

# Draft Gulf of Mexico Ecosystem Based Fishery Management Road Map Implementation Plan

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## Introduction

NOAA Fisheries has long recognized the importance of ecosystem-based fisheries management (EBFM), and recently formalized its commitment to advancing ecosystem science and management with the release of a national EBFM policy (National Marine Fisheries Service (NMFS) Policy Directive 01-120; May 23, 2016). NOAA Fisheries defines EBFM 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** by working with collaborators to support the development of Fishery Ecosystem Plans and/or EBFM policies
2. **Advance our understanding of ecosystem processes** through targeted research and reporting of ecosystem processes
3. **Prioritize vulnerabilities and risks of ecosystems** such that species or habitats of particular concern are addressed
4. **Explore and address trade-offs within an ecosystem** with the use of management strategy evaluation and other tools, in both single-species and ecosystem frameworks
5. **Incorporate ecosystem considerations into management advice** quantitatively and qualitatively, within existing modeling platforms and frameworks
6. **Maintain resilient ecosystems** by understanding the effects of management actions and external drivers on both biological and human communities.

Recognizing that effective EBFM implementation needs to be tailored to the system in which it is applied, the national EBFM Policy directs each region to create a Road Map which describes how to operationalize the above guiding principles. Many EBFM efforts are already underway, and the Road Map 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 present Gulf of Mexico 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. The document should serve to: 1) document the efforts that the Southeast Fisheries Science Center (SEFSC) 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 with ecosystem-level planning. Successful completion of the ongoing research efforts described below 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.

The primary audience for this document is intended to be the Gulf Council, interested public, the NOAA Fisheries Southeast region, and its collaborating partners. The content is tailored specifically to the Gulf region, although some elements may be applicable to the larger Southeast region; note that separate EBFM Implementation Plans exist for the U.S. South Atlantic and Caribbean regions. This document is intended to motivate a dialogue on how EBFM can be effectively applied in the Gulf of Mexico, taking into account stakeholder views, regional capacity, and the current state of the science.

## **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<sup>1</sup>. 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. Present shortcomings in ecosystem-based science structure put the Gulf behind the other Regions with respect to EBFM in that the SEFSC and Southeast Regional Office (SERO) lack delineated ecosystem research divisions, and the Gulf of Mexico Fishery Management Council (Gulf Council) has yet to develop a Fishery Ecosystem Plan or other formal policy document. Notwithstanding these seeming insufficiencies, 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: stock assessments, baseline monitoring, climate change, multi-species interactions, connectivity, habitat conservation, and human dimensions. Each theme area

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<sup>1</sup> 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.

contains research and management activities that address several of the National EBFM Policy guiding principles.

## **Stock assessment**

The Gulf is home to diverse populations of exploited species and protected resources of economic and/or ecological importance. 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 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.

### ***The life cycle of an ecosystem indicator: red tide***

Severe fish die-offs attributed to harmful algal blooms known as “red tides” have occurred in the Gulf for hundreds of years. A

severe red tide event in 2005

spurred awareness 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 to provide guidance in cases

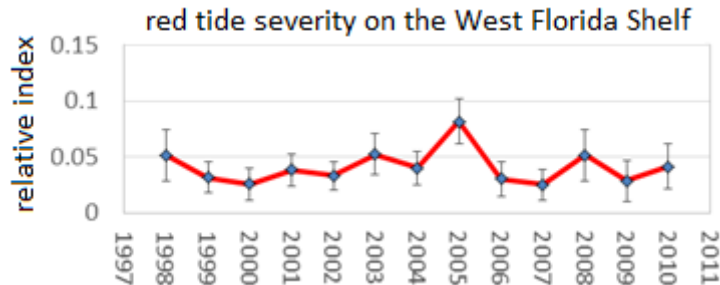
where stocks are confronted with episodic mortality events. It was found that precautionary

catch limit reductions could perform in meeting management objectives as well as a “reactive”

approach, where assessments are performed immediately after mortality events. Ongoing work

is considering management performance under scenarios where the frequency of episodic

mortality events increases into the future.



The SEFSC has made progress 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 studies on the [effects of temperature](#) and [eddy activity on king mackerel catch rates](#). 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 planned 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 that the resources to operationally support ecosystem data inputs are justified.

## Baseline monitoring and 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 Gulf data streams for measuring baseline levels – in this case, against which damages and restoration could be measured. Much of the near-term post-spill monitoring is taking place under the [Gulf Spill Restoration Trustee Implementation Group strategic frameworks](#), which have been developed for birds, marine mammals, oysters, and sea turtles. Another significant protected resource 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 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, 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 know 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. Obtaining baseline information 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 SEFSC 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.

## **Climate change**

Baseline conditions, against which the impacts of various management actions are measured, may be constantly shifting due to 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 to some extent within management; for example, the spiny lobster annual catch limit is now established based on the likely status of environmental conditions affecting the stock, and the benchmark is reevaluated if conditions are thought to have declined. 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 SEFSC 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 SEFSC is expected to hire 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 priority research area is to understand climate effects on range shifts of economically-important species, as well as the habitats on which they depend.

## **Habitat considerations**

Identifying and understanding the role of different habitats in the Gulf of Mexico 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. 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 the Mississippi River diversions project and the Everglades Restoration in Florida Bay. The SEFSC has conducted extensive research 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](#), experimental work to [evaluate relationships between environment and growth](#), and the [development of individual-based production models](#) to supplement the stock assessment process. Productivity of stocks in the Gulf of Mexico 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 of the coastal pelagic fisheries species follow specific water mass properties throughout the season; thus, 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 these 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 between Scripps Institution of Oceanography and SEFSC researchers, funded through the National Academy of Sciences, 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 also has carried out investigations on the importance of pelagic habitat characteristics to economically important species such as Bluefin tuna, including a [recruitment index developed in collaboration with AOML](#).

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 Fishery Management Plans (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. An amendment to the Coral FMP was recently introduced to identify priority areas for consideration as habitat areas of particular concern, based on abundance and diversity of coral species in those locations. The Gulf Council submitted a [5-year review of essential fish habitat](#) (EFH) information for the Southeast Region in 2017. In 2018, SERO will review and evaluate how the Gulf Council considered ecosystem information and will include recommendations back to the Gulf Council for considering ecosystem-level information, habitat areas of particular concern, and habitat conservation objectives/indicators in future EFH updates and 5-year reviews. 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.

## **Multi-species interaction**

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 and circle hooks and weak hooks in 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](#). Ecopath/Ecosim models have been developed within the SEFSC, and a major project recently funded by RESTORE seeks to understand the [role of menhaden in the Gulf](#). Recently completed projects sought to [inventory ecosystem models](#) of the Gulf and improve the integration of [existing data sources](#), which should be useful for identifying and refining existing modeling efforts. With respect to protected resources, another recently funded RESTORE 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 very small population. Increased ecosystem modeling capacity may be useful for highlighting areas where multi-species management could be more efficient.

## **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, U.S. Waters contains elements of spatial management such as seasonal closures to maximize the value of the resource and to reduce conflict between overlapping fisheries. 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-funded spawning aggregation database project](#), which summarizes current knowledge for a large suite of species. The FMP for Coastal Migratory Pelagics Resources in the Gulf of Mexico 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 gray snapper and blueline tilefish. A regional science 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 issue 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. The SEFSC has carried out substantial research on the annual hypoxic zone at the outflow of the Mississippi River watershed. Additionally, a series of projects funded by NCCOS will better inform how to [manage fisheries in the face of hypoxia \(NGOMEX\)](#). Another recently funded RESTORE project will elucidate the [flow of nitrogen through the plankton food web and to the pelagic environment](#). A proposed Mississippi River diversion project to stem the loss of Louisiana coastal wetlands is of concern for its unknown impacts on marine and human communities and therefore advancing ecosystem modeling and socioeconomic impact assessments is a regional priority. Two projects are underway to understand the potential impacts of diversions; a socio-ecological modeling effort funded by the Gulf Integrated Ecosystem Assessment (IEA) program, and a study on the effects of diversions on bottlenose dolphin. 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 [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.

## **Human dimensions**

The importance of human communities as key components of the Gulf ecosystem is widely acknowledged, and research is needed to predict the social and economic effects of management actions. Developing models to accurately assess the economic impacts of new fishing regulations is necessary for effective management, and new capabilities are in development. 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 developed to evaluate the biological and economic impact of different Texas and Louisiana Shrimp Closure scenarios. SEFSC social scientists 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.

## **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.

### **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 SEFSC and other NOAA line offices currently exist, but these efforts have typically been informal or ephemeral. With an outline of EBFM priorities, partner agencies can better support the SEFSC in meeting its objectives, and collaborations can be more targeted and formalized. Such collaborations will be the focus of an upcoming AOML-SEFSC 2018 joint workshop, which will also include 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:

- Use biophysical modeling to understand larval transfer rates across management jurisdictions (page 8)

- Increase collaborations with Mexico and Cuba to study and manage species that cross international boundaries (page 9)
- Develop of a stakeholder engagement strategy for the Plan (page 12)

## **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:

- Conduct research to determine the environmental drivers of stock dynamics (page 4)
- Develop and maintain core data streams; pilot new ecosystem-focused surveys (page 5)
- Publish Ecosystem Status Reports at some regular interval (page 5)
- Understand past and predict future biogeochemical changes in the Gulf (page 6)
- Conduct research on the linkages between nearshore habitats and fishery production (page 7)
- Conduct research on the influence of pelagic habitat on stocks and protected species (page 8)

## **3. Prioritize vulnerabilities and risks of ecosystems**

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:

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

## **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 SEFSC will rely heavily on external capacity for ecosystem modeling, to elucidate various trade-offs among different ecosystem components, and among competing management objectives. The SEFSC 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:

- Continue work on determination of whether existing control rules are robust to episodic natural mortality events (page 6)
- Increase capacity for MSE work by filling vacant MSE staff position (page 6)
- Support ecosystem modeling efforts to identify significant trade-offs between ecosystem components (page 8)

## **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:

- Include ecosystem considerations quantitatively in stock assessment models, when appropriate (page 4)
- Introduce “research track” stock assessments, which allow additional time for data exploration, stakeholder input, and mechanistic research into stock-environment relationships (page 4)
- Improve bycatch assessment and monitoring (page 7)
- Support ecosystem modeling to understand important trophic interactions (page 8)
- Gain a better understanding of how to manage fisheries under the influence of hypoxia (page 10)

## **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:

- Conduct research to understand the potential impacts of Mississippi River diversions, including socio-ecological modeling efforts (page 10)
- Develop models to more accurately assess the economic impacts of new fishing regulations (page 10)

## **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, academic institutions, state agencies, 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 the Science Center and the Gulf Council 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. 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-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.

### ***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. The Institute 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.

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 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. Engaging stakeholders can help identify “elephants in the room” that are critical for inclusion in stock assessments. More broadly, there are opportunities to increase stakeholder input through 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. Lessons learned from these activities should pave the way for more formal engagement opportunities.