Gulf of Mexico
Fishery Ecosystem Plan

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LGL Ecological Research Associates, Inc.

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Cover photo by Jesse Cancelmo, author of *Texas Coral Reefs* and *Glorious Gulf of Mexico*, TAMU Press. The photo was taken at Stetson Bank in the Flower Garden Banks National Marine Sanctuary.

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ABBREVIATIONS USED IN THIS DOCUMENT

BOEM	Bureau of Ocean Energy Management
C-CAP	Coastal Change Analysis Program
CRP	Cooperative Research Program
EBFM	Ecosystem Based Fisheries Management
ENOW	Economics: National Ocean Watch
EFH	Essential Fish Habitat
EPA	Environmental Protection Agency
ESI	Environmental Sensitivity Index
ESR	Ecosystem Status Report
ETC	Ecosystem Technical Committee
FEP	Fisheries Ecosystem Plan
FEI	Fishery Ecosystem Issues
FMP	Fishery Management Plan
GDP	Gross Domestic Product
Gulf	Gulf of Mexico
Gulf Council	Gulf of Mexico Fishery Management Council
HAPC	Habitat Areas of Particular Concern
IEA	Integrated Ecosystem Assessment
LGL	LGL Ecological Research Associates, Inc.
MODIS	Moderate Resolution Imaging Spectrometer
MPA	Marine Protected Area
MSE	Management Strategy Evaluation
MTL	mean trophic level
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPP	Net Primary Productivity
RFMC	Regional Fishery Management Council
RFP	Request for Proposals
SEAMAP	Southeast Area Monitoring and Assessment Program
SEDAR	Southeast Data Assessment and Review
SERO	Southeast Regional Office
SEFSC	Southeast Fisheries Science Center
SSC	Scientific and Statistical Committee

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EXECUTIVE SUMMARY

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) is increasingly urging an Ecosystem Based Fisheries Management (EBFM) approach that considers fisheries within their holistic ecosystem context and seeks to optimize benefits among a diverse set of societal goals. Fishery Ecosystem Plans (FEP)s are the primary tools with which Regional Fisheries Management Councils (RFMCs) are implementing EBFM. Success has been demonstrated in each region, but implementation has been limited by the lack of actionable guidance.

The Gulf of Mexico Fishery Management Council (Gulf Council) explicitly requested that this FEP be an "actionable" structured process with associated decision-support tools for EBFM implementation in the Gulf of Mexico (Gulf). The FEP has been developed based on extensive review of existing literature and the experiences of other RFMCs. This FEP has adapted the widely accepted "Next Generation FEP Loop" as a framework for long-term, region-wide fishery ecosystem planning.

In addition, this FEP includes a framework to address specific, sub-regional Fishery Ecosystem Issues (FEIs) that may not be considered within the single stock management paradigm. The "FEI Loop", defined herein as a structured process that moves an FEI towards its goals, serves as the operational unit for EBFM implementation.

Primary recommendations for implementation include:

- Articulate a common vision of the desired future state of the Gulf, managed under EBFM
- Institutionalize FEIs into the current management process
- Expand the quantity, quality, equity, and methods for stakeholder engagement
- Expand the Cooperative Research Program
- Expand and foster institutional partnerships to support research and to address issues affecting Gulf fisheries resources that are outside of Gulf Council jurisdiction

If successfully implemented, the Gulf Council will have institutionalized EBFM, operationalized FEIs, and expanded cooperative research and institutional partnerships. Adopting the EBFM approach would contribute to resilience and sustainability of Gulf fisheries and the ecosystem services they provide.

CHAPTER 1. INTRODUCTION: VISION, GOALS, AND OBJECTIVES

1.1 Introduction

The National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) has enacted policies and procedures designed to end overfishing which has reversed the downward trend for many of the nation's most valuable, federally managed fishery stocks. This progress can largely be attributed to a traditional management approach that focusses on the management of single stocks, as mandated by the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (2007). Nonetheless, NMFS has long recognized the need for an Ecosystem Based Fisheries Management (EBFM) approach to managing the nation's fisheries, to address issues that transcend multiple stocks, jurisdictions, and that consider the fisheries within their holistic ecosystem context (Evans et al. 1987).

The NMFS definition of EBFM is "a systematic approach to fisheries management in a geographically specified area that contributes to the resilience and sustainability of the ecosystem, recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals" (NMFS 2016a; 2016b).

The Gulf of Mexico Fishery Management Council (Gulf Council) has already made great strides in its use and incorporation of EBFM principles within existing management practices. As a specific example, the Gulf Council considered ecosystem effects of red tide on red grouper stocks, included this information in stock assessments and adjusted management actions accordingly (Sagarese et al. 2015; Marshall et al. 2018b). While this and many other examples exist, they have been implemented on an ad hoc basis, rather than as part of a holistic plan.

This document is designed to provide structure to facilitate EBFM implementation that includes and expands beyond existing work. The Gulf Council has appointed the Ecosystem Technical Committee (ETC) as an advisory body to assist with the development of a Fisheries Ecosystem Plan (FEP). In March 2020, the ETC proposed the following mission statement for the FEP:

"To provide a framework for integrating ecosystem science into the Gulf Council's decision making for long-term ecological and socioeconomic sustainability of Gulf of Mexico resources".

Following guidance from the Gulf Council, the ETC, lessons from other Regional Fishery Management Council (RFMC) experiences, and available guidance documents, this FEP offers a framework, mechanisms, and decision support tools for actionable implementation.

1.2 Background

The NMFS mandate to implement EBFM stems from a long history of incremental policy and legislative steps, starting with the establishment of the Fisheries Commission in 1871. The history is briefly summarized in Heyman et al. (2021). There is broad agreement on the value of an EBFM approach among scientists, managers, and a broad suite of fisheries stakeholders, but it has been challenging to implement (Pikitch et al. 2004; Fulton et al. 2014; NMFS 2016a; 2016b; Levin et al. 2018; Marshall 2018a). NMFS NOAA's EBFM Policy and EBFM Roadmap (NMFS 2016a; 2016b) recommend that FEPs should be the primary tool for Regional Fisheries Management Councils (RFMCs) to incorporate EBFM into management efforts. All RFMCs are developing and using FEPs to varying degrees. Given the wide geographic range of RFMC jurisdictions, environments, fisheries productivity and value, governance capacity and other factors, there exists a concomitant variation in the scale, scope and efficacy of FEPs among regions (Link and Marshak 2019). Though success is demonstrated in each region, FEP implementation has been limited by a general lack of actionable guidance (Levin et al. 2018).

The Gulf Council has been working on incorporating EBFM within the management framework since 2004 when it established the Gulf Ecosystem Scientific and Statistical Committee (SSC) (Figure 1.2.1). Since then, the Gulf Council has increasingly incorporated EBFM principles into various aspects of management; however, this has occurred without the overarching structure of an FEP. The Gulf Council appointed the ETC as an advisory body to assist with the development of an FEP.

The Gulf Council contracted LGL Ecological Research Associates, Inc. (LGL) in January 2021 to assist the ETC in developing this FEP. The contract included four deliverables as follows: *Case Studies and Lessons Learned from Fishery Ecosystem Planning* (Heyman et al. 2021); *Indicator Development for Fishery Ecosystem Planning: Summary Report* (LGL 2021), and *Stakeholder Assessment & Concept Mapping in support of Fishery Ecosystem Planning for the Gulf of Mexico: Summary Project Report* (Scyphers et al. 2021). The fourth deliverable is this document, *Gulf of Mexico Fishery Ecosystem Plan. Version 1.0* (Figure 1.2.1). This Version 1.0 FEP was developed in large part, based on the studies completed as part of this contract as well as the wealth of preceding case studies and guidance documents and discussions with acknowledged people.

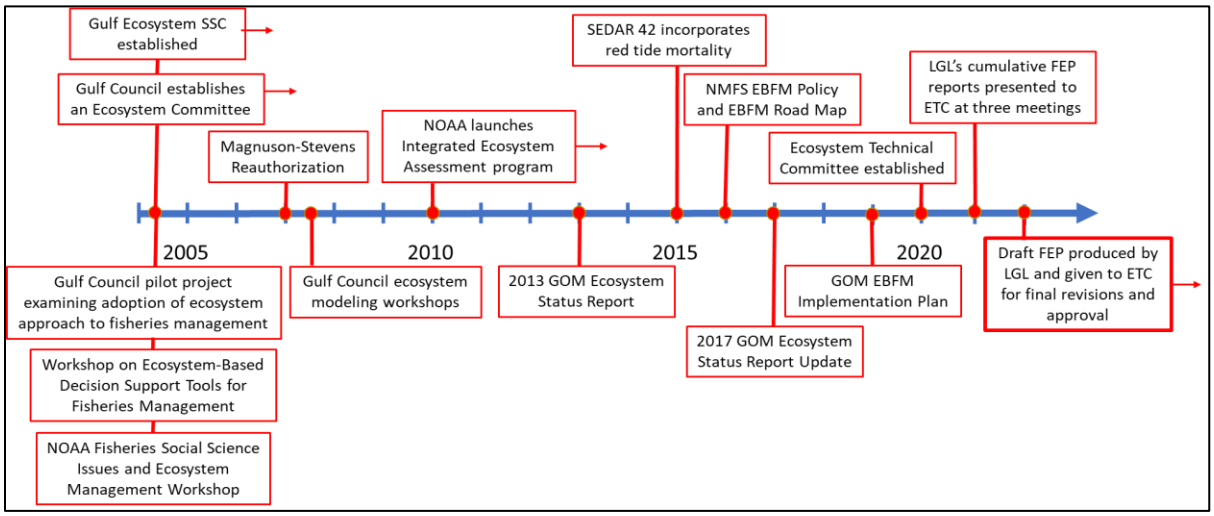

Figure 1.2.1. Major milestones in the history of EBFM and FEP development in the Gulf of Mexico. Note that this timeline does not include publication of many important studies and guidance documents, nor examples of how EBFM has been incorporated in various aspects of Gulf Council decision-making as both are too numerous for this graphic.

Each of the nation's RFMCs has embarked on the same path, i.e., to develop and implement EBFM through FEPs, yet each region has unique physical, ecological, social, cultural, and governance characteristics. The EBFM experiences have been reviewed recently in part to glean lessons and provide guidance for future FEPs (e.g., Essington et al. 2016; Levin et al. 2018; Link and Marshak 2019; Dell'Apa et al. 2020). The range of issues addressed, and the methods and techniques to address them provide a rich diversity of examples for the Gulf Council to consider in developing its own plan.

Yet the Gulf is distinct from other regions and requires a tailored approach. The structure and style of this FEP is based on the explicit request of the Gulf Council that it be "actionable". This FEP is therefore intentionally short and focused on providing processes and actions that will expand EBFM in the Gulf of Mexico (Gulf).

1.3 Visioning for the Fishery Ecosystem Plan

To achieve functional EBFM in the Gulf will require a collective vision of what "success" looks like at specific times in the future. Yet there is a wide diversity of fishery stakeholders in the Gulf, some with conflicting interests. However, if mutually held values among stakeholders can be identified, these can form the basis of a shared vision that can be used to increase the likelihood of achieving EBFM. At first glance, it appears that various sectors of stakeholders have little common ground and that a shared vision may be challenging to identify and express. Yet there is likely more common ground desire for EBFM than what is immediately obvious.

The Ecosystem Status Reports (ESRs) (Karnauskas et al. 2013; 2017) document ecological, socio-economic, and management trends in the Gulf including:

- Fisheries management has helped rebuild many fish stocks, which has resulted in increased size and abundance of large predators, such as red snapper
- Sea-level is rising
- Seawater temperatures are rising which has likely contributed to observed changes in the distribution of some fisheries stocks in the Gulf.
- Human populations and coastal development are increasing
- There has been an increased severity and frequency of harmful algal blooms and hypoxia events
- Hurricanes are increasingly a threat to fisheries infrastructure and industry resilience

The challenge is to articulate common understanding of present conditions and a common, high-level vision of the desired future state of the Gulf, managed using EBFM principles, that is supported by a large majority of the diverse stakeholders in the region. Recalling the NMFS definition, EBFM is "a systematic approach to fisheries management . . . that contributes to the resilience and sustainability of the ecosystem. . . and seeks to optimize benefits among a diverse set of societal goals" (NMFS 2016a; 2016b).

To speed adoption of EBFM and reduce potential conflicts in getting there, the Gulf Council could develop and implement a streamlined process to reach and articulate a common vision for EBFM in the Gulf. To be most useful, the common vision should offer specifics about the desired future state of Gulf ecosystems and their management within specific future time frames (e.g., 5, 10, 25 years).

The primary goal of this FEP is to provide a structured and systematic planning process that, if adopted, will allow managers to maintain multiple services that ecosystems provide while accounting for relationships among fishery system components. Stated another way, Marshall et al. (2018a) offers that a primary goal of an FEP is to achieve triple bottom line sustainability. The triple bottom line approach aims to achieve environmental, economic, and social sustainability whereby components are defined as:

Environmental sustainability: healthy and resilient marine and coastal ecosystems that support multi-species fisheries and a culture that embraces the value of non-harvested resources

Economic sustainability: sustainable and resilient multi-species fisheries and dependent economies

Social sustainability: conditions that support equitable access to fisheries resources, thriving coastal communities, cultural preservation, sustainable employment, a healthy workforce, and working waterfronts.

There are many available resources to support a visioning process and that have been used by other RFMCs (Koehn et al. 2020). The time and resources needed to attain a shared vision vary by the characteristics of the region and the approach selected. The work could likely be conducted by Gulf Council Staff supported by contractors and facilitators in two years or less, following the process outlined in Figure 1.3.1. Nonetheless, most components of this FEP can be initiated before visioning is complete.

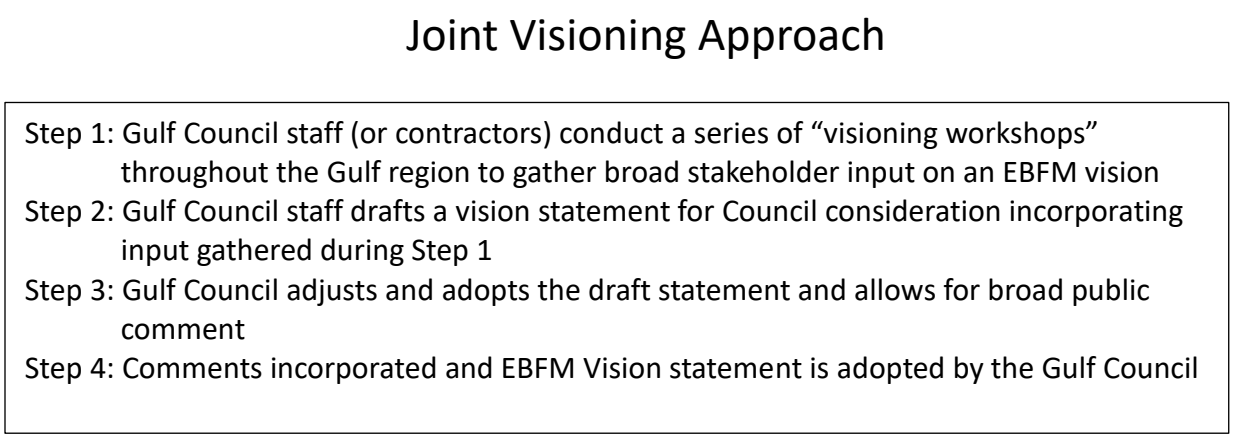

Figure 1.3.1. Suggested steps in developing a joint vision for the FEP.

1.4 FEP Structure, Goals and Objectives

The goal of this FEP is to provide an overarching framework that will systemize EBFM implementation. During discussions with the ETC in December 2021, it was recommended that the FEP be structured around the concept of "Issue-based Action Modules". These are modelled after "Ecosystem Initiatives" used by the Pacific Fishery Management Council and "Action Modules" used by the North Pacific Fishery Management Council (Heyman et al. 2021). For the Gulf, the concept will be called Fishery Ecosystem Issues (FEIs) which are defined in section 2.1 with processes and procedures defined in Chapter 4 with additional guidance from decision support tools provided in Appendix A.

To address data and information gaps and maximize meaningful stakeholder engagement during the planning process, this FEP proposes an expanded Cooperative Research Program (CRP). The expanded program could serve the information needs of specific FEIs and provide a cooperative study fleet that can be mobilized rapidly to sample emerging or acute ecosystem issues. To address long-term, ecosystem monitoring needs, this FEP proposes expanded

Research Institutional Partnerships between the Gulf Council and other relevant state and federal agencies, academic institutions, NGOs, and private industry. To address threats to Gulf fishery ecosystems that are outside of Gulf Council jurisdiction, this FEP proposes Extra-Jurisdictional Partnerships (Figure 1.4.1).

FEP Goal: Institutionalize this FEP framework and structured planning process to incorporate and systemize EBFM implementation in the Gulf.

Objective 1: Develop, review and adopt a systematic planning framework to select, prioritize and address FEIs that can inform management actions.

Objective 2: Develop and institutionalize an expanded CRP, Research Institutional Partnerships and Extra-Jurisdictional Partnerships. Proposed programs could also be used to address information and management needs for traditional fishery management (e.g., stock assessments).

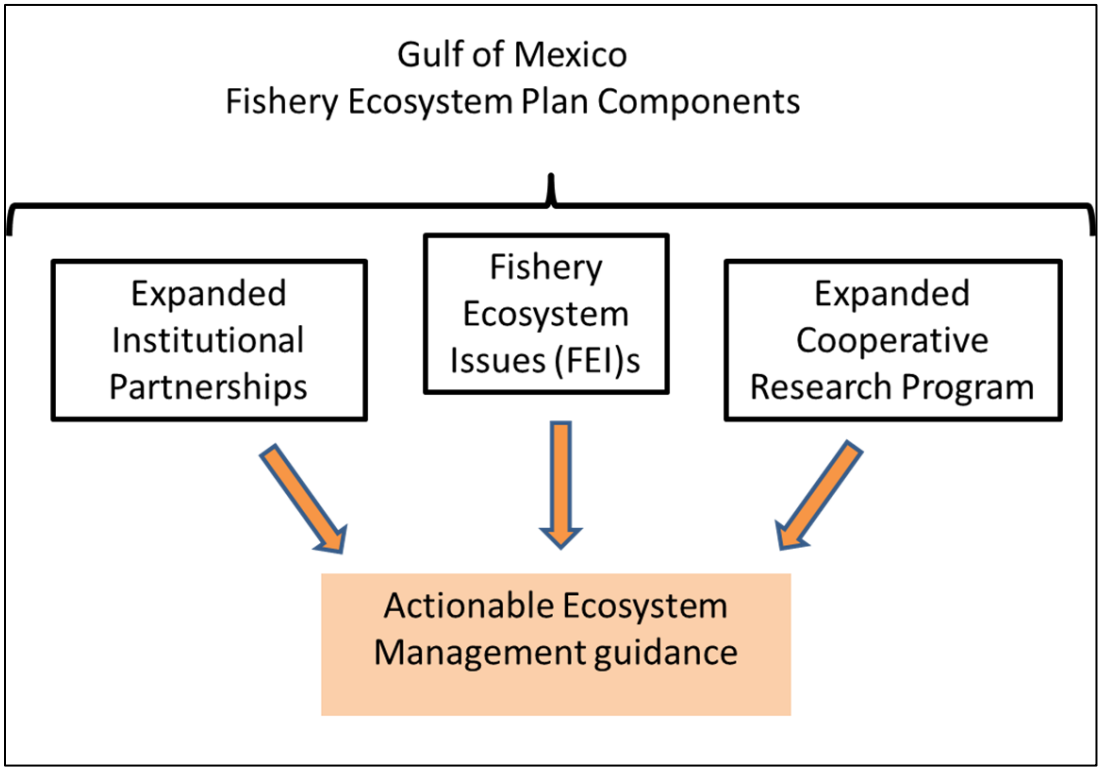

Figure 1.4.1. This plan has three major components: 1) Expanded Institutional Partnerships, 2) FEIs and, 3) Expanded Cooperative Research Program. Together these will lead to actionable ecosystem management guidance.

CHAPTER 2. FEP GUIDING PRINCIPLES AND OVERARCHING CONCEPTS

Fishery ecosystem planning is described as a structured planning process that uses adaptive management to operationalize Ecosystem Based Fishery Management (EBFM). Following a national mandate and policy guidelines, all U.S. Regional Fishery Management Councils (RFMC) have begun or completed one or more Fishery Ecosystem Plans (FEP) in their respective regions. Early FEPs were more often descriptive than prescriptive, have been difficult to implement, and have been limited in their influence on management action.

To provide guidance on how to make FEPs more actionable, The Lenfest Ocean Program supported a Fishery Ecosystem Task Force which produced the guidance document, *Building Effective Fishery Ecosystem Plans* (Essington et al. 2016). The main recommendation from the Task Force is that "Next Generation FEPs" (also referred to as Next Gen FEPs) follow the proposed "FEP Loop" to create a structured process for establishing goals and translating them into action (Figure 2.1).

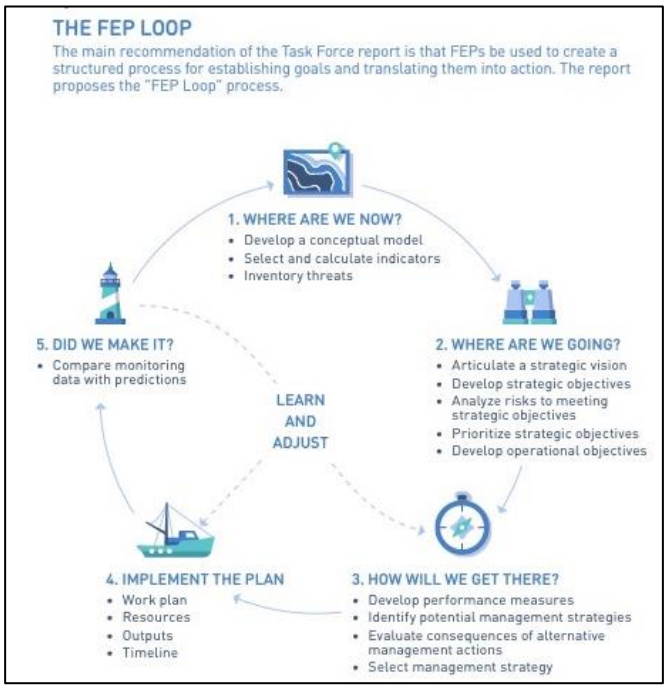

Figure 2.1. The Next Generation FEP Loop - a structured, adaptive planning process (Essington et al. 2016).

Essington et al. (2016) and subsequent guidance (e.g., Levin et al. 2018; Dell'Apa et al. 2020) noted that FEP definitions were flexible and that RFMCs had interpreted the guidance in ways that varied along a continuum between generality and specificity. At one end of the spectrum, FEPs are considered generic planning tools. At the other end of the spectrum, FEPs are considered specific, placed-based plans and processes that guide specific management decisions. Large scale FEPs address entire management regions (e.g., South Atlantic or Caribbean) while other FEPs address smaller geographic areas or subregions of a given RFMC (e.g., the Bering Sea). FEP scale is inversely related to specificity and actionability (Figure 2.2).

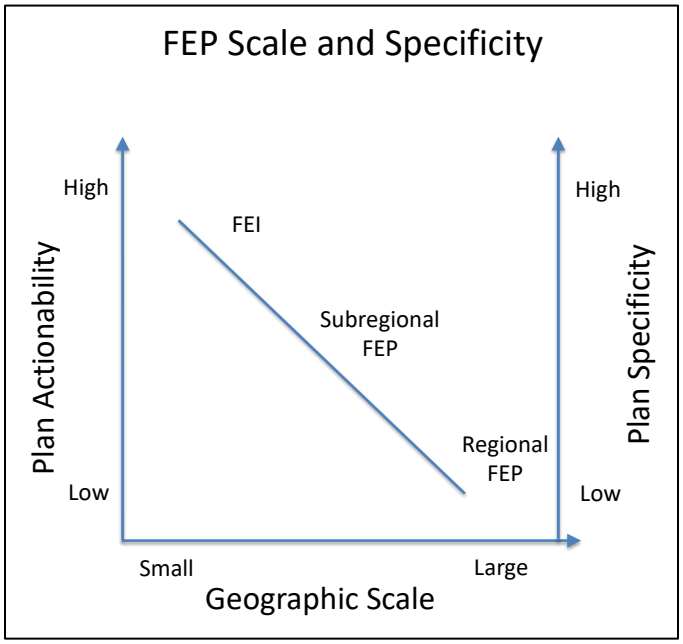

Figure 2.2. The geographic scale of Fishery Ecosystem Plans is often inversely related to their specificity and the ability to be actionable.

This FEP has adopted the Next Gen FEP Loop as the overall structure for fishery ecosystem planning in the Gulf with some adjustments (Figure 2.3). In order to increase specificity and utility of the Gulf FEP in guiding management action, this FEP centers around the concept of FEI as the unit, or focal scale for FEP implementation. The FEI mechanism incorporates much of the FEP Loop elements, described above, with some important differences detailed below. Most importantly, the FEI construct will allow the Gulf Council to direct detailed attention to several issues simultaneously. Resolutions from each of these FEIs will contribute to the overall FEP process.

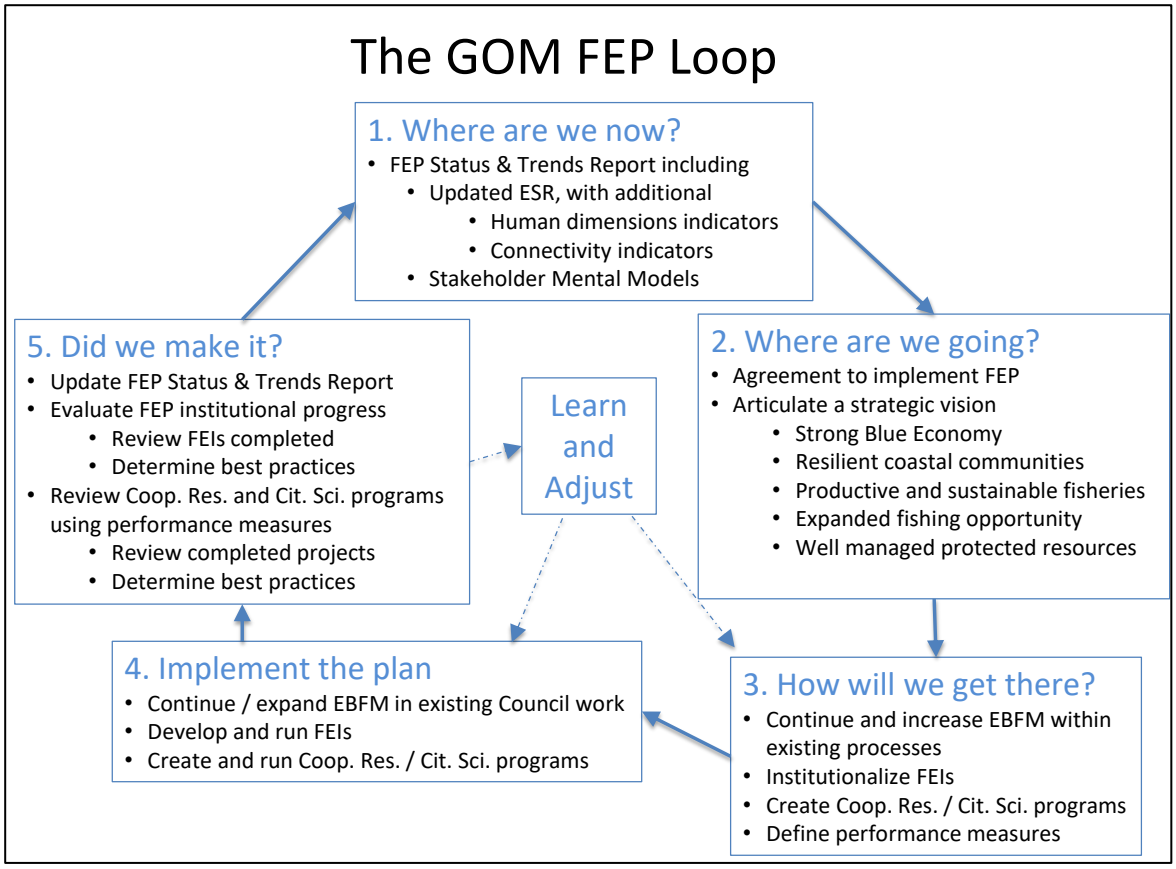

Figure 2.3. The Gulf of Mexico FEP Loop specifies components of the Next Gen FEP Loop.

2.1 Fishery Ecosystem Issues (FEIs)

Fishery Ecosystem Issues (FEI) will form the primary structured planning process by which this FEP is implemented. FEIs are modelled after the Next Generation Fishery Ecosystem Planning Loop (FEP Loop), the primary recommendation from the Lenfest Oceans Report (Essington et al. 2016; Figure 2.1). Yet, according to Marshall et al. (2018a), "a full FEP cycle may take about a decade, but targeted activities on prioritized issues would occur on a shorter time scale". FEIs, in contrast to FEP Loops, are structured, action-oriented planning processes that address specific fisheries issues as defined below and occur on timeframes between 4 months and 3 years. The FEI concept is very similar to both "Action Modules" and "Ecosystem Initiatives" adopted by the North Pacific Fishery Management Council and the Pacific Fishery Management Council, respectively.

FEI combines three terms: Fishery, Ecosystem and Issue, defined individually as follows:

Fishery: A fishery is a system wherein marine resources are harvested for commercial or recreational purposes. The system consists of linked biophysical and human subsystems with interacting ecological, economic, social, cultural and institutional components.

Ecosystem: A defined geographic area or system that includes all the biotic and abiotic system components, including humans, their interactions and associated ecosystem services.

Issue: An important topic or problem that could potentially be solved or addressed through Gulf Council action

A Fishery Ecosystem Issue (FEI) is a specific fishery management issue or problem that occurs within the Gulf, or a subregion of the Gulf, that may be addressed or solved through Gulf Council action. FEIs provide a structured process to address ecosystem issues that may not otherwise be considered within the single stock management paradigm.

In principle, the seed of an FEI begins when a fishery stakeholder observes some kind of ecosystem change or pattern. This could be a gradual change over time, or a sudden change caused by a large disruptive event such as a hurricane, harmful algal bloom, or oil spill. The stakeholder discusses the issue with their peers in light of the observations and possible impacts to the fishery ecosystem. These stakeholders will in turn raise the issue with additional stakeholders and their professional communities of scientists, private businesses, state and federal managers and others. The specificity and complexity of the FEI will increase and evolve as additional people and institutions contribute.

Often, FEI seeds may be articulated by highly experienced fishers that are still actively fishing (e.g., Figure 2.1.1). However, FEIs can be developed by any engaged stakeholder including seafood consumers, seafood dealers, or non-consumptive stakeholders such as divers, boaters, coastal residents, ecotourists, NGOs, scientists, or coastal residents. For example, an FEI could be developed by scientists following new research that changes our understanding of Gulf ecosystems.

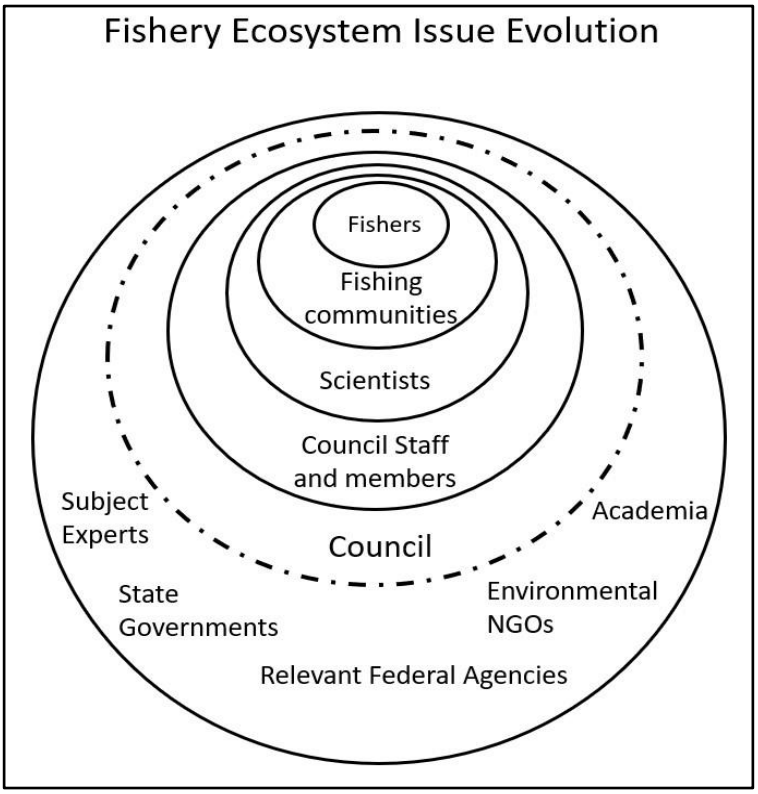

Figure 2.1.1. Fishery Ecosystem Issue (FEIs) evolution: In this case, the FEI was initiated by a fishers and other individuals and institutions weigh in over time.

While the resolution of the issue will not be obvious and different stakeholders will articulate it with differing conceptual models, the FEI will eventually reach a level worthy of Gulf Council consideration. At any time during this phase someone such as a Gulf Council Member or Staff, or an ETC or AP member willing to "Champion" the FEI will articulate it in writing following specific guidelines and submit it to the ETC for vetting. FEIs that meet minimum requirements can be submitted to a pool or "FEI Hopper" (digital repository) for Gulf Council consideration. If selected by the Gulf Council, the FEI will be addressed by an empaneled task force with a workplan that includes specific deliverables and associated timelines to generate actionable management guidance and a pathway by which the Gulf Council can take action and evaluate outcomes (Figure 2.1.2). Specific details and guidance on FEI documentation, prioritization, and selection, as well as the subsequent processes, procedures, and decision support tools for FEI Loops, are detailed in Chapter 4 and Appendix A, respectively.

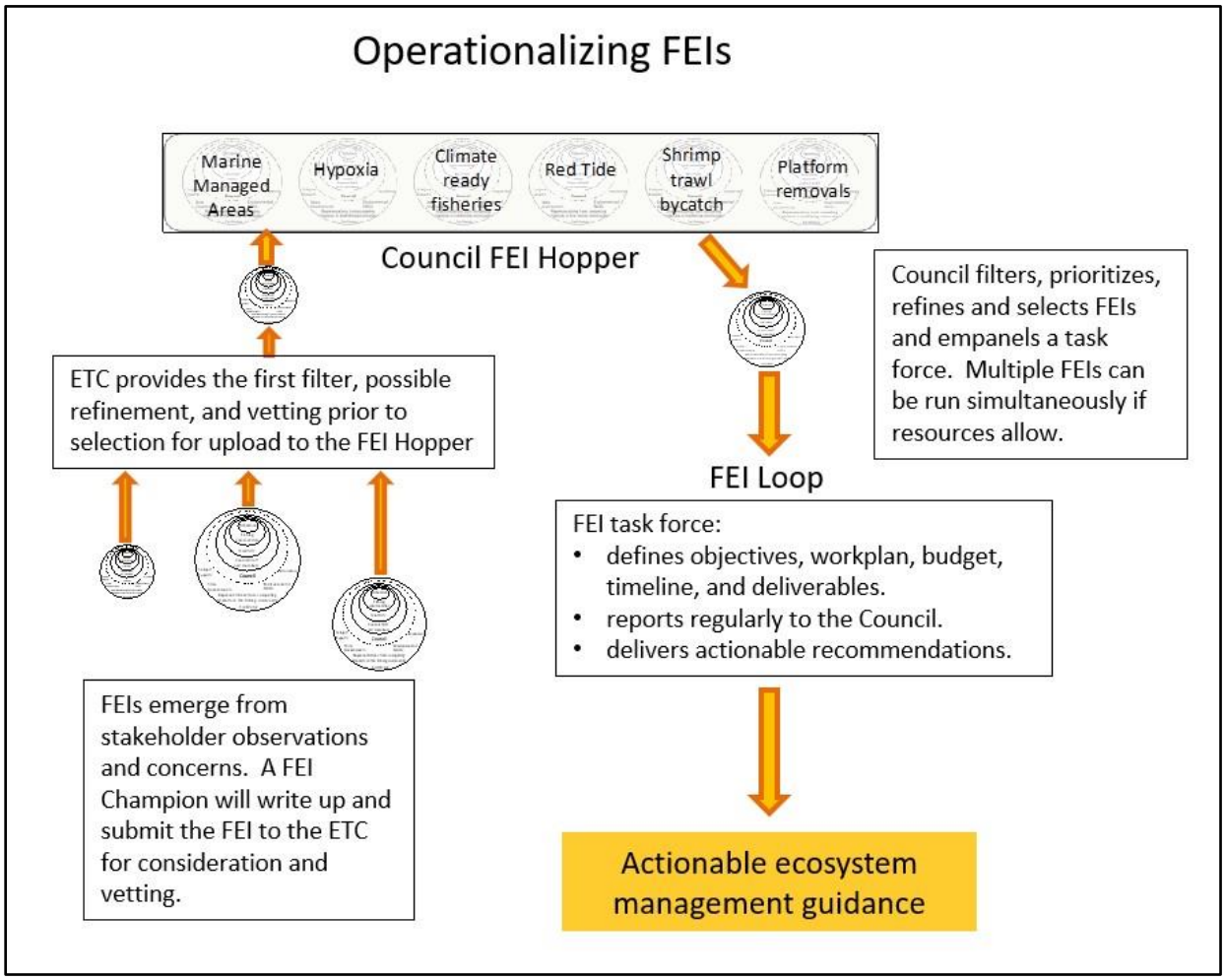

Figure 2.1.2. Fishery Ecosystem Issues emerge from stakeholder concerns, are submitted to the ETC for vetting and refinement and then uploaded to the FEI hopper for Gulf Council consideration and selection. The Gulf Council selects FEIs and empanels a task force to drive the FEI Loop and generate actionable management guidance.

2.2 Stakeholder Engagement

Effective, continuous, and meaningful stakeholder engagement has been identified as a critical component of fishery ecosystem planning within every guidance document and existing plan (e.g., Essington et al. 2016; Marshall et al. 2018a; Levin et al. 2018). The Gulf Council already has several mechanisms in place for stakeholder engagement. Indeed, the entire Gulf Council process is designed around stakeholder involvement and guidance for decision-making, starting with the appointment of Gulf Council members. There are several formal and informal

processes, and mechanisms in place for additional stakeholder involvement including for example, scoping, oral and written public comment periods, and responses to what has been called "Fisherman Feedback" (formerly "Something's Fishy", a tool to gather feedback on fish species undergoing stock assessments). A summary of the existing process that illustrates opportunities for stakeholder engagement along with suggestions for additional mechanisms proposed herein is provided in Figure 2.2.1.

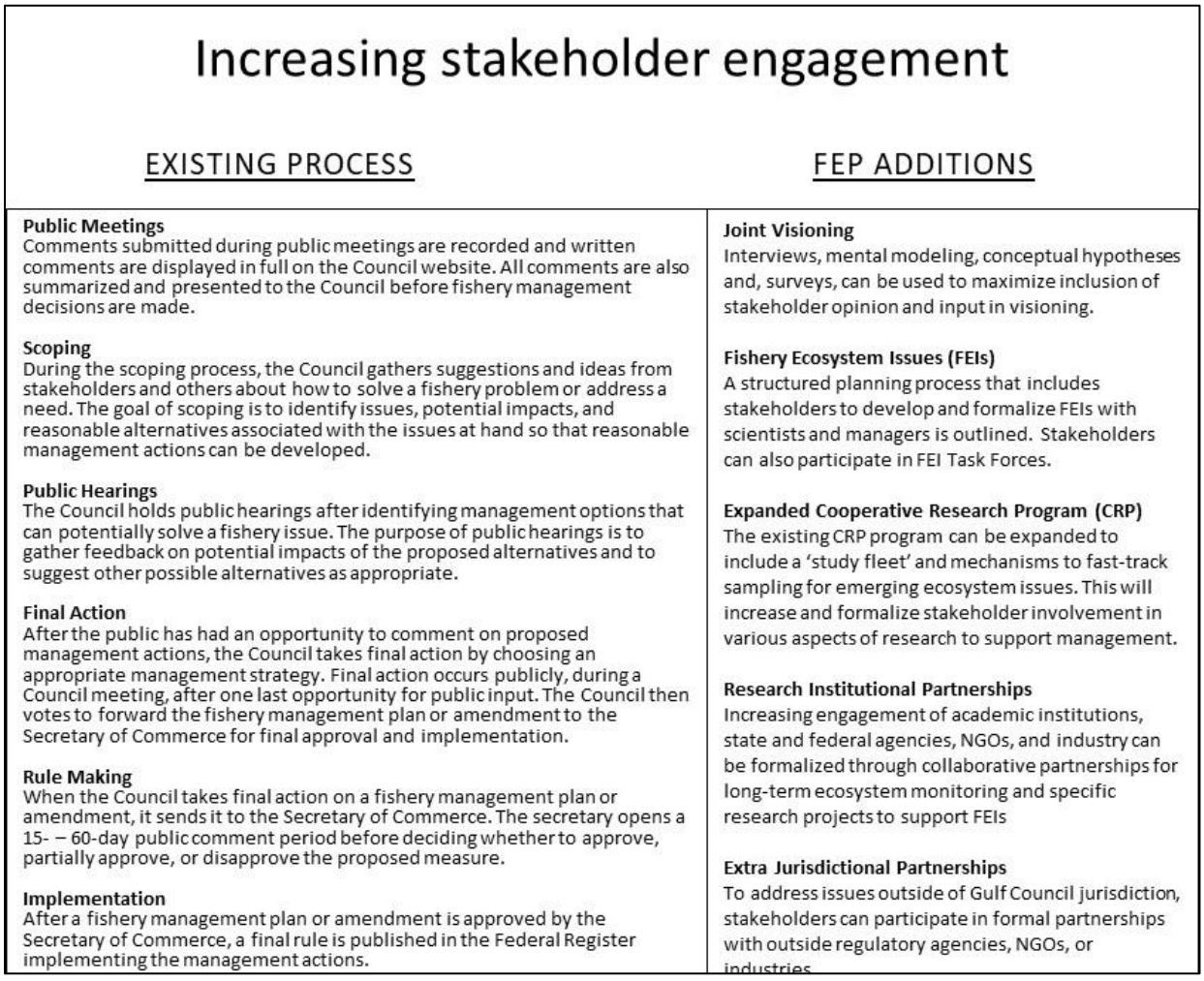

Figure 2.2.1. Stakeholder engagement is well integrated into existing fisheries management procedures in the Gulf, e.g., the steps in developing amendments to fisheries management plans (left panel). Additional mechanisms (right panel) can expand involvement through visioning, Fishery Ecosystem Issues, Cooperative Research, Research Institutional Partnerships and Extra Jurisdictional Partnerships.

Though existing processes for engagement are in place and engage many individuals, it is unclear how representative these individuals are of the diverse constituencies interested in Gulf fisheries. To build on and enhance these programs, this FEP has benefited from the report, *Stakeholder Assessment & Concept Mapping in support of Fishery Ecosystem Planning for the Gulf of Mexico: Summary Project Report* (Scyphers et al. 2021). The report offers detailed guidelines and tools to engage stakeholders in rigorous, inclusive, and equitable ways.

One such tool illustrates the major categories of potential stakeholders for Gulf fisheries. The stakeholder mapping template (Figure 2.2.2) is designed to evaluate which groups are represented and to populate the template with a list of highly knowledgeable stakeholders, or "key informants", that can provide insights on a fishery and developing FEIs. The list of Primary and Secondary stakeholder categories is not intended to be comprehensive, and not all categories may apply to all fisheries. This list should be modified to meet the needs of the specific fisheries management context. This and other tools are provided in the report and are included in Appendix A.

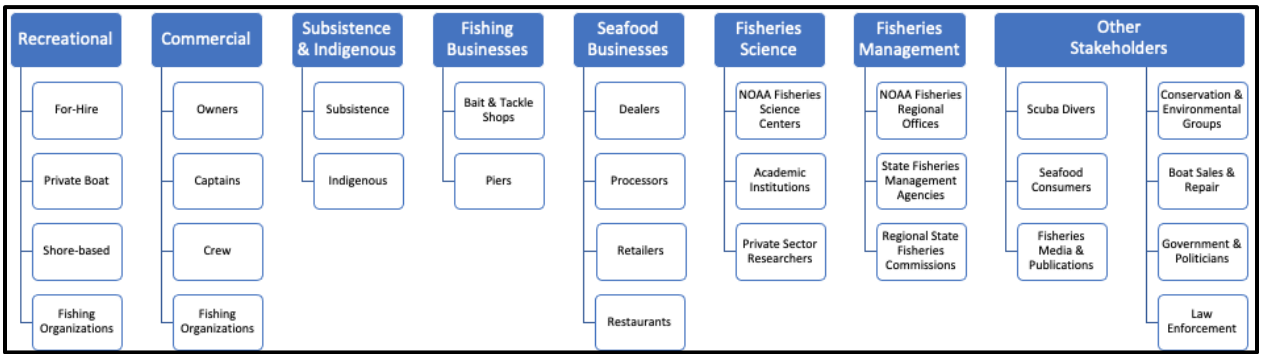

Figure 2.2.2. Tiered list of major stakeholders that could be considered for Gulf of Mexico fisheries ecosystem planning.

While there are many effective and valuable ways to engage stakeholders (NOAA 2015), nearly all share a unified goal of integrating diverse stakeholder knowledge to improve management processes (Mikason and Jentoft 2001). For instance, stakeholders maintain in depth knowledge or 'mental models' of fisheries ecosystems, which can help understand and develop testable hypotheses about complex processes (Gray and Scyphers 2017). These conceptual models are generally based on direct observations and interaction with the ecosystem over many years (e.g., experienced fishers). Although representing and sharing these models may be difficult in that they are often relayed as stories, and stakeholder knowledge has been dismissed as "anecdotal information", there are various ways in which stakeholders' conceptual models can be captured and presented including:

- Participatory Workshops (e.g., dolphin wahoo management workshops in the Southeast region: https://safmc.net/cit-sci/dolphin-wahoo-participatory-workshops/)
- Oral Histories (e.g., Karnauskas et al. 2019)

- Scenario modeling using Mental Modeler Software (e.g., as used by Scyphers et al. 2021)
- Process Diagrams (e.g., as presented in ESRs for most FEPs)

The dolphin wahoo participatory workshops mentioned above serve as one of the best examples of engaging stakeholders in defining ecosystem issues from their perspectives, graphing mental models, and participants articulating testable hypotheses and management recommendations. Selected outputs from the process are included in Appendix A.

Stakeholders can also be engaged through participating in research and monitoring, often through either Cooperative Research or Citizen Science with details provided later in Chapter 3.

2.3 Regional Subdivisions

This FEP by definition, addresses the entire Gulf. Yet the Gulf is not uniform. There are enormous differences among subregions of the Gulf, starting with underlying geology, major landforms, substrate and habitat type, environmental factors and climate. The Gulf benefits from an enormous diversity of cultures, fisheries, and socio-economic drivers. Yet currently, with a few exceptions such as commercial king mackerel and private-vessel recreational red snapper, most species are managed with uniform fishing regulations throughout the Gulf. A primary rationale of the approach described herein, is to help the Gulf Council address sub-regional management issues with scale-appropriate science and stakeholder input.

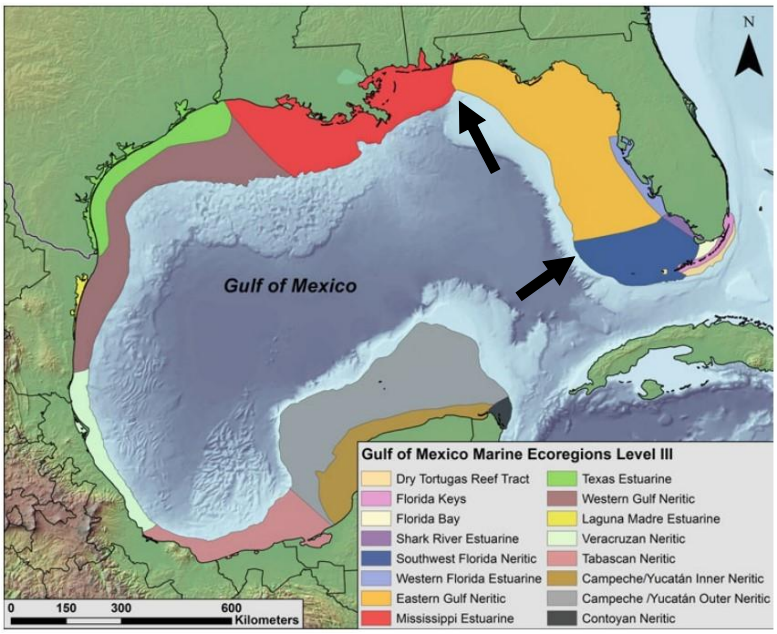

Figure 2.3.1. From Ward (2017), a map depicting different ecoregions within the Gulf. Black arrows indicate the separation between the Mississippi Estuarine and Eastern Gulf Neritic ecoregions, and Southwest Florida Neritic ecoregions that may be particularly relevant to EBFM efforts in the Gulf.

We are not proposing that the federal waters of the Gulf be divided into strict subregions for management, nor that the Southeast Fisheries Science Center (SEFSC) or the Gulf Council be expected to tailor every assessment or management decision to subregions. Nonetheless, the proposed

structure should allow some Gulf Council decisions to address subregional issues of concern as guided by an empaneled FEI Task Force. By considering specific species, times, areas and the most relevant stakeholders, the Gulf Council can provide management action more surgically in space and tailored to relevant stakeholders.

Many FEIs can be better addressed at smaller regional scales. When subregional boundaries are drawn to focus management, they should be flexible and issue-specific. Boundaries used to address one FEI may not be appropriate or relevant to other FEIs under consideration. Ideally, appropriate regional subdivisions will be identified as part of the FEI definition. However, appropriate regional subdivisions will often be identified during the FEI development process and will be included in the FEI's recommended final management actions.

As an example of possible subdivisions within the Gulf, Figure 2.3.1 shows different ecoregions within the Gulf (Ward 2017). DeSoto Canyon marks the division between the Mississippi Estuarine and Eastern Gulf Neritic ecoregions. There are significant differences in the ecosystems and fisheries east and west of DeSoto Canyon. To the east, seagrasses and mangroves provide habitat for juvenile groupers that are important to the regions extensive reef fisheries. To the west, there are large freshwater inputs from the Mississippi River, and abundant saltmarsh provides habitat for juvenile white and brown shrimp. The western Gulf also provides habitat for menhaden which supports the Gulf's largest fishery. Reef habitats in high salinity areas of the western Gulf (i.e., depths > 20 m) are largely inhabited by red snapper and other species that complete their entire life history offshore (Gallaway 1981).

These differences in habitat and species composition result in differences in directed fishing effort in these two subregions. Within the Gulf's reef fisheries, red snapper are prevalent in landings from the western Gulf, while red grouper and gag are largely landed in the eastern Gulf (Figure 2.3.2; Figure 2.3.3). Differing fishing effort in different regions of the Gulf may require different regulations to obtain desired management goals (Figure 2.3.4).

FEIs can be designed and focused to recognize subregional differences in habitats and natural ecosystems, socio-economic conditions (e.g., population size), fishing effort, or other factors. Geographic focus of FEIs will in turn allow more focused discussions and emerging management recommendations.

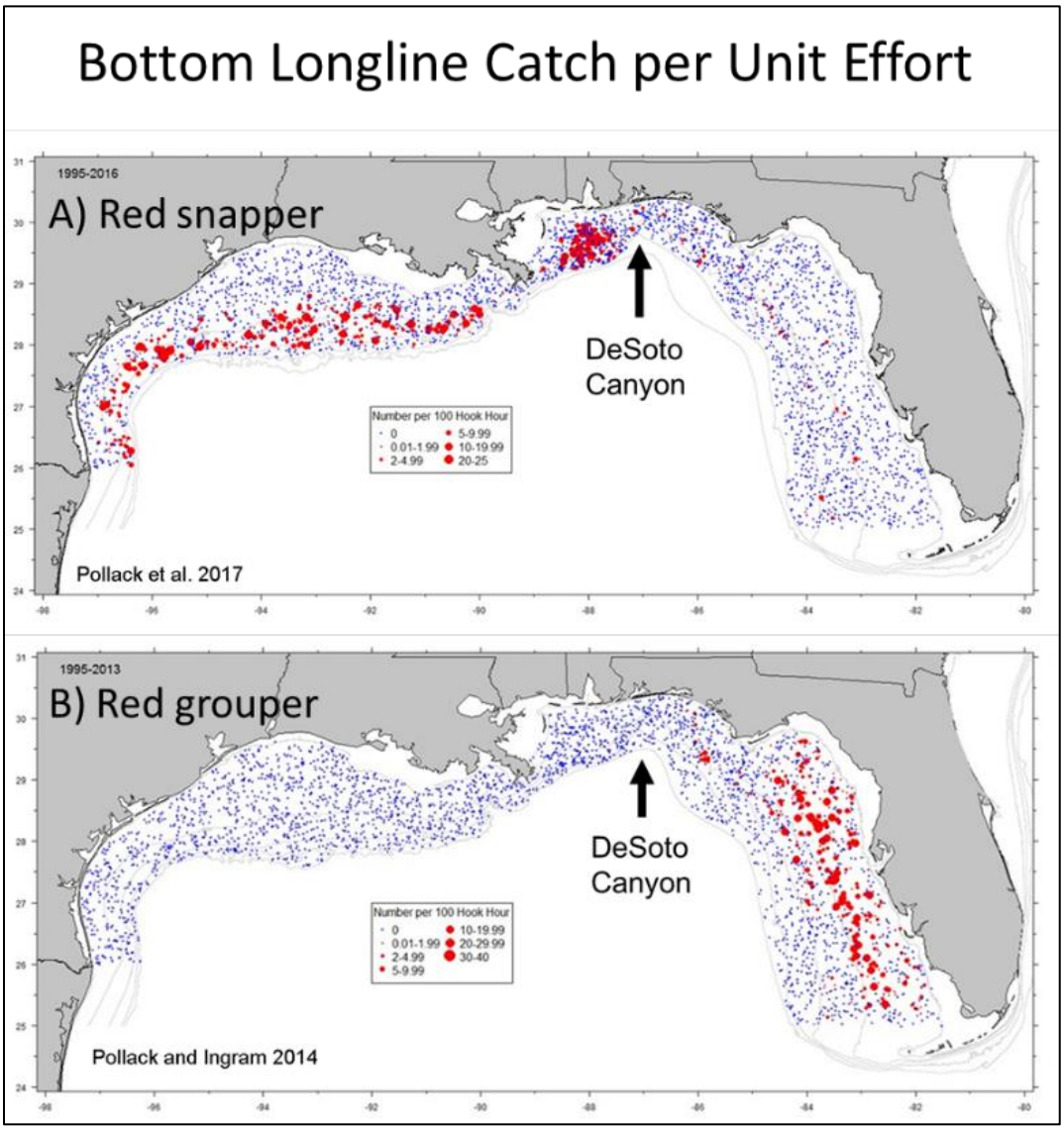

Figure 2.3.2. Catch per unit effort of A) red snapper and B) red grouper for bottom longline surveys in the Gulf. Note that red snapper are often caught in the western Gulf with much lower occurrence east of DeSoto Canyon, while red grouper are commonly encountered east of DeSoto Canyon and almost absent in the western Gulf. Due to differences in species distributions, management efforts may require different actions, and involve different stakeholders in different regions of the Gulf.

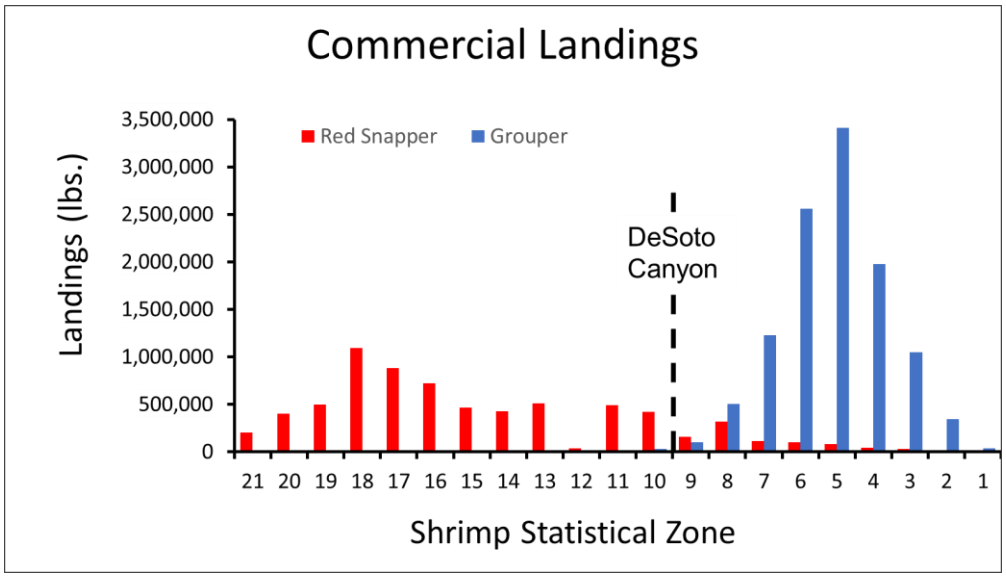

Figure 2.3.3. Mean landings from the NMFS Self-Reported Commercial Coastal Logbook of red snapper, and grouper (red grouper and gag combined) between 1992 and 2016. An ecosystem shift is evident around DeSoto Canyon, with red snapper, which complete their lifecycle offshore, dominating landings west of DeSoto Canyon, and grouper, which have an inshore juvenile stage, almost exclusively landed east of DeSoto Canyon. This is an example of patterns that could be easily explored with further development of the data visualization dashboard.

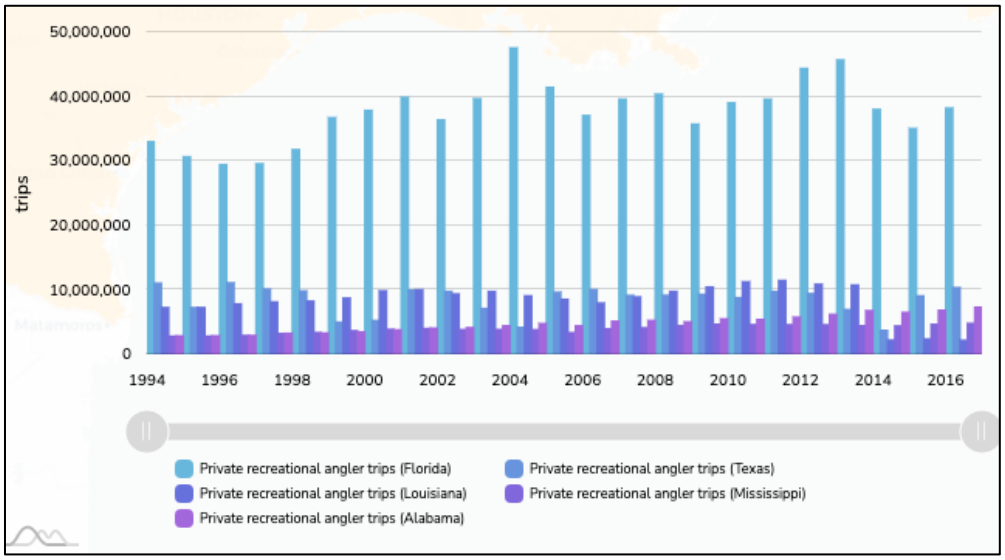

Figure 2.3.4. The number of private recreational vessel trips taken in each of the Gulf states each year. The Gulf Coast of Florida has far more private recreational trips per year than any other Gulf State. FEIs may be better addressed if the Gulf is divided into subregions, where solutions could be tailored to the level of fishing effort within different regions of the Gulf. (Graphic produced from the data visualization dashboard version 1.0; http://lgl.theiscience.org/)

2.4 Conceptual and Ecosystem Modeling

FEPs require models of the ecosystem for stakeholders and managers to visualize and make predictions about how fishery ecosystems function. There are a range of model types that vary in their degree of complexity and specificity. The simplest types of ecosystem models are Conceptual Models that qualitatively depict linkages among ecosystem components, human activities, and management actions. At the other side of the complexity spectrum are "end-to-end" Mathematical Ecosystem Models, such as Ecopath with Ecosim and Atlantis models (Grüss et al. 2017). Such models simulate full ecosystems: from oceanography to foodwebs and fisheries, operate on a spatial framework, link to physical oceanographic models and allow multiple ways to implement human behaviors involving fishery catch, fleet movement, or other impacts such as nutrient loading or climate change effects (Kaplan and Marshall 2016). Both Conceptual and Mathematical Ecosystem Models are used to describe present conditions, predict possible future conditions and evaluate the efficacy of management actions. Both types of models can be considered a means of conducting "thought experiments", with Mathematical Ecosystem Models formalized and constrained by equations that describe the magnitude of relationships among interacting ecosystem components. Conceptual Models necessarily underpin Mathematical Ecosystem Models (Grüss et al. 2017).

Conceptual Models

There exist many tools, methods, and approaches to develop and present conceptual models. Methods include mental modelling, participatory workshops, oral histories, anecdotal observations, and ethnographic interviews, among others. Conceptual models are typically developed to guide management with the expectation that further analysis, distillation, and explanation would be required before they are used to make precise management directives (Grüss et al. 2017). The utility of conceptual models may be increased when presented in formats accessible to a wide suite of stakeholders (Ault et al. 2012).

Conceptual models can be used as the starting point (Stage 1: Where are we now?) in the Gulf FEP Loop (Figure 2.3) and the FEI Loop (Figure 4.2.1. below). Conceptual models can also be used to evaluate the consequences of potential outcomes of various alternative management actions (FEP Loop stage 3: How will we get there?). Tradeoffs among potential outcomes can be made explicit and be weighed by the Gulf Council to inform choices using Management Strategy Evaluation (MSE) and other means. Conceptual models can in turn be used as the basis for testable hypotheses about future conditions that can be evaluated using well-designed monitoring and evaluation programs to compare outcomes with predictions (FEP Loop Stage 5, Did we make it?, Figure 2.3; Figure 4.2.1 below).

The utility of conceptual modelling was recently demonstrated in the South Atlantic region. The South Atlantic Council's Citizen Science Program partnered with the SEFSC to conduct a series of participatory workshops with fishers in locations that spanned the entire region, from North Carolina to Florida. The workshops resulted in regionally specific conceptual models of the

dolphin and wahoo fishery in an ecosystem context, based on the perceptions of fishers (https://safmc.net/cit-sci/dolphin-wahoo-participatory-workshops/). Participation in the workshops has elevated trust and communication between fishers and scientists. Selected workshop results are presented in Appendix A.

Mathematical Ecosystem Models

Mathematical Ecosystem Models used in fisheries management range from models that address single stocks, through multiple species and trophic models, to more complex full ecosystem models. In the most general terms, scenario models of future climate impacts have been used to educate and engage stakeholders (e.g., in the Pacific Region as facilitated by The Nature Conservancy). For more specific issues and regions, comprehensive and complex ecosystem models have been developed to guide management actions. Sagarese et al. (2017) made an attempt to parameterize a Next Gen ecosystem model for the Gulf. This study, and other similar efforts may provide more quantitative weighting of tradeoffs between potential management actions. In another example, the NEFSC is comparing predicted outcomes of possible EBFM using four candidate ecosystem models, and comparing alternative management procedures and actions using a MSE process.

While Mathematical Ecosystem Models may be successful in explaining how ecosystems function, there may not always be a direct link between the output and a particular management action. As noted by Grüss et al. (2017), "Most ecosystem models are not yet to a maturity stage where they can be sufficiently validated for the purpose of short-term forecasts of absolute quantities, such as species-specific biomasses," rather such models are "generally better geared toward investigating a wide range of strategic management questions (e.g., the broad impacts of harvest quotas)." Perhaps the most effective use of Mathematical Ecosystem Models is within a hypothesis-testing framework, such as to formally examine the outcomes of differing Conceptual Models and to bracket the uncertainty of multiple scenarios through sensitivity analyses in which key parameters are varied (Grüss et al. 2017; Ainsworth et al. 2018). In the context of a GOM FEP, it may be beneficial to formally prioritize this use of Mathematical Ecosystem Models by having the ETC contribute to the development of a suite of "standard operating" models that are available to explore impacts of possible council actions. This would complement existing research and management tools, rather than serving as replacements. In this way, Mathematical Ecosystem Models provide another source of information for managers to consider but are not burdened with the requirement of being sufficiently accurate or precise to definitively prescribe a particular course of action (Grüss et al. 2017).

2.5 Addressing Extra Jurisdictional Issues

Many of the greatest threats and negative impacts to Gulf fishery resources are generated outside of the federal waters of the Gulf (e.g., coastal development, upland sources of pollution, and climate change). The solutions to these problems, in many cases, are outside of the jurisdiction

of the Gulf Council. As FEIs are developed, issues will be identified that cannot be resolved by the Gulf Council alone. There may be a need for broad collaboration with NGOs, academic institutions, state and federal agencies, industry representatives, and others to address these extra jurisdictional issues. FEIs should identify what outside actions are necessary to achieve the desired results, and which agencies have the authority to take such actions.

2.6 Ecosystem Status Reports and Indicators

NOAA's Integrated Ecosystem Assessment (IEA) Program, a precursor to fishery ecosystem planning (Figure 1.2.1), was designed to provide a framework for RFMCs to prioritize and monitor various ecosystem parameters that could together and individually offer a proxy snapshot of the status and trends in regional ecosystem conditions. The aim was that this information would be used to support multi-species fishery and ecosystem management decisions. A primary way that IEAs support ecosystem-based management is through selection of a suite of indicators that are monitored and presented in ESRs. The IEA process and resultant ESRs play a key role in measuring progress towards FEP goals and objectives.

The initial ESR for the Gulf was an impressive compilation of data with the goal to "summarize the various focal ecosystem components in the Gulf necessary to consider from an ecosystem perspective" (Karnauskas et al. 2013). The report considered more than 100 indicators within the broad categories of climate drivers, physical pressures, state of benthic habitats, state of lower trophic levels, state of upper trophic levels, fishing indicators, and socioeconomic indicators. Five years later, the ESR streamlined the indicators presented, aiming to make the report more robust and easily interpretable (Karnauskas et al. 2017). The streamlined report used indicators that were drawn from 7 broad categories: climate drivers, physical and chemical pressures, habitat state, lower trophic states, upper trophic states, ecosystem services, and human dimensions.

The most recent Gulf ESR (Karnauskas et al. 2017) provides an excellent overview of the status and trends of various indicators of Gulf ecosystems. Updates to the ESR could play an important role in the Gulf FEP Loop i.e., *Stage 1: Where are we now?* (Figure 2.3). The ESR provides a backdrop for the Gulf Council and stakeholders to build a consensus understanding of the state of the Gulf. Individual Gulf Council members and stakeholders can use the ESR to contextualize their own experiences and observations into conceptual models of the processes affecting Gulf fishery ecosystems. However, the most recent Gulf of Mexico ESR was produced in 2017, nearly five years prior to the date of this document and the direct relationship between most ecosystem indicators and fisheries productivity and status are not well correlated. By contrast, the North Pacific IEA program produces annual ESRs, which serve as the contextual backdrop for nearly all management decisions in the region (NPFMC 2020). The reports are streamlined and concise, i.e., less than 20 pages and supported by easily interpreted graphical summaries of indicator values and trends in relation to identified reference points.

Therefore, the Gulf's IEA program may have only limited utility in supporting fishery ecosystem planning in its present form. The style, frequency, and utility of Gulf ESRs should be evaluated in light of their costs and benefits, relative to other priorities. Updates and changes to the program may be warranted to support this FEP.

CHAPTER 3. EXPANDED RESEARCH INFRASTRUCTURE

Implementing this FEP will require various resources, particularly creative mechanisms to fund and implement appropriate research that can guide management action. The existing work of the SEFSC and other academic and industry institutions provides an excellent base. Yet the research and analysis required to support fishery ecosystem planning are outside the scope and existing capacity of the SEFSC and the Gulf Council. Indeed, no single entity or institution is equipped or designed to support the research needs of fishery ecosystem planning in the Gulf.

Broadly, research to support EBFM is inherently complex. In addition, funding for research is limited, and many EBFM questions cannot be answered without broad cooperation. Multiple approaches and tools will be required to support EBFM research needs, and these should be used adaptively and as efficiently as possible.

The IEA process and resultant ESRs (section 3.1) offer ways to measure progress towards FEP objectives and goals. For FEIs, however, additional, more detailed information will generally be required to advise management actions. There are several ways to efficiently gather relevant information and to increase stakeholder involvement in the FEP process. Two of these are Cooperative Research and Citizen Science. Though there are some overlaps in the definitions of Cooperative Research and Citizen Science, for the purposes of this FEP, they are differentiated in two ways: the number of participants and the level of their involvement. Citizen Science programs typically include a large number of participants that need less training and have less direct involvement whereas Cooperative Research typically relies on a small number of well-trained, highly involved stakeholders.

The level of stakeholder participation in research with scientists can be characterized along a continuum. Participation ranges between contracts, contribution, collaboration, co-creation and ultimately to colleagues (Shirk et al., 2012; Table 3.1). Increased participation and collaboration between scientists and other stakeholders (e.g., fishers) has two primary benefits. First, stakeholder engagement in research expands their buy-in, trust and ownership in the process. Second, the resulting science can effectively and efficiently provide management guidance that may be more actionable than what groups could generate independently. Heyman (2011) provides an example of applied co-creation in which fishers and scientists developed a functional biophysical hypothesis and tested the hypothesis collaboratively. The results led directly to ecosystem based fishery management action.

Fully co-created science conducted by fishers and scientists benefits from the unique contributions, perspectives, experiences, resources, and skills that each group can offer. Fishers bring years of experience based on direct observation on the water that can be articulated in conceptual hypotheses that are often referred to as anecdotal information. Fishers can sample in locations, times and conditions that may not be accessible to scientists. Scientists can provide testable hypotheses and statistically robust sampling designs that can generate clear results and

withstand rigorous peer review. Cooperative pathways to support FEI research information needs include: Cooperative Research (section 3.2), Citizen Science (section 3.3), and Research Institutional Partnerships (section 3.4). Of these approaches, Cooperative Research and Research Institutional Partnerships are the two recommended priority pathways, given that they will lead to actionable guidance most efficiently.

Table 3.1. How public participants interact with scientists through public participation in scientific research (from Shirk et al. 2012).

Public action in each PPSR model	Members of the public...
Contract	... ask scientists to conduct a scientific investigation and report on results
Contribute	... are asked by scientists to collect and contribute data and/or samples
Collaborate	... assist scientists in developing a study and collecting and analyzing data for shared research goals
Co-create	... develop a study and work with input from scientists to address a question of interest or an issue of concern
Colleagues	... independently conduct research that advances knowledge in a scientific discipline

3.1 Ecosystem Status Reports and Indicators

As discussed above, the IEA process and ESR indicators are well-suited for use in the FEP Loop – provided that ESRs are updated at least every 5 years. However, use of ESR indicators alone may not be sufficient for FEIs for two reasons. The ESR is designed to illustrate the status and major trends in selected indicators for the entire Gulf (descriptive science), whereas FEIs are often articulated in the form of a particular question to answer (hypothesis-driven science). Furthermore, as noted in the above section on "Regional Subdivisions", many FEIs need to be considered at a subregional scale with indicators tailored to their relevant spatial extent.

Thus, ESR indicators should be considered during the scoping phase of an FEI, with the expectation that only a subset of those indicators may be useful, and that additional indicators may need to be selected. Within an FEI, indicators may be used for conceptual scenario modeling to evaluate the consequences of alternative management actions, or selected as performance measures to determine if management decisions had the intended/predicted outcomes. Selected indicators must be measured at appropriate temporal and spatial scales so that the outputs can be "operationalized" to inform specific actions for fisheries management, or to be used as metrics for measuring the outcome of FEIs. FEI indicator development and monitoring could be supported through Research Institutional Partnerships (see section 3.4,

below). Finally, a key aspect of making indicators useful is to provide ways for the Gulf Council, the ETC, and stakeholders to visualize and explore relationships among ecological, socio-economic and governance indicators. A user-driven, interactive data visualization dashboard could serve this purpose. To this end, LGL developed a beta version of an "FEP Dashboard" for the Gulf, presently available at: http://lgl.theiscience.org/.

3.2 Cooperative Research Program Expansion

As FEIs run their course, research needs will be identified, and Cooperative Research represents a powerful tool to address these needs. Cooperative Research does occur in the Gulf through a CRP operated by the Southeast Regional Office (SERO). The SERO CRP funds research using annual Requests for Proposals (RFPs) and competitive grants. The existing CRP can be used to address some research needs identified through FEIs, by listing them as priorities in RFPs.

However, the existing CRP is not structured to address many of the research and data needs for EBFM as identified in this FEP. The existing CRP is not well equipped to support sampling of events that are rapidly emerging, unexpected, newly observed, ephemeral, or acute (e.g., measuring the extent of hypoxia, red tide, or an oil spill). Sampling for these events will need to occur responsively, in near real time, and would not be feasible within the typical timeframe for a CRP grant cycle. These events may also be logistically difficult to sample through other government operated sampling programs. Additionally, the existing CRP does not serve to support long term data collection, which is needed to analyze trends in ecosystem indicators, their interactions, and their potential impacts on fishery resources. Expanding the CRP mandate and budget could help to fill identified information needs for EBFM.

An expanded Gulf CRP could be modeled on the successful Northeast CRP. Some projects undertaken by the Northeast CRP include industry-based, enhanced bio-sampling, where industry partners are directed to collect biological samples for focused short-term studies on age, growth, reproductive dynamics, and bioenergetics (Figure 3.2.1). This can help fill data gaps at times when, or in areas where, other surveys do not occur, or to collect information on data poor species. The Northeast CRP also conducts cooperative environmental monitoring, where commercial fishing partners deploy oceanographic equipment, allowing for near real time data collection for variables such as bottom temperature. To a lesser extent, this approach has already been used in the Gulf, whereby water quality sampling has been completed by commercial fishers to support observations of emerging red tide and hypoxic events (Turley et al. 2021; 2022). This is a type of cooperative research that could be greatly expanded in the Gulf to gather data necessary for ecosystem modeling or indicator development. The Northeast CRP has also

assembled a study fleet of 50 commercial vessels, which collect high resolution catch, effort, and environmental data that has been used to estimate fishery footprints, develop catch-per-unit-effort indices for stock assessments, examine the potential impact of offshore wind development, and inform oceanographic models. A study fleet may be a valuable tool for collecting data in the Gulf.

An independent review of the Northeast CRP was conducted in 2016, which provides valuable information about the successes and shortcomings of the Northeast CRP, and should be consulted when expanding the Gulf CRP (Kennelly 2016; NOAA 2017). The Northeast CRP requires the services of 12 Northeast Fisheries Science Center employees. An expanded Gulf CRP may eventually require similar resources, although the size of the program could be increased adaptively. Research needs for the expanded Gulf CRP will largely be identified through FEIs, and the existing Southeast Data Assessment and Review (SEDAR) stock assessment processes. Selection and prioritization of research projects and sampling efforts, however, will have to be dictated by the ETC, SSC, and the Gulf Council.

Figure 3.2.1. Fishers participating in the Northeast Fisheries Science Center's Cooperative Research Program. https://www.fisheries.noaa.gov/new-england-mid-atlantic/cooperative-research-building-collaboration-future-fisheries

A Gulf study fleet modeled off the Northeast CRP has the potential to collect long term data sets, but could also be quickly mobilized to collect data for unpredictable or short term events such as hypoxia or red tide events, or oil spills. A study fleet may be able to collect this data at a lower cost than traditional surveys using scientists and government owned vessels, but these relative costs cannot be evaluated until specific study goals and objectives are determined. While the Northeast CRP and study fleet largely focuses on commercial fishers, a Gulf study fleet could also incorporate recreational fishers or charter-for-hire captains, and develop methods to estimate recreational spatial effort, bycatch and discards, which are challenging to measure with traditional surveys and dockside sampling.

Finally, the expanded Gulf CRP could provide explicit mechanisms to facilitate cooperation between fishers and scientists with something as simple as a digital message board modelled after a dating app. Fishers could post their interests, vessel type and gear. Scientists could post their interests or advertise for needed research support. This simple mechanism might facilitate

meaningful dialogue and support partnerships for competitive CRP proposals. Perhaps the largest benefits of an expanded Gulf CRP program would be increased stakeholder engagement in research and management.

3.3 Citizen Science

While a CRP can engage a small community of well-trained, highly involved stakeholders, Citizen Science can involve a much larger number of stakeholders. For example, citizen science projects from the Cornell Lab of Ornithology have engaged thousands of participants that collectively generate 10s of millions of observations annually (Bonney et al., 2009). Citizen science initiatives may be especially useful for gathering data across the Gulf ecosystem that is difficult to obtain by other means, because traditional approaches to sampling would otherwise not be possible or be cost-prohibitive. For example, it is unlikely that observers could be placed on private recreational vessels to collect information on depredation of catch, but with a citizen science program in place, individual anglers can report their own observations. The voluntary nature of such programs, the limited training that participants may receive, and the perception that fishers may not willingly provide information that could go against their self-interests limits the applications of citizen science, and often calls into question the validity of the results from such studies. Citizen science programs can also suffer from low engagement, or decreasing engagement over time as participants lose interest. However, these difficulties can be overcome if projects are designed to answer appropriate questions, and proper mechanisms to ensure data quality are put in place. While citizen science is not an appropriate tool for many ecological research questions, it should be considered as a possible approach when an appropriate research need is identified by an FEI.

Bonney et al. (2021) described the process used by the South Atlantic Council to establish its citizen science program that would be beneficial to consult prior to developing a citizen science program in the Gulf. One issue with citizen science programs identified by the South Atlantic Council is the potential to create mistrust in scientific and management processes if fishers provide information, but that information is not used in stock assessments or management. The South Atlantic Council developed a vision for their citizen science program: to advance science and increase trust, one project at a time. The South Atlantic Council determined it was crucial to develop program infrastructure early because of the high quality that would be required for data to be used in fisheries management, and the high potential to build mistrust with fishers if a project was completed, and the data was not used by managers. The initial pilot program undertaken by the South Atlantic Council's citizen science program used a mobile app to collect size data on scamp released in the commercial, recreational, and recreational for-hire fisheries. A second project, referred to as FishStory, collected historical photos of catches from headboat

Figure 3.3.1. Photo from 1954 submitted to the FISHStory program (*https://safmc.net/safmc-fishstory/*).

docks to provide data on size and species composition of fish landed prior to the establishment of dockside sampling programs in the 1970s (Figure 3.3.1). The South Atlantic Council also used social media data harvest, a citizen science tool, to collect images of catches from charter for hire trips as part of their dolphin wahoo workshops (Figure 3.3.2). Nearly 4,000 photos were analyzed, and allowed for analysis of trends in catch by region or season.

Citizen science programs can be costly, projects should be chosen carefully and well designed to ensure that the appropriate tools are used to answer the question at hand, and the results are of high enough quality to be used in management efforts. In the Gulf, a citizen science program has the potential to begin filling information gaps for the private recreational fishing sector. As was done by the South Atlantic Council, a mobile app could be used to allow fishers to report the species and size of fish discarded. This information is critical to the existing single stock management system and will be important as the Gulf transitions to EBFM and begins to explore more complex species relationships. Citizen science might also emphasize having fishers collect data on the ecosystem that could be analyzed in a straightforward way (e.g., presence only data); for instance, uploading georeferenced photos with date/time stamps of *Sargassum* algae (https://five.epicollect.net/project/sargassum-watch), sea turtles (https://texasseagrant.org/programs/iseaturtle/index.html), or marine mammals (https://five.epicollect.net/project/sj-dolphin-watch/data). While unlikely that these could be used

Figure 3.3.2. A social media image analyzed as part of the South Atlantic Council's dolphin wahoo workshops.

as formal indicators within the IEA framework, they could provide independently collected data by which to compare modeled predictions of distributions or give broader context to other work. Importantly, these could be valuable tools for stakeholder engagement and education.

3.4 Research Institutional Partnerships

The Gulf Council is responsible for managing the Gulf's fisheries but will always be limited by the availability and quality of data and information. Fortunately, the Gulf Council's data needs are supported by many state and federal agencies, academic researchers, regional monitoring programs, and through access to many publicly available data sets. Yet the data and information needed to support fishery ecosystem planning, are different from the needs of traditional fishery management. By contrast, ecosystem studies need to account for interactions between and among managed and unmanaged species, abiotic factors, and social and economic forces. Further, research tools are needed to help evaluate tradeoffs between management options and the benefits and costs to various stakeholders. In short, there exists no single entity or institution with a mandate for research supporting the emergent needs of EBFM.

As a possible example for the Gulf, EBFM information needs are largely being met for the North Pacific Fishery Management Council. Annual ESRs are developed and produced with the support of hundreds of institutional partners (NPFMC 2020) that share data and information. The program offers management guidance that is incorporated in nearly all management decisions in the region. The process and the products benefit everyone involved. The Council and fisheries stakeholders benefit from access to an enormous pool of data and information that support timely management decisions. Academic researchers benefit from their enhanced understanding of the fishery management process and data needs, which in turn increases their potential access to future funding for applied research.

Institutional partnerships to support fishery management already exist in the Gulf but could be fostered and expanded to support EBFM and this FEP. The data and information needs can be evaluated and serve to help design and implement integrated monitoring programs. Partnerships could be made or expanded with existing institutions such as the Gulf Coast Ocean Observing System (GCOOS), the RESTORE Science Program, Offshore Operators Committee (OOC), Bureau of Ocean Energy Management (BOEM), the emerging offshore wind industry and a myriad of academic institutions.

3.5 Extra-Jurisdictional Partnerships

There are many issues and processes affecting Gulf fishery resources, that are generated outside the federal waters of the Gulf and are beyond the jurisdiction of the Gulf Council. Though some naturally occurring issues cannot be addressed (e.g., increased severity and frequency of hurricanes) other, human-generated impacts on Gulf fisheries might be regulated or mitigated by existing federal or state regulatory agencies. Coastal water quality, for example, can affect juvenile habitat for federally managed reef fish. While the Gulf Council does not have jurisdiction, state water management districts and the Environmental Protection Agency (EPA) may. If water, coastal habitats, or other effects are generated from non-point or distant sources (e.g., high nutrient and sediment loads in Mississippi River discharge), the Gulf Council can develop or contribute to institutional partnerships with NGOs, agricultural interests, or others to address impacts on Gulf fishery ecosystems. In some cases, Gulf fishery stakeholders may have influence in other sectors and may be willing to play a role in such partnerships, aimed at win-win solutions. Efforts and resources invested in such partnerships must be carefully weighed based on the scale of the impacts to Gulf fishery ecosystems, the relative likelihood of mitigating those impacts, and other competing resource needs. Since partnerships and institutional arrangements must be developed on a case-by-case basis, no specific guidance is provided herein.

CHAPTER 4. PROCESSES AND PROCEDURES

4.1 Identifying FEIs

As described in section 2.1, FEIs may originate from observations and concerns from Gulf fishery stakeholders. As these issues gain attention and are discussed with an increasing number and diversity of stakeholders, and addressed through Public Comment or Fisherman Feedback, the FEI concept will be refined and focused. Ultimately, the FEI will be written up by the FEI Champion and submitted to the ETC for review and vetting. Key components for an acceptable FEI description are outlined in Figure 4.1.1. The ETC may request that the FEI Champion refine and resubmit the FEI, which, when recommended by the ETC, will be submitted to the Gulf Council for consideration. Figure 4.1.2 and Figure 4.1.3 offer considerations for FEI selection and focus.

Terminology

FEI: A specific fishery management issue or problem that occurs within the Gulf, or a subregion of the Gulf, that may be addressed or solved through Gulf Council action. FEIs provide a structured process to address ecosystem issues that may not otherwise be considered within the single stock management paradigm.

FEI Loop: The structured process that moves an FEI towards its goals.

FEI Champion: An individual that articulates an FEI and ushers the concept through the FEI Loop. Champion could be Gulf Council Staff or Member, ETC or AP member.

FEI Hopper: An active list of all potential FEIs recommended by the ETC maintained in the Gulf Council's records.

FEI Task Force: appropriate stakeholders and experts appointed by the Gulf Council, specifically dedicated to the individual FEI.

Components of an FEI Description

- Title
- Name of FEI Champion
- Description of the management issue (the problem; what changes have been observed)
- The fishery or fisheries involved
- Geographic area of focus including habitats
- Key environmental factors believed to be influencing the issue (both natural and anthropogenic)
- Key actors and *institutions affected by* the issue and their interests
- Relevant *institutions that can affect the outcome* or contribute to the solution (including state and federal government agencies, NGOs, private businesses, and academics)
- Data or information gaps
- Suggested Task Force members
- Vision of success

Figure 4.1.1. Suggested components to include in defining an FEI.

Some Considerations for FEI Selection and Focus

- Does the FEI emanate from the concerned of engaged stakeholders?
- Does the FEI address issues that span multiple Fishery Management Plans?
- Does the FEI target a specific sub-region of the Gulf?
- Will focusing on the FEI have a high probability of generating actionable guidance?
- Will recommended actions be within, or outside of Gulf Council jurisdiction?
- Will focus and proposed guidance from the FEI lead to triple bottom line benefits?

Figure 4.1.2. Some considerations for FEI selection and focus.

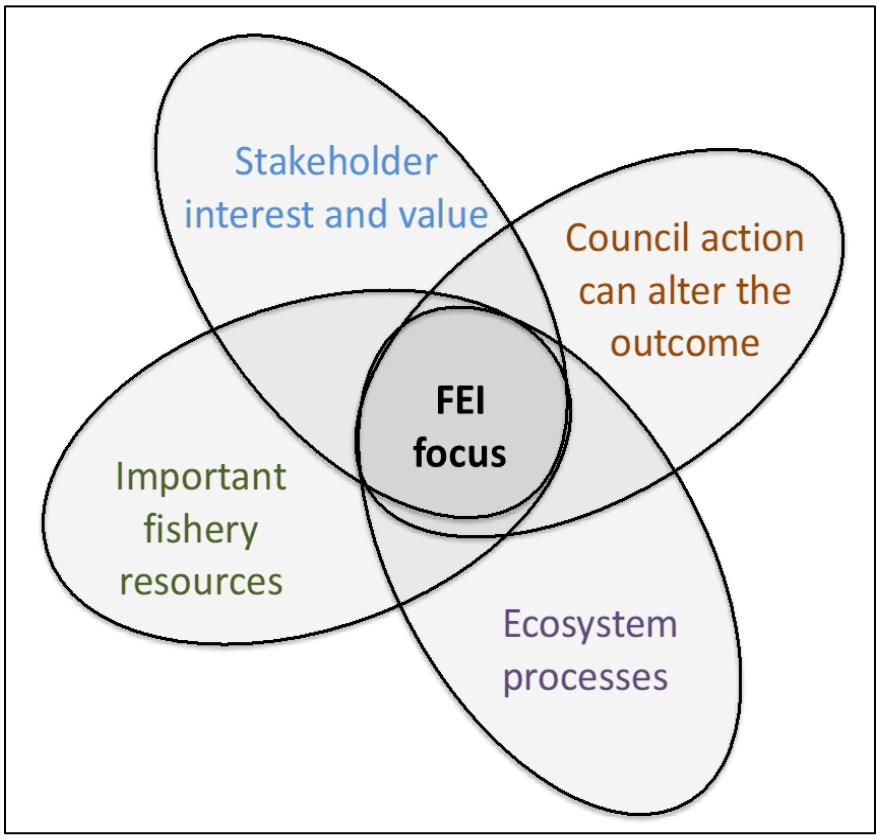

Figure 4.1.3. Considerations and criteria tool to help prioritize and select FEIs to be addressed.

4.2 Timeline for Initiating, Updating, and Reassessing FEIs

Scheduling FEP and FEI action plans is important in order to maintain regular revision of new and active FEIs and to create routine and efficient communications on FEI implementation. Regular meetings of the ETC and the Gulf Council will be utilized in tracking these actions, thereby giving the Gulf Council latitude to rapidly adapt and respond to issues or changes as they arise. This rapid adaptability is a key feature of progressive fisheries management in a context of changing ecosystem dynamics.

An active list (FEI Hopper) of all potential FEIs recommended by the ETC will be maintained in the Gulf Council's records, including a brief project description, and a timeline of major milestones. A preliminary list of potential FEIs is provided as an example in Appendix B. At

Gulf Council meetings (at an appropriate interval to be selected) a session could be scheduled for FEI reviews. Within these meetings, the ETC will provide an update on the status of each FEI underway and propose new FEI's for consideration. The Gulf Council can then prioritize, select and initiate an FEI or multiple FEIs for implementation.

Once an FEI is approved, the Gulf Council will empanel a FEI Task Force, made up of appropriate stakeholders and experts, dedicated specifically to the individual FEI. These representative stakeholders may be selected with guidance from Stakeholder Selection and Mapping Templates (Scyphers et al. 2021; Appendix A.7), Gulf Council agencies (e.g., the ETC itself, relevant Advisory Panels), and/or relevant scientific and management agencies (e.g., NOAA, NGOs). The FEI Task Force will then follow the process in the FEI Loop, including initial scoping, workplan development, implementation, management action, and evaluation, as described below (Figure 4.2.1).

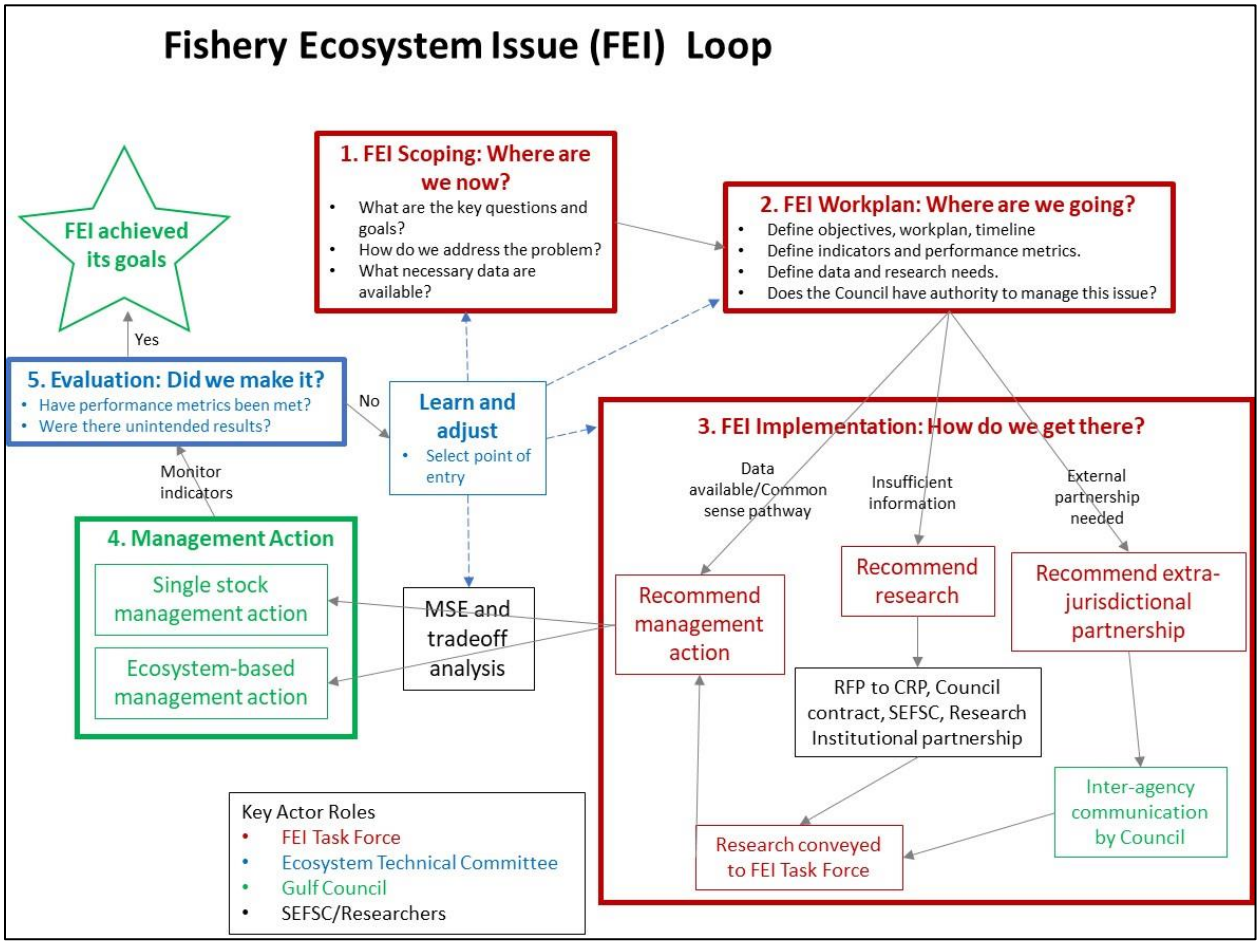

Figure 4.2.1. A Fishery Ecosystem Issue (FEI) Loop for the Gulf

1. FEI Scoping: Where are we now?

The FEI scoping process will begin with dissemination of the FEI description and any related materials to FEI Task Force members immediately following FEI Initiation for review prior to assembly. An initial meeting will be scheduled for scoping, during which the Task Force will begin with identification of clear questions and goals of the FEI and with filling in any further relevant information needed in the FEI description. Once the key questions and goals are clarified, preliminary discussion on starting points (i.e., necessary and available sources of information) may be used to begin charting courses to potential solutions.

2. FEI Workplan: Where are we going?

The workplan process will use the preliminary information gathered during scoping to direct next steps toward potential resolution. This stage will solidify and detail the tasks and information needed to develop management actions. Key components of this phase will include:

- **Define objectives, workplan, and timeline.**
    - What specific tasks are necessary to address the key scoping questions? What work products will be developed during this process? Along what timeline are these tasks and products expected to be completed?
- **Define indicators and performance metrics.**
    - Which indicators and performance metrics will be needed to measure progress towards the goals of the FEI? Are these indicators linked to others which might be influenced by ripple effects? What are the most meaningful metrics for post-implementation evaluation?
- **Define data and research needs.**
    - What data gaps exist that are critical to answering the key questions? What further research is necessary before taking action?
- **Determine if the Gulf Council has authority to manage this issue.**
    - Will external support and collaboration be needed to develop and/or execute meaningful management action?

Updates from each FEI Task Force will be routinely provided to the ETC (to be scheduled at ETC meetings as needed) and will include new information and any implementation recommendations to the Gulf Council. The ETC will then provide routine interim summaries of FEI Task Force updates to the Gulf Council annually or as necessary, until management actions are recommended, as described below. Each FEI project, including all status updates, work products, conclusions and recommendations will be compiled in a designated FEI project file in active or archived lists in the ETC and Gulf Council records.

3. FEI Implementation: How do we get there?

Once a concrete workplan is formulated, the FEI Task Force will be able to recommend the next steps along one of three paths: recommend management action, recommend research, recommend extra-jurisdictional partnerships (Figure 4.2.1).

- **Recommend Management Action**: If sufficient data are available to answer the key questions, or if common sense dictates a clear path for addressing the problem, the FEI Task Force may progress directly to recommended management action.
- **Recommend Research:** In the case of significant knowledge gaps that prevent resolution of the issue, the Task Force may recommend further research on the matter. When feasible, this may be addressed by analyses by Gulf Council staff and/or a sole-source contract from the Gulf Council. Another potential pathway to fast-track data collection could occur through the expanded Gulf CRP as described in section 3.2, in which field data may be more efficiently collected in near real time by a cooperative fishing fleet, allowing for greater adaptability in the FEI Loop and resulting management response. In the case of larger data gaps, an FEI may require development of an RFP, directed through the most capable institution(s) given the FEI context and available funding (e.g., the SERO CRP, NOAA Fisheries SERO, other partnerships).
- **Recommend Extra-jurisdictional Partnerships:** If the Task Force determines that the management action needed falls outside of the jurisdiction of the Gulf Council, they may recommend external agencies for the Gulf Council to communicate and partner with in order to achieve FEI resolution. This path may continue forward to management action by the Gulf Council (e.g., if the issue may at least in part be addressed by immediate Gulf Council action, or once inter-agency communication has been translated into further useful information and/or collaborative management actions).

After recommendation of management action by the FEI Task Force, Gulf Council the SEFSC and other researchers as appropriate will be enlisted to conduct an MSE to illustrate tradeoffs among various possible management actions. The SSC will review the scientific rigor and tradeoff analyses and recommend options for Gulf Council action.

4. Management Action

Upon completion of evaluation, the Gulf Council will receive the reviewed recommendations for management action from the FEI Task Force, the rationale for these recommendations, and any other highly relevant materials from the FEI process. The Gulf Council may then articulate motions and propose actions.

Management actions may fit into the scope of a single stock or FMP, which include common management measures implemented by the Gulf Council, such as adjusting catch levels, size and bag limits, and seasonal and spatial closures for a given species. Alternatively, in support

of holistic ecosystem-based fisheries management, some FEI recommendations may affect multiple or previously unregulated species and may include measures such as Marine Protected Area (MPA) establishment, gear regulations, or bycatch reduction efforts.

FEI Action Timeline Summary

- ETC will review FEI Hopper/Active List at meetings and recommend acceptance of additional proposals to the Gulf Council (and removal of past FEIs as necessary).
- Gulf Council will review comprehensive list of potential FEIs, annually at minimum, to determine which issues merit attention in the immediate future and will vote to initiate an FEI or FEIs if merited.
- FEI Task Forces will follow the FEI Loop on indeterminate, flexible timelines.
- ETC will receive updates from ongoing FEI Task Forces as project developments occur and convey pertinent information to Gulf Council.
- Gulf Council will receive recommendations for management action from FEI Task Forces and the SSC (after MSE).
- Gulf Council will take management action as appropriate.

Figure 4.2.2. A summary of the FEI action timeline.

5. Evaluation: Did we make it?

The ETC will be responsible for monitoring the progress of each FEI Task Force, using indicators and performance metrics from the FEI workplan and reporting to the Gulf Council. If the FEI has had the intended results as set out in goals and objectives, the Gulf Council may consider it resolved. If instead the FEI has not met predetermined goals and/or has had unintended effects, further action may be taken as deemed necessary. In this "learn and adjust" phase, the ETC will try to ascertain points within the previous FEI process in need of improvement, upon which they may reevaluate management strategies and adjust recommended actions, or return to the FEI Task Force for additional, more thorough FEI reevaluation (Figure 4.2.1; Figure 4.2.2).

4.3 Scientific Review Process

Scientific review and vetting will be provided at various stages in both the FEP Loop and FEI Loops and use best available science. The ETC will provide review and vetting of FEI proposals and track Task Force progress. The SSC will review FEI Task Force recommendations for management actions recommended for Gulf Council consideration. The ETC and SSC may suggest revisions during their respective reviews, to ensure scientific rigor.

4.4 Integrating with Management

EBFM principles have already been incorporated within Gulf Council processes and will continue to be expanded and supported through this FEP. FEIs will serve as the primary institutional framework through which this FEP will be implemented (Appendix A1). Nonetheless, the concept will require further development. Further operational guidelines, processes and procedures will need to be developed and adopted, following Gulf Council guidance, but much of the proposed activity can occur within existing institutional structures. For example, there are many existing Gulf Council Committees and Advisory Panels that can review, support, participate in, vet, and guide FEI Task Forces (https://gulfcouncil.org/council-committees/).

The ETC has helped guide development of this FEP. It is proposed that the ETC play a role in vetting FEIs, recommending their elevation to the level of Gulf Council consideration (i.e., placed within the FEI Hopper) and reviewing progress of FEIs. Perhaps most importantly, the ETC will have a parallel role to the Standing SSC, in vetting and recommending management options from FEIs for Gulf Council consideration. This will serve to elevate ecosystem considerations, as the Gulf Council considers the various management tools at their disposal, e.g., choosing single-stock and stock complex catch levels, gear restrictions, seasonal and area closures, Essential Fish Habitat (EFH) and Habitat Areas of Particular Concern (HAPC) designation. In many of the most complex cases, the SSC will review MSEs to illustrate, transparently, the tradeoffs among recommended management actions. Kaplan et al. (2021) offers a summary of ecological model-based MSE and other regional case studies with lessons learned, as well as progress and further challenges of MSEs in the EBFM context.

4.5 Measuring Progress of the FEP and FEIs

The FEP Loop cycle may take five to ten years to complete (Marshall et al 2018a). By contrast, FEI Loop cycles may take as long as five years, but ideally would be completed in 1-2 years or less. In all cases, progress towards selected goals and objectives will be measured using indicators and reference points as defined by either the Gulf Council (for the FEP) or by the Task

Forces for individual FEIs. FEP Loop progress will be measured using both institutional and ecosystem yardsticks.

Institutional yardsticks are relatively simple to use, e.g., how many FEIs were completed; what elements or examples of CRPs were enacted and when? How many stakeholders have been engaged in participatory workshops and were they selected using appropriate tools? Standard monitoring and evaluation templates or log frames can be used to track institutional indicators.

Ecosystem-level progress is more difficult to track, but ideally, could be measured through selection of indicators and reference points for critical single-stock and ecosystem level parameters. This is already being done to some extent through the Integrated Assessment Program and the production of ESRs (e.g., Karnauskas et al. 2013; 2017). As stated in sections 2.6 and 3.1, this will require more frequent updates to the ESR and some modifications to its contents. These changes would likely include further human-relevant (socio-economic and governance) considerations, and quantified stakeholder perspectives on resource status and trends. A suite of the most relevant ecosystem indicators is already being tracked and assessed such as seawater temperature, wetland loss, sea-level rise, single-stock evaluations, frequency and severity of hypoxic and red tide events, coastal populations, revenue and landings from commercial and recreational sectors, and IFQ share prices. Selecting appropriate FEP and FEI indicators will remain a challenge and an area requiring additional focus, possibly using an FEI. Nonetheless, by using visualization tools such as the FEP visualization dashboard, and clearly articulated conceptual models, common sense solutions can be selected and acted on efficiently.

CHAPTER 5. SUMMARY AND RECOMENDATIONS

This document offers a structured planning process and associated decision support tools to facilitate implementation of EBFM in the Gulf of Mexico. The planning process centers around Fishery Ecosystem Issues (FEI)s and the FEI Loop, a structured process designed to address important ecosystem issues in Gulf or subregions of the Gulf.

The document includes rationale and methods to:

- Implement FEP Loops and FEI Loops
- Articulate a common vision of the desired future state of the Gulf
- Expand the quantity, quality, equity and methods for stakeholder engagement
- Expand the Cooperative Research Program
- Expand and foster institutional partnerships to support research and to address extra-jurisdictional issues affecting Gulf fisheries resources but that are outside of Gulf Council jurisdiction
- Measure progress of FEP implementation using pre-selected indicators and performance measures

If successfully implemented, this plan would contribute to resilience and sustainability of Gulf fisheries and the ecosystem services they provide.

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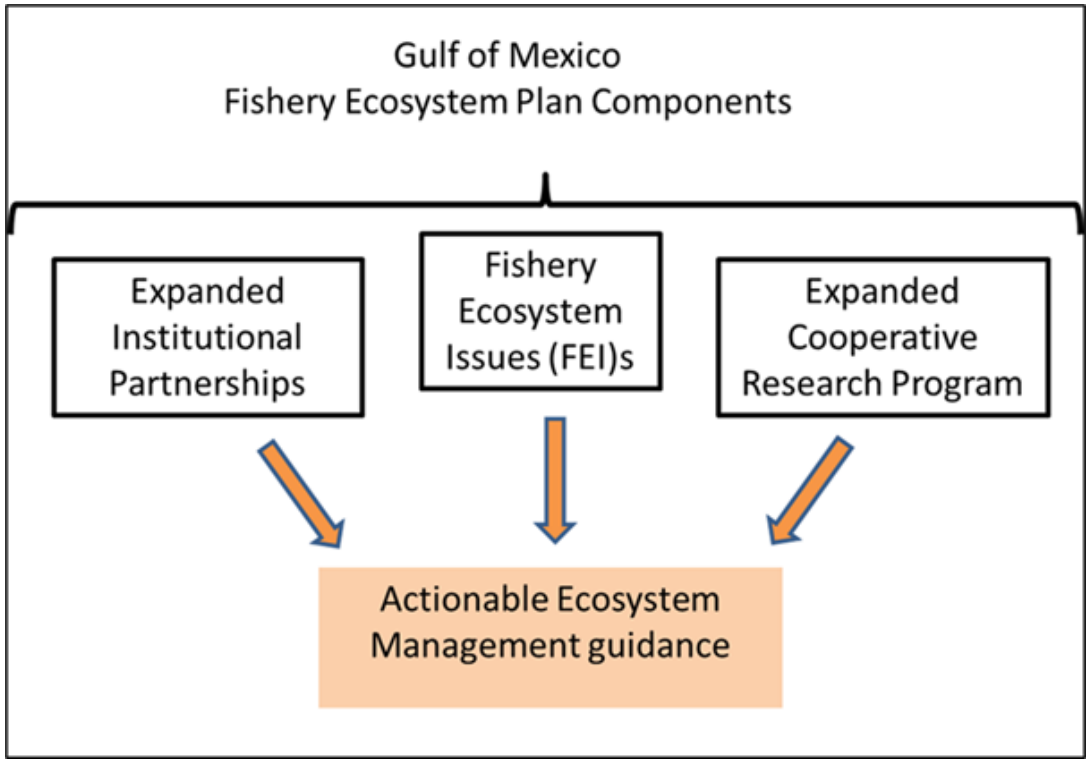
APPENDIX A. DECISION SUPPORT TOOLS

1. Primary components of the Gulf of Mexico Fishery Ecosystem Plan
2. Joint Visioning Approach
3. FEI definition and development
4. Operationalizing FEIs
5. Criteria to be considered for selecting FEIs.
6. Indicator Visualization Dashboard
7. Stakeholder Prioritization and Mapping Template
8. Mental Modeler Tool
9. Participatory Workshop Tools
10. Fisherman Feedback Tool
11. List of preliminary indicators

Appendix A1. Primary components of the Gulf of Mexico Fishery Ecosystem Plan

FEIs are the primary implementation tool for the EBFM development in the FEP. In addition, the FEP includes the existing EBFM work of the Gulf Council which should be recognized, continued and expanded. Cooperative Research, Citizen Science, and Institutional partnerships will support data and information needs for the overall FEP and specific FEIs. These programs will support science needs for EBFM, increase stakeholder engagement, and reduce response time to sample for emerging ecosystem issues. These programs will also help the SEFSC and the Gulf Council to fill data gaps for other needs e.g., stock assessments, or targeted, rapid-response sampling of emergent conditions or events.



Appendix A.2. Joint Visioning Approach

Joint Visioning Approach

Step 1: Gulf Council staff (or contractors) conduct a series of "visioning workshops" throughout the Gulf region to gather broad stakeholder input on an EBFM vision
Step 2: Gulf Council staff drafts a vision statement for Council consideration incorporating input gathered during Step 1
Step 3: Gulf Council adjusts and adopts the draft statement and allows for broad public comment
Step 4: Comments incorporated and EBFM Vision statement is adopted by the Gulf Council

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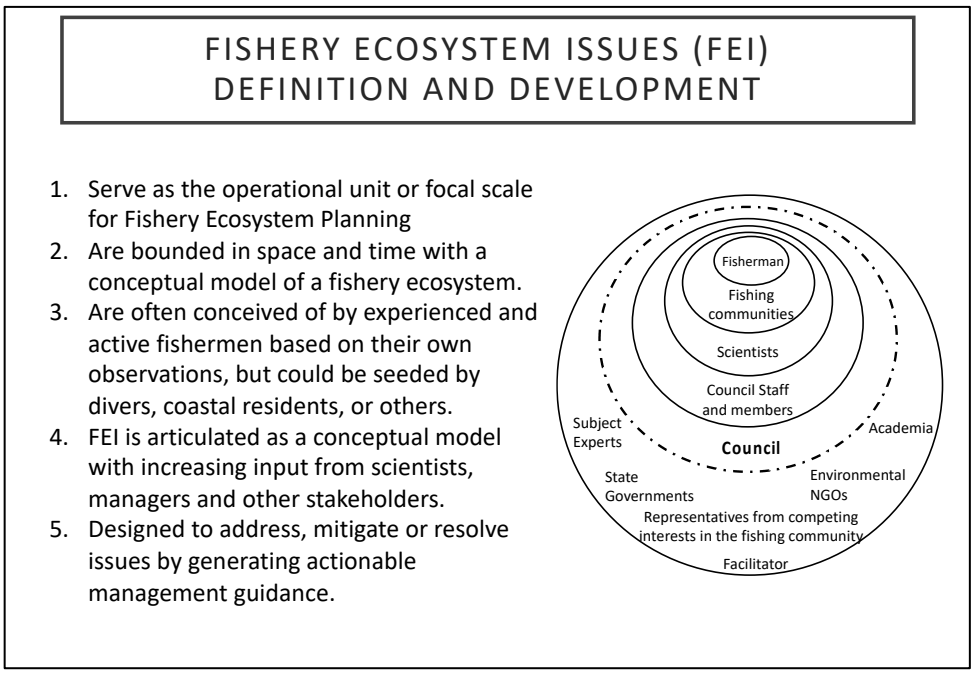
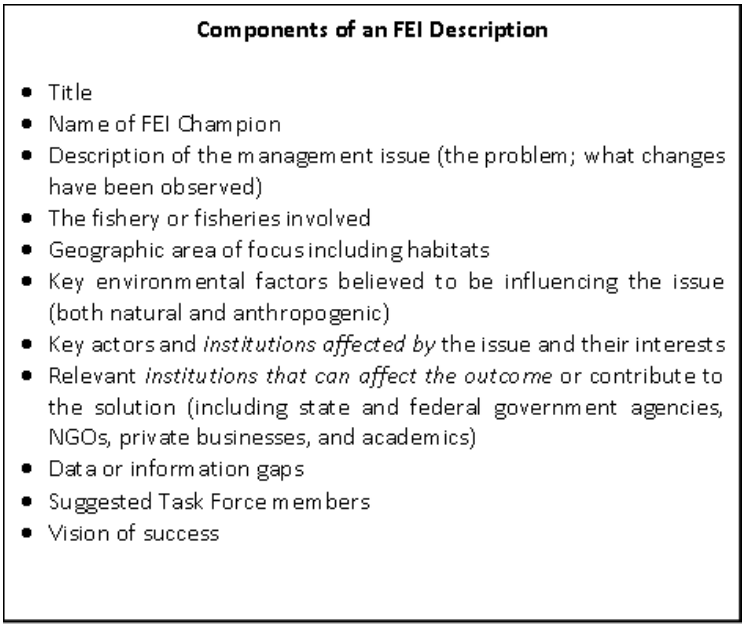
Appendix A.3. FEI definition and development.

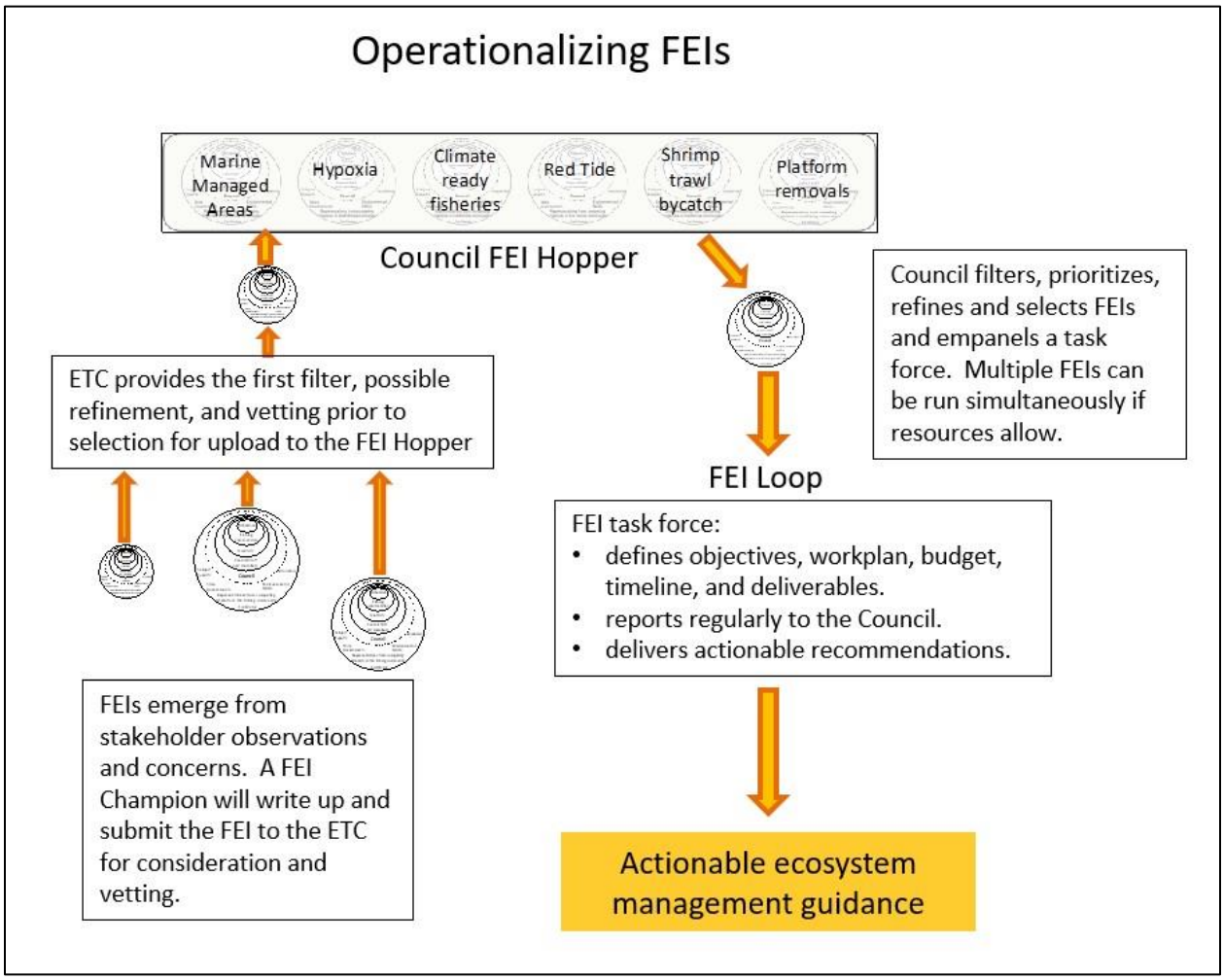
Top: Organic evolution of FEIs often starts with observations and a call for concern from fishers or other stakeholders such as divers, boaters, coastal residents, NGOs or scientists. The idea evolves and is clarified as additional people and institutions contribute.
Bottom: Components of an FEI description



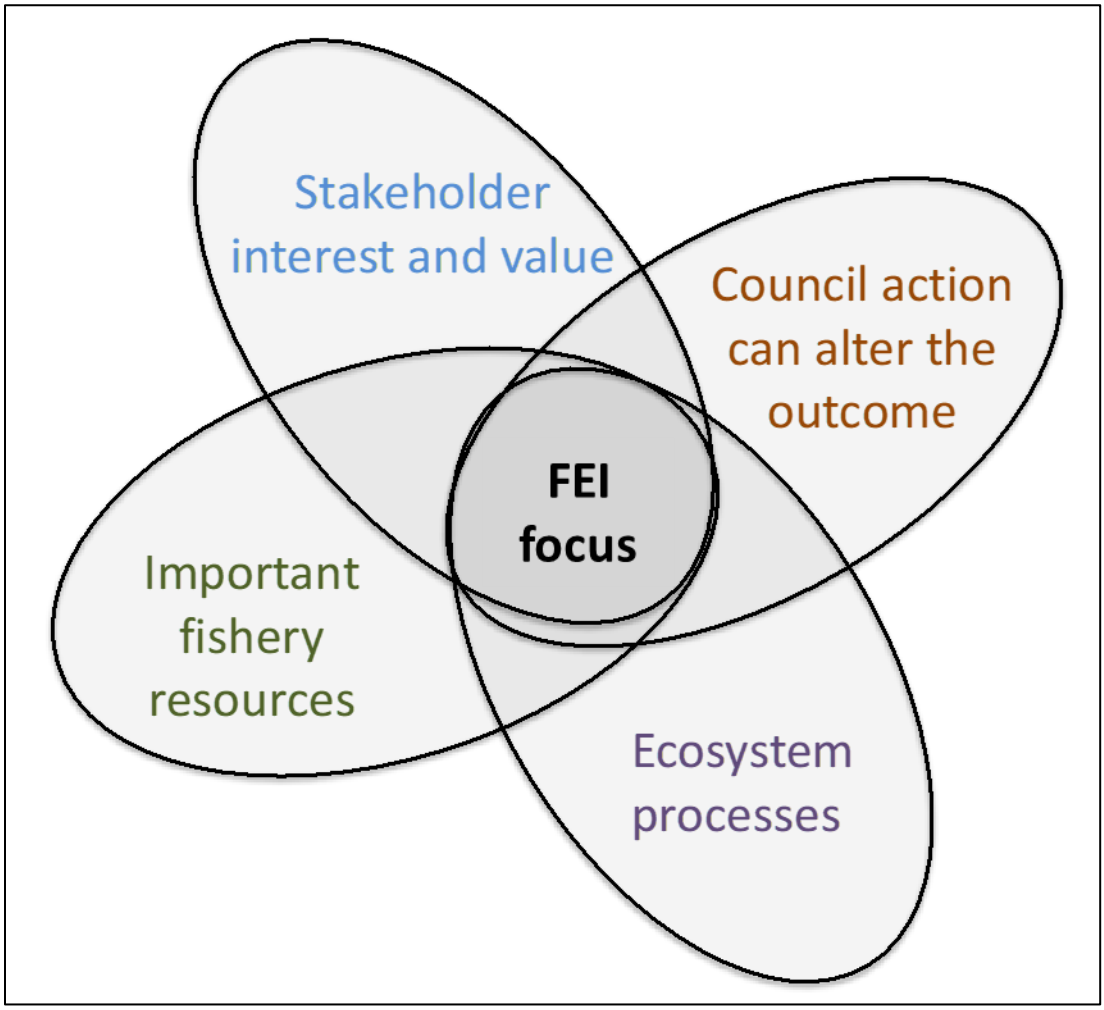


Appendix A.4. Operationalizing FEIs

The broad framework or FEI development and submission to the ETC, prioritizing and selection and the beginning of implementation. FEIs should produce actionable outcomes.



Appendix A.5. Criteria to be considered for selecting FEIs.



Appendix A.6. Indicator Visualization Dashboard

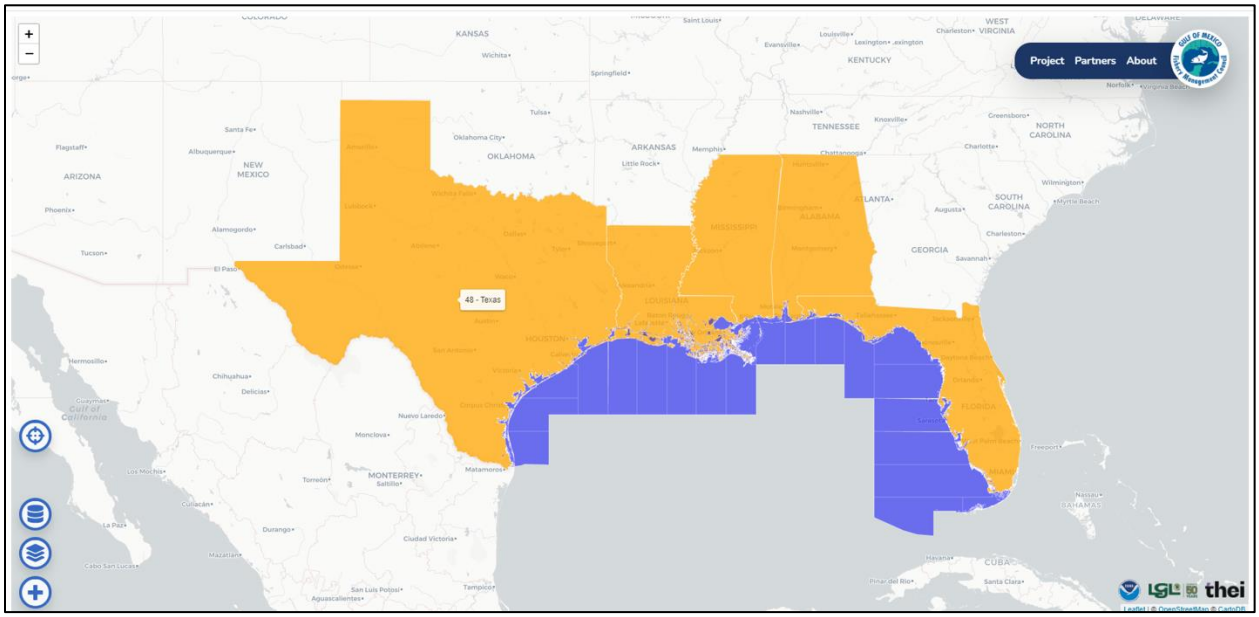
LGL produced a beta Indicator Visualization Dashboard in collaboration with THEI Consulting that is housed on an LGL server with the relevant spatial domains defined. Example indicator datasets have been uploaded. The beta Indicator Dashboard is available at: http://lgl.theiscience.org/. If the Gulf Council wishes to further develop the Visualization Dashboard, input from potential users should be sought, so that appropriate revisions can be made.

List of indicators initially uploaded to the Indicator Visualization Dashboard.

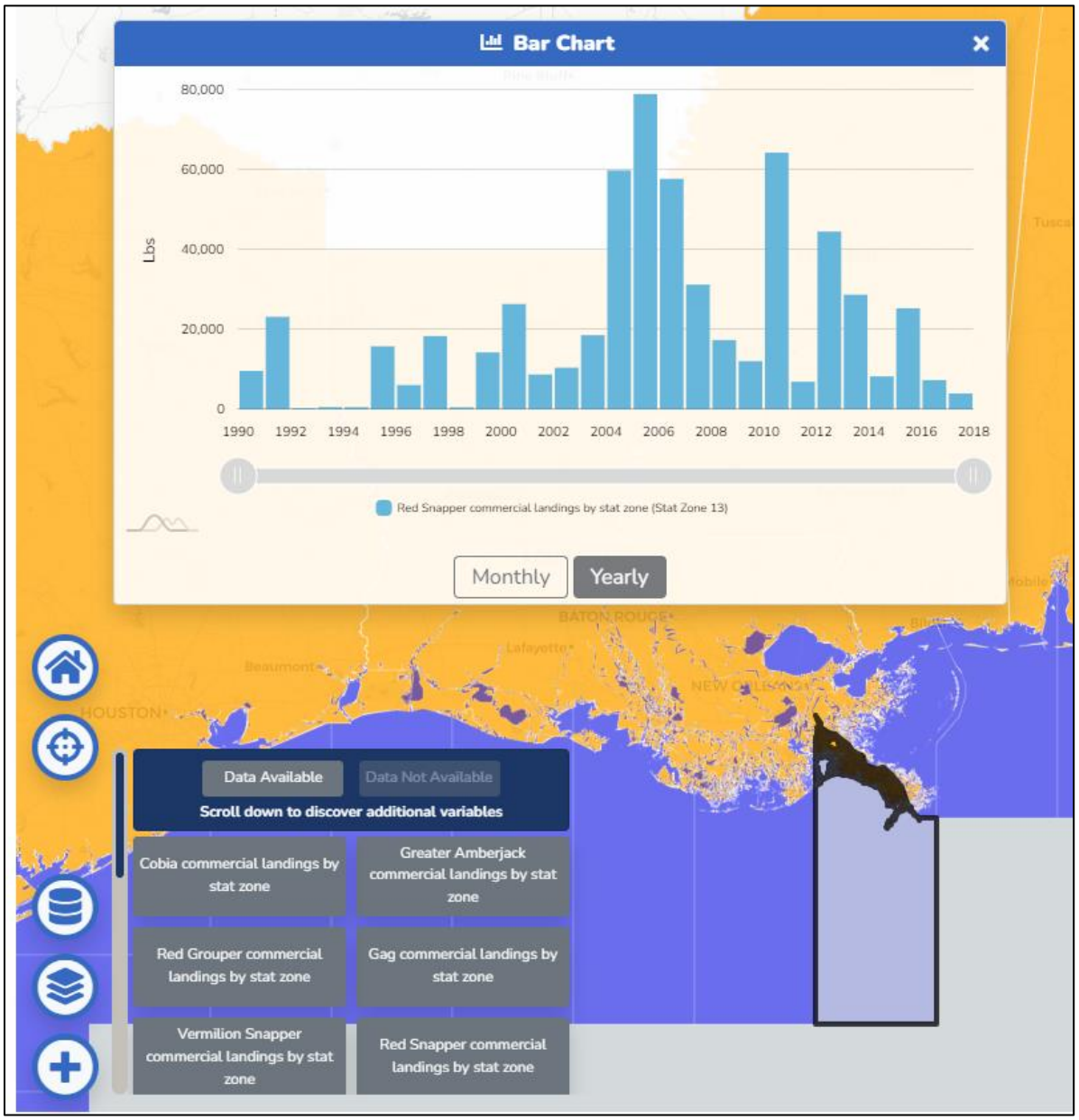
Base Indicators		
Indicator Name	**Temporal Scale**	**Spatial Scale**
Buoy effort (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Cast net effort (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Bandit effort (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Hook and line (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Powerheads / bangsticks (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Spear (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Bottom longline (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Gillnets (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Traps (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Other gear (commercial trips)	Annual (1994-2016)	NMFS Stat Zone
Cobia commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Gag commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Gray Triggerfish commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Greater Amberjack commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Red Grouper commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Red Snapper commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Vermillion Snapper commercial landings (lbs.)	Monthly (1994-2016)	NMFS Stat Zone
Private Recreational Angler Trips	2 x yearly, high/low season* (1994-2016)	State
Charter Recreational Angler Trips	2 x yearly, high/low season* (1994-2016)	State
Cobia recreational landings (lbs.)	2 x yearly, high/low season (1994-2016)	State
Gag commercial landings (lbs.)	2 x yearly, high/low season* (1994-2016)	State
Gray Triggerfish recreational landings (lbs.)	2 x yearly, high/low season* (1994-2016)	State
Greater Amberjack recreational landings (lbs.)	2 x yearly, high/low season* (1994-2016)	State
Red Grouper recreational landings (lbs.)	2 x yearly, high/low season* (1994-2016)	State
Red Snapper recreational landings (lbs.)	2 x yearly, high/low season* (1994-2016)	State

Vermillion Snapper recreational landings (lbs.)	2 x yearly, high/low season* (1994-2016)	State
Human Population	Annual (1990-20019)	County
Human Population Projections	Per 5 years (2020-2100)	County

Home screen of the beta Indicator Visualization Dashboard.



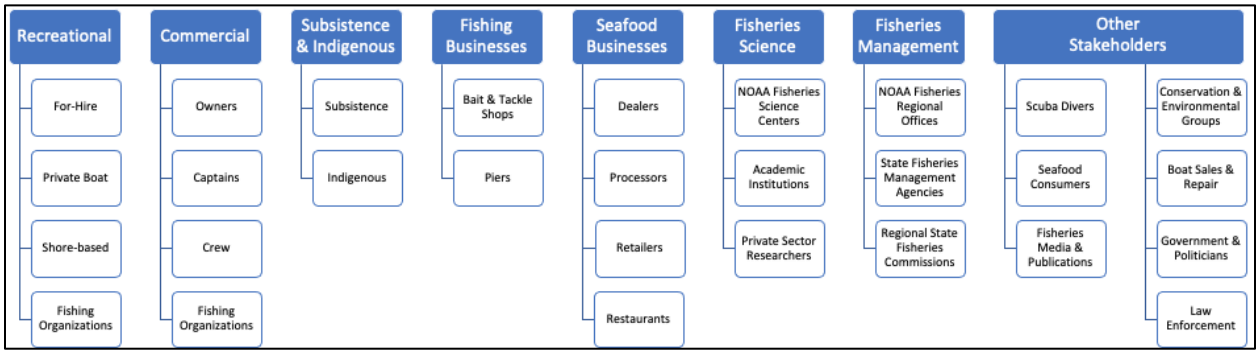
Example of data available in indicator dashboard for statistical zone 13, and the graphing functions of the dashboard.



Appendix A.7. Stakeholder Prioritization and Mapping Templates.

A stakeholder mapping template was developed including a detailed list of major categories of potential stakeholders for Gulf fisheries. The template is designed to populate a list of highly knowledgeable stakeholders, or "key informants", for gaining insights on a fishery and developing Fishery Ecosystem Plans or Issues (FEP/FEIs). The spreadsheet is designed to be filled out through informal interviews or conversations aimed at identifying highly knowledgeable individuals associated with a fishery. These preliminary contacts may include Gulf Council staff, State or Federal fishery managers, Advisory Panel (AP) members, among others.

The list of Primary and Secondary groups is not intended to be comprehensive, and not all categories may apply to all fisheries. This list should be modified to meet the needs of the specific fisheries management context. While all individuals are assigned to a single stakeholder group, it should be noted that in general many individuals may represent multiple categories of stakeholders. Future work should explore potential ways to represent cross-group stakeholders.



Tiered list of major stakeholders that could be considered for Gulf fisheries ecosystem planning

Image of Stakeholder Prioritization Template.

FISHERY ECOSYSTEM PLAN - STAKEHOLDER PRIORITIZATION

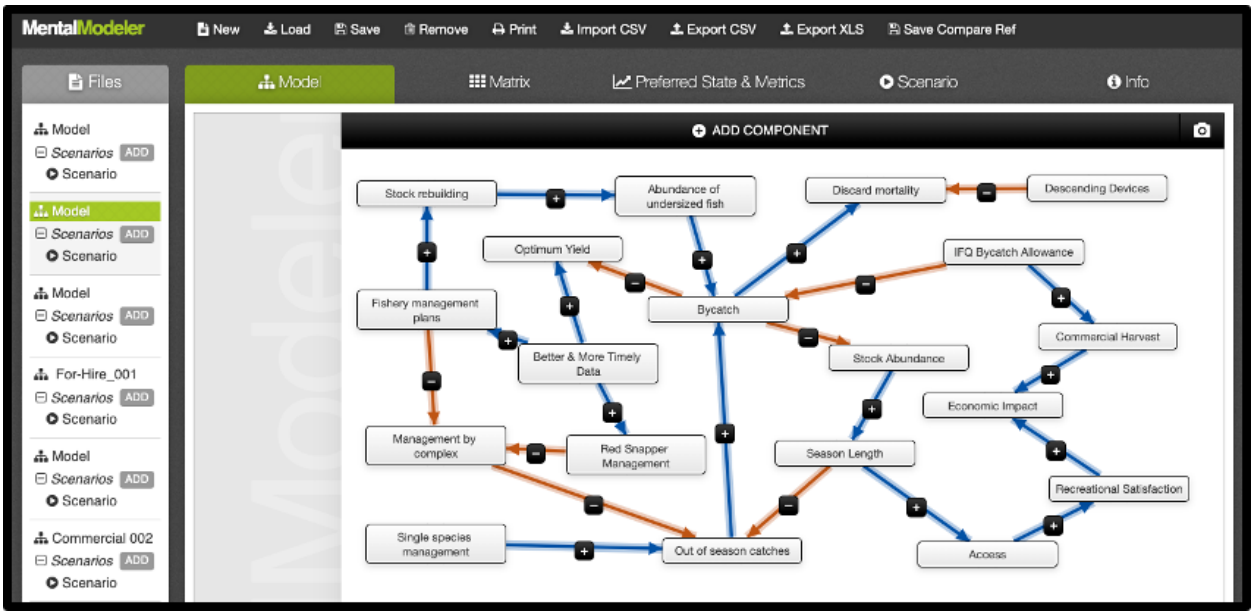
Instructions: This template is designed to prioritize categories of stakeholders for engagement for understanding and addressing specific fisheries issues. The First Step is to Score each Secondary Group for their Power, Legitimacy, and Urgency for the specific issue of interest. Power can be defined as a group's direct or potential influence on the issue. Urgency reflects the immediate importance of the issue for each stakeholder group. Legitimacy can be considered as the relative experience and potential insight each group could provide on the issue. Each criteria should be scored as Not Applicable (0), Low (1) Medium (3), or High (5). Next, select a final priority for each group based using the Total Score values.

PRIMARY GROUP	Secondary Group	*Power*	*Urgency*	*Legitimacy*	Total Score	Priority
Recreational	For-hire				0	
	Private boat				0	
	Shore-based				0	
	Fishing organizations				0	
	(Enter other)				0	
Commercial	Owner				0	
	Owner Operator				0	
	Captains				0	
	Crew				0	
	Fishing organizations				0	
	(Enter other)				0	
Subsistence / Indigenous	Subsistence				0	
	Indigenous				0	
	(Enter other)				0	
Fishing Businesses	Bait-n-tackle shops				0	
	Piers				0	
	(Enter other)				0	
Seafood Businesses	Dealers				0	
	Processors				0	
	Retailers				0	
	Restaurants				0	
	(Enter other)				0	
Fisheries Science	NOAA Fisheries Science Centers				0	
	Academics / Universities				0	
	Private sector researchers				0	
	(Enter other)				0	
Fisheries Management	NOAA Fisheries Regional Offices				0	
	State Fisheries Management				0	
	Regional State Fisheries Commissions				0	
	(Enter other)				0	
Other Stakeholders	SCUBA divers				0	
	Fishing Media / Publications				0	
	Seafood consumers				0	
	Environmental & Conservation				0	
	Boat sales & repair				0	
	Governments & Politicians				0	
	Law Enforcement				0	
	(Enter other)				0	

Appendix A.8. Mental Modeler Tool

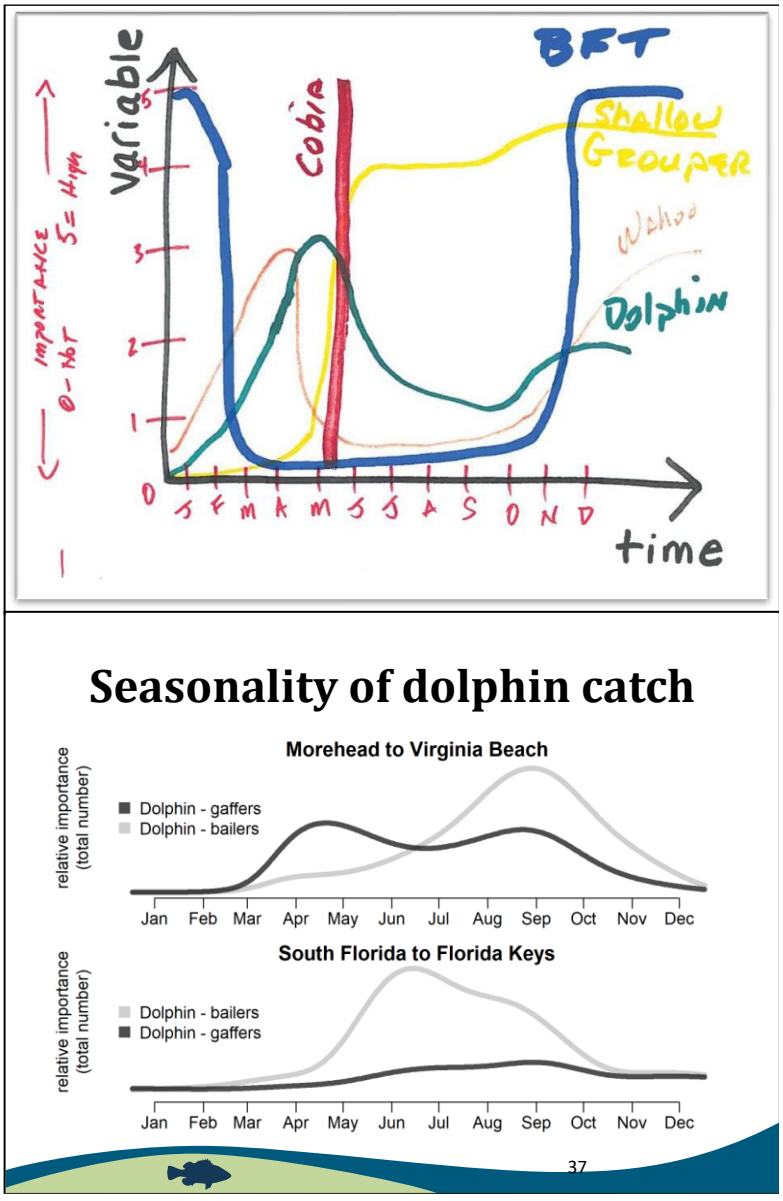
Participatory modeling can be conducted visually using the stakeholder-focused online software program Mental Modeler (www.mentalmodeler.com).

Mental model of bycatch created in Mental Modeler software. This specific model was produced by an individual from a Recreational Fishing Organization.

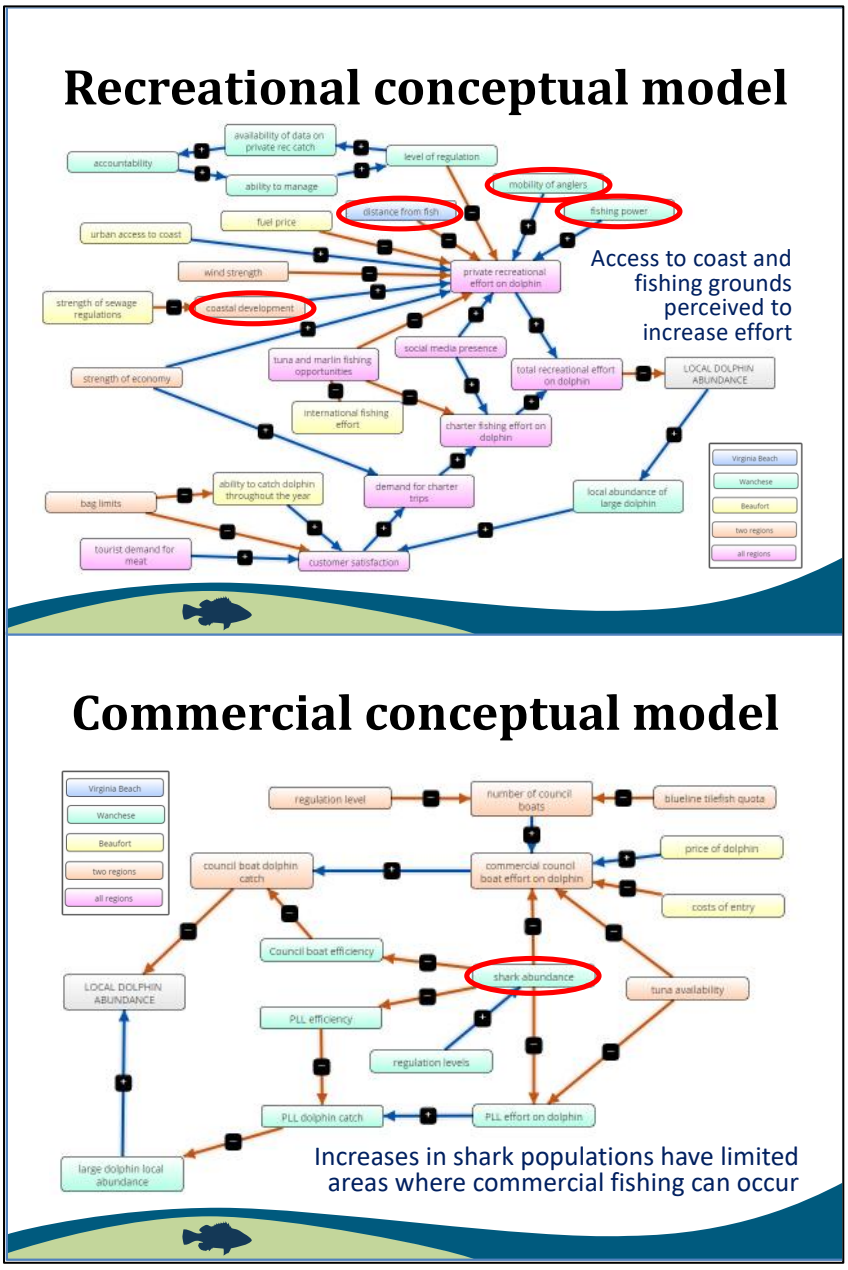


Appendix A.9. Participatory Modelling Workshop Tools

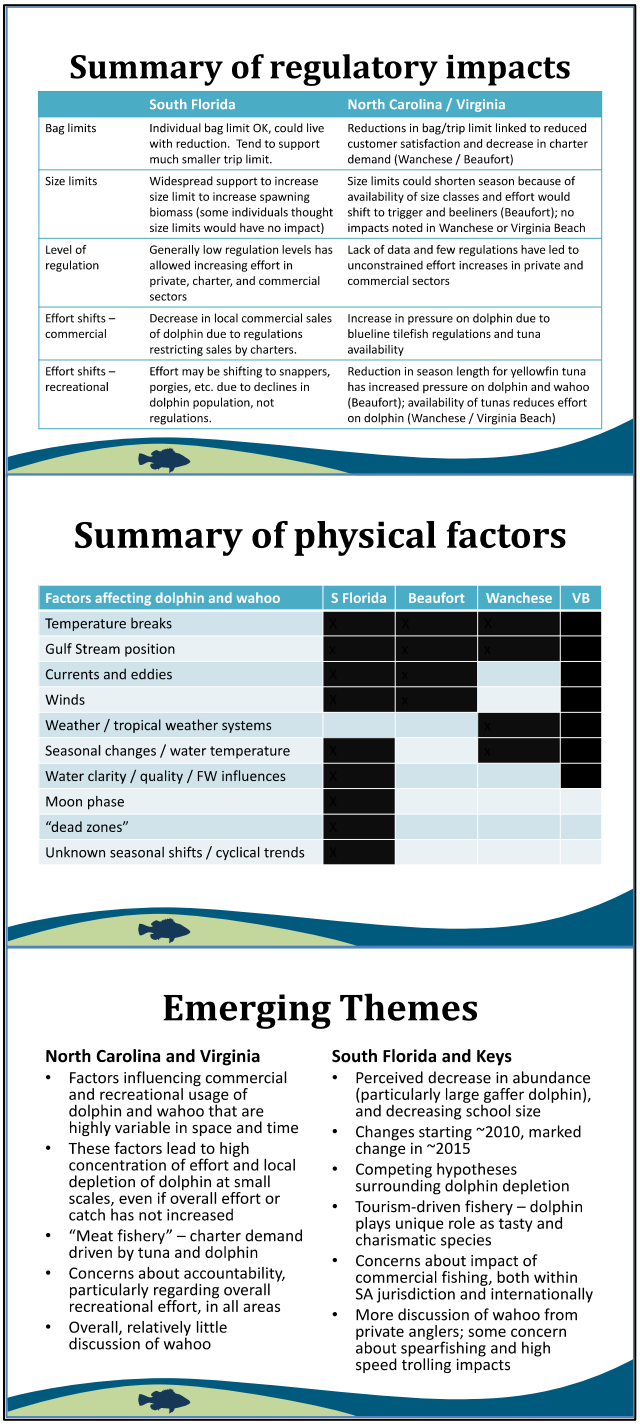
The following slides are extracted from (Byrd et al. 2021) and summarize some of the results of a series of Participatory Workshops. The approach is highly relevant to this FEP in that it provides many of the required elements of successful ecosystem planning.



Participatory Workshop Results: In each location, fishers plotted the relative importance of various target species to their fishing operations throughout the year (top). Data combined from fishers in different regions shows regional and seasonal variations in the relative importance of dolphin bailers and gaffers (Byrd et al. 2021).



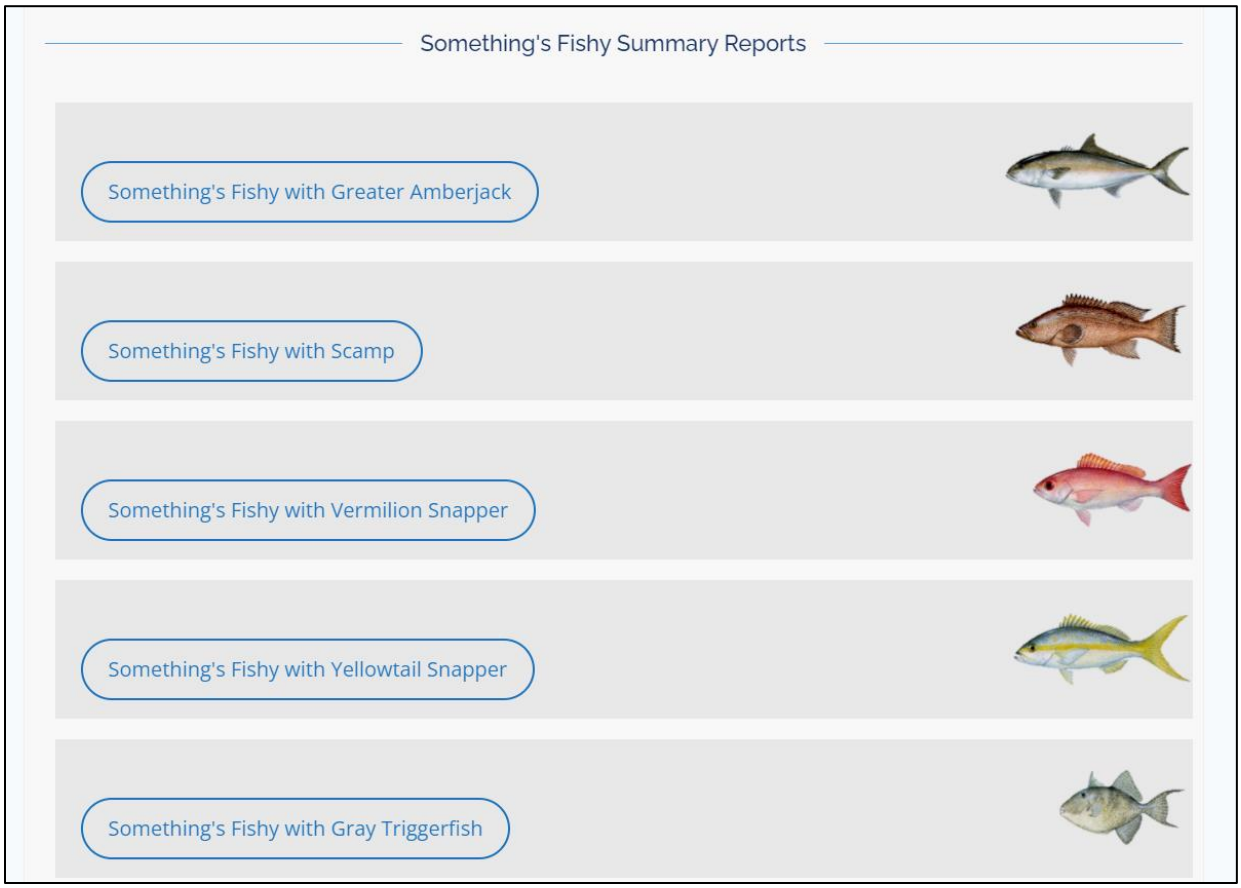
Participatory Workshop Results: Mental models from some recreational fishers that perceive access has increased fishing pressure (top). Mental models from some commercial fishers showing that increased shark populations have limited areas where commercial fishing can occur (bottom). (Byrd et al. 2021)



Participatory Workshop Results showing regulatory impacts, physical factors and emerging themes based on fisher perceptions.

Appendix A.10. Fisherman Feedback Tool

The Gulf Council uses its Fisherman Feedback tool, available: https://gulfGulf Council.org/fisheries-science/#1612797471561-f64fecad-7fab, to gather information from fishers about what is happening on-the-water. The Gulf Council solicits input for the fish species it manages ahead of each scientific stock assessment. The information provided is analyzed and delivered to the scientists and managers to help to inform their current understanding of each fish stock. This tool can also be used to identify issues that should be considered as FEIs.



Appendix A.11. List of preliminary indicators

The table below summarizes parameters of the main indicators used in the 2017 Gulf of Mexico Ecosystem Status Report & https://ecowatch.noaa.gov/regions/gulf-of-mexico. At the end of the larger categories, we have also included some additional indicators to consider (*in italics*). These additions are not necessarily exhaustive nor systematically considered but serve as a repository for some of the ideas being discussed and are based on what (1) might be straightforward to obtain in time-series form and (2) may be an important part of the ecosystem to consider, either as an ecosystem driver or response variable. Our goal for this list is to identify examples of what has been considered indicative of Gulf ecosystem health.

Indicator	Spatial Resolution	Temporal Resolution	Updated	Data Source	Indicative of what?
Climatological					
North Atlantic Oscillation	Basin	Yearly	Yearly	https://www.cpc.ncep.noaa.gov/data/teledoc/nao.shtml	Relative position and strengths of low atmospheric pressure over Iceland and high atmospheric pressure over the Azores. This aspect of climate may alter hurricane tracks and precipitation, which broadly influence fisheries ecology (see, e.g., https://aquila.usm.edu/cgi/viewcontent.cgi?article=1578&context=fac_pubs)
Atlantic Multidecadal Oscillation	Basin	Yearly	Yearly	https://psl.noaa.gov/data/climateindices/	Basin-wide temperature variability: related to precipitation, hypoxia, water column stratification which broadly influence fisheries ecology (see, e.g.,

					https://www.frontiersin.org/articles/10.3389/fmars.2017.00282/full)
Physical - Chemical					
Sea Surface Temperature	Western / Central/ Eastern Gulf	6 month moving average	?	https://www.ncdc.noaa.gov/oisst	Ocean temperature impacts the rate of all physical, chemical, and most biological processes occurring in the ocean.
Sea Level	State	?	?	NA	Sea level has direct impacts on coastal communities and certain habitats (e.g., marsh vs. mangrove) in terms of susceptibility to extreme weather, erosion, and a variety of coastal processes.
Hypoxia	LA / TX	Summer / Fall		Southeast Area Monitoring and Assessment Program (SEAMAP) trawl and hydrographic survey	Hypoxia is low dissolved oxygen (<2 mg per L), may result in die-offs, reduced growth/reproduction, or movement out of an area by mobile species.
Carbon fluxes – ocean acidification	NA	monthly		CMIP 5	When CO2 enters the ocean, pH is reduced (more acidic) which might have negative impacts on calcification of calcium-carbonate shells or even alter fish behavior by disrupting neurotransmitters. Actual effects in the Gulf are not well-established.
Eutrophication (Nitrogen oxides,	5 river systems	Yearly		U.S. Geological Survey. Coastal Rivers - Nitrate Loads and	Eutrophication results from excess nutrients, i.e., an imbalance in productivity. This can cause shifts from

total nitrogen, total phosphorus)				Yields. 2016. [Online]. Available: https://nrtwq.usgs.gov/nwqn/#/	benthic primary producers (seagrasses) to phytoplankton and contributing to hypoxia when increased organic material is consumed by bacteria.
Additional Indicators for consideration (not part of EcoWatch or the 2017 Gulf Ecosystem Status Report)					
Upland Sources of Pesticides?					In addition to nitrogen and phosphorus, pesticides from agriculture may have negative impacts on marine organisms. This may be related to eutrophication and hypoxia in some circumstances, but could act independently in others.
Wave height	Gulf-wide, gridded <0.1 deg lat/lon			https://polar.ncep.noaa.gov/waves/viewer.shtml?-multi_1-latest-gmex-hs-	Wave height is related to wind conditions, and may be an important consideration for fishing activity (particularly recreational). Fewer trips or less time on the water may be expected when wave height is larger. Units to consider might by # of days with mean wave height > 4 ft for a given state?
Tropical Storms				https://www.nhc.noaa.gov/data/	Tropical storms typically act as stressors to human coastal communities. Storms can have a variety of impacts on the ecosystem (e.g., mixing the water column can minimize hypoxic condition or reduce thermal stress on corals; changes to surface circulation can influence the dispersal of marine organisms). Annual counts easily obtained.

Biological					
Benthic seagrass cover	Florida, Tampa, Pensacola, Mobile, MS Sound, and Galveston Bays	Annual	Rarely	USGS Seagrass Status and Trends report, Emergent Wetlands Status and Trends report, the Tampa Bay National Estuarine Program, Alabama Department of Conservation and Natural Resources oyster reef data, Southwest Florida Water Management District seagrass data, and the Florida Fish and Wildlife Conservation Commission's Florida Fish and Wildlife Research Institute	A variety of species depend upon seagrass habitats to complete some elements of their life-cycle, either as spawning, nursery, or foraging grounds including economically valuable species and protected species. Increases in this habitat provides more resources to those species. Decreases in this habitat may also be indicative of ecosystem disturbances.
Wetland use and land cover	Gulf-wide			Coastal Change Analysis Program (C-CAP)	Wetlands provide a variety of ecosystem services in terms of buffering coastal areas from storm damage, erosion, improving water quality, and providing wildlife habitats. Decreases in this indicator imply greater coastal vulnerability.

Net Primary Productivity (NPP)	Northern Gulf			Moderate Resolution Imaging Spectrometer (MODIS) observations. Adapted from Muller-Karger et al. (2015). Progress in Oceanography, 134, 54-76.	NPP is the net production of carbon by organisms at the base of the foodweb (primary producers), such as phytoplankton. NPP gives an indication of food availability to higher trophic levels, with higher NPP typically translating to more food and the potential to support higher species abundances. This is often related to insolation, ocean mixing, winds, and riverine inputs.
Zooplankton biomass	Northern Gulf	Spring / Fall		Southeast Area Monitoring and Assessment Program (SEAMAP)	Zooplankton are an important part of marine foodwebs serving as predators and prey for a variety of species. Higher abundances tend to indicate larger abundances and diversity of fish can be supported.
Menhaden (age 1+) biomass	Northern Gulf			NMFS Stock Assessment	Mendhanden are a forage fish that contribute to the diets of a wide number of species and supply a massive industrial fishery. Biomass may indicate the potential available forage within the Gulf, but since it only contributes to 2-3% of most species diets a direct correspondence may not exist.
Species Richness	LA / TX	Summer / Fall		Southeast Area Monitoring and Assessment Program (SEAMAP)	Species richness is the number of species observed and indicates ecosystem health in that more resilient ecosystems tend to have more species.

Species Diversity	LA / TX	Summer / Fall		Southeast Area Monitoring and Assessment Program (SEAMAP)	Shannon-Wiener diversity index combines species richness and relative abundance and is a metric of biodiversity, higher indices indicate more species that are more even in terms of relative abundance.
Mean trophic level (MTL) of commercial finfish landings	Northern Gulf			NOAA Fisheries commercial landings statistics from the Southeast Fisheries Science Center	MTL is an average of the assigned trophic level for species (or groups of species) weighted by total poundage of each group. Decreases in MTL may indicate "fishing down the foodweb" or changes driven by market force / regulation for commercial fisheries.
Mean trophic level (MTL) of finfish in survey	Northern Gulf	Summer		Southeast Area Monitoring and Assessment Program (SEAMAP)	MTL is an average of the assigned trophic level for species (or groups of species) weighted by total poundage of each group. Because SEAMAP mainly targets smaller, juvenile fish and trophic levels are assigned by adult diet, this index may be slightly misleading taken at face-values.
Proportion of stocks undergoing overfishing	Gulf-wide			https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates	Stocks subject to a fishing rate that does not produce maximum sustainable yeild over the long term. A decrease in this index is indicative of improved management that corresponds to the ecological status of a species.

Proportion of stock in overfished state	Gulf-wide			https://www.fisheries.noaa.gov/national/population-assessments/fishery-stock-status-updates	Stock size is below that which produces maximum yeild on a continuing basis. A decrease in this index is indicative of improved management that has contributed to a population increase.
Estimated abundances / biomass of economically important fish	Gulf-wide	Annual		SEDAR: Gray triggerfish, greater amberjack, gag, red grouper, vermillion snapper, cobia, Spanish mackerel, red snapper, Atlantic sharpnose shark, hogfish, king mackerel	Stock size (biomass or abundance) of these fish species are indicative of both ecosystem health and opportunity for commercial and recreational fisheries.
Bird relative abundance (probability of presence)	Northern Gulf			Cornell Lab of Ornithology eBird Reference Dataset: brown pelican, magnificent frigatebird, roseate spoonbill, white ibis, wood stork	Waterbirds in particular are useful because they often occupy higher trophic levels, are highly mobile and can respond quickly to environmental change, and are conspicuous and easy to monitor. They also have value for tourism. Pelagic seabirds are not well represented, but these 5 species are likely of value for coastal habitats.
Additional Indicators for consideration (not part of EcoWatch or the 2017 Gulf Ecosystem Status Report)					
Sargassum coverage				https://www.aoml.noaa.gov/phod/sargassum_inundation_report/	Role as habitat to ecologically valuable species (tunas, amberjack, mahi, sea turtles); Negative impacts to coastal human communities via beaching; Can be

					highly variable among years; relatively easily monitored
Sea Turtle Nesting (W. Florida, Texas, Tamaulipas MX)				[a] annual nest counts of loggerheads, green, leatherback in Florida (https://myfwc.com/research/wildlife/sea-turtles/nesting/beach-survey-totals/); [b] annual nest counts in Kemp's ridley in Texas (https://seaturtles.org/turtle-count-texas-coast/); [c] annual nest counts of Kemp's ridley in Tamaulipas;	Sea turtles drive many of the management decisions related to fisheries in the Gulf. Specifically considering the reproductive output of Kemp's ridley, green turtles, and loggerhead turtles in different areas of the Gulf (W. Florida, Texas, and Tamaulipas MX) could be useful for the Gulf Council to consider. For the noted species/regions, annual counts should be easily obtained.
Protected Species Strandings (marine mammals, sea turtles)				[a] annual number of marine mammal Unusual Mortality Events (https://www.fisheries.noaa.gov/national/marine-life-distress/active-and-closed-unusual-mortality-events); [b] annual bottlenose dolphin strandings; [c] annual manatee counts	Sea turtles and marine mammals contribute to many of the management decisions related to fisheries in the Gulf. Strandings of marine mammals and sea turtles can be indicative of both natural and anthropogenic stressors to the ecosystem (e.g., cold snaps, boat strikes) as well as provide information on the distribution and abundance of these protected species. Data are recorded across the Gulf and could provide useful

				(https://myfwc.com/research/manatee/research/population-monitoring/synoptic-surveys/);	context for certain Gulf Council decisions.
Human Dimensions					
Oil Platforms	Northern Gulf			Bureau of Ocean Energy Management (BOEM)	Representative of fishing opportunity, particularly for recreational anglers.
Intentional artificial reefs	(excluding TX)				Representative of fishing opportunity.
Human population abundance in coastal watershed counties	States			American Community Survey 3-year estimates and decadal Census	Representative of resource use; strain on ecosystems via pollution and extraction
Human population density in coastal watershed counties	Gulf-wide			American Community Survey 3-year estimates and decadal Census	Representative of resource use; strain on ecosystems via pollution and extraction
Coastal Urban Land use	Gulf-wide			American Community Survey 3-year estimates and decadal Census	Representative of strain on ecosystems via pollution and extraction
Shoreline condition	Gulf-wide			NOAA Environmental Sensitivity Index (ESI)	Representative of coastal habitats (marshes, mangroves, beaches) and

					artificial structures (bulkheads, seawalls, revetments)
Employment in the ocean economy	Gulf-wide, by state and county	Annual		NOAA Office for Coastal Management Economics: National Ocean Watch (ENOW) program	Representative of contributions of Gulf ecosystem to coastal economies
Ocean-related Gross Domestic Product (GDP)	Gulf-wide	Annual		NOAA Office for Coastal Management Economics: National Ocean Watch (ENOW) program	Representative of contributions of Gulf ecosystem to national economy
Revenue from commercial fishery landings ($)	Gulf-wide				Representative of contributions of Gulf ecosystem to national economy
Amount of commercial fishery landings (tons)	Gulf-wide but with granularity that goes down to level of state, port, county, species?				Representative of contributions of Gulf ecosystem to national economy
Social Connectedness	Gulf-wide			Decadal Census; National Center for Charitable Statistics;	

				voter participation rates	
Commercial Fishing Engagement	Gulf-wide			NOAA Fisheries Social Indicators https://www.st.nmfs.noaa.gov/data-and-tools/social-indicators/	Commercial and recreational fishing engagement are absolute measures of fishing activity as measured by the absolute numbers of that activity. For commercial fishing we used permits, pounds and value of landings and number of dealers for commercial fishing.
Commercial Fishing Effort	Gulf-wide				
Recreational Fishing Effort	Gulf-wide				
Additional Indicators for consideration (not part of EcoWatch or the 2017 Gulf Ecosystem Status Report)					
Political Connectedness ($ lobbying congress)					*How much political "clout" certain groups and/or regions have within the Gulf may influence a variety of ecosystem processes Perhaps this could be based on the number of lobbyists or amount of money spent lobbying.* *These may include recreational anglers, different commercial fisheries, coastal developers; states, counties*
Population composition				*https://spo.nmfs.noaa.gov/sites/default/files/TM129.pdf*	*Population composition is comprised of variables that correspond to the demographic makeup of the population.*

					These variables, which measure the percentage of minorities, the percent of young children and female-headed households and the ability to speak English well are all common components identified as indicators of socially vulnerable populations. Higher factor scores equal higher levels of vulnerability for this index.
Poverty Index				*NOAA Fisheries Social Indicators* *https://spo.nmfs.noaa.gov/sites/default/files/TM129.pdf*	*Our poverty index contains several different poverty variables that cover all facets of the concept including the elderly, young and families in poverty along with the general percent of population receiving assistance. Higher factor scores equal higher levels of vulnerability for this index, as well.*
Labor force composition				*NOAA Fisheries Social Indicators* *https://spo.nmfs.noaa.gov/sites/default/files/TM129.pdf*	*Labor force structure includes variables that are indicative of the types of engagement within the labor force by examining the percent of the total population and the number of females that are in the labor force, the percent of those who may be retired and those who are self-employed. These variables combined lend themselves to a characterization that provides an indication of the strength and stability of the labor force*

Recreational Access Points	*Gulf-wide (except TX)*			*https://www.fisheries.noaa.gov/recreational-fishing-data/public-fishing-access-site-register*	*MRIP - APAIS fishing site registry. Includes details on fishing sites, infrastructure, amenities.*
Environmental Justice Communities	*Gulf-wide*			*https://www.epa.gov/ejscreen*	*Environmental Protection Agency (EPA) mapping program that includes social and environmental indicators.*
Recreational activity patterns	*Gulf-wide*			*http://releases.naturalcapitalproject.org/invest-userguide/latest/recreation.html*	*Natural Capital Project InVEST recreation tool has been used to map spatial patterns of recreational use in coastal and marine environments based on geotagged photos posted to social media.*
Recreational and Commercial angler opinions	*Gulf-wide*			*Gulf Council Fisherman Feedback Tool*	*Gulf Council's Fisherman Feedback tool. The positive or negative sentiment of angler comments could be tracked through time.*
Recreational Angler Satisfaction	*?*			*Academic studies*	

APPENDIX B. EXAMPLE FISHERY ECOSYSTEM ISSUES

Noting that FEIs will be developed by stakeholders and defined following specific guidelines, there are several issues that have been mentioned to the plan development team. These are listed here, without any suggestion that these should be prioritized or selected, but instead to offer an idea of the various themes and types of issues that might be addressed.

- Evaluation and possible designation, elimination, or **re-alignment of MPAs** (Madison Swanson, the Edges, Steamboat, Marine Sanctuaries, Florida Keys and Flower Garden Banks) or proposed spatial management measures (EFH designation)

- **Grouper dynamics and ecosystem management** in relation to red tide, juvenile habitat requirements, pre-spawning aggregation habitats and behavior, seasonality of fishing in relation to spawning times, hermaphrodite development, climate driven changes in spawning locations, and possible natural cycles. Can upland sources of nutrients be addressed through extra-jurisdictional processes? Should MPAs be moved? Should seasonality of fishing be adjusted?

- Ecosystem management implications of energy generating infrastructure installation and removal (**oil and gas platforms, offshore wind turbines).**

- The use of **TEDs and BRDs to address sea turtle bycatch**. Given changes in shrimp effort and new life history information, plus economic losses to Shrimp industry, should policies be re-evaluated?

- Evaluating the effects of **shrimp bycatch effects on red snapper** population status using Electronic Logbooks (past example could be re-evaluated)

- Evaluating the effects of **Red Snapper use of mud bottom habitats and possible management implications -** first led to nearshore longline ban, now is leading to spurious stock assessments.

- Multi-species fisheries management through **spawning aggregation protection** (examples include protection of Riley's Hump in the Dry Tortugas. Additional spawning areas are known within the expanded FGBNMS. Other spawning areas have moved north, outside of existing MPAs, to areas that are not presently protected.

- **Climate change adaptation**. How to manage towards "climate ready fisheries".