2019 Gulf of Mexico Ecosystem Based Fisheries Management Implementation Plan

NOAA FISHERIES

2019 Gulf of Mexico EBFM Implementation Plan

Introduction

NOAA Fisheries has long recognized the importance of ecosystem-based fisheries management (EBFM). The Ecosystem-Based Fishery Management Policy and Road Map describe how NOAA Fisheries implements EBFM based on six guiding principles. NOAA Fisheries defines EBFM in the Policy as "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." To implement EBFM, the Policy identifies and outlines six guiding principles:

1. Implement ecosystem-level planning
2. Advance our understanding of ecosystem processes
3. Prioritize vulnerabilities and risks of ecosystems
4. Explore and address trade-offs within an ecosystem
5. Incorporate ecosystem considerations into management advice
6. Maintain resilient ecosystems

The EBFM Roadmap calls for the development of implementation plans to guide NOAA Fisheries' efforts in implementing EBFM over the next 5 years. The present Gulf of Mexico (Gulf) EBFM Road Map Implementation Plan thus describes how these guiding principles can be translated into actionable steps, using current capacity and ongoing activities as a foundation for development. Many EBFM efforts are already underway, and this document is intended to communicate the continuing evolution of how NOAA Fisheries can better meet its mandates, rather than prescribe additional requirements for meeting these mandates.

The document serves to: 1) document the efforts that the Southeast Fisheries Science Center (SEFSC), Southeast Regional Office (SERO), and other regional partners have completed to date, 2) guide the organization of ecosystem science within the Southeast region, 3) clarify regional priorities in order to facilitate collaboration, and 4) assist the Gulf of Mexico Fishery Management Council (Gulf Council) with ecosystem-level planning. Successful completion of the activities described within is expected to advance basic research, increase efficiencies in operations, create better flow of information from science to management, and increase stakeholder participation and buy-in to the scientific and management process.

Separate EBFM Road Map Implementation Plans exist for the U.S. South Atlantic Region and the Atlantic Highly Migratory Species Fisheries, and the activities in these

plans will be coordinated moving forward. Many of the milestones within the three plans will inform inter-jurisdictional issues, and the scientific advances and lessons learned from one region can be adopted for adjoining regions.

The primary audience for this document is intended to be the Gulf Council, the Gulf States Marine Fisheries Commission, interested public, the NOAA Fisheries Southeast region, and its collaborating federal, state, academic, nongovernmental, and citizen group partners. This document is intended to motivate a dialogue on how EBFM can be effectively applied in the Gulf, taking into account stakeholder views, regional priorities and capacity, and the current state of the science.

1.0 Regional Context

The Gulf of Mexico (Gulf) is an ecologically and economically productive ecosystem, generating over 1.3 billion pounds in commercial fishery landings and a recreational fishing industry worth an estimated $10 billion[1]. Fishing industries interact with other major regional economic drivers and natural phenomena, and are exposed to a multitude of stressors, many of which are unique to the Gulf ecosystem. These stressors can be chronic in nature (e.g., hypoxia, coastal development, increasing temperatures) or episodic (e.g., red tides, hurricanes, oil spills, market shocks). Due to the complexity of these stressors and their significant effects on exploited species and protected resources, EBFM is an inherent property of science and management in the Gulf. For example, major industries such as oil extraction and shipping have reshaped the Gulf's coastal and marine habitat landscapes, and such alterations can have both beneficial and damaging impacts on the resources and the way that people extract benefits from the system. The SEFSC and SERO lack delineated ecosystem research divisions for carrying out EBFM, and the Gulf Council has yet to develop a Fishery Ecosystem Plan or other formal policy document stating EBFM objectives; nonetheless, a large suite of activities within the portfolio of Gulf research and policy contain elements of EBFM. Broadly, these activities fall under the following theme areas: advancing stock assessments, tracking ecosystem trends, climate change, multi-species interactions, connectivity, habitat conservation, and human dimensions. Each theme area contains research and management activities that address several of the National EBFM Policy guiding principles.

1.1 Advancing stock assessments

The Gulf is home to diverse populations of exploited species and protected resources of economic and/or ecological importance, and current scientific and management capacity cannot address all the potential ecosystem effects on the full suite of managed species. Thus, research is needed to understand which species or species groups are most at risk of management failures for lack of considering or predicting processes external to their own population dynamics. The Southeast region's stock assessment process, SEDAR (Southeast Data, Assessment, and Review), strives to balance tradeoffs between transparency, thoroughness, and timeliness. Regional science priorities are to: improve the SEDAR process to be more responsive to stakeholder

[1] Karnauskas M, Schirripa MJ, Kelble CK, Cook GS, Craig JK, eds (2013) Ecosystem status report for the Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFSC-653.

concerns, better acknowledge and communicate scientific uncertainty, and increase stakeholder buy-in. SEFSC and SERO data analysts, stock assessment scientists, Gulf Council staff, and stakeholders all have a shared desire to more thoroughly consider and incorporate ecosystem effects into stock assessments where justified; however, there is constant demand for increased throughput of management advice. Due to the complexity of fisheries in the region, and challenges with available data streams (e.g., indices of abundance derived from recreational fisheries, sparse or absent fishery-independent data sets for some species, lack of age composition data, discards with high uncertainty) the stock assessment process in the Southeast is already stretched to capacity.

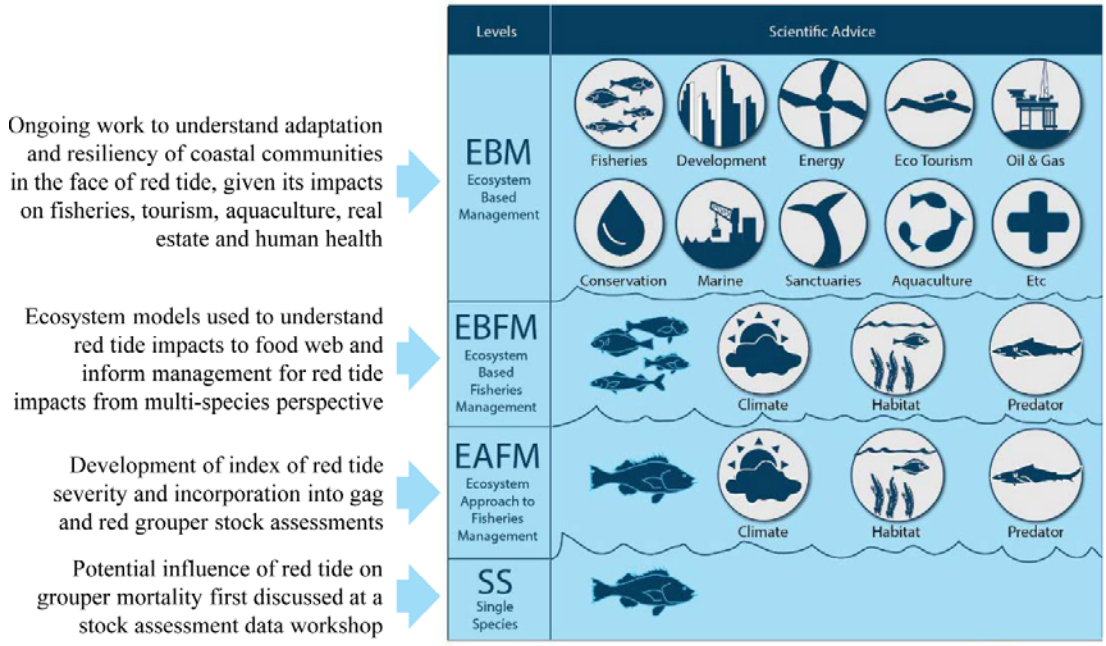
Much progress has been made in including ecosystem considerations in stock assessments; for example through the inclusion of red tide mortality in grouper species, development of predictions of recruitment strength due to oceanographic influences for red snapper, and the development of individual-based brown shrimp production models to supplement the stock assessment process. Ecosystem information can also be qualitatively included in the stock assessment process; for example, through consideration of ecosystem indicators that are thought to be tied to critical aspects of population dynamics. The implementation of "research track assessments" in the SEDAR process will allow not only for increased examination of potential environmental influences on a given stock, but also for a more thorough screening of basic data inputs that might reveal where there are anomalies or irregularities needing further study. Additional research is needed to determine where the inclusion of ecosystem processes is of sufficient benefit to management advice, such that the resources to operationally support ecosystem data inputs are justified.

1.2 Tracking ecosystem trends

Monitoring is crucial for tracking not only individual stock and protected species dynamics, but also for understanding changes in the larger system in which these organisms reside. The occurrence of the *Deepwater Horizon* oil spill in 2010 brought to light a general paucity of data streams with which to track Gulf ecosystem change, and the occurrence of the event itself spurred massive data collection efforts which may serve as a useful baseline for the future. The *Deepwater Horizon* Natural Resource Damage Assessment Trustee Council's Regionwide Trustee Implementation Group (TIG) has developed strategic frameworks for birds, marine mammals, oysters, and sea turtles, which identify key regional monitoring needs and other information gaps relevant to implementing restoration for those four resources. Similarly, the Open Ocean TIG is in the process of developing a Monitoring and Adaptive Management Strategy that will identify priority data and science needs for the open ocean restoration area. Future restoration monitoring implemented through these two TIGs, and the TIGs for the five Gulf states, may contribute valuable data that can be used to help to fill some of the gaps in existing Gulf of Mexico monitoring. Another significant monitoring activity includes the recently added Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS; extended from a similar Atlantic survey effort), which is a multi-agency partnership to collect and disseminate broad-scale data on the abundance, distribution, habitat use, and behavior of marine mammals, sea turtles, and seabirds in the Gulf. These data form the basis for

Climbing the EBFM ladder to get ahead of the impacts of red tide

Fish die-offs attributed to harmful algal blooms known as "red tides" have occurred in the Gulf for hundreds of years, and a severe bloom event in 2005 spurred awareness of the issue within the stock assessment framework. The first attempt to quantify red tides, based on statistical modeling using satellite data, was made in 2013. Later, multi-species modeling approaches were considered, with the goal of understanding the potential ecosystem effects on species that interact with groupers via trophic connections. Combined, these research efforts were effective in estimating the magnitude of red tide mortality on groupers and improving the accuracy of stock assessment output. In 2014, another red tide event occurred – but in the absence of a stock assessment with which to estimate its impact, the appropriate path for management was uncertain. A management strategy evaluation was carried out in both single species and ecosystem model simulation frameworks to provide guidance for management in cases where stocks are confronted with episodic mortality events. It was found that precautionary catch limit reductions could perform in meeting management objectives as well as a "reactive" approach, where assessments are performed immediately after mortality events. Ongoing simulation work is considering management performance under scenarios where the frequency of episodic mortality events may increase. In response to the severe 2018 red tide event, the Integrated Ecosystem Assessment Program has developed a new initiative to respond to these events in light of concerns of regarding the effects on habitat conditions, commercial and for-hire fishing businesses, aquaculture, tourism, protected species, and human health.



The EBFM "ladder." Ongoing red tide research efforts in the Southeast region inform a broad range of management approaches.

protected species stock assessments and can be used to improve mitigation and monitoring for impacts of human activities, including those related to the oil and gas industry, and are required to inform National Environmental Policy Act (NEPA) documents and consultations related to Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), Migratory Bird Treaty Act (MBTA), and other statutes.

Advanced technologies are expanding our capacity for monitoring; for example, passive acoustic monitoring is being used to understand changes in marine mammal density for post-oil spill restoration monitoring, provide information on fish spawning events, identify distribution and habitat needs for rare mammals, and track trends in ocean noise. In the spring of 2018, a pilot ecosystem survey was implemented, which combined advanced sampling technologies (e.g., towed cameras, eDNA, molecular identification of plankton) with traditional methods for comparison with the long-term surveys in the region. The data from this pilot exercise can be analyzed to understand the informational content of these approaches, and how they might be applied on larger scales. Results should be used to refine existing efforts and plan future surveys, with the goal of capturing more comprehensive information across ecosystem components.

Ecosystem Status Reports, which summarize the current status and trends of all components of the Gulf ecosystem, were produced in 2013 and 2017, and are useful for tracking changes in a variety of ecosystem components. Managers are now faced with new questions on what the "desirable" state of the Gulf is, and whether it is even possible to bring resources back to previously observed conditions. There is a need to understand how carrying capacities of marine populations have changed over time, so that the Gulf Council can consider whether or how these changes should alter present-day management benchmarks. Tracking ecosystem trends is also important for demonstrating and increasing the benefits of habitat conservation efforts to fisheries and protected resources. There is a need to enhance basic monitoring data in the Southeast region, such as fishery-independent surveys, for many species of primary economic importance. This topic was addressed in a recent workshop to evaluate the information content of existing surveys. From a system-level perspective, major data gaps include habitat, primary and secondary productivity, and trophic information. The latter issue in particular impedes our ability to use ecosystem models for management in the region, as diet data are lacking for many species.

1.3 Climate change

Measuring the ecosystem response to various management actions is complicated by the presence of long-term chronic stressors such as changing ocean temperatures, increasing ocean acidification, and sea-level rise. Future alterations of the physical ocean and coastal environment, as predicted with climate change, are expected to have significant impacts on fisheries, fishermen, stakeholders, and coastal communities in the Gulf. These effects are already recognized within management; for example, the final rule for Regulatory Amendment 4 to the Fishery Management Plan (FMP) for Spiny Lobster in the Gulf of Mexico and South Atlantic increased the spiny lobster annual catch limit based on a longer time series of data. The original ACL was based

on time series of landings that were at a historic low. It was determined that the fishery fluctuates due to environmental conditions affecting the stock a longer time series of landings that captures higher landings could be used to specify the annual catch limit. Also, amendments to the FMP for the Coastal Migratory Pelagic Resources of the Gulf of Mexico and Atlantic Region have considered how environmental influences have changed migratory patterns over time, which has resulted in modifications to migratory group management boundaries. Research is needed to identify other species that may be candidates for climate-sensitive fishery control rules or benchmarks, or for additional risk assessments. The Southeast region is making progress on Climate Vulnerability Analyses for suites of both exploited fishery species and protected resources; these outputs will strengthen the foundation of fishery management by improving the data used in decision-making and will be useful for identifying species of particular concern within the region.

Risk analyses and management strategy evaluations (MSE) are other valuable tools for determining the robustness of policies and management actions in a changing environment. Such exercises have already been undertaken in the Gulf; for example, an MSE was used to determine whether existing red grouper control rules are robust to episodic natural mortality events such as red tides. Building capacity for this type of research is a NMFS priority, and the SESFC has hired an additional staff member dedicated to carrying out management strategy evaluations. Much of the physical modeling expertise in the Southeast region is housed within academic institutions and the Atlantic Oceanographic and Meteorological Laboratory (AOML) within the NOAA Research line office. Collaborations between NOAA Fisheries and these partners are required in order to gain a better understanding of the effects of climate change on fisheries, protected resources, and human communities. The SEFSC is currently collaborating with AOML on a project to predict biogeochemical changes in the Gulf, and on a project to quantify food-limitation of coastal pelagic species in the Gulf; these are just some examples of climate-related research that can improve management of exploited species. In addition, the SEFSC and SERO, in collaboration with AOML, have developed a regional action plan for the Gulf to implement NMFS' Climate Science Strategy. This action plan contains many elements of EBFM and emphasizes the importance of collaboration in achieving objectives.
Among the many climate issues in the Gulf, a unique phenomenon is the increased "tropicalization" of plants and animals inhabiting the Gulf, and the geographic boundaries of the Gulf that limit the northern range expansion of species. This results in changing species distributions for those species undergoing range expansion, and range compression or shifts in depth distributions for those species in the northern Gulf that can no longer expand north. At a finer scale, competitive interaction between the plants that influence animal life history will change distributions based on those interactions. For example, the northern migration of the black mangrove has structurally changed (and continues to change) many areas that were once *Spartina*-dominated marshes. A new research effort seeks to determine whether habitat shifts in estuarine systems will affect the growth rates of juvenile penaeid shrimp, thus affecting the productivity needed to support a sustainable shrimp fishery in the Gulf of Mexico. A priority research area is to understand climate effects on resilience in

human communities and on range shifts of economically-important species, as well as the habitats on which all of these depend.

How will EBFM contribute to improved decision-making?

A key to effective EBFM will be determining the most expedient "onramps" for ecosystem information to be fed into the management system. Possibilities for information transfer include the following:

- **Ecosystem Status Reports** can inform the overall state of the ecosystem and provide an effective backdrop against which management decisions can be evaluated and considered. More frequent updates, communicated to the Council and its advisory bodies on a regular basis, would allow for consideration of ecosystem factors in decision-making.
- **Species profiles** can accompany stock assessment documents and can identify additional economic, social, and biological considerations that can inform concepts such as Optimum Yield. Species profiles have been developed for gray snapper and yellowtail snapper as part of a pilot project to understand their potential utility to management.
- **Local ecological knowledge** can contribute to a greater ecosystem understanding by harnessing the insights of individuals who observe the ocean regularly. Stakeholder input occurs regularly within the SEDAR process, but other opportunities exist. For example, insights from stakeholders may be particularly useful for capturing events in recent history that have occurred after the terminal data year of the assessments.
- **Risk assessments** can offer guidance to decision-makers to inform whether management practices are robust to various unknowns or shocks, such as environmental factors. For example, a management strategy evaluation was conducted to examine whether current harvest control rules are robust to possible future changes in frequency of red tide events.
- **Biophysical modeling of larval transport** can be useful for estimating connectivity between management jurisdictions and for informing management boundaries. These approaches can also be used to predict annual fluctuations in recruitment strength.
- The Gulf **Integrated Ecosystem Assessment (IEA) Program** can be leveraged to provide expertise at various stages in the science and management. During the 2013 gag grouper assessment, the IEA formed a special working group which collaborated with stock assessment analysts which led to the incorporation of two environmental variables.

1.4 Habitat considerations

Identifying and understanding the role of different habitats in the Gulf is a serious challenge to the implementation of EBFM. Many of the habitats are simply not identified, poorly quantified, routinely changing, or are currently being restored. For example, many of the deep-water habitats that have corals have only recently been identified through advances in technology. To properly understand the impacts on fisheries and protected resources, changes in these habitats will need to be monitored

and understood. Improving understanding of mesophotic and deep sea communities has been identified as a specific goal for *Deepwater Horizon* NRDA restoration for these resources and it is anticipated that studies to better characterize habitat distributions and community characteristics will be included as part of the overall restoration effort for those communities. The RESTORE Council Monitoring and Assessment Program is also conducting a comprehensive inventory of existing habitat and water quality monitoring programs, which should provide a useful backdrop for evaluating the effectiveness of restoration activities and other management decisions. Coastal wetlands and mangrove forests in the Gulf are critical nursery areas and affect the productivity of many fishery species; therefore, research on the linkages between nearshore habitats and fishery production is a regional priority. This is particularly relevant given the major restoration projects that are underway, such as planning for multiple large-scale Mississippi River diversion projects and the Everglades Restoration in Florida Bay. Extensive research has been conducted on such linkages, particularly for estuarine-dependent species like penaeid shrimp, and this work has been incorporated into habitat science and stock assessments. Active projects involve examining the distribution of fishery organisms in various wetland habitats and experimental work to evaluate relationships between environment and growth of white shrimp. Productivity of stocks in the Gulf may also be influenced by the installation of artificial habitats; these structures have consequences for fishery access, and the combined effects of artificial habitats on fish and fisheries is of primary concern for effective management in the Gulf.

Another major difficulty with respect to habitats is recognizing the water column as a viable habitat with certain characteristics rather than just describing physical properties of the water. For example, many pelagic species follow specific water mass properties and it is critical to better define these characteristics and recognize the water column as a habitat with certain characteristics that are not spatio-temporally fixed. Much of the essential habitat for coastal pelagic species is simply defined as the "coastal waters of the Gulf of Mexico" without any reference to water column characteristics, but emerging research will address the influence of pelagic habitat. A recent collaborative project is developing new models of cetacean habitat in the deep waters of the Gulf by integrating the high-temporal resolution cetacean density data associated with moored passive acoustic instruments, high-spatial resolution cetacean density data from large-scale ship-based visual surveys, and *in situ* and remote satellite oceanographic data to elucidate the environmental drivers of cetacean occurrence. The SEFSC and AOML have also carried out investigations on the importance of pelagic habitat characteristics to economically important species, including studies on favorable conditions for Bluefin tuna larvae. A new research effort also seeks to investigate the link between nutrients, food availability, and the survival of Atlantic bluefin tuna larvae, which can be used to improve stock assessments for this species.

Many of the economically important species in the Gulf are heavily dependent on the quantity and quality of various habitats, and this is reflected in existing Gulf Council FMPs. The original FMP for Reef Fish Resources in the Gulf of Mexico considers both natural and artificial habitats, and a stated objective is to conserve and increase

reef fish habitats in appropriate areas for both adult and juvenile stages. The creation of a "stressed area" designation to limit fishing was based on heavy fishing activity affecting the stocks and environment. The Gulf Council recently identified priority areas for consideration as habitat areas of particular concern, based on abundance and diversity of coral species in those locations, and ultimately approved a plan to protect over 300 square miles of deep-sea corals. In 2017, the Gulf Council also submitted a 5-year review of essential fish habitat (EFH) information for the Southeast Region. SERO completed a review of this report and provided a response to the Council in 2018. In general, SERO was supportive of the Council's recommendations to improve the quality of habitat information used to identify EFH, as well as the Council's efforts to consider ecosystem information in their FMPs. Increased focus on habitat research would address regional priorities such as facilitating EFH assessments, determining critical habitat for threatened and endangered marine mammal species, and developing habitat restoration and mitigation plans.

1.5 Multi-species interactions

The importance of multi-species interactions – including both trophic and fishery-induced – are well recognized in the Gulf and are contained within a number of existing Gulf FMPs. Multiple Reef Fish FMP amendments incorporate multispecies complexes or identify multiple species that need similar management benchmarks (such as annual catch limits). Due to the diversity of both fisheries operations and fished species in the system, many of the important multi-species interactions in the Gulf revolve around fishery bycatch issues. To account for bycatch, reef fish management decisions have been based partly on the status of other benchmarks in other fisheries; for example, quotas for red snapper were increased based on the bycatch reduction success programs in the shrimp fishery. Regional priorities include improved monitoring of bycatch, assessment of bycatch and impacts through multi-species modeling efforts, and reduction of bycatch in managed fisheries by advancing the innovation and coordination of bycatch solutions (e.g., turtle excluder devices in trawl gear, circle hooks in the reef fish fishery, and weak hooks in the pelagic longline gear). These activities will benefit both sustainable fisheries and protected resources.

Research is needed to identify the significant trophic interactions in the Gulf that should be accounted for in management, as this has the potential to create efficiencies (e.g., by facilitating multi-species quotas) and help maximize the benefit of resources (e.g., by directly or indirectly managing the prey base for economically important species and protected species). Some project to evaluate trophic interactions have already been established; for example, a recent project is using stable isotope analysis to construct habitat-specific food webs in wetland habitats, to identify production sources and differences in resource use by shrimp. Progress in ecosystem modeling of the Gulf region has been made through extensive collaboration with academic partners, including: the GoMexSI trophic interaction database, the Atlantis ecosystem model, and the OSMOSE ecosystem model. Several Ecopath/Ecosim models have been developed for the Gulf of Mexico, and a major project recently funded by the RESTORE Science Program seeks to understand the role of menhaden in the Gulf. Recent efforts have been made to review the current status and information needs of ecosystem models used in the Gulf of Mexico and inventory the use of existing

monitoring programs for parameterizing ecosystem models, which should be useful for identifying and refining existing modeling efforts. With respect to protected resources, another recently funded RESTORE Science Program project will consider the Gulf of Mexico Bryde's whale's trophic interactions and habitat requirements, which are needed to develop recovery plans for this endangered population. Increased ecosystem modeling capacity may be useful for highlighting areas where multi-species management could be more efficient.

1.6 Spatial scales and connectivity

Another challenge is to determine the relevant spatial scales at which ecosystem processes should be managed or accounted for – and this requires understanding connectivity within and among regions, and from watersheds to pelagic environments. A major challenge is the spatial scale at which various data are collected; for example, fishery-dependent and fishery-independent data are not collected in formats that are transferable or translatable, which limits the information content that can be extracted. Fishing activities in the Gulf are also highly heterogeneous and require consideration of space, both for the conservation of resources and with respect to interactions among fishery sectors. For example, the FMP for the Shrimp Fishery of the Gulf of Mexico contains elements of spatial management such as seasonal closures to maximize the value of the resource and to reduce conflict between overlapping fisheries. Also, a number of marine reserves and fishing closures have been established by the Gulf Council for the purpose of protecting spawning reef fish and highly migratory species. Future efforts to protect spawning stock biomass through spatial management will be facilitated with the completion of a recent RESTORE Science Program-funded spawning aggregation database project, which summarizes current knowledge for a large suite of species. The FMP for Coastal Migratory Pelagic Resources of the Gulf of Mexico and Atlantic Region is a joint FMP with the Gulf Council and South Atlantic Fishery Management Council based on species range, which requires an understanding of adult connectivity between regions. The extent of larval connectivity between regions, particularly with the adjacent South Atlantic management jurisdiction, also comes up frequently with reference to assumptions of stock delineation and has complicated recent assessments of scamp and blueline tilefish. A regional priority is to use biophysical modeling to understand larval transfer rates between management jurisdictions and ground truth these results with genetics or otolith microchemistry data. Finally, incorporating these spatial processes into the stock assessment process – and understanding the most appropriate scales at which to conduct assessments – is another topic requiring further investigation; research on this topic is currently underway.

Although the terrestrial environment is outside the management jurisdiction of the Gulf Council, the linkages between land-based processes and Gulf fisheries are well-recognized and may impact the ability to attain effective management. Substantial research has been carried out on the annual hypoxic zone at the outflow of the Mississippi River watershed, and a series of projects funded by NCCOS will better inform how to manage fisheries in the face of hypoxia (NGOMEX). Several proposed Mississippi River diversion projects to stem the loss of Louisiana coastal wetlands are of concern for their unknown impacts on marine and human communities and

therefore advancing ecosystem modeling and socioeconomic impact assessments is a regional priority. A socio-ecological modeling effort is underway to understand the potential impacts of diversions. Finally, it is recognized that the Gulf is a water body connected to other nations, and collaborations with Mexican and Cuban counterparts are actively being advanced through the Gulf Integrated Ecosystem Assessment (IEA) program, GoM-LME project and MexUS-Golfo bilateral meetings between the U.S. and Mexico. Many of our commercially fished species and protected resources have broad distributions encompassing the U.S., Mexico, and Cuba, and effective management can require study and consideration of their broader regional dynamics.

1.7 Human Dimensions

The importance of human communities as key components of the Gulf ecosystem is widely acknowledged, and there are ongoing efforts to more accurately assess the economic impacts of new fishing regulations, as is necessary for effective management. For example, an ecological-economic model is being developed to evaluate alternate stock rebuilding strategies in a multiple-species catch share fishery, and an enhanced bioeconomic model is being considered for evaluating the biological and economic impact of different Texas and Louisiana Shrimp Closure scenarios. Social scientists in the region are also using existing tools for application to the Gulf; the FishSET Spatial Economic Toolbox for Fisheries is being implemented to predict how different management actions may affect fishing behavior and location choices, and the BLAST model (Bio-economic Length Structured Angler Simulation Tool) is being used to assess the effects of management actions on angler participation in recreational fisheries in the southeast region. The most recent Gulf Ecosystem Status Report had an increased focus on human dimensions, reflecting growing recognitions of the importance of tracking human health and well-being as an integral part of ecosystem science.

Following the severe red tide event of 2017-2018, the SEFSC and AOML developed a new initiative to work with the fishing communities along the Florida west coast to better understand red tides and their impacts on society. This effort includes conducting informal oral history interviews focused on red tides, in order to tap into local ecological knowledge and obtain key information and hypotheses regarding the ecological, social, and economic impacts of red tides. Key social, economic and ecological indicators are also being compiled for the purpose of understanding the short- and long-term impacts of red tide events on fishing communities, fish populations and habitats in west Florida. The overall goal is to gain an understanding of the causes and impacts of red tides, and develop recommendations for measures that can be adapted to increase the resilience of fishing communities in the face of red tide events.

What are our EBFM priorities?

In the absence of a formal policy statement or Fishery Ecosystem Plan stating ecosystem goals and objectives for the Gulf of Mexico, delineation of specific priorities is challenging. A participatory approach known as community based system dynamics is useful for understanding complex systems and prioritizing useful research directions. The SEFSC and SERO piloted a series of community based system dynamics workshops with diverse groups of stakeholders, including fishermen, processers, managers, and researchers to develop group models of the snapper-grouper fishery complex of the West Florida Shelf. The resulting set of models can be used to inform key leverage points which would serve as priorities for evaluating risk, identify the most critical information gaps to inform priorities for future targeted research, and understand what stakeholders value in the system.

Participatory fisheries system dynamics modeling in action (Pine Island, Florida, 2018)

2.0 Expected outcomes and benefits

The existence of the Gulf EBFM Implementation Plan itself, as well as successful completion of the activities described within, should lead to a variety of outcomes and benefits specific to the six EBFM guiding principle areas as described below.

2.1 Guiding Priciple 1: Implement ecosystem level planning

This Gulf of Mexico EBFM Implementation Plan is intended to clarify the existing ecosystem science capacity and ability to address management priorities in the Gulf, and provide some context for development of a Gulf of Mexico Fishery Ecosystem Plan or other policy documents with EBFM relevance. The next step would be for the Gulf Council to demonstrate the management and policy efforts they have completed thus far, to further EBFM approaches.

This Plan clarifies Southeast ecosystem science priorities and thereby facilitates collaboration and planning with partner agencies. A number of collaborative efforts between NOAA Fisheries and other NOAA line offices currently exist, but these efforts have typically been informal or ephemeral. With an outline of EBFM activities and priorities, partner agencies can better support the Southeast region in meeting its

objectives, and collaborations can be more targeted and formalized. Such collaborations were the focus of an AOML-SEFSC 2018 joint workshop, which included a plan for organizing efforts to target funding opportunities for meeting stated objectives. This Plan, and the workshop should also set the groundwork for other potentially valuable collaborative opportunities, such as addressing ocean and coastal acidification research via AOML's GoMECC research cruises.

Specific actions in this Plan which support this guiding principle include:
Road Map Action Item 1a2: Develop National and Regional EBFM engagement strategies

- Develop of a stakeholder engagement strategy for this EBFM Road Map (page 16)

Road Map Action Item 1a3: Develop best practices where there are overlapping jurisdictions

- Use biophysical modeling to understand larval transfer rates across management jurisdictions (page 10)
- Increase collaborations with Mexico and Cuba to study and manage species that cross international boundaries (page 11)

Road Map Action Item 1b3: Assist Councils, Commissions, regional fisheries management organizations, and other bodies as requested, in their development of new, or revision of existing FEPs

- Support the Gulf Council as needed as they consider creating an Ecosystem Plan or other policy documents relating to EBFM

2.2 Guiding Priciple 2: Advance our understanding of ecosystem processes

Research described in the Plan is intended to increase understanding of the major drivers of the dynamics of managed fish stocks, protected species, and habitats. This information can be used to understand recruitment patterns, predict strength of recruitment in recent years, and thus improve short-term projections in stock assessments. The various modeling capabilities described in this Plan will help managers to better understand integrated ecosystem responses to physical change. One benefit from these activities is increased lead times for managers to take action; another is to help managers disentangle fishing impacts from environmental forces. Improved short-term forecasts from stock assessments will enable faster response to high or low recruitment years. Additionally, managers will be better equipped to understand the indirect impacts of management regulations, and may allow a greater awareness of the potential unintended consequences of management actions.

Specific actions in this Plan which support this guiding principle include:
Road Map Action Item 2a1: Advance resources to conduct EBFM

- Conduct regular joint workshops with AOML and SEFSC to discuss EBFM objectives and identify targeted collaborations and funding opportunities (page 16)
- Conduct research on the linkages between nearshore habitats and fishery production (page 8)

- Conduct research on the influence of pelagic habitat on stocks and protected species (page 8)
- Work collaboratively with federal, state, academic, non-profit, and citizen science partners to better understand red tide bloom ecology, as well as the immediate and successional impacts of red tide events on biological and human communities (page 11)

Road Map Action Item 2a4: Develop and maintain core data and information streams

- Develop and maintain core data streams; pilot new ecosystem-focused surveys and evaluate the utility of these surveys (page 5)
- Collect broad-scale data on distribution and abundance of marine mammals, sea turtles, and seabirds, and develop seasonally- and spatially-explicit density estimates (page 3)
- Develop and integrate acoustic and eDNA technologies to identify habitat and distribution of the Gulf of Mexico Bryde's whale (page 5)

Road Map Action Item 2b2: Establish routine, regular and dynamic reporting of ecosystem status reports for each large marine ecosystem

- Publish Ecosystem Status Reports, as requested by Council or other management bodies (page 5)
- Understand past and predict future biogeochemical changes in the Gulf (page 6)
- Collaborate with state, academic, nongovernmental, and citizen science groups to pool available physical data for the West Florida Shelf and screen for developing anomalous events such as hypoxia (page 11)

2.3 Guiding Priciple 3: Prioritize vulnerability and risks to ecosystems and their components

Products such as the climate vulnerability analysis and ecosystem status reports can be used to help prioritize stock assessment activities in terms of timing, complexity, and species to be addressed. For example, species estimated to be most vulnerable to changes in environmental conditions might be prioritized for assessment, or assessed more frequently, than species thought to be less vulnerable.

Specific actions in this Plan which support this guiding principle include:

Road Map Action Item 3a1: Conduct Systematic Risk Assessments for relevant NOAA regional ecosystems

- Complete climate vulnerability assessment for marine mammals and fish stocks (page 6)

2.4 Guiding Priciple 4: Explore and address trade-offs within an ecosystem

A broad outcome of EBFM should be improved decision-making and elucidation of potential trade-offs associated with different management actions. The Southeast region will rely heavily on external capacity for ecosystem modeling, to elucidate various trade-offs among different ecosystem components and among competing management objectives. The region will also rely on the expertise of partner agencies to gain a better understanding of future physical changes expected in the Gulf; this information is an important component of MSE work, which seeks to understand how management schemes will perform under different scenarios.

Specific actions in this Plan which support this guiding principle include:
Road Map Action Item 4b1: Develop functional system-level management strategy evaluations (MSEs)

- Increase capacity for MSE work by filling vacant MSE staff position (page 6)

Road Map Action Item 4b2: Explore novel HCRs and develop associated guidelines, as appropriate and consistent with National Standards

- Continue research to guide whether existing control rules are robust to episodic natural mortality events (page 6)

2.5 Guiding Priciple 5: Incorporate ecosystem considerations into management advice

Many of the activities described in the Regional Context section have the goal of producing more accurate management advice, leading to a better understanding of how management can adapt to a changing environment, and providing increased lead times for managers to respond. A primary reason for moving toward EBFM is to incorporate a wider range of processes in management advice, while maintaining or improving operational efficiency. For example, a more flexible stock assessment enterprise could be attuned to the strength of external drivers such as those reported in the Ecosystem Status Reports. These indicators could be used to identify years of anomalous conditions, which might trigger fast-track assessments for species of particular concern. A range of modeling activities can also help to search for efficiencies, for example, to define species complex catch limits in cases where single-species catch limits are not feasible. Ecosystem models can be used in this context to identify the most suitable components or indicator species for tracking, and to formulate adaptive management schemes.

Specific actions in this Plan which support this guiding principle include:
Road Map Action Item 5b2: Support consistent and effective implementation of the MSA NS1 Guidelines, which includes guidance on incorporating ecosystem information into stock management

- Gain a better understanding of how to manage fisheries under the influence of hypoxia (page 10)
- Investigate the link between nutrients, food availability, and the survival of Atlantic bluefin tuna larvae which can be used to improve stock assessments (page 8)
- Integrate information on ecosystem stressors and predator-prey interactions into the fisheries assessment and management process in the Gulf of Mexico (page 9)
- Understand the effects of climate change on the distribution of economically important penaeid shrimp species and the habitats on which they depend and provide habitat-specific information on growth rates for shrimp, to inform stock assessment (page 6)

Road Map Action Item 5c2: Implement National Bycatch Reduction Strategy

- Improve bycatch assessment and monitoring; explore development of a dynamic management tool for the region (page 9)

Road Map Action Item 5c5: Review long-term protected species recovery and rebuilding plans to ensure they account for the potential effects of near-term and long-term climate change, particularly relating to alterations to food web structure

- Develop a comprehensive ecological understanding of Gulf of Mexico Bryde´s whales, including the physical, oceanographic, and biological features defining their habitat and their ecological role in Gulf of Mexico marine food webs (page 10)

2.6 Guiding Priciple 6: Maintain resilient ecosystems

Increasing the flexibility of stock assessments, to better incorporate stakeholder observations and socioeconomic considerations, would be beneficial for maintaining resilient ecosystems. Incorporating additional flexibilities, while initially arduous, would likely lead to a more efficient process over the long-term. For example, incorporating stakeholder observations early in the stock assessment process could help analysts better interpret data streams. Modifying stock assessment outputs so that they could be integrated seamlessly into socioeconomic modeling platforms (e.g., BLAST model) would allow for more efficient analysis of economic impacts. Of course, any proposed activity needs to be planned in consideration of the data availability and quality to support the analysis; otherwise, it will be challenging to make robust management recommendations.

Specific actions in this Plan which support this guiding principle include:
Road Map Action Item 6b1: Explore community health and well-being socio-economic metrics

- Conduct research to understand the potential impacts of Mississippi River diversions, including socio-ecological modeling efforts (page 11)
- Develop models to more accurately assess the economic impacts of new fishing regulations (page 11)
- Compiling time series of key social, economic and ecological indicators to understand the impacts of red tide events on fishing communities in west Florida (page 11).

3.0 Engagement strategy

The challenges ahead in managing the Gulf ecosystem will be varied and complex and successful EBFM will require cooperation between scientists, managers, and stakeholders. Partners in this effort include the SEFSC, SERO, AOML, Gulf Council, the Gulf States Marine Fisheries Commission and its member state agencies, academic institutions, and stakeholder groups. A number of opportunities are available for transferring information across the various bodies involved in EBFM. More formal collaborative efforts with AOML, such as joint workshops, will augment science capacity in the region. Information transfer between organizations can also be bolstered through efforts to increase participation in various settings. For example, Gulf Council staff have recently become involved in the IEA program, and participation in meetings and program activities has been a valuable opportunity for scientists to understand manager needs. Increased attendance by scientists at Council meetings would provide many opportunities for science-management interaction.

Opportunities for collaborating on EBFM in the Southeast

The following programs could potentially be built upon to engage stakeholders in EBFM efforts and research activities in the Southeast:

NOAA's Integrated Ecosystem Assessment (IEA) process is considered the "analytical engine to carry out EBFM," analogous to how stock assessments are used to support single-species management. The IEA program is supported by multiple NOAA line offices and facilitates collaboration among experts of diverse backgrounds, as is required to tackle many of the major EBFM challenges at hand.

The Marine Resource Education Program (MREP) is a series of workshops that are run and designed by fishermen, for fishermen. The program covers the fisheries science and management process, and equips stakeholders with the tools necessary to become more deeply engaged in the process. It also provides an opportunity for stakeholders to meet the individuals who carry out the science and management and share feedback.

The Cooperative Institute of Marine and Atmospheric Sciences (CIMAS) is the SEFSC's partner cooperative research institute. CIMAS allows federal scientists to more easily leverage the expertise of neighboring universities, engage the academic community, and obtain research assistance to meet short-term needs. CIMAS supports the SEFSC in multiple topical areas, including climate research, ecosystem modeling, ecosystem management, and restoration.

NOAA's Cooperative Research Program (CRP) provides a mechanism for fishermen to get involved in the collection of fisheries data to support science and management. In the cooperative research process, stakeholders partner with NOAA and academic scientists in all phases of the research. Benefits of the program include: improving stakeholder understanding of the data and science, improving fishery data and the efficiency of data collection, and building respect among fishermen and scientists.

The National Coral Reef Monitoring Program (NCRMP) is a focused monitoring effort carried out in collaboration with governmental and academic partners. The goals of the program are to develop consistent coral reef monitoring methods, develop partnerships, and to use data in periodic assessments of coral reef ecosystems.

Finally, partner agencies engage in research relevant to EBFM in the Gulf, but sometimes are challenged to make direct linkages to decision-making. Many of the recent RESTORE Science Program-funded projects have specific guidance for engaging with management bodies. Technical monitors of these projects should

ensure that principal investigators work with management bodies early and often to create meaningful engagement and increase the likelihood that project outputs are transferred appropriately.

Some of the responsibility for engaging partners in EBFM lies with individual scientists, who can explore new methods for communicating information. For example, simple decision tables can be built to convey the predicted outcomes of management actions, in the face of uncertainty about a particular process that may affect outcomes. Efforts can also be made to put scientific results in a more system-level context. For example, a new ecosystem considerations infographic product is being piloted alongside the 2018 gray snapper assessment. The visual product summarizes the inputs to the stock assessment and external factors that potentially affect stock dynamics and is targeted towards a broad management and stakeholder audience. Additionally, there are ways that SEFSC, SERO, and the Council can work more closely together to integrate science and management needs. For example, one ongoing project seeks to automate stock assessment projections through a GUI-based web interface, so that SERO analysts and other managers can directly explore the consequences of various management actions; in this way, the science-management interface becomes more seamless and efficient.

Many ecosystem factors that influence managed components of the system will be difficult to detect or may occur completely outside the temporal and spatial scales of our monitoring efforts. As the ecosystem continues to change, potentially entering states not previously observed, reliance on stakeholder participation will increase. In the stock assessment process, the SEFSC and SERO should work to liaise with Council staff and advisory panels, to continue to find meaningful ways for obtaining and including stakeholder input. For example, in the recent Gulf data-limited species stock assessment (SEDAR 49), a "contributions from stakeholders" section was included, which outlines the specific feedback that was received and how it was factored into the stock assessment; such a section could be valuable in every assessment. More broadly, there are opportunities to increase stakeholder input through formal bodies such as Council Advisory Panels, programs such as the Marine Resource Education Program (MREP), and the IEA Program. For example, graduates of MREP could be considered a unique resource for the region and could be used as a "sounding board" for addressing emerging ecosystem issues. The IEA program is also putting increased emphasis on stakeholder scoping, and is exploring novel techniques for participatory learning, such as community-based system dynamics. These new approaches may offer meaningful opportunities to engage stakeholders and other partners in EBFM priority-setting, as described in the inset box above.