation is unlikely to be the simple sum of single-species OY, or even sum of OY within an FMP. Rather, systemic OY can only be addressed by looking across all fisheries holistically, considering direct and indirect effects of fisheries on each other, food webs, and coastal communities.

Both FEPs and FMPs will be involved in operationalizing EBFM to some extent. FEPs can integrate across FMPs and address those issues not effectively captured in FMPs. However, if Councils are to achieve their EBFM goals, it is absolutely necessary that the FEP process include explicit steps to modify FMPs with the results of the FEP work projects. Councils can use both FEPs and FMPs in whatever proportion they choose to advance EBFM.

Western Grebe (*Aechmophorus occidentalis*) with fish prey, Monterey Bay, California (top left). Woman deploying a bouy line for commercial halibut longline fishing, Southwest Alaska (top right). Colorful corals deep underwater in Fiji (bottom).

THE NATURE OF NEXT-GENERATION FEPS

This section describes the Task Force's high-level vision of the nature of next-generation FEPs. A more detailed proposal for creating FEPs is provided in the next chapter.

As stated above, our main recommendation is that FEPs be used to create a structured process for translating EBFM principles into action. This means developing *actionable* components for FEPs – ways in which ecosystem considerations lead to management responses. At the same time, FEPs need to be aspirational, to identify the broader system-level goals for the fishery system. This is key to placing system-level thinking at the forefront of fishery management and to placing fisheries firmly in a holistic system context. Without the aspirational component, the FEP can become overly narrow and miss opportunities to make advances from the status quo.

Calls for FEPs to be actionable and aspirational may appear to be at odds. We argue that FEPs can achieve both by *prioritizing* the set of issues that will be considered for management action during the life of a particular plan. The overarching process will involve strategic vision and long-term goals, but the immediate actions will be based on a prioritized list of issues that can be given practical effect over the life of the plan (likely between five and 10 years).

FEPs will be addressing issues for which there is substantial uncertainty – this is a fundamental feature of EBFM. Taking actions under uncertainty requires an adaptive approach to management. This means that managers take action without precisely knowing the outcomes. Instead, they define the risks and benefits of alternative solutions and identify vulnerabilities to key uncertainties, which allows them to identify the actions that are most robust to uncertainty. The adaptive approach to management also means that knowledge of the system is improved by taking action and learning how the system responds (Walters, 1986). Thus, the assessment of outcomes in implementing EBFM must be conducted regularly, and the FEP updated on a schedule so that it evolves in an adaptive fashion. This process is further described in Chapter 3.

Examples of FEP actions and how to implement them

The actionable component of FEPs can take several forms. For instance, it is within the scope of FEPs to:

- identify system-level performance measures and develop management responses to be taken when reference points are approached or exceeded;
- modify or replace harvest control rules to take into account multiple stocks and the relationships among them and the whole system;
- specify the process for updating biological reference points in response to measured ecosystem changes;
- develop a strategy to identify vulnerable nontarget species (either from bycatch or indirect effects of fisheries), monitor changes in risk or population status, and trigger management responses when risk crosses thresholds;
- prioritize vulnerable and valuable habitats for protection and monitoring;
- modify the allocation of fishing opportunities among users to achieve broad social objectives;
- specify the Council's strategy for coordinating with local, regional, and federal authorities regarding ocean uses by multiple sectors; and
- establish standards for information to be formally included in assessment or management decisions. This may include setting forth ways to use local and traditional ecological knowledge; describing what environmental data are suitable and appropriate to enhance assessment; and describing how highly localized information (e.g., much anthropological information) is to be used in regional decision-making.

HOW FEPS CAN ADDRESS THE KEY CHALLENGES TO EBFM

Next-generation FEPs are designed to address many of the perceived challenges to EBFM implementation. These challenges include complexity, uncertainty, unclear objectives, and difficulty reconciling trade-offs. We elaborate on each of these and show how a FEP can overcome them. In addition, Appendix B provides a detailed table of challenges to EBFM identified from the scientific literature, with suggestions for how next-generation FEPs can overcome them (see www.lenfestocean.org/EBFM).

Complexity

Perceived challenge: The complexity of fishery systems is thought to make EBFM costly and time-consuming to implement (Leslie and McLeod, 2007; Tallis et al., 2010; Hilborn, 2011; Cowan et al., 2012; Leslie et al., 2015). This is thought to necessitate new science tools to capture the key feedbacks and responses of systems to fishery regulations and external drivers (Cowan et al., 2012). These science tools are perceived as so complex that decision-makers and stakeholders will not readily understand them. Some claim that complexity in fishery systems defies translation into readily understood and easily tracked indicators, reference points, and simple decision rules (Frid et al., 2006).

FEP solution: FEPs prioritize issues for action, thereby simplifying and focusing decision-making and the science activities that support it. Prioritization also means that actions are taken on a limited number of issues, so that indicators, reference points, and decision rules can be tailored to issues at hand. FEPs provide decision support that can be applied at all levels of information availability.

Uncertainty

Perceived challenge: Our limited ability to predict system behavior means that science is insufficiently precise to guide management (Frid et al., 2006). Even modest extensions to models used to predict fish population status – such as adding environmental information into a stock assessment – can reduce management performance if not done carefully (Punt et al., 2014).

FEP solution: Next-generation FEPs are designed specifically to guide decisions given uncertainty. That is, FEPs are a framework for making decisions under uncertainty by evaluating alternative actions to determine which are robust to key uncertainties and using management actions to reduce uncertainty.

Unclear objectives

Perceived challenge: EBFM has been said to lack clear objectives (Cowan et al., 2012; Hilborn, 2011; Mace, 2001) because EBFM means different things to different people (Christie et al., 2007) and because there is no coherent policy framework to provide them. In contrast, conventional management often has clear, legally mandated objectives.

FEP solution: A central part of next-generation FEPs is development of specific, operational objectives. These objectives reflect the desired states of the fishery system as revealed through engagement with a broad coalition of stakeholders.

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CHAPTER 3

THE STRUCTURE AND PROCESS OF FISHERY ECOSYSTEM PLANS

INTRODUCTION

Decision-making in an ecosystem-based fisheries management (EBFM) context needs to be structured and deliberate to account for uncertainty and trade-offs among multiple, potentially competing objectives (Walters, 1986; Polasky et al., 2011). By structured, we mean that there is a logical, sequenced process, and by deliberate, we mean the process is conducted with clearly articulated intentions to achieve specific goals.

Here, we describe a Fishery Ecosystem Plan (FEP) process that is intended to support this kind of decision-making, thereby translating the concepts and principles of EBFM into action. This process relies on the active participation of stakeholders throughout FEP development. It allows for both the long-term aspirational nature of EBFM and the need for actionable, practical steps in the short term.

Our approach, summarized in Figure 3.1, is founded on the concept of adaptive management (Holling, 1978; Walters, 1986), a structured approach for improving resource management by systematically learning from management outcomes (Williams et al., 2009; Westgate et al., 2013). This approach shares many features of the Integrated Ecosystem Assessment process already employed by NOAA and others (Levin et al., 2009, 2014) but builds upon that process by focusing on management actions.

The framework we outline describes the FEP process in five well-defined stages, with the whole cycle being repeated over time. Learning and adaptation occur at two distinct time scales. Over short time scales (perhaps one to three years), management actions will be implemented and their results monitored and analyzed. Based on this information, management actions can be adjusted relatively quickly in an attempt to achieve the desired outcomes. At longer time scales (perhaps five to 10 years), monitoring and evaluation will yield insights on the wisdom and efficacy of the strategic approach being employed, allowing for adaptation in choice of objectives and the overall approach. FEPs, then, are tactically adjusted in the short term and strategically adapted in the longer term.

This "FEP Loop" does not offer a ready-made cookbook for EBFM. The Task Force decided this was not useful to decision-makers because of the diversity of regional conditions, needs, and constraints, and because Councils will undoubtedly need and want to customize their approach to FEP development and implementation. As an adaptive framework, we expect that it will change and that Councils will improve and modify our guidelines. We provide instead a blueprint that outlines key activities, their intended outcomes and purposes, and the sequence with which they should occur to guide the development of next-generation FEPs.

The next section describes the five steps in the development of an FEP. Detailed guidance on the first three steps of the FEP Loop is provided in the Implementation Volume. We do not provide detailed guidance on the last two steps because the Councils are already familiar with these actions (namely, implementing a plan and monitoring results).

Red grouper swimming in a coral reef, Dry Tortugas National Park, Florida (left). Fishing vessel, Florida Keys (right).

Figure 3.1

THE FEP LOOP

The main recommendation of the Task Force report is that FEPs be used to create a structured process for establishing goals and translating them into action. The report proposes the "FEP Loop" process.

THE FEP STEPS

Step 1: “Where are we now?”

The purpose of this step is to systemically inventory the status and trends of key components of the fishery system, then assess the risks that the system faces. Key actions associated with this step include:

- **Develop a conceptual model:** Stakeholders, tribes, managers, and scientists co-create a model that provides an inventory of key components of the fishery system and how they interact (EPAP, 1999). This reveals direct and indirect connections within and among social and ecological components of fishery systems.
- **Select and calculate indicators:** Describe the state of the system by documenting status and trends of key fishery system components. This involves a robust process of identifying “vital sign” indicators, measurable properties of the system that reflect system state.
- **Inventory threats**: Work with stakeholders, tribes, managers, and scientists to identify threats to the system and other pressures (see Table 3.1 for examples).

Table 3.1

EXAMPLES OF THREATS AND OTHER PRESSURES POTENTIALLY AFFECTING FISHERY SYSTEMS

Finfish and shellfish aquaculture	Coastal development and engineering
Atmospheric pollution	Dredging
Commercial shipping	Freshwater retention
Fishery removals	Light pollution
Invasive species	Nutrient input/hypoxia/harmful algal blooms
Marine debris	Offshore oil and gas activities
Ocean-based pollution	Power plant operation
Organic pollution	Recreational use
Climate change	Ocean acidification
Global fish markets	Degraded fish habitat
Construction of benthic structures	

Sources: Drawn from Andrews et al., 2015; Halpern et al., 2007

Step 2: "Where are we going?"

The objective of this step is to collaboratively articulate a purpose and direction for the FEP. This includes key actions that embody the aspirational and actionable nature of FEPs. This step identifies broad system level goals, prioritizes issues for action, and identifies tangible, measurable management objectives. Most of these activities involve collaboration with stakeholders, tribes, managers, and scientists.

- **Create a vision statement:** Create a vision statement that declares a management body's core values and purpose. This statement provides the foundation for clear goals for the fishery system. Unlike conventional management vision statements, which are generally focused on individual fishery sectors or species, these encompass goals for the entire fishery system. (See Table 3.2.)
- **Develop strategic objectives:** Strategic objectives are high-level statements of what is to be attained. Unlike vision statements that refer to the fishery system as a whole, strategic objectives are more focused on individual social, ecological, institutional, or economic components of the fishery system. Thus, there will be several strategic objectives underlying the FEP vision. (See Table 3.2 and Example Box 1.)
- **Analyze risks to meeting strategic objectives:** Determine the likelihood that one or more components of the fishery system will reach or remain in an undesirable state.
- **Prioritize strategic objectives:** With information gathered from previous steps, managers and stakeholders identify high-priority strategic objectives based on risk, cost and feasibility, logistics, governance, and stakeholder support. (See Example Box 2.)
- **Develop operational objectives:** Unlike strategic objectives, operational objectives are specific, measureable, achievable, realistic, and time-bound. In other words, they clearly and unambiguously articulate what desired outcomes look like. Operational objectives are therefore the basis for developing actions to achieve EBFM.

Katrina Outland/shutterstock

Small city of Unalaska, Port of Dutch Harbor, Alaska, part of the Aleutian Islands.

Table 3.2

SAMPLE VISION STATEMENTS, STRATEGIC OBJECTIVES, AND OPERATIONAL OBJECTIVES

VISION STATEMENTS	The Vision for the Eastern Scotian Shelf is of healthy and sustainable ecosystems, economies, and communities supported by collaborative, integrated, and harmonized governance and management. Eastern Scotian Shelf Integrated Management Plan (Fisheries and Oceans Canada, 2007)
	Healthy and productive marine ecosystems supporting thriving, sustainable marine fisheries that provide the greatest overall benefit to stakeholders (MAFMC, 2013)
	Maintain biologically diverse and productive marine ecosystems and foster the long-term sustainable use of marine resources in an ecologically and culturally sensitive manner through the use of a science-based ecosystem approach to resource management (Western Pacific Council FEP)
STRATEGIC OBJECTIVES	Maintain the biomass of keystone species at levels that will ensure maintenance of their specific role in ecosystem function (Fletcher, 2010)
	Diversity of benthic, demersal, and pelagic community types is conserved. (Fisheries and Oceans Canada, 2007)
	"[M]inimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat," (Magnuson Stevens Act, 2007)
OPERATIONAL OBJECTIVES	Maintain or increase regional/local employment in the fishery and related industries (Fletcher, 2010)
	Increase the overall abundance of spawning herring to 19,380 tons by 2020 (Puget Sound Partnership website: http://www.psp.wa.gov/)

The boxes in this chapter provide a mix of hypothetical and real examples of how steps of the FEP Loop might be carried out. These are meant as illustrations of the scope of FEPs, the types of issues that might be addressed, and how the FEP Loop leads to EBFM.

EXAMPLE BOX 1: VISIONING AND STRATEGIC OBJECTIVES

The North Pacific Fishery Management Council (NPFMC) report "Ecosystem Based Fishery Management (EBFM) development process and actions, May 2014" illustrates both vision statements and strategic objectives:

> *The Council envisions sustainable fisheries that provide benefits for harvesters, processors, recreational and subsistence users, and fishing communities, which (1) are maintained by healthy, productive, biodiverse, resilient marine ecosystems that support a range of services; (2) support robust populations of marine species at all trophic levels, including marine mammals and seabirds; and (3) are managed using a precautionary, transparent, and inclusive process that allows for analyses of tradeoffs, accounts for changing conditions, and mitigates threats.*

The first portion of this statement "*The Council envisions sustainable fisheries that provide benefits for harvesters, processors, recreational and subsistence users, and fishing communities*" is the vision statement – the enduring, fundamental, ambitious sense of purpose that is pursued over many years.

The rest of this statement describes the strategic objectives, the high-level statements that indicate what is to be attained. They are *(1) maintain healthy, productive, biodiverse, resilient marine ecosystems that support a range of services; (2) support robust populations of marine species at all trophic levels, including marine mammals and seabirds; and (3) manage using a precautionary, transparent, and inclusive process that allows for analyses of tradeoffs, accounts for changing conditions, and mitigates threats.*

EXAMPLE BOX 2: PRIORITIZATION

Prioritization involves considering all potential issues and threats to the fishery system, and judges the risk each poses to the strategic objectives. This process asks, "What is the extent and likelihood that each of the issues would prevent fishery management goals (these are the strategic objectives) from being met?" and "What is the likely effectiveness of management intervention?"

The Aleutian Islands FEP provides an example of a qualitative risk assessment of potential systemic issues (NPFMC, 2007), which partially illustrates this step. The potential issues were divided into five categories: climate and physical interactions, predator-prey interactions, fishing effects interactions, regulatory interactions, and other socio-economic activity interactions. Each issue was given three scores based on the probability of it occurring, the impact it would have on the biophysical system (ecosystem impact), and the human system (economic impact) (NPFMC, 2007). Scores were assigned as high, medium, low, or unknown.

In Table 3.3, we show the category for potential impacts from fisheries, to illustrate scoring.

Continued on next page

Table 3.3

PROBABILITY AND IMPACT OF FISHING EFFECTS FROM ALEUTIAN ISLANDS FEP

	PROBABILITY	ECOSYSTEM IMPACT	ECONOMIC IMPACT
Total removals from the ecosystem due to fishing impact ecosystem productivity	Medium	High	High
Differences between spatial stock structure and the spatial scale of fishery management may affect managed species	Medium	High	High
Impact of one fishery on another through fishing impacts on habitat	Medium	Medium	Medium
Impact of a fishery on other biota through fishing impacts on habitat	Unknown	Unknown	Low
Impact of bycatch on fisheries	High	Medium	Medium
Commercial fisheries may affect subsistence uses	Medium	Low	Medium

Source: NPFMC (2007)

This assessment did not *score* issues on the potential effectiveness of management response, but it did provide a narrative summary of potential consequences of management for each issue. It also characterized what the Council was already doing to address the issue and what opportunities (strategies) existed to mitigate the risk. This type of information could inform the management response scores that our process calls for. (See Implementation Volume.)

In the FEP Loop, this information will then be used to identify a subset of issues that score high on probability of occurring, severity of impact, and effectiveness of intervention. These high-scoring issues are good candidates for management action.

Step 3: “How will we get there?”

In this step, FEP developers will prepare to operationalize the plan by considering performance measures and potential management actions. Suggested actions include:

- **Develop performance measures:** Performance measures are the metrics describing the fishery system and desired (or avoided) levels for each. They relate directly to the measurable quantities described in the operational objectives as a way to gauge performance and progress towards those objectives.
- **Identify potential management strategies:** Managers and stakeholders should create a thorough list of possible actions and formulate them into alternative management strategies. A management strategy comprises multiple coordinated actions designed to reach the operational objective. It should also specify predetermined management actions that are triggered in response to performance measures. The goal of this stage of the FEP development process is to identify multiple candidate-management strategies, whose likely performance can then be evaluated. The development of management strategies in an EBFM context is enhanced through the explicit consideration of linkages among system components.
- **Evaluate consequences of alternative management actions:** Predict the likely outcomes for each performance measure under each alternative management strategy and judge the sensitivity to key uncertainties. This step screens out poorly performing management strategies, identifies approaches that are robust to various types of uncertainty, and reveals the trade-offs from selecting one strategy over another. A range of tools exists to give effect to this step, including management strategy evaluation and cost benefit analysis. (See Implementation Volume.)
- **Select management strategy:** Managers determine how this step should be carried out, including how to incorporate stakeholder input from across the process.

Strategies should be adaptive, responding to changes in the fishery system. Monitoring and evaluation are therefore critical. (See Example Boxes 3 and 4.)

EXAMPLE BOX 3: BIOLOGICAL REFERENCE POINTS AS PERFORMANCE MEASURES

This box illustrates step 3 of the FEP Loop using the hypothetical example of a fishery system that experts suspect has undergone an environmental regime shift. We posit a fishery that targets several species whose productivity and abundance have been low for several years. It is unclear whether this is due to poor environmental conditions caused by a regime shift or to fishing. Consequently, there is debate over whether the performance measures currently used to judge stock status accurately reflect the health of the stock. These biological reference points are the biomass and fishing mortality rate that produce maximum sustainable yield.

The Council seeks to develop a robust process that uses environmental information to revise/modify biological reference points to account for the possibility of regime shifts. The key concerns

Continued on next page

are failing to detect a regime shift and thereby incorrectly declaring stocks to be in poor status, and erroneously detecting a regime shift and thereby incorrectly declaring stocks to be in good status relative to their reference points.

The Council selects the following performance metrics to judge management success: probability of overfishing, probability of underfishing, precision in estimates of biological reference points, the frequency of stock assessment, cost of management, probability of recruitment impairment, long-term average catch, long-term average landed value, and frequency of fishery closures.

In addition to these conventional fisheries management indicators, systemic indicators consider indirect effects from policies. For instance, low catch quotas that result from incorrectly estimating low stock status (e.g., by triggering a rebuilding plan) might prompt fishermen to switch to different target species and use gears that potentially damage sensitive benthic habitats. Or it may prompt them to fish in areas with higher encounters with threatened, endangered, or protected species to avoid catching stocks erroneously deemed to be overfished. So additional performance metrics might include intensity of fishing on vulnerable habitat and number of interactions with threatened, endangered, or protected species, or other possible outcomes caused by fleet behavior.

These metrics are translated into performance measures by specifying either target levels, levels to be avoided, or desired directions of change for each.

Consultation with stakeholders, scientists, and Council staff produces the following alternatives (ordered from most static to most dynamic):

- Status quo. Biological reference points (including overfished threshold) are static and represent a long-term average.
- Perform expert review of stock assessments whenever a set percentage of stocks are substantially above or below biological reference points, to evaluate whether any biological reference points should be adjusted.
- Adopt a standard-of-evidence approach (as in Klaer et al. [2015]) for identifying regime shifts and adjusting biological reference points.
- Adopt a moving window approach. Biological reference points are based on growth, mortality, and recruitment patterns over most recent time periods (Punt et al., 2014).
- Adopt a dynamic approach. Unfished biomass and other biological reference points are based on very near-term conditions (e.g., what would biomass be this year if there had been no fishing of extant cohorts) (MacCall et al., 1985).
- Apply forward-looking biological reference points that predict changes in stock size by anticipating growth, mortality, and recruitment based on biophysical conditions.

The alternatives could be tested in a number of ways. A qualitative review would identify strengths and vulnerabilities for each approach. Expert opinion could be used to score performance measures (e.g., asking experts whether performance metrics are highly likely, likely, unlikely, or highly unlikely) to reach targets. Simulation models could be used to evaluate performance under a variety of scenarios (e.g., different types of stocks, different data availabilities, different intensities of regime shifts, the degree to which low biomass stocks can be avoided by fishing gear).

EXAMPLE BOX 4: CONSTRAINING STOCKS AND INCIDENTAL TAKE IN A MIXED-SPECIES FISHERY

This box illustrates step 3 of the FEP Loop using the hypothetical example of a fishery that targets several groundfish stocks, some of which are below their biomass limit reference point and therefore need rebuilding. Challenges in rebuilding include bycatch and rapidly increasing abundance of predators of the overfished species. Low quota of overfished species severely constrains fishing opportunities for the fleet. Further, these costs are not spread equally, as overfished species are associated with habitats that are clustered near specific fishing ports. Finally, participants in this fishery are switching to other, state-regulated fisheries and are not catching their quota for groundfish stocks, thereby diminishing economic returns for processors.

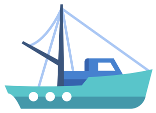
The Council has prioritized this complex issue for attention in an FEP. The problem has multiple dimensions: food web linkages, incidental catch, potential technical and economic solutions, and economic and social consequences that have ripple effects. An operational objective might be to institute a set of management measures as part of a comprehensive strategy that will allow overfished species to recover within Magnuson-Stevens Act-mandated time frames while improving economic performance of the fleet and associated industries.

Through engagement with stakeholders and policymakers, the following alternative policies are proposed:

- status quo; maintain recovery plan through conventional management (low catch quotas for overfished stocks);
- spatial management; establish spatial protections for overfished stocks;
- apply a multiyear quota system, so that annual quota overages do not shut down the fishery;
- develop and encourage gear programs that provide incentives that can selectively harvest predator species and reduce bycatch of overfished species (e.g., risk pools); and
- mitigate effects on affected fishing communities by granting them access to other fisheries (noting that this would result in reduced allocation to existing participants in these other fisheries).

The outcomes of alternative policies, expressed specifically through performance measures, are evaluated through qualitative or quantitative means. Qualitative analysis might involve structured workshops, qualitative modeling, leading to scoring or ranking of outcomes for each performance indicator across each alternative policy. Quantitative analysis would involve statistical modeling, systems modeling, economic modeling to simulate outcomes. All of these would involve close collaboration among policymakers, scientists, and stakeholders.

In some cases, this evaluation might reveal that unique combinations of policy measures are needed. For example, spatial protection might be deemed ineffective because predator abundance would increase in these areas. Thus, a mixture of spatial protections and selective predator harvest is needed. This evaluation might also identify win-win solutions, such as promoting catches in a piscivore fishery to improve economic performance and enhance rebuilding of overfished stocks. At a minimum, the evaluation will identify strategies that generally perform better than others while also identifying trade-offs.



Step 4: "Implement the plan"

Next, Councils will need to implement the FEP. The implementation of the FEP transforms all the work described above into accomplishments through tangible work projects. This includes development of a formal FEP work plan that describes each project, including but not limited to the following details:

- **work plan:** the actual work to be performed, who will perform it, and how regulatory changes in FMPs, if necessary, will be made;
- **resources:** the resources needed, including funding, staff time, and time commitments by stakeholders and partners;
- **outputs:** the outputs, including the form and level of detail needed to inform subsequent decisions; and
- **timeline.**

Step 5: "Did we make it?"

After implementation, it is critical to assess the performance of the FEP. Ongoing monitoring and evaluation of performance measures and management strategies is an integral part of the FEP process. In particular, FEP evaluation will:

- assess the status of the fishery system to determine whether management strategies are meeting their goals (performance measures); and
- determine if unanticipated outcomes or trade-offs have occurred since implementation of the management strategy (vital sign indicators).

Planning for monitoring and evaluation is critical and thereby is a part of all steps of the FEP process. Monitoring and policy evaluation considerations are a key part of indicator selection, selecting performance measures, and designing management strategies that seek to enhance knowledge of the fishery system.

REPEATING THE STEPS: LEARN AND ADJUST

Adaptive management is critical for EBFM. Systematic learning from management experiences is how we gain better understanding of fishery systems. For example, when we implement catch shares, we learn about incentives that drive fleet behavior and how these behaviors feed back to impact ecosystem indicators (Hilborn et al., 2005; Grafton et al., 2006). When we protect habitats from potentially destructive fishing practices, we reveal how fishing practices affect benthic habitats (Lambert et al., 2014). When we create no-take fishery reserves, we learn about productivity of stocks, their levels of depletion, their dispersal, and in some cases the food web connections (Sainsbury, 1993; Russ et al., 2004; Kellner et al., 2010; Wilson et al., 2014). The FEP therefore needs to include a plan for how information gained in monitoring will be used in subsequent iterations to improve policies and lead to better outcomes.

MANAGEMENT STRATEGIES SHOULD SPECIFY PREDETERMINED ACTIONS THAT ARE TRIGGERED IN RESPONSE TO PERFORMANCE MEASURES.

Oil rig in the ocean (left). Silhouette of a fisherman in action (top right). NOAA Fisheries survey ship underway (bottom right).

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CHAPTER 4

KEY CONSIDERATIONS FOR THE FEP LOOP

Chapter 3 proposes an adaptive planning cycle for ecosystem-based fisheries management (EBFM). This "FEP Loop" is purposefully not prescriptive so that implementation can be customized to regional needs and constraints. The process will undoubtedly be conducted in different ways by different Regional Fishery Management Councils, and the Implementation Volume provides detailed guidance on technical tools available to implement the loop. (available at www.lenfestocean.org/EBFM)

This chapter focuses on three broad observations the Task Force believes should guide the creation and implementation of Fishery Ecosystem Plans (FEPs): (1) existing tools and processes are sufficient to develop FEPs and implement EBFM, (2) stakeholder input is critical and should be central to fishery system planning, and (3) managers must rely on both science and societal value judgments in setting explicit, measurable goals, identifying alternative strategies, and choosing among them.

A pelican dries its feathers while a shrimp boat trawls in the background (left). A school of herring, a forage fish (center). People fishing in the surf (right).

EXISTING TOOLS AND PROCESSES ARE SUFFICIENT TO DEVELOP NEXT-GENERATION FEPS AND IMPLEMENT EBFM

Achieving EBFM through FEPs will involve using and adapting existing scientific tools and policy instruments. This section reviews these two categories.

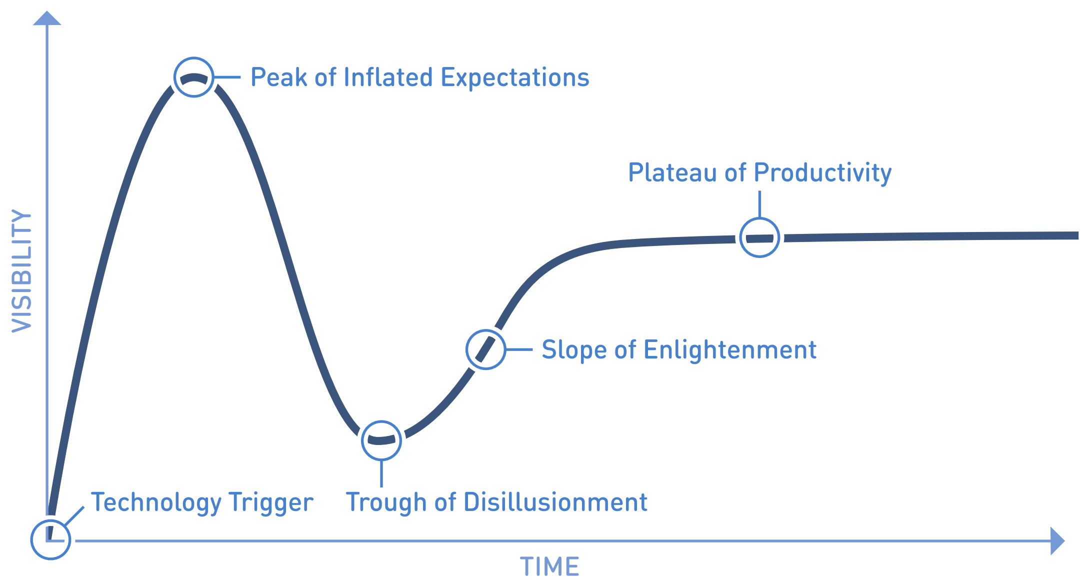
Science Tools

Our review of EBFM activity in selected case studies (Chapter 5) and in our in-depth overview of tools for FEP steps (Implementation Volume) reveal that existing scientific tools are already being used and applied for all parts of the FEP process. These tools cover a broad range of qualitative, semi-quantitative, and quantitative methods and span socio-cultural, economic, and ecological dimensions of fisheries. We therefore conclude, as have others, that scientific tools exist to support the FEP process at many levels of information availability and technical capacity (Smith et al., 2007; FAO, 2009; Lester et al., 2010; Patrick and Link, 2015). This finding opposes the common objection that we lack the ability to provide a technical basis for EBFM. Available science tools span a range of information needs and scientific capacity, meaning that Councils can choose the tools that are the most appropriate given their access to technical experts and data availability. FEPs do not necessarily require large, complex systems models.

This view that science is limiting arises partly from a tendency to hold EBFM science tools to the same technical standards as those used today in conventional fisheries management. These technical standards are unrealistic and inappropriate, in part because EBFM tools are new in comparison to conventional fisheries tools such as stock assessments. In the case of single-species tools, years of experience and development of stock assessment methods have led to a highly standardized process of application, evaluation, and interpretation. Prior to arriving at this point, these tools followed the "hype cycle" (Figure 4.1). With many EBFM tools, we are only somewhere near the peak in the first cycle of technology adoption. Thus, as these tools are used, disappointment and tension should not be viewed as failure of EBFM but as normal, healthy development and adoption, just as single-species tools developed and were adopted. Moreover, it is important to note that single-species tools were used for many years before the performance of the models was fully understood, and managers did not wait to use them until they reached present-day capabilities.

Figure 4.1

THE HYPE CYCLE



The Hype Cycle is a branded graphical presentation developed and used by American Information Technology (IT) research and advisory firm Gartner Inc. for representing the maturity, adoption, and social application of specific technologies. The Hype Cycle provides a graphical and conceptual presentation of the maturity of emerging technologies through five phases.

Source: Gartner's Research Hype Cycle: https://commons.wikimedia.org/wiki/File:Gartner_Hype_Cycle.svg by Jeremy Kemp, used with permission under Creative Commons license BY-SA 3.0: https://creativecommons.org/licenses/by-sa/3.0/deed.en

In addition, EBFM tools should be applied early in any process of assessment or analysis and not delayed until all of the data and information deemed necessary are available. There is a misconception about EBFM tools, and modeling tools in general, that they should be the last step in analyses and should not be attempted with incomplete or imperfect information (Starfield, 1997). EBFM tool development, like most analyses, is best done iteratively, with the initial attempts made early on to identify critical unknowns so that subsequent applications become increasingly robust and relevant to management. Often the model will identify a different set of critical information needs than conventional wisdom or intuition would suggest (Walters, 1986).

Because tools to support EBFM are diverse, the translation of best practices into standards will be different for each type of tool. Clearly articulating best practices that apply to all tools is therefore critical. For instance, it is reasonable to expect that the properties and behaviors of each type of tool are well-understood and vetted in some capacity by decision-makers (Kaplan and Marshall, 2016). In addition, the broad nature of EBFM tools often means that scientists, stakeholders, managers, and decision-makers need to work collaboratively to ensure that science considers key system feedbacks and appropriately addresses the policy issue at hand (Fulton et al., 2013).

Policy Instruments

We expect FEPs to use novel mixtures of existing policy instruments. Councils have already been testing these policy instruments in conventional management settings, and we contend that thoughtfully designed portfolios of these policies can also achieve FEP goals. That is not to say that the current applications of these instruments are always consistent with an EBFM approach or that there is nothing new in the implementation of EBFM. Rather, these instruments have mostly been designed under current objectives, and a new design might be more appropriate under EBFM. These instruments include harvest control rules, community development quotas, catch shares, time and space management, bycatch quotas, risk pools, and quota baskets.

We describe two real-world examples to illustrate the following points regarding the modification of existing policy instruments for EBFM:

- ecosystem-based management strategies often consist of conventional fisheries policy instruments, modified to achieve management objectives for the fishery system; and
- modifications to policy instruments can be based on simple calculations rather than complex models.

In the first example, from the Barents Sea, capelin is an important commercially fished species, as well as a key prey species for cod, seabirds, and pinnipeds. Capelin undergo wide fluctuations in population productivity based on environmental conditions and predator abundances (Hjermann et al., 2004; Hjermann et al., 2010). The Joint Norwegian-Russian Fishery Commission, which overseas fisheries management in this region, has dual objectives of sustaining capelin fisheries while conserving adequate prey for predators. To meet the objectives, a strategy was chosen using the conventional idea of a harvest control rule, but modified based on the idea that management should minimize the risk of capelin recruitment failure. To this end, a harvest control rule was modified, wherein annual catches are set such that there is a 95 percent probability of maintaining the capelin spawning stock biomass above a limit reference point of 200,000 metric tons (mt), after accounting for estimated predation removals by the cod population. The limit reference point was selected by identifying the smallest spawning biomass in the capelin data set that had produced a strong recruitment event (100,000 mt), which was then doubled to account for assessment uncertainty (ICES, 2014).

THOUGHTFULLY DESIGNED PORTFOLIOS OF EXISTING POLICY INSTRUMENTS CAN ACHIEVE FEP GOALS.

In the second example, from the Bering Sea-Aleutian Islands ecosystem of Alaska, fisheries catch numerous groundfish species, principally highly valued walleye pollock, Pacific cod, sablefish, and several flatfish species. The North Pacific Fisheries Management Council (NPFMC) set an ecosystem strategic objective to "assure the continued health of the target species themselves and to mitigate the impact of commercial groundfish operations on other elements of the natural environment." An operational objective was to avoid significant and adverse changes to the productivity of the Bering Sea and Aleutian Islands fisheries (NPFMC, 2015). To achieve this objective, the NPFMC modified a conventional single-species catch cap to instead limit combined landings of all groundfish at 2 million mt annually. This reference point was based on the notion that productivity levels of the groundfish species are interdependent. However, quantifying those dependencies is challenging, and existing science tools were not capable of reliably estimating multispecies maximum sustainable yield (MSY). The Council therefore took a simple approach of setting a cap on yields that was within the range of MSY levels summed over all stocks, reduced to account for uncertainty and to make MSY levels closer to optimum yield. The 2 million mt cap has been triggered multiple times since the policy was implemented. Consequently, exploitation rates are commonly less than MSY.

STAKEHOLDER INPUT IS CENTRAL TO FISHERY SYSTEM PLANNING

We envision that stakeholders will contribute to next-generation FEPs in a number of ways (Gray and Hatchard, 2008). They provide important knowledge of biophysical systems, socio-cultural systems, and technical (gear) aspects of fisheries. This information is critical for describing a system and identifying alternative management strategies. Further, stakeholder participation is necessary to understand and account for their values, needs, and desires for the fishery system. This information is critical for setting objectives, performance indicators, and reference levels. Finally, stakeholder participation can help build a sense of ownership and trust in the FEP process.

The Task Force recognizes that effective stakeholder participation can be challenging to achieve. One main challenge is ensuring appropriate representation. Generally, if the cost of participation is high, groups with greater financial resources will be disproportionately represented (Osborn et al., 2000; Berinsky, 2004). Participation costs can be substantial – travel costs and time commitment can dissuade many stakeholders. While such costs cannot be eliminated, they can be reduced by careful planning, selection of appropriate participation tools, and efficient conduct of meetings. The rotation of meeting locations by Councils already is an important step. An additional challenge is that effective participation requires a degree of trust among stakeholders. Well-trained facilitators are generally needed, particularly for the more contentious steps (Gregory et al., 2012). Shared construction of qualitative fishery system models can be an effective way of building trust and shared understanding among diverse stakeholders.

MANAGERS MUST RELY ON BOTH SCIENCE AND SOCIETAL VALUE JUDGMENTS IN SETTING EXPLICIT, MEASURABLE GOALS, IDENTIFYING ALTERNATIVE STRATEGIES, AND CHOOSING AMONG THEM

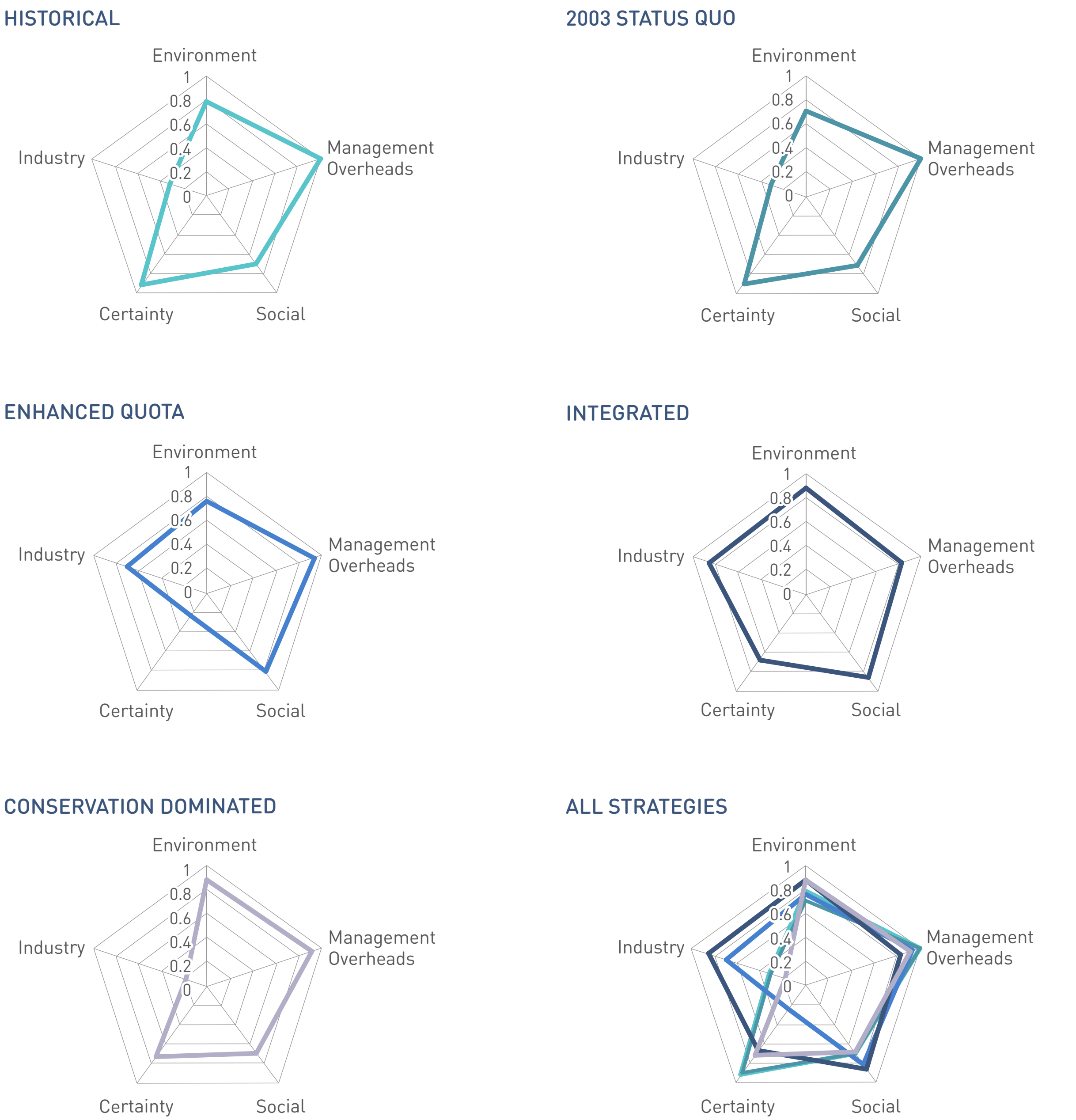
Both scientific analysis and societal values contribute to the FEP process. Science can inform decisions, but answering questions such as "what is important to us," "what are desired states of fishery systems," and "what is the best choice given trade-offs" requires value judgments. We emphasize this point because unrealistic expectations for science can lead to delays in taking action in hopes that additional scientific study will simplify decision-making.

This concept is not unique to EBFM. In fact, conventional fisheries management already embeds values in the choice of stock population targets and limits. Biomass target levels (e.g., $B_{MSY,}$ B_{MEY}) for fisheries are informed by scientific principles, but the levels that fisheries should use are based upon societal values and goals. Similarly, the choice of biomass limits defining overfished (in the U.S., half of B_{MSY} levels) is informed by science (the risk of recruitment impairment), yet science does not determine the level of acceptable risk. We expect progress on EBFM despite limits of scientific guidance, much in the same way that conventional management has progressed.

We illustrate the interplay between science and values to inform EBFM decisions using a recent example from southeastern Australia (Fulton et al., 2014). Like most fishery systems, the southern and eastern scalefish and shark fishery in Australia is complex, with many distinct stakeholders, legal mandates, and objectives. Beginning in the early 2000s, poor economic performance and deteriorating ecological status prompted managers to engage stakeholders and scientists to identify management objectives, select performance measures, and identify alterative management strategies. Technical science staff used this information to establish modeling experiments to predict how performance measures would likely respond to each strategy and then summarized the findings to reveal the trade-offs among strategies tested (Figure 4.2). A key finding was that no single strategy outperformed all others on each performance measure. Rather, there were trade-offs that could not be completely eliminated via additional scientific study or strategy evaluation. Thus, decision-making required the judgment of policymakers, who selected the "integrated" strategy because it demonstrated the best balance across management objectives.

Figure 4.2

PREDICTED OUTCOMES FOR 5 ALTERNATIVE STRATEGY SCENARIOS IN AUSTRALIA



A score of 1 indicates good performance, 0 indicates poor performance. No strategy outperformed others across every management dimension, and no strategy can clearly be removed from consideration.

Source: From Fulton et al., 2014

CLOSING COMMENTS

This chapter highlighted important concepts for operationalizing EBFM through next-generation FEPs. These concepts are key because they each span nearly all of the steps of the FEP Loop. Application of FEPs will require attention to many additional considerations that apply to individual steps in the planning process. Detailed guidance on individual steps is provided in the Implementation Volume. (Access at www.lenfestocean.org/EBFM)

Trawlers in a harbor, Perth, Australia.

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CHAPTER 5

CAPACITY TO DEVELOP NEXT-GENERATION FEPS: AN EVALUATION OF CASE STUDIES

Chapter 3 provides a structured process for translating the principles of ecosystem-based fisheries management (EBFM) into action. This chapter examines case studies in the U.S. and abroad to highlight where the steps in this process have been implemented. These case studies suggest that U.S. Regional Fishery Management Councils and similar bodies already have the tools and capacity to develop next-generation Fishery Ecosystem Plans (FEPs) using current management structures and resources.

CASE STUDIES AND APPROACHES

We compiled case studies based on the extensive expertise, knowledge, and geographic scope of the Lenfest Fishery Ecosystem Task Force members. The U.S. case studies span a wide geographic range, with examples from Canada, Europe, and Australia providing additional coverage (Figure 5.1). This was not intended to be a comprehensive review but to provide examples of activities already occurring that fit with our proposed "FEP Loop" process to illustrate the capacity to develop next-generation FEPs.

Figure 5.1

MAP OF CASE STUDIES AND THE MAIN TOPICS COVERED

To compile the case studies, the Task Force gathered information to answer two questions: "what is the major fishery system issue relevant to management?" and "what actions have occurred to address that issue (if any)?" Table 5.1 summarizes the actions in our next-generation FEP framework that have been taken for each case study. Table 5.2 gives details on the management activity that fits each step. For the U.S., we focused on steps taken by the Councils and by one other authority, the Atlantic States Marine Fisheries Commission (ASMFC). We also considered NOAA work presented to or intended for Council use, such as integrated ecosystem assessments (IEAs) and the Chesapeake Bay FEP. For international case studies, we focused on actions taken by Canada's Department of Fisheries and Oceans (DFO); the European Commission and the International Council for the Exploration of the Sea (ICES), which provides scientific advice to the Commission; and the Australian Fisheries Management Authority (AFMA). Every region described has additional EBFM actions underway, but we did not include these, either because they are not complete or are not as illustrative of our FEP framework. Appendix C provides full descriptions of each case study (see www.lenfestocean.org/EBFM). The remainder of this chapter presents the overall findings and key lessons from the case studies.

Man and child going fishing on a dock with crab trap (top). Popular local fish market in Ketchikan, Alaska (bottom left). Close-up of a lobster swimming underwater (bottom right).

Table 5.1

RESULTS OF THE 10 CASE STUDIES

This table shows 10 case studies of management bodies that have undertaken EBFM (see report for full details). A checkmark indicates that parts of the FEP Loop have been developed for one or more species. This illustrates that the process is feasible using existing tools. However, most of these actions did not take place within the systematic framework of an FEP and therefore did not realize the main advantages of EBFM.

STEPS	NEW ENGLAND GROUNDFISH	MID-ATLANTIC BUTTERFISH	ATLANTIC MENHADEN	GULF OF MEXICO GAG GROUPER	PACIFIC SARDINES	PACIFIC WHALES AND SALMON	ALASKA GROUNDFISH	WESTERN SCOTIAN SHELF FISH AND INVERTEBRATES	BALTIC COD, HERRING, AND SPRAT	AUSTRALIAN SMALL PELAGICS
1. WHERE ARE WE NOW?										
System inventory and conceptual model	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Select indicators		✓		✓	✓	✓	✓	✓	✓	
Inventory threats							✓			
2. WHERE ARE WE GOING?										
Vision statement		✓	✓				✓	✓	✓	
Strategic objectives	✓	✓	✓		✓	✓	✓	✓	✓	
Assess risk to objectives						✓	✓			✓
Prioritize objectives										
Operational objectives	✓						✓			✓
3. HOW WILL WE GET THERE?										
Performance measures	✓				✓		✓			✓
Management strategies	✓				✓	✓	✓			✓
Evaluate strategies	✓				✓	✓	✓			✓
Select strategy	*	✓	✓	✓	✓	✓	✓		✓	✓
4. IMPLEMENTATION		✓	✓	✓	✓		✓		✓	✓
5. DID WE MAKE IT?					✓					

* Management alternatives have been voted on by the Council but not adopted.

Table 5.2

CASE STUDY SUMMARIES

CASE STUDY	SUMMARY OF ACTIONS THAT MATCH THE NEXT-GENERATION FEP PROCESS
NEW ENGLAND GROUNDFISH HABITAT	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The NOAA Northeast Fisheries Science Center reviewed the status and trends of the Northeast region (including New England) in the Ecosystem Status Report of the Northeast Shelf Large Marine Ecosystem (Ecosystem Assessment Program, 2012). This report covers a broad range of topics (as with most step 1 actions) and includes indicators such as zooplankton size index, ratio of pelagic to demersal fish biomass, coral distributions, and fisheries revenue. **Step 2.2, strategic objectives:** The New England Fishery Management Council adopted an objective from the essential fish habitat (EFH) mandate in the Magnuson-Stevens Act: "minimize to the extent practicable adverse effects on such habitat caused by fishing, and identify other actions to encourage the conservation and enhancement of such habitat" (Grabowski et al., 2014; Magnuson-Stevens Fishery Conservation and Management Act, 2007). **Step 2.5, operational objectives:** The Fishery Management Plan (FMP) for this fishery includes objectives related to groundfish habitat, such as identifying seasonal closed areas to reduce impacts on spawning. **Step 3.1, 3.2, 3.3, performance measures, identify and evaluate management strategies:** A Closed Area Technical Team (appointed by the Council) identified alternative spatial management strategies. The team then evaluated the strategies based on performance indicators, such as overlap with existing EFH, unique habitat features, and species diversity indices within the areas proposed for protection. **Step 3.4, select strategy:** In June 2015, the Council adopted multiple new and revised closed areas. As of August 2016, the amendment document and accompanying environmental impact statement are undergoing final review by NOAA Fisheries.
MID-ATLANTIC BUTTERFISH	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The Council initiated an EAFM Guidance Document in 2011 (Mid-Atlantic Fishery Management Council [MAFMC], 2015). The first draft (April 2016) has an inventory that includes forage fish, climate, and trends in indicators such as temperature and landings. The draft also has a conceptual model of habitat interactions in the mid-Atlantic. **Step 2.1 & 2.2, vision and strategic objectives:** The MAFMC Strategic Plan (MAFMC, 2013) vision statement is: "Healthy and productive marine ecosystems supporting thriving, sustainable marine fisheries that provide the greatest overall benefit to stakeholders." One strategic objective from the plan is: "Develop management approaches that minimize adverse ecosystem impacts." **Step 3.4, select strategy:** The Council adopted a strategy to improve the stock assessment for butterfish using an ecosystem approach. It involved using a thermal niche model to determine annual estimates of availability of butterfish to the trawl survey. In the end, a constant availability (from the model) was used and directly incorporated into the 2014 assessment (Adams et al., 2015). This improved the assessment and led to updating butterfish reference points.

CASE STUDY	SUMMARY OF ACTIONS THAT MATCH THE NEXT-GENERATION FEP PROCESS
ATLANTIC MENHADEN	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The Chesapeake Bay FEP includes information on Atlantic menhaden, food web interactions, habitat, patterns of total removal, externalities, and economic and social dimensions (Chesapeake Bay Fisheries Ecosystems Advisory Panel, 2006). The FEP also includes a section on indicators of ecosystem health and biological reference points, including an index of ecosystem integrity and multispecies habitat suitability indices. Finally, the FEP includes conceptual models of food webs and habitat webs (diagrams linking fisheries, the ecosystem, and habitat management). **Step 2.1 & 2.2, vision and strategic objectives:** From ASMFC (2012): "The goal of Amendment 2 is to manage the Atlantic menhaden fishery in a manner that is biologically, economically, socially and ecologically sound, while protecting the resource and those who benefit from it." In addition, a "fundamental" objective from the recent ASMFC memorandum is to "Sustain menhaden to provide for predators." To that end, ASMFC is developing ecosystem-based reference points for Atlantic menhaden that will serve to ensure adequate menhaden numbers as forage while allowing a sustainable fishery. **Step 3.4, select strategy:** The ASMFC selected strategies to both improve Atlantic menhaden assessment and protect feeding opportunities of predators within the Chesapeake Bay. Menhaden stock assessments use information on predator consumption of menhaden to better estimate mortality rates and update reference points for menhaden. In the Chesapeake Bay, menhaden catch was capped at 87,200 (mt) (SouthEast Data, Assessment, and Review [SEDAR], 2015) to reduce the probability of localized depletion.
GULF OF MEXICO GAG GROUPER AND RED TIDE	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The Ecosystem Status Report for the Gulf of Mexico (Karnauska et al., 2013) inventories and presents status and trends for individual species, fisheries, and environmental components, such as red tides. A "driver, pressure, state, impact, and response" conceptual model was used to select indicators (Kelble et al., 2013). **Step 3.4, select strategy:** The Gulf of Mexico Fishery Management Council selected a strategy to improve the gag grouper stock assessment by including the large mortality caused by a red tide in 2005 (SEDAR, 2014). This resulted in updated reference points used in existing harvest management strategies.

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CASE STUDY	SUMMARY OF ACTIONS THAT MATCH THE NEXT-GENERATION FEP PROCESS
PACIFIC SARDINES AND TEMPERATURE	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The Pacific Fishery Management Council's (PFMC) Pacific Coast FEP summarizes information on the ecosystem and includes information on Pacific sardines and the relationship with sea surface temperature (PFMC, 2013a). The IEA for the California Current includes a conceptual model of the integrated socio-ecological system, as well as status and trends indicators of forage availability, sea lion pup counts, and seabird at-sea densities (Levin et al., 2013; NOAA's California Current region website). **Step 2.2, strategic objectives:** One objective for the coastal pelagic species FMP (which includes sardines) is to "Provide adequate forage for dependent predators" (PFMC, 2013a). **Step 3, "How will we get there":** The Council convened a workshop to determine new potential management strategies (PFMC, 2013b). Hurtado-Ferro and Punt (2014) performed a management strategy evaluation using an age-structured population model and evaluated strategies based on performance criteria such as variance of catch, mean catch, and spawning stock biomass. The resulting harvest control rule included the use of a new temperature index and a fishery closure when biomass is below 150,000 metric tons (mt). **Step 5:** The sardine stock assessment calls for continued monitoring of the relationship between temperature and sardine productivity.
INTERACTING PROTECTED SPECIES – PACIFIC KILLER WHALES AND CHINOOK SALMON	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The Pacific Coast FEP summarizes information on the entire California Current ecosystem, including salmon in the diet of killer whales (PFMC, 2013a). The IEA for the California Current has a conceptual model (see sardine case study) and includes status and trend indicators of salmon abundance and condition, climate drivers such as El Niño-Southern Oscillation, and sea lion pup counts (Levin et al., 2013). **Step 2.2, strategic objectives:** Objectives stemming from the killer whale recovery plan (mandated by the Endangered Species Act) include: "Ensure adequate habitat to support a recovered population of Southern Resident killer whales. Habitat needs include sufficient quantity, quality, and accessibility of prey species" (NOAA Fisheries, 2008). **Step 2.3, risk assessment:** One study assessed risks to killer whales from salmon fisheries (in Hilborn et al., 2012) but did not link them to an explicit objective. **Step 3.3 & 3.4:** Hilborn et al. (2012) conducted an evaluation of the management strategy to close ocean chinook salmon fisheries. They concluded that complete cessation of fishing would increase chinook abundance by a maximum of 25% and that the effects would be difficult to predict but unlikely to translate to increased prey for killer whales, so the Council chose the status quo strategy.

CASE STUDY	SUMMARY OF ACTIONS THAT MATCH THE NEXT-GENERATION FEP PROCESS
ALASKA GROUNDFISH AND AVOIDING ECOSYSTEM OVERFISHING	**Steps 1a & 1b, system inventory/conceptual model, select indicators:** The Ecosystem Considerations Report for the Alaska Regions (North Pacific Fisheries Management Council [NPFMC], 2015a) and Aleutian Islands FEP (NPFMC, 2007) contain thorough inventories with status and trends of indicators such as the Pacific Decadal Oscillation, sea ice extent, catch per unit effort of structural epifauna, diatom abundance anomalies, and groundfish mortality rate. **Step 1.3, inventory threats:** The Aleutian Islands FEP provides a qualitative inventory of threats or risks for the whole ecosystem, including risks of ocean acidification, coastal development, and impacts of fisheries on other biota (see Chapter 3, Example Box 2). **Steps 2.1 & 2.2, vision and strategic objectives:** The Council's vision statement is: "The Council envisions sustainable fisheries that provide benefits for harvesters, processors, recreational and subsistence users, and fishing communities, which (1) are maintained by healthy, productive, biodiverse, resilient marine ecosystems that support a range of services; (2) support robust populations of marine species at all trophic levels, including marine mammals and seabirds; and (3) are managed using a precautionary, transparent, and inclusive process that allows for analyses of tradeoffs, accounts for changing conditions, and mitigates threats" (NPFMC, 2014). The groundfish FMP (NPFMC, 2015b) for the Bering Sea/Aleutian Islands has multiple ecosystem strategic objectives, including "Preserve food web." **Step 2.3 & 2.5, assess risk to strategic objectives and develop operational objectives:** The Alaska Groundfish Programmatic Supplemental Environmental Impact Statement (PSEIS) (NOAA Fisheries, 2004) assesses risk for all objectives. Within the PSEIS and groundfish FMP are specific operational objectives, including "Maintain or adjust current protection measures as appropriate to avoid jeopardy of extinction or adverse modification of critical habitat for ESA-listed Steller sea lions." **Step 3, "How will we get there":** In 2004, the PSEIS reanalyzed management alternatives. Based on performance measures in the PSEIS for various ecosystem metrics (and implied desired directions for metrics), the Council selected the strategy of a systemwide cap of 2 million mt on groundfish catch (NPFMC, 2015b). This cap has been triggered in multiple years, leading to reductions in catch limits, and exploitation rates are thereby commonly less than single-species maximum sustainable yield for most species.
WESTERN SCOTIAN SHELF FISH AND INVERTEBRATE FISHERIES	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** The State of the Ocean Report for the Scotian Shelf, as well as the Ecosystem Status and Trends Report for the Gulf of Maine and Scotian Shelf (Worcester and Parker, 2010) presents a system inventory, as well as time series data on multiple indicators in this system, such as North Atlantic Oscillation index, pH trends, and Bray–Curtis Index of similarity of species. **Step 2.1 & 2.2, vision and strategic objectives:** The vision statement from the DFO Regional Oceans Plan for the Maritimes Region is "Healthy marine and coastal ecosystems, sustainable communities and responsible use supported by effective management processes" (DFO, 2014). Overarching all fisheries in the region are conservation and social objectives (see DFO [2013] as an example) such as: "Biodiversity: Do not cause unacceptable reduction in biodiversity in order to preserve the structure and natural resilience of the ecosystem."

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CASE STUDY	SUMMARY OF ACTIONS THAT MATCH THE NEXT-GENERATION FEP PROCESS
BALTIC COD, HERRING, AND SPRAT	**Step 1.1 & 1.2, system inventory/conceptual model, select indicators:** A Working Group on Integrated Assessments of the Baltic Sea (WGIAB) produced assessments of the various subsystems of the Baltic Sea (ICES, 2015). These assessments include multivariate analyses of time-series for ecosystem indicators encompassing abiotic (nutrients, hydrography) as well as plankton and fish time-series. **Step 2.1 & 2.2, vision and strategic objectives:** The Common Fisheries Policy of the European Union (EU) gives the following goal: "Fish stocks should be brought up to healthy levels and be maintained in healthy conditions." A strategic objective for herring, cod, and sprat specifically is to "ensure that the Baltic stocks of cod, herring and sprat are exploited in a sustainable way according to the principles of maximum sustainable yield and of the ecosystem approach to fisheries management" (COM, 2013). **Step 3.4, select strategy:** The EU adopted a strategy to improve stock assessments by updating sprat and herring reference points using single-species stock assessments with mortality parameters determined by multispecies models (ICES, 2015). These updated reference points are used in the harvest strategy.
AUSTRALIAN SMALL PELAGIC FISHERY AND ECOSYSTEM IMPACTS	**Step 2.3, risk assessment:** Daley et al., (2007) carried out an ecological risk assessment for the fishery that examines the risks to five ecological components: target species; byproduct and bycatch species; threatened, endangered, and protected species; habitats; and ecological communities. **Step 2.5, operational objectives:** Management endorsed the use of the Marine Stewardship Council's (MSC) criteria for evaluating the impacts of fishing low trophic-level species on the ecosystem that were suggested by the group of fishery scientists reviewing the fishery. The criteria are: (1) no more than 15% of other species or groups are impacted by more than 40% and (2) no species is impacted by more than 70% (MSC, 2014). **Step 3 "How will we get there":** The objectives included a specific performance measure – change in biomass of species – and stated the need to avoid a change of more than 40%. Management strategies were identified by a group of fishery scientists with considerable interaction with AFMA and stakeholders in the fishery. Researchers used an ecosystem model (Smith et al., 2015) to evaluate management strategies. They concluded that the status quo target stock size (50% of unexploited biomass) met the performance measure, and AFMA selected it as the management strategy.

Note: Step 4 is not shown in the table. In general, when step 3 has been carried out, so has step 4.

OVERVIEW OF FINDINGS

Across the case studies, managers have already undertaken activities (actions corresponding to individual steps or substeps) that correspond to the majority of the steps of the Task Force's FEP process (Table 5.2). Moreover, within most case studies, managers have usually undertaken a majority of the substeps. Looking across steps, some activities were fairly common (e.g., step 1, "Where are we?"), whereas activities for step 5 ("Did we make it?") were less common. We note that additional relevant activities may be occurring in the regions covered by our case studies but not documented in a way that we could identify.

Within the first two steps, earlier substeps were more likely to be implemented than later ones, suggesting that continued development of existing EBFM projects would provide benefits. For example, in "Where are we?" there were many examples of system inventories or conceptual models, developing system indicators, and evaluating status and trends, but fewer examples of an explicit process evaluating and listing potential threats to the fishery system. For step 2, "Where are we going?" many case studies had examples of strategic visions and objectives, but none had an explicit prioritization process of those objectives and only three developed more specific operational objectives (to our knowledge). Additionally, there were few examples of risk assessment pertaining to objectives. However, we did find examples of risk assessment without explicit objectives.

For step 3, "How will we get there?" the later activities in our FEP process were more common. There were many cases in which managers identified alternative management strategies and evaluated them against one or more criteria or performance measures (sometimes within FMPs), but fewer cases where the performance measures were explicitly linked to specific operational objectives. It is possible that operational objectives were identified but not explicitly documented; it is also possible that the evaluation of management strategies was conducted without context related to objectives. Additionally, in most cases performance measures did not have specific targets (e.g., desired levels). However, it is possible that in these cases reference directions (preferred directions for change without numerical targets) were used to choose management strategies, although we did not find explicit documentation of this.

There were several examples of management strategies that modified conventional reference points using ecosystem information (steps 3.4 and 4). For example, the harvest strategy for gag grouper used a stock assessment model that explicitly considers mortality due to red tide effects.

KEY LESSONS

The capacity for management to develop next-generation FEPs already exists

Looking across all case studies, nearly all FEP steps have been conducted in some manner, usually in multiple regions. If we also consider scientific research not initiated by management, even more examples emerge that fit within our vision for next-generation FEPs. This includes economic risk assessment for cod, herring, and lobster fisheries in the Gulf of Maine (Ryan et al., 2010), and impacts of climate-driven range shifts of summer flounder (Pinsky and Fogarty, 2012). Still more examples come from work by management that is in progress or completed but not in use. This includes work in the Baltic Sea to calculate multispecies maximum sustainable yield from multispecies models for herring, cod, and sprat (European Commission, 2014; ICES, 2013) and research to develop ecosystem reference points for menhaden by the Atlantic menhaden technical team and the Biological-Ecological Reference Points work group (SEDAR, 2015). Thus, managers have many jumping off points to develop next-generation FEPs using existing science tools, policy instruments, and management structures.

The Australian small pelagic fishery (SPF) was one of a handful of case studies in which managers used an explicit operational objective and corresponding performance measures to evaluate alternative management strategies (see also the New England groundfish and Alaska groundfish case studies). Public concern about the impact of the SPF on predators, protected species, and other fisheries arose in 2012 when a large factory trawler (later dubbed a supertrawler) was brought into the country for use in the SPF (Tracey et al., 2013). This led to a number of government inquiries and to intense scrutiny of the management of the fishery and a call for a review of the SPF harvest strategy. This review was undertaken in collaboration with fishery scientists, AFMA, and stakeholders in the fishery. Operational objectives were: the abundance levels of no more than 15 percent of other species or groups are affected by more than 40 percent, and no species is affected by more than 70 percent (a threshold derived from MSC [2014] recommendations). Management endorsed these criteria and reference points, and researchers then tested management strategies using an ecosystem model (Smith et al., 2015) to determine which met the operational objectives. They found that a target harvest strategy of B50 (50 percent of unexploited biomass) for the target SPF species met the criteria.

Next-generation FEPs can streamline management by placing existing activities in a structured framework

Despite the many steps that have already been undertaken, these activities are rarely conducted as part of a structured decision-making process such as the one described in Chapter 3. The Task Force believes that ongoing activities could have greater impacts on decision-making and improve efficiency if they were integrated using an FEP. In particular, none of these case studies had an explicit prioritization process that we could identify based on expert knowledge or documentation. It is possible that prioritization occurred implicitly or by a process that was not clear to us. Regardless, prioritization is a critical step to reduce a potentially overwhelming situation into a tractable one.

The case study of Atlantic menhaden illustrates how a structured process might have streamlined a management process. In 2015, the ASMFC'S Atlantic Menhaden Technical Team had identified potential performance measures (such as environmental indicators, indices of forage abundance, and prey-predator biomass ratios) and alternative strategies (e.g., cap on annual menhaden catch within the Chesapeake Bay). However, it noted that without clear statements of system goals by the Commission, it could not make recommendations on which potential performance measures were most appropriate (SEDAR, 2015, Appendix E). The Commission has since identified strategic objectives (but not operational), and the Biological-Ecological Reference Points Workgroup is working to select one or more models to develop reference points (analogous to performance measures) based on the objectives (ASMFC, 2015). This example is by no means unique; multiple other case studies had metrics, but few had a formal process for selecting metrics and few related metrics to targets or limits.

FEP-like activities were accomplished in a variety of ways

Commonly conducted activities such as "taking inventory" appear in several forums. Some inventories appear as part of an existing FEP, such as the Pacific FEP (PFMC, 2013a) and the Chesapeake Bay FEP (Chesapeake Bay Fisheries Ecosystem Advisory Panel, 2006). Others exist outside of FEPs, including the Ecosystem Status Report for the Gulf of Mexico (Karnauskas et al., 2013), Ecosystem Status Report for the Northeast Shelf Large Marine Ecosystem (Ecosystem Assessment Program, 2012), Alaska Marine Ecosystem Considerations Report (NPFMC, 2015a), the State of the Ocean Report for the Scotian Shelf, and the Integrated Assessments of the Baltic Sea (ICES, 2015).

Another example of diverse approaches comes from step 3.3, "Evaluating management strategies." In some cases, large ecosystem models are used (e.g., Australia small pelagics) whereas others used single-species models with environmental information (e.g., Pacific sardine). In still other cases, multiple tools are used, including in the Alaska groundfish example, where alternatives were evaluated using a multispecies model, a habitat impact model, and a socio-economic extension of the multispecies model (NOAA Fisheries, 2004).

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CHAPTER 6

MAIN FINDINGS AND RECOMMENDATIONS

1. OPERATIONALIZING EBFM REQUIRES A STRUCTURED PLANNING PROCESS THAT LEADS TO ACTION

Finding: Existing Fishery Ecosystem Plans (FEPs) are strong on descriptive information, particularly for the biophysical component of fishery systems. However, they generally do not fulfill the Ecosystem Principles Advisory Panel's 1999 recommendations to (1) direct how that information should be used in the context of Fishery Management Plans (FMPs) and (2) set policies by which management options would be developed and implemented. Instead, ecosystem-based fisheries management (EBFM) in the U.S. has proceeded in a piecemeal fashion and without a structured planning process whose goal is to inform management action. Consequently, action has been delayed because there is no process to prioritize among objectives or to make decisions in the face of uncertainty and trade-offs.

Recommendation: The highest priority for next-generation FEPs should be moving from description to actions that operationalize EBFM in the face of multiple objectives, trade-offs, and uncertainty. This should begin with a structured planning process such as the one described in this report. Specifically, FEPs should:

- specify how the FEP leads to changes in FMPs that initiate or modify management actions;
- clearly define goals for the fishery system, recognizing that the goals of different stakeholders may be diverse or conflicting;
- create a process of prioritization that leads to operational objectives, performance measures, and reference points for the fishery system;
- create a process for identifying alternative management actions and evaluating trade-offs among them;
- specify predetermined management actions that are triggered in response to performance measures;
- create a process to monitor management effectiveness; and
- be adaptive, so that lessons learned from implementation are used to iteratively improve management.

2. FEPS CAN BE DEVELOPED USING EXISTING TOOLS AND PROCESSES

Finding: The challenges to implementing EBFM are surmountable using present science tools, policy instruments, and management structures. Although EBFM is often assumed to require complex, sophisticated technical inputs, science tools are available to support the FEP process at all levels of data availability and technical capacity. Policy instruments already used in conventional fisheries management can be used to support FEP goals, and the existing statutory requirements and management structures can accommodate EBFM.

A key challenge to EBFM is understanding and coping with uncertainty. There will always be uncertainty about the fishery system's response to management actions, regardless of management approach. FEPs do not banish uncertainty; they help managers identify it and incorporate it into their decision-making. FEPs are a framework for adaptive management, which reduces uncertainty over time by generating new data from the outcomes of management actions.

Recommendation: The Lenfest Fishery Ecosystem Task Force recommends that U.S. Regional Fishery Management Councils create actionable FEPs using existing tools and processes.

For example, Integrated Ecosystem Assessment (IEA) teams have developed conceptual models, biophysical and socio-cultural indicators, and tools to define and evaluate reference points for several fishery systems. In addition, Councils already have policy instruments from conventional management that can be modified and combined into portfolios to support FEP goals and objectives. Examples include harvest control rules, catch shares, bycatch quotas, and spatial and seasonal management.

3. FEPS CAN INTEGRATE SOCIAL, ECONOMIC, AND ECOLOGICAL GOALS

Finding: Fundamental to EBFM is the conceptualization of fisheries as systems that consist of linked biophysical and human subsystems with interacting ecological, economic, socio-cultural, and institutional components. However, existing FEPs tend to focus on biophysical subsystems and not on human subsystems or linkages between the subsystems.

Recommendation: FEPs should include ecological, economic, and social goals and set forth a process by which decision-makers and stakeholders can address issues and anticipate likely outcomes that span all of these dimensions.

4. FEPS CAN PROMOTE TRANSPARENCY IN DECISION-MAKING AND TRADE-OFFS

Finding: Council decision-making would be improved by using a transparent process to evaluate trade-offs. Confronting trade-offs—i.e., making decisions with full awareness of the attendant costs and benefits – is arguably the single most important function of EBFM.

Recommendation: FEPs should enhance transparency by engaging stakeholders to help define and prioritize objectives, performance measures, and alternative management strategies. These steps are particularly important to implement EBFM because of the large number of potential systemic issues that could be addressed, the large number of performance measures that management will seek to attain, and the diversity of management actions that might be implemented. Selecting among policy alternatives usually involves subjective weighting and trade-offs among performance measures by decision-makers. Transparency and engagement are helpful in making this process responsive to stakeholders and society.

In addition to these findings, the Task Force recognizes that regional experimentation with FEP development presents an opportunity for learning and for sharing lessons across regions. The Task Force therefore also recommends that NOAA and the Councils establish a timetable for a national review of FEPs to compare their structures and outcomes, and to identify what worked and what failed.

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