Climate and Fisheries Initiative

Implementation Approach

APRIL 2021

Policymaker Summary

The Challenge
The National Oceanic and Atmospheric Administration (NOAA) currently lacks the nationally-integrated modeling and decision-support system needed to deliver the climate information required to meet NOAA's Living Marine Resource (LMR) mandates across the marine and Great Lakes ecosystems. The current NOAA modeling and science infrastructure fall short of NOAA's needs for a variety of reasons including: (1) the lack of essential climate information (particularly high-resolution regional ocean and biogeochemistry predictions and projections) prevents development and delivery of climate-informed management advice; (2) the lack of shared data standards and limited data dissemination impedes updates to climate predictions and projections; (3) the gaps in understanding of the impacts of climate change and variability on species and ecosystems inhibits decisions and actions; and (4) the lack of operational capacity to translate climate information into ecosystem projections, risk assessments, management strategies, and other climate-informed advice hinders the application of this information in fisheries, protected resources, and marine protected area (MPA) conservation decision making.

NOAA's Response
To deliver the best scientific information available to decision makers, the Climate and Fisheries Initiative (CFI), a cross-NOAA program, will create and implement a nation-wide operational ocean modeling and decision-support system that addresses four core requirements: (1) operational delivery of ocean forecasts and projections for use by National Marine Fisheries Service (NMFS) and others; (2) operational capability to turn ocean forecasts into climate-informed management advice; (3) capacity for continuous validation and innovation through observations and research; and (4) increased capability to use climate-informed advice to reduce risks and increase the resilience of resources and the people that depend on them. The CFI System will be built by leveraging existing capabilities and making critical new investments in the following elements:

Advancing Climate, Ocean, and Ecosystem Understanding
The Earth's climate and oceans are changing, and these changes are causing significant impacts on the distribution and abundance of marine and coastal species and placing at risk the Nation's valuable marine resources as well as the many people, communities, and economies that depend upon them. As called for in the NMFS Climate Science Strategy (NCSS), NMFS needs information on past, current, and future climate and ocean conditions across management relevant temporal and spatial scales to ensure informed, climate ready LMR management and protected resources conservation in the face of rapid environmental change. By enhancing ocean modeling capabilities, expanding targeted ocean- and marine-life observations, and supporting research programs to understand how marine species respond to climate variability and change, the CFI fills key gaps in the ocean and ecosystem science that are impeding the full adoption of NOAA's ecosystem-based fisheries management policy.

Operational Climate, Ocean and Ecosystem Decision Support System
At CFI's core is a coordinated, national network of high-resolution ocean and biogeochemical (BGC) models, fueled by NOAA's High-Performance Computing (HPC) toproduce hindcasts, predictions, and projections across relevant time and spatial scales for climate-informed decision making. Regional Ocean Modeling Teams, composed of NOAA scientists and academic partners, will ensure operational production and delivery of this information to Fisheries and Climate Decision Support System (FACSS) Core Teams for use in developing regionally-tailored management advice. The CFI's Data Portal Team will establish a comprehensive information hub that will provide scientists, managers, and other decision makers with access to the broad suite of information on changing climate and oceans needed for climate-informed management of fisheries and protected resources. The combined products of the Regional Ocean Modeling Teams and the Data Portal Team will inform the development of a variety of socio-ecological models and decision-support tools produced by the FACSS Core Teams at each NMFS Science Center to develop and deliver ecosystem forecasts including socio-ecological system forecasts and projections of the performance of current and alternative management strategies under a changing climate, forecasts of ecological tipping points for triggering conservation action to preserve ecosystem integrity and protect human health, and early warnings of extreme events (e.g., marine heatwaves, harmful algal blooms).

Climate Ready Decision Making
NOAA and partners will provide the infrastructure and dedicated resources to co-develop an end-to-end operational system that provides decision makers with the reliable, regionally-tailored products and services needed for climate-informed LMR management. The system includes rigorous feedback loops for continuous innovation and improvement based on input between product makers and users following the NOAA Service Delivery Framework. Driven by the needs of the end-users in both the science and management community, the CFI products and services include, but are not limited to, ecosystem assessments, ecosystem-linked stock assessments, climate-informed harvest rates and recovery targets, climate-informed species distribution and habitat maps, bycatch management, scientific risk assessments, emergency response tools, climate-informed management strategies, climate ready survey designs, and adaptation options.

Nationally Integrated Operational Climate, Ocean, and Ecosystem Decision Support Systems

▶ Advancing Climate, Ocean, and Ecosystem Understanding

▶ Operational Climate, Ocean, and Ecosystem Decision Support Systems

▶ Climate Ready Decision Making

SCIENCE AND DEVELOPMENT
Drives Innovation and Skill

OPERATIONS AND INFRASTRUCTURE
Drives Dissemination and Decision Support

EXTENSION AND ENGAGEMENT
Drives Service Delivery and Knowledge Transfer

National Community of Practice

The CFI will leverage the collective expertise and infrastructure of NOAA and the broader community to convene a nationwide community of practice that will guide the development of NOAA's regional modeling systems to provide climate and ocean information for LMR applications across time and spatial scales.

Enhanced Observations

NOAA will expand ocean- and marine-life observing capabilities and the capacity to deliver and use this information in assessments and decision making.

Targeted Research that Fuels Innovation

NOAA will fund a robust collaborative research program to use observations, laboratory experiments, reanalyses, and model hindcasts/predictions to understand LMR responses to past climate variability and change and assess our capacity to predict responses.

Enhanced Ocean Modeling Capabilities

NOAA will enhance its ocean and earth system models and High-Performance Computing (HPC) capacity to provide a strong, sustainable foundation for the CFI's regional and global modeling efforts while committing to open-development paradigms to fuel partnerships and innovation.

Regional Ocean Modeling and Prediction

Reliable production and delivery of nationally-coordinated ocean hindcasts, forecasts, and projections to meet marine resource management needs will be supported by five Regional Ocean Modeling Teams, composed of scientists from across NOAA Line Offices and academic partners.

CFI Information Hub

CFI will launch a comprehensive Information Hub to support the dissemination of CFI-generated high spatial resolution reanalysis, hindcasts, predictions, and projections optimized for management applications as well as existing LMR-relevant climate and biological information.

Fisheries and Climate Decision Support System

NOAA will establish expert teams to accelerate the production of climate-informed assessments and management advice designed to sustain fisheries, conserve protected resources, and maintain ecosystem services in collaboration with existing programs and external partners.

Ecosystem Prediction

The FACSS—in concert with cross-NOAA and external experts—will provide a variety of products and services for use in LMR management advice and decision making including regular, dependable, standardized information on projected future ecosystem conditions.

Increasing Capacity for Climate Ready Decisions

NOAA will increase the capacity for climate-informed decision making for the Nation's valuable marine and coastal LMR and the many people that depend on them through the production and delivery of reliable products and services, engagement and support for decision makers, and continuous innovation and improvement with NOAA science centers, regional offices, and national programs.

Rapid Response

Forecasts, early warnings, plans, and responses to near-term extreme events to triage impacts, provide assistance, and enable adaptation.

Climate Smart Decision Support Tools

Climate-enhanced stock assessments, climate-informed advice, tools, and dynamic management.

Improve Surveys and Research

Improved research and climate ready survey design and increased speed of response.

Coordinated Science and Advice

Inter- and intra-agency coordination, national strategies aligned with regional priorities, efficient information sharing, and reduced redundancy.

The Takeaway

Working across NOAA and with external partners, the CFI will provide the foundational ocean, coastal, and ecosystem information needed to help scientists, managers, industries, and communities identify risks, options, and best management and adaptation strategies for rapidly changing climate and ocean conditions.

NOAA is uniquely positioned to address these complex challenges building on its existing capacity and new opportunities in climate and marine sciences. Finally, the outcomes described in the CFI will require the support of Congress.

Implementing the NOAA Climate and Fisheries Initiative

Introduction

The Earth's climate and oceans are changing, and these changes are significantly impacting the Nation's valuable marine and Great Lakes ecosystems. Warming waters, rising seas, decreasing sea ice and oxygen levels, changing currents and productivity, and increasing ocean acidification and extreme events (e.g., marine heatwaves, harmful algal blooms) are affecting the distribution and abundance of the Nation's valuable LMRs. These changes affect the National Oceanic and Atmospheric Administration's (NOAA) ability to fulfill its mandates for sustainable fisheries and protected resources conservation, placing at risk the Nation's valuable marine resources and the many people, businesses, communities, and economies that depend upon them. For example, the United States (U.S.) commercial fishing and seafood and recreational fishing industries together generate approximately $212 billion annually in sales, contribute $100 billion to the gross domestic product, and support over 1.7 million full- and part-time jobs across the broader economy.[1]

The number, frequency, and magnitude of impacts are expected to increase with continued changes in the Earth's climate system. There is much at stake, and action is needed now to provide decision makers with the information, tools, and capacity they need to reduce risks and increase resilience. NOAA is uniquely positioned to address these complex challenges by building on its existing capacity through new opportunities in climate and marine sciences.

Vision: NOAA and stakeholders have robust climate and ocean hindcasts, predictions, and projections, and the decision support needed to guide rapid responses and climate-informed management strategies that reduce risks and increase the resilience of marine/coastal resources and the many people that depend on them.

The Challenge

NOAA currently lacks the nationally-integrated modeling and decision-support system needed to deliver the climate information required to meet NOAA's LMR mandates across the marine and Great Lakes ecosystems[2]. The current NOAA modeling and science infrastructure fall short of NOAA's needs for a variety of reasons, including: (1) the lack of essential climate information (particularly high-resolution regional ocean and biogeochemistry predictions and projections) that prevents development and delivery of climate-informed management advice; (2) the lack of shared-data standards and limited data dissemination that impedes climate prediction and projection updates; (3) gaps in understanding of the impacts of climate change and variability on species and ecosystems; and (4) the lack of operational capacity to translate climate information into ecosystem projections, risk assessments, management strategies, and other climate-informed advice and apply this information in fisheries, protected resources, and MPA conservation decision making. These challenges have been highlighted in other venues including a recent report from NOAA's Science Advisory Board on Advancing Earth System Prediction[3].

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[1] National Marine Fisheries Service. 2018. Fisheries Economics of the United States, 2016. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/SPO-187, 243. www.fisheries.noaa.gov/resource/document/fisheries-economics-united-states-report-2016

[2] NOAA Fisheries Climate Science Strategy, 2015. U.S. Dept. of Commerce, NOAA Technical Memorandum NMFS-F/SPO-155, 70p.

[3] NOAA Science Advisory Board, 2021. Advancing Earth System Prediction.

The NOAA Climate and Fisheries Initiative
Beginning in March 2019, Expert Teams from across NOAA developed recommendations that served as the foundation for the Climate and Fisheries Initiative (CFI) White Paper[4]. This implementation approach brings to life these three strategy documents to address the need to build a nationwide operational ocean modeling and decision-support system (Figure 1) that addresses four core requirements: (1) operational delivery of ocean forecasts and projections for use by the National Marine Fisheries Service (NMFS) and others; (2) operational capability to turn ocean forecasts into climate-informed management advice; (3) capacity for continuous validation and innovation through observations and research; and (4) increased capability to use climate-informed advice to reduce risks and increase the resilience of resources and the people that depend on them. As shown in the system diagram, the CFI System is composed of three interdependent elements, each with core components and feedback loops that ensure that the system is agile and continuously innovates and improves.

Benefiting multiple sectors and stakeholders
The CFI is specifically designed to support climate-informed decision making by multiple sectors involved in the management and/or use of marine and coastal resources through the delivery of essential forecasts, projections, and assessments of climate, ocean, and marine ecosystems. With the rapidly-changing ocean conditions and ocean uses (e.g., shifting distributions of marine species, expansion of wind and wave energy, expanded shipping in the Arctic, and changing patterns of inland water use and freshwater inflows), CFI will expand the national climate, ocean, and ecosystem modeling infrastructure to provide decision makers with the ocean and coastal information needed to address these issues across multiple time and spatial scales. This system will provide the essential information needed for climate-informed decision making by many sectors and stakeholders, including:

Sustainable Fisheries // NOAA Fisheries is responsible for the stewardship of the Nation's ocean resources and their habitat. NOAA provides vital services for the Nation: ensuring productive and sustainable fisheries and safe sources of seafood, overseeing the recovery and conservation of protected resources, and monitoring healthy ecosystems—all through sound science and an ecosystem-based approach to management.

Protected Resources // NOAA conserves and recovers marine and anadromous species and works to improve their adaptability and resilience to environmental change. NOAA will continue to ensure protection of these species and their habitats as new technologies and measures to combat climate change are implemented.

Navigation and Ports // NOAA is responding to one of the Nation's most significant challenges—improving the economic efficiency and competitiveness of U.S. maritime commerce while reducing risks to life, property, and the coastal environment.

Coastal Zone Management // NOAA is helping communities prepare for and adapt to a changing climate by creating sea level rise inundation models and supporting the development of climate change adaptation plans, regulations, and policies at the state and local levels.

Coastal Flood Risk Prediction // NOAA conducts coastal flood risk prediction and resilience research and development to accelerate community resilience to coastal flood risk. The Nation's resilience to the impact of coastal flood risk underpins our National security and economic competitiveness.

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[4] NOAA Climate and Fisheries Initiative. 2020. "NOAA Climate and Fisheries Initiative Steering Committee White Paper."

Nationally Integrated Operational Climate, Ocean, and Ecosystem Decision Support Systems
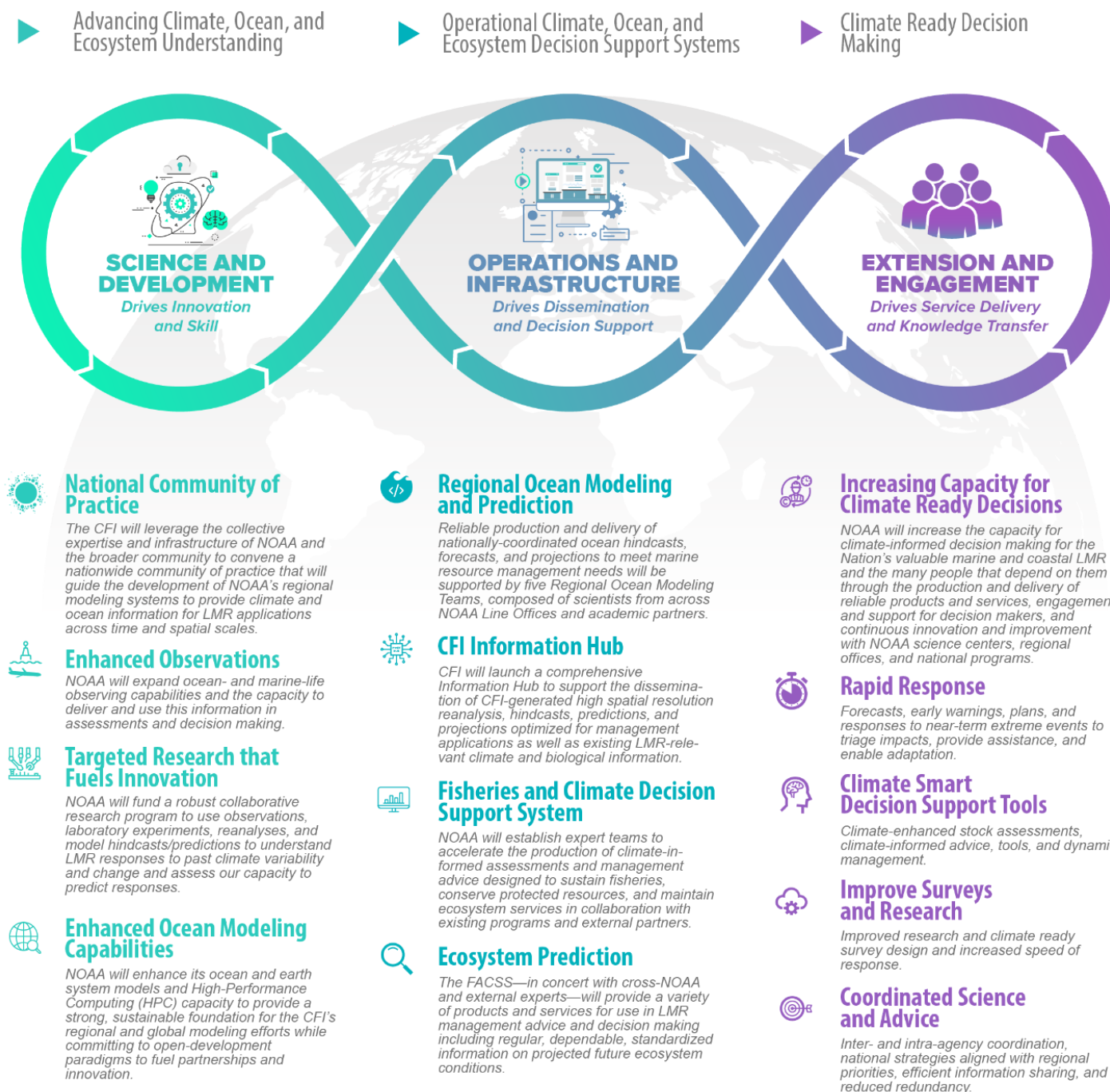
▶ Advancing Climate, Ocean, and Ecosystem Understanding

▶ Operational Climate, Ocean, and Ecosystem Decision Support Systems

▶ Climate Ready Decision Making

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National Community of Practice

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Enhanced Observations

NOAA will expand ocean- and marine-life observing capabilities and the capacity to deliver and use this information in assessments and decision making.

Targeted Research that Fuels Innovation

NOAA will fund a robust collaborative research program to use observations, laboratory experiments, reanalyses, and model hindcasts/predictions to understand LMR responses to past climate variability and change and assess our capacity to predict responses.

Enhanced Ocean Modeling Capabilities

NOAA will enhance its ocean and earth system models and High-Performance Computing (HPC) capacity to provide a strong, sustainable foundation for the CFI's regional and global modeling efforts while committing to open-development paradigms to fuel partnerships and innovation.

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Figure 1. Details of the elements and core components that make up the nation-wide operational climate, ocean, and ecosystem decision support system.

Embracing continuous engagement
The CFI is designed to continuously engage with decision makers (e.g., Fisheries Management Councils), communities, industry, and the public to gather and use their input to strengthen trusted relationships and improve the delivery of products and services as outlined in the NOAA Service Delivery Framework. Some notable ways in which the community has and will be engaged throughout the CFI are:

- Over the past six years, NOAA has actively sought input from external sources and conducted its own assessments on the climate information and services needed to fulfill its resource stewardship mandates in a changing climate (e.g., NOAA Fisheries Climate Science Strategy and Regional Action Plans).
- NOAA will establish a process to continue to solicit input from internal and external user communities throughout the CFI development and implementation process to ensure that the system is effectively responding to the needs of its target audiences.
- Within the first year, the CFI will host the "Climate and Ocean Information for Living Marine Resource Science and Management" workshop to gather LMR scientists' and managers' operational requirements for climate and ocean information to inform LMR decisions and to identify existing products and gaps.
- Driven by the requirements identified with the community, the CFI will convene an "Ocean Modeling, Reanalysis, and Prediction to Meet NOAA's LMR Mandates" workshop to refine the pathway toward an integrated, regional ocean-modeling system that robustly delivers climate and ocean information for NOAA's LMR Mandates across timescales and within operational requirements.
- In addition to these workshops, the community will be engaged through a National Community of Practice that leverages NOAA's and the community's collective expertise and infrastructure to guide the development and best practices for NOAA's regional modeling system. Through coordination with the Regional Offices and NMFS Science Centers, the FACSS will establish mechanisms for regular feedback with the user community that will inform co-development of the use-inspired products and services needed to implement climate-informed resource management.
- NOAA Fisheries will expand coordination between its resource science and management programs to ensure robust input on the design, production, delivery, and use of climate-related information for decision making.

What is in the remainder of this document?
This Implementation Approach provides a roadmap for building the CFI system in a manner that integrates with and builds upon current and prospective core institutional research, modeling, and observational and computational components from across NOAA Line Offices while maintaining productive partnerships with the external research community through open development and competitive research opportunities. The remainder of this document provides information on the three major elements of the CFI system and each of their core components: 1) **advancing climate, ocean, and ecosystem understanding;** 2) **operational climate, ocean, ecosystem decision-support systems;** and 3) **climate ready decision making.** Each of these elements has an overview, a description of the system requirements, an outline of the key components, and a summary of how each component fits together, followed by detailed tables outlining the high-priority activities, indicators of positive progress, organizational outcomes, and support structure (teams).

Advancing Climate, Ocean, and Ecosystem Understanding

Overview

The Earth's climate and oceans are changing, and these changes are causing significant impacts on the distribution and abundance of marine and coastal species and placing at risk the Nation's valuable marine resources and the many people, communities, and economies that depend upon them. As called for in the NCSS, NMFS needs information on past, current, and future climate and ocean conditions across management-relevant temporal and spatial scales to ensure informed, climate ready LMR management and protected resources conservation in the face of rapid environmental change. By enhancing ocean-modeling capabilities, expanding targeted ocean- and marine-life observations, and supporting research programs to understand how marine species respond to climate variability and change, the CFI fills key gaps in the ocean and ecosystem science that are impeding the full adoption of NOAA's ecosystem-based fisheries management policy.

System Requirements

Scientific understanding of climate impacts on ecosystems // Users need information about how climate and ocean conditions may change over short and longer timeframes and how those changes could impact marine and coastal species and ecosystems.

Robust and adaptable modeling infrastructure // A comprehensive and flexible modeling infrastructure combining robust NOAA support to ensure sustainability and a commitment to open development to empower partnerships is needed to support a nationally-coordinated ocean modeling effort to meet NOAA's LMR mandates.
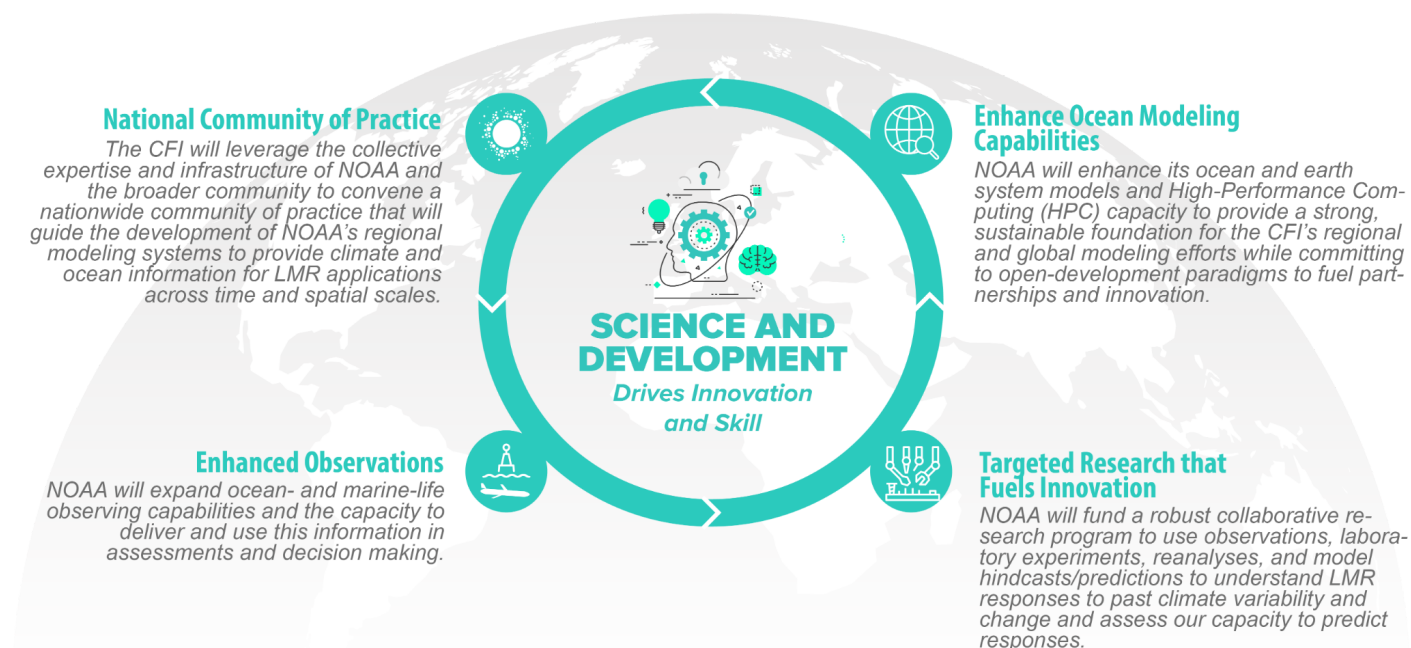
Improved usability of climate and ocean information // The integration of climate predictions and projections with management has been impeded by a lack of best practices and shared data standards.

Improved observations // NOAA needs high-priority biological observations to advance and verify NOAA's forecast systems and improve the accuracy of LMR predictions and projections and generate understanding of climate-biological-human mechanistic linkages and feedback to better inform managers and management.

Fisheries-critical global climate modeling advances // Gaps exist in NOAA's present physical and BGC prediction capabilities at seasonal-to-multi-annual horizons to provide crucial boundary information for high-resolution regional predictions of ecosystem stressors (e.g., acidification, hypoxia) crucial for management decisions on these time horizons.
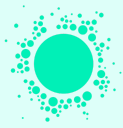
Key Components

For NOAA to advance climate, ocean, and ecosystem understanding, it will require investments in the following areas:

National Community of Practice
The CFI will leverage the collective expertise and infrastructure of NOAA and the broader community to convene a nationwide community of practice that will guide the development of NOAA's regional modeling systems to provide climate and ocean information for LMR applications across time and spatial scales.

Enhance Ocean Modeling Capabilities
NOAA will enhance its ocean and earth system models and High-Performance Computing (HPC) capacity to provide a strong, sustainable foundation for the CFI's regional and global modeling efforts while committing to open-development paradigms to fuel partnerships and innovation.

SCIENCE AND DEVELOPMENT
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Enhanced Observations
NOAA will expand ocean- and marine-life observing capabilities and the capacity to deliver and use this information in assessments and decision making.

Targeted Research that Fuels Innovation
NOAA will fund a robust collaborative research program to use observations, laboratory experiments, reanalyses, and model hindcasts/predictions to understand LMR responses to past climate variability and change and assess our capacity to predict responses.

How do these components connect?

Annual meetings of the National Community of Practice will cultivate the interdisciplinary teams needed to resolve key methodological challenges, define best practices, and promote new integrations of ocean modeling and LMR science and management. Throughout the Initiative, NOAA will release targeted requests for proposals (RFPs) to focus community effort on key bottlenecks, including improving the skill and application of ocean and ecological predictions, improve understanding of climate impacts on LMRs, and evaluate management strategies. A focus on assessing, maintaining, and expanding critical observations will ensure that managers have the information needed to make timely decisions and that the models are properly constrained and evaluated to facilitate model development and build trust in their outputs. Concurrently, robust investments will be made to address current gaps in NOAA's global and regional climate and ocean modeling infrastructure, providing a strong foundation upon which to innovate, build, and sustain the high-resolution ocean predictions and projections required to meet NOAA's LMR-management mandates. This will ensure continuity in the provision of mission-critical information and seamless refinement across versions of the modeling system.

National Community of Practice

The CFI will leverage the collective expertise and infrastructure of NOAA and the broader community to convene a nationwide community of practice that will guide the development of NOAA's regional modeling systems to provide climate and ocean information for LMR applications across time and spatial scales.

High-Priority Activities.
- "Climate and Ocean Information for Living Marine Resource Science and Management" and "Ocean Modeling, Reanalysis, and Prediction to Meet NOAA's LMR Mandates" workshops convene representatives from all NOAA Line Offices with external partners to define operational requirements for the delivery of climate and ocean information for LMR applications across time scales, refine the pathway to achieving these requirements, and lay the foundation for a National Community of Practice.
- The National Community of Practice works to resolve key methodological challenges associated with the provision of LMR-critical climate and ocean information (e.g., downscaling and bias correction; ensemble generation) using competitive research grants with targeted RFPs to entrain outside expertise.
- Engage with existing NOAA Ecosystem-based Management (EBM) programs to leverage existing networks for integration and coordination (e.g., Ecosystem-based Fisheries Management (EBFM) working group, Integrated Ecosystem Assessments (IEA) program, Loss of Sea Ice (LOSI), and NCSS Regional Action plans (RAPs)).
- Coordinate with international and non-NOAA entities and strategic initiatives (e.g., International Center for the Exploration of the Sea (ICES)/North Pacific Marine Science Organization (PICES), Food and Agriculture Organization (FAO), Regional Fisheries Management Organizations (RFMOs), Intergovernmental Panel on Climate Change (IPCC), Arctic working groups, Coordinated Regional Downscaling Experiment (CORDEX), OceanPredict, UN Decade of Ocean Science).
- Establish annual meetings and task teams of the National Community of Practice to coordinate efforts across regions, establish best practices, remove barriers to management integration, and spur innovation.

Indicators of Positive Progress.
- Annual meetings of the interdisciplinary National Community of Practice are established.
- The National Community of Practice—buoyed by new competitive research funding—provides best practices guidance for the provision of climate and ocean information for LMR applications across time scales.
- Users' (i.e., NMFS and National Ocean Service (NOS) scientists and decision makers supporting LMR management) operational requirements for global and regional climate/ocean information have been determined via the "Climate and Ocean Information for Living Marine Resource Science and Management" workshop.
- Task teams are established to address cross-cutting needs formed from the national community of practice.
- Cross-region/timescale coordination and progress is maintained through annual meetings.
- The first-generation regional ocean/BGC modeling systems are demonstrated to regional earth system configurations.
- CFI connections with existing EBM programs and plans (e.g., IEA, NCSS, EBFM, Fisheries Integrated Modeling System (FIMS)) and regional decision-support tools are codified.

Organizational Outcomes/Metrics.
- Decision makers have access to a coordinated, standardized, and consistent national network with regional tailoring of ocean modeling systems for LMR applications that can be defended in a management context.
- Maximize scientific and technical innovation advances across regions of interest.
- Maximize integration with other national efforts (e.g., Earth Prediction Innovation Center (EPIC), Unified Forecast System).

Enhanced Observations

NOAA will expand ocean- and marine-life observing capabilities and the capacity to deliver and use this information in assessments and decision making.

High Priority Activities.
- Identify observations of highest priority for data assimilation to support LMR applications, for example through observation impact studies or Observing System [Simulation] Experiments (OSE/OSSEs) as conducted by Office of Oceanic and Atmospheric Research's (OAR's) Quantitative Observing System Assessment Program (QOSAP).
- Develop a coordinated plan across NOAA for updating observations to meet LMR management, ecosystem assessment, and MPA management needs.
- Establish the first-level capability for a unified Marine Life Data Assembly Center (DAC) as well as other platforms and products to support the observing data targets and requirements assessment.
- Coordinate with the Integrated Ocean Observing System (IOOS) on data management, modeling, and new technology deployments and partners to ensure that appropriate data and formats are provided to users at multiple levels to manage, mitigate, or remediate.
- Establish a Marine Life Program within the IOOS Office.
- Develop a 5-year deployment plan that identifies planned ecosystem moorings, including new moorings and/or enhancements to existing moorings as well as operations and maintenance plans to ensure continuous operations.
- Make observations available for ongoing model evaluation necessary to build confidence in model outputs.

Indicators of Positive Progress.
- The coordinated plan for the implementation of expanded marine life observing capabilities and capacity to inform decision support, ecosystem assessment, and place-based management has begun.
- An operational Marine Life DAC establishes new capacity for national-level data aggregation, display, management, and delivery with a scalable, state-of-the-art cyberinfrastructure.
- Collection of animal movement, habitat, and biodiversity data; status and trends indicators; and large-scale oceanographic indices are expanded, streamlined, and integrated with other biological and environmental observations, and data are available via the IOOS Marine Life DAC.
- The capacity for analyzing LMR responses to changing BGC and physical properties of the ocean—including development and use of new technologies such as Artificial Intelligence and Machine Learning as well as cyberinfrastructure support—is expanded or initiated.
- Data synthesis, models, products, and tools are co-developed with site or assessment managers to support condition and ecosystem assessment reports, management, and decision making.
- Sites for restoration, monitoring, and protection are identified and managed based on IOOS-supported observing, modeling, and analysis.
- New observational data sets suitable for integration with NOAA's reanalysis efforts are identified.

Organizational Outcome/Metric.
- NOAA has the ability to execute vulnerability and adaptation strategies to ensure resilience and stability of LMRs and the coastal communities that derive coastal protection and economic benefit from them and to implement place-based and ecosystem-based management of LMRs and habitats.

Targeted Research that Fuels Innovation

NOAA will fund a robust collaborative research program to use observations, laboratory experiments, reanalyses, and model hindcasts/predictions to understand LMR responses to past climate variability and change and assess our capacity to predict responses.

High Priority Activities.

Advance development, skill, and applications of ocean and ecological predictions and decision-support tools:

- Identify existing proof-of-concept tools for LMR applications in each of the five regions and support their operationalization with NOAA's regional modeling infrastructure.
- Optimize survey designs and observational asset deployment for model validation and data assimilation.
- Develop best practices in support of the National Community of Practice.

Improve understanding of climate impacts on LMRs and communities that depend on them:

- Track, understand, and identify mechanisms underlying climate-ecological linkages.
- Accelerate the transition of climate-informed LMR management guidance from research to operations by developing products and capabilities to use climate model output in biological models.
- Systematically explore functional linkages between the climate, ocean, high-priority species, harmful species, and socio-ecological systems that are federally managed.
- Conduct laboratory physiological experiments, diet analyses (in the lab), and genetic evaluations to understand relationships between physiology and climate, including temperature, ocean acidification, and dissolved oxygen.
- Support and coordinate genetic evaluation of stock structure, environmental DNA (eDNA), and other genetic survey methods.

Fund research to evaluate management strategies to enhance the resilience of LMRs and coastal communities to changing climate conditions.

Indicators of Positive Progress.

- Increased number of research projects aimed at understanding climate impacts on high-priority species, ecosystems, and marine-dependent human communities and commerce.
- Increased number of ecosystem-linked assessments (i.e., stock assessments that include environmental influences) and climate-enhanced projections of LMR that include other human stressors (e.g., fishing, water quality, and pollution dispersion).
- Increased understanding of multiple stakeholders impacted directly and indirectly by climate-driven changes to LMR, and inclusion of multiple perspectives in tradeoff analyses and management strategy evaluations (MSEs).
- Diagnostic testing will reveal cases with model misspecification or in which adaptation has occurred and will target research to improve understanding of ecosystem linkages, ensuring that management decisions are based on the best-available scientific information.
- Sensitivity studies using population dynamic models of different levels of ecological complexity and whole ecosystem models will reveal key processes that require additional research. These will guide the design and implementation of targeted process studies (field or laboratory).

Organizational Outcomes/Metrics.

- Improved understanding of climate-LMR interactions leading to more accurate LMR predictions and projections to inform management.
- Improved understanding of climate-biological-human mechanistic linkages and dynamic feedback.
- Coordinated protocols and shared methods for establishing mechanistic linkages between physiological, behavioral, trophic, and ecosystem-wide responses to climate-driven changes in ocean conditions that advance ecological forecasts and projections in multiple ecosystems simultaneously.

Enhanced Ocean Modeling Capabilities

NOAA will enhance its ocean and earth system models and High-Performance Computing (HPC) capacity to provide a strong, sustainable foundation for the CFI's regional and global modeling efforts while committing to open-development paradigms to fuel partnerships and innovation.

High Priority Activities.
- Build a transformative capacity of at least 30,000 processors for high-resolution regional ocean modeling in support of CFI goals, accelerating development and enabling predictions and projections to span the range of ocean futures to support robust decision making.
- Secure sustained investments in cloud HPC through partnerships with EPIC and the Big Data Project.
- Convene "Ocean Modeling, Reanalysis, and Prediction to Meet NOAA's LMR Mandates" workshops to develop a detailed "pathway to operations/reliable delivery" plan supported by NOAA's supercomputing and data storage/data portal capacity.
- Expand NOS coastal modeling and prediction infrastructure to provide real-time to seasonal timescales spanning the entire U.S. coastline.
- Enhance OAR's earth system modeling capacity to provide regional, seasonal-to-multi-decadal ocean and BGC predictions and projections with the coast-wide scope required to address cross-boundary LMR issues (see Figure 2). These developments would also provide a foundation for expansion to terrestrial and land components in accordance with LMR mandates.
- Enhance global modeling capabilities in OAR and National Weather Service (NWS)/Environmental Modeling Center (EMC) to deliver global BGC predictions and projections on subseasonal-to-decadal time horizons.
- Increase consistency between BGC and physical fields while reducing model spin-up times.
- Leverage the cross-Line-Office National Community of Practice to ensure that NOAA's regional climate and ocean modeling across timescales is built on established best practices in a consistent manner across all U.S. marine ecosystems.
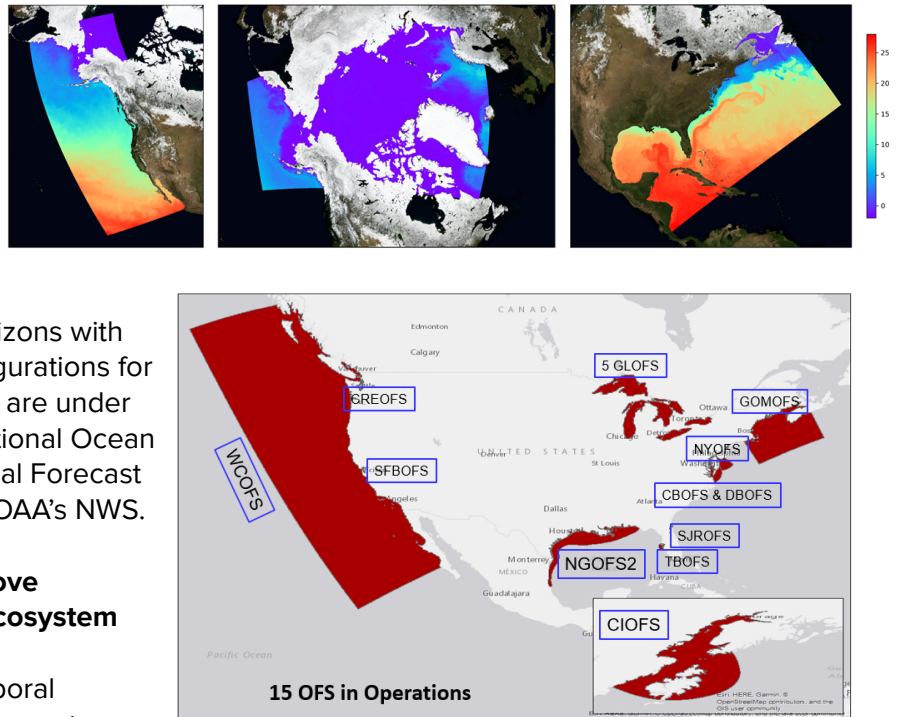
Indicators of Positive Progress.
- Ocean prediction/projection delivery requirements for LMR Mandates are defined at each time scale.
- Personnel and computational resources capable of meeting these requirements are procured/identified (e.g., NOS/NWS partnerships and operational computing for weather-to-seasonal timescales critical for rapid tactical decisions).
- Research and development computing and partnerships are secured to provide information for strategic decisions on multi-annual to multi-decadal timescales.
- Initial coast-wide Modular Ocean Model (MOM) 6 configurations delivered in Q1 of Fiscal Year 2023 to the Regional Ocean Modeling Teams for further development and regional optimization for LMR applications.
- The first-generation regional ocean/BGC modeling systems are demonstrated for regional earth system configurations.

Organizational Outcomes/Metrics.
- Transformative computational capacity for high-priority coastal modeling applications.
- Cross-fertilization of model development across global and regional scales, time horizons, and line offices through coordinated development on shared platforms, carefully selected components, and a commitment to open development.

Figure 2. (Top) Prototype coast-wide configurations based on NOAA's MOM6 ocean model for climate and earth system applications. Configurations have resolutions an order of magnitude finer than those of typical global earth system models and would focus on seasonal-to-multi-decadal time horizons with physical and BGC dynamics. Configurations for the Pacific Islands and Great Lakes are under development. (Bottom) NOAA's National Ocean Service's Coastal Ocean Operational Forecast Systems. Source: U.S. IOOS and NOAA's NWS.

How will this understanding improve operational ocean, climate, and ecosystem prediction systems?

The CFI will provide the spatiotemporal coverage and resolution needed to meet NOAA's LMR Mandates by enhancing and integrating a range of existing ocean and BGC modeling systems and by augmenting NOAA's computational capacity. This nationally-integrated regional modeling infrastructure will be capable of producing skillful ocean/BGC hindcasts, predictions, and projections across LMR management timescales. A National Community of Practice will be developed to coordinate the effort, accelerate model development, unify data standards, and define best practices that are justifiable in a management context. The innovations funded through the initiative will be used by the Regional Ocean Modeling Teams in partnership with LMR scientists and managers to tailor the operational ocean, climate, and ecosystem models in the next section to provide region-specific projections to better assess ecosystem impacts, evaluate response strategies, and inform LMR management advice.

Operational Climate, Ocean, and Ecosystem Decision-Support Systems

Overview

At CFI's core is a coordinated national network of high-resolution ocean and BGC models—fueled by NOAA HPC that produce hindcasts, predictions, and projections across relevant time and spatial scales for climate-informed decision making. Regional Ocean Modeling Teams, composed of NOAA scientists and academic partners, will ensure operational production and delivery of this information to FACSS Core Teams for use in developing regionally-tailored management advice. The CFI's Data Portal Team will establish a comprehensive Information Hub that will provide scientists, managers, and other decision makers with access to the broad suite of information on changing climate and oceans needed for climate-informed management of fisheries and protected resources. The combined products of the Regional Ocean Modeling Teams and the Data Portal Team will inform the development of a variety of socio-ecological models and decision-support tools produced by the FACSS Core Teams at each NMFS Science Center to develop and deliver ecosystem forecasts including social-ecological system forecasts and projections of the performance of current and alternative management strategies under a changing climate, forecasts of ecological tipping points for triggering conservation action to preserve ecosystem integrity and to protect human health, and early warnings of extreme events (e.g., marine heatwaves, harmful algal blooms).
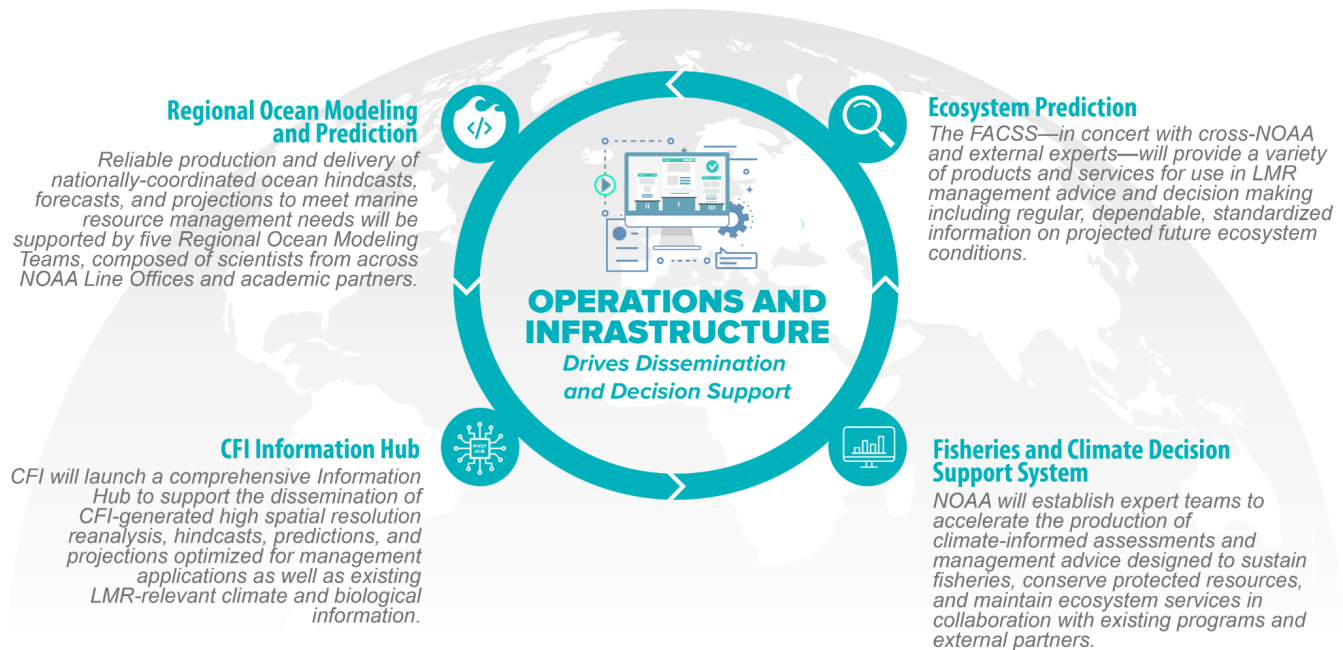
System Requirements

Reliable // LMR management requires operational production and delivery of robust ocean hindcasts, predictions, and projections that have been regionally optimized following best practices defined by the community.

Delivery // Scientists and managers require efficient access to and reliable delivery of ocean predictions and projections with timing and data quality sufficient to meet the operational requirements of LMR management.

Translation // Managers and stakeholders require expert synthesis of ocean hindcasts, predictions, and projections with the ecosystem and socioeconomic data to produce actionable analytics that support decision making.

Key Components

For NOAA to build and maintain operational, climate, ocean, and ecosystem decision-support systems, investments will be required in the following areas:

Regional Ocean Modeling and Prediction

Reliable production and delivery of nationally-coordinated ocean hindcasts, forecasts, and projections to meet marine resource management needs will be supported by five Regional Ocean Modeling Teams, composed of scientists from across NOAA Line Offices and academic partners.

Ecosystem Prediction

The FACSS—in concert with cross-NOAA and external experts—will provide a variety of products and services for use in LMR management advice and decision making including regular, dependable, standardized information on projected future ecosystem conditions.

CFI Information Hub

CFI will launch a comprehensive Information Hub to support the dissemination of CFI-generated high spatial resolution reanalysis, hindcasts, predictions, and projections optimized for management applications as well as existing LMR-relevant climate and biological information.

Fisheries and Climate Decision Support System

NOAA will establish expert teams to accelerate the production of climate-informed assessments and management advice designed to sustain fisheries, conserve protected resources, and maintain ecosystem services in collaboration with existing programs and external partners.

OPERATIONS AND INFRASTRUCTURE
Drives Dissemination and Decision Support

How do these components connect?

The ocean forecasts and projections developed by the Regional Ocean Modeling Teams will be hosted on the CFI Information Hub with support from the Data Portal Team. The products of the Regional Ocean Modeling Teams and the Data Portal Team will inform the development of full system models produced by the FACSS Core Teams at each NMFS Science Center to develop and deliver ecosystem forecasts including socio-ecological system forecasts and projections of the performance of current and alternative management strategies under a changing climate, forecasts of ecological tipping points for triggering conservation action to preserve ecosystem integrity and to protect human health, and early warnings of extreme events (e.g., marine heatwaves, harmful algal blooms).

Regional Ocean Modeling and Prediction

Reliable production and delivery of nationally-coordinated ocean hindcasts, forecasts, and projections to meet marine resource management needs will be supported by five Regional Ocean Modeling Teams, composed of scientists from across NOAA Line Offices and academic partners.

High Priority Activities.
- Form dedicated Regional Ocean Modeling Teams.
- Establish capacity to run regional MOM6 configurations across NOAA labs and partner institutions on new HPC targeted for regional ocean modeling.
- Establish basic workflows for seasonal-to-decadal predictions and multi-decadal projections with regional MOM6 systems and refine best practices for bias correction and ensemble generation.
- Demonstrate routine capacity and establish basic workflows to produce hindcast and reanalysis products for LMR management needs from NOS regional Operational Forecasts System (OFS) models.
- Hire ocean/BGC modeling Full Time Equivalents (FTEs) at each fisheries science center to ensure regional ocean model outputs are fit for the intended LMR applications and reliably produced.
- Hire ocean/BGC/ecological modeling and model application FTEs to enhance NOS regional OFS with full coverage of U.S. coastlines and with predictions at longer timescales (weekly to seasonal) that meet LMR management needs.
- Collaborate with LMR scientists and managers to optimize regional ocean configurations for LMR applications and assess with a robust set of LMR-critical diagnostics to establish model skill.
- Fund full (~5 year) cycles for co-development and application with academic partners through Cooperative Institutes or other long-term partnership mechanisms to enable robust research and development contributions to lasting modeling capacity.
- Harness NOAA HPC to produce the high-resolution regional ocean state estimates, hindcasts, predictions, and projections required to meet NOAA's LMR management needs.

Indicators of Positive Progress.
- Regional ocean modeling teams include members from across NOAA Line Offices and academic partners.
- Refined hindcasts, including biogeochemistry, are complete and incorporate expertise from regional teams.
- NOAA's OFS system reaches national coverage with improved state estimation, nowcast, and short-term (weather to subseasonal) forecast capabilities.
- The skill of regional MOM6-based seasonal-to-multi-annual reforecasts is quantified and used to refine NMFS operational requirements.
- Ensemble regional climate projections, forced by Coupled Model Intercomparison Project (CMIP) 6, are complete.
- Regional ocean model outputs are available on data portals and incorporated into NMFS science and management.

Organizational Outcomes/Metrics.
- Regional ocean modeling efforts benefit from NOAA's model development and computation capacity while maintaining a high level of regional expertise and strong feedback between model development and LMR scientists and managers who apply models to meet LMR Mandates.
- Regular communication between regional and global modelers accelerates development at both scales.
- Climate-LMR applications build upon robust ocean modeling platforms supported by regional teams, allowing investments to focus on new integrations and extension to LMR decisions.
- Provision of comprehensive regional ocean projections consistent and comparable across U.S. coastal waters for future National Climate Assessments (NCA).

Regional Ocean Modeling Teams

Five Regional Ocean Modeling Teams—composed of scientists from across NOAA Line Offices and academic partners—will provide the deep knowledge of the ocean and BGC dynamics shaping each region that is needed to appropriately configure models for LMR applications. Coast-wide configurations will address climate-fisheries issues spanning management boundaries and will provide a tractable pathway for the reliable delivery of products across waters relevant to NOAA's mandates. These teams will harness NOAA's regional models and infrastructure and partner with LMR scientists and managers in each region to deliver the climate and ocean information needed to project ecosystem impacts, evaluate response strategies, and integrate this information into LMR management advice. Long-term grants through Cooperative Institutes will be used to provide substantive federal-academic partnerships. Regional tailoring will be tempered with best practices defined by the National Community of Practice to balance the needs for flexibility with the consistency required for national applications within the management arena. External partners and innovators will be entrained through NOAA's competitive extramural funding pathways. Regional Ocean Modeling Teams will work closely with the new LMR science FTEs as part of the FACSS as well as a broader science community engaged through competitive funding pathways (Targeted innovation, Climate Program Office (CPO)/Coastal and Ocean Climate Applications (COCA), CPO/Modeling, Analysis, Predictions and Projections (MAPP), IOOS/Coastal and Ocean Modeling Testbed (COMT)) to apply and/or augment regional modeling systems.

Informing the Climate Information Hub

The operational products from the Regional Ocean Modeling Teams will be hosted on the CFI Information Hub in the next section in close collaboration with the Data Portal Team. The CFI Information Hub will be a data and information portal that includes comprehensive links to existing NOAA data portals with CFI-relevant observational and modeling products, based upon clear descriptions and data access protocols to enable users to effectively harness these diverse resources to meet NOAA's LMR management mandates.

CFI Information Hub

CFI will launch a comprehensive Information Hub to support the dissemination of CFI-generated high spatial resolution reanalysis, hindcasts, predictions, and projections optimized for management applications as well as existing LMR-relevant climate and biological information.

High Priority Activities.
- Form dedicated data portal development team.
- Increase access to extensive physical/BGC hindcasts, retrospective forecasts, predictions, and projections, accelerating the integration of climate and ocean information into LMR science and management.
- In partnership with existing NOAA climate data providers, coordinate an inventory of existing observational programs, platforms, and databases, reanalysis products, and modeling efforts relevant to LMR science and management.
- Develop an initial CFI Information Hub leveraging and linking to existing data portals (e.g., IOOS regional association) and showcase current climate-LMR applications efforts leveraging IOOS Data Management and Cyberinfrastructure (DMAC) expertise and certified data standards.
- In partnership with the user community, detail the optimal technical specifications for the data portal to support the dissemination of large volumes of standardized, quality-controlled regional and global climate data of interest to NOAA's LMR Mandates.
- Develop an assessment of cloud-based approaches for data portal design in coordination with EPIC and NOAA's Big Data Project.
- Develop a next-generation CFI Information Hub to support the high volume of regional data products generated by the Regional Ocean Modeling Teams.
- Develop high-priority data visualizations and analysis tools according to needs identified in partnership with the user community.
- Identify user needs for climate-data training and develop training courses to increase proficiency in the access and application of climate information at multiple spatiotemporal scales.

Indicators of Positive Progress.
- Data Portal Team FTEs have been hired.
- Increased capacity exists to serve existing high-priority LMR-critical climate and ocean datasets and modeling products.
- Detailed Data Portal plan completed based on input from initial CFI workshops and meetings of the National Community of Practice.
- High-priority LMR-relevant variables have been identified and provided to Regional Ocean Modeling Teams with the necessary underlying rationale, standardization, quality controls, and metadata as well as the points of contact.
- The annually-updated, global and regional climate and ocean information inventories and record of information gaps are available on CFI Information Hub and via links to existing portals.
- Existing high-priority LMR-relevant variables are available to LMR scientists/managers on CFI Information Hub via links to existing data portals and queryable access protocols.
- Scripts to efficiently download global and regional LMR-relevant climate variables are made available in a code repository.
- A series of climate data training courses have been hosted in-person at fisheries science centers and as web-based courses.
- In coordination with FACSS Core Teams, integrated pilot applications have been established for LMR management needs and are showcased on the CFI Information Hub.

Organizational Outcomes/Metrics.
- Highly-spatially-resolved, LMR-relevant, regional, physical/BGC variables are available via state-of-the-art data repositories and analysis platforms.
- An increased number of scientists and managers working to meet NOAA's LMR mandates are trained in the use of climate data.

Data Portal Team
The CFI will establish a Data Portal Team composed of data scientists, computer science specialists, developers of existing data portals, communication experts, representatives from NOAA's Big Data Project, NOAA's National Centers for Environmental Information, NOAA's Regional Collaboration Network, stakeholders from EPIC, and LMR scientists and managers. The Data Portal Team will develop the CFI's Information Hub and generate tools for rapid data storage, access, and basic analysis of regional climate information to meet NOAA's LMR Mandates. Ultimately, this team will increase NOAA's capacity to provide new and existing high-priority, LMR-critical climate and ocean datasets and modeling products. A designated data-portal liaison for each Regional Ocean Modeling Team will work with the Data Portal Team to make model products available to LMR scientists and managers in a manner consistent with delivery requirements defined through the pathway to operations workshop.

Informing the Fisheries and Climate Decision Support System
The products of the Regional Ocean Modeling Teams and the Data Portal Team will inform the development of full system models produced by the FACSS Teams at each NMFS Science Center to deliver science products and tools critical to enabling decision makers to prepare for and adapt to changing oceans, reduce climate impacts, and increase the resilience of marine resources and the communities that depend upon them.

Fisheries and Climate Decision Support System (FACSS)
NOAA will establish expert teams to accelerate the production of climate-informed assessments and management advice designed to sustain fisheries, conserve protected resources, and maintain ecosystem services in collaboration with existing programs and external partners.

High Priority Activities.
- Form dedicated expert teams at each Science Center to work with existing programs and partners to increase production and delivery of climate-informed assessments and management advice as part of the FACSS.
- Document relationships between CFI and NOAA's existing ecosystem and climate-related programs, plans, and projects to ensure smooth operations and complementarity.
- Establish mechanisms to foster communication and collaboration between regional FACSS to help ensure consistency, avoid duplicative efforts, and increase sharing of lessons learned and new approaches across regions and science teams.
- Accelerate the transition of environment-linked assessments and climate enhanced forecast and projection models from research to operations by developing

Indicators of Positive Progress.
- Through new FTEs (FACSS Core Teams) and competitive grants, NOAA will accelerate the uptake of high spatial and temporal resolution data at relevant time scales for use in developing decision-support tools, ecological forecasts, and long-term projections.
- FACSS Core Teams efficiently and effectively work with existing programs to deliver key products and services and advance synergistic research to support climate-informed LMR management.
- Increased number of ecosystem-linked assessments (i.e., stock assessments that include environmental influences) and climate-enhanced projections of LMR that include other human stressors (e.g., fishing, water quality, and pollution dispersion).

Organizational Outcomes/Metrics.

- products and capabilities to use climate model output in biological models.
- Design and implement demonstration of proposed product control measures to accelerate the approval of models for operational use and ensure they are based on the best available scientific information (e.g., independent expert review).
- Systematically explore functional linkages between the climate, ocean, high-priority species, harmful species, and the socio-ecological systems that are federally managed.
- Establish and share protocols for laboratory and field experimental evaluation of climate and physiological relationships underpinning coupling relationships.
- Apply the integrated socio-ecological models to identify trade-offs in current and alternative management strategies and inform risk assessments to identify adaptation strategies.
- Review and evaluate climate-enhanced forecasts, projections, and ecosystem-linked assessments for use in management advice.

- Stakeholders, managers, and the public will be more informed about the implications of climate change on LMRs and regional marine ecosystems.
- LMR managers will have access to climate-informed management strategies and advice based on the best available scientific information.
- Accounting of the cross-sectoral risk, trade-offs, costs, and opportunities associated with climate-driven changes to LMRs and adaptation actions will improve.
- Ecosystem-based management efforts are accelerated and coordinated at national and regional scales.

Key Products and Services:
The FACSS—which include FACSS Core Teams, existing programs, and academic partners—will accelerate production and delivery of key products and services to support climate-informed decision making including:
- Advice on climate-informed harvest rates (annual)
- Climate-informed species distribution maps (simulations - seasonal - annual - multi-decadal)
- Climate-informed habitat distributions (simulations - seasonal - annual - multi-decadal)
- Climate-informed recovery targets (projections)
- Skill testing of management tool performance (simulations - hindcasts)
- Indicators for Ecosystem Status Reports (seasonal - annual)
- Risk assessment and adaptation plans (annual, short-term forecasts, projections)
- Emergency response tools (nowcasts, forecasts)
- Bycatch and entanglement avoidance (nowcasts, seasonal-to-annual forecasts)

FACSS Core Teams

The FACSS will include dedicated groups of experts (FACSS Core Teams) that will serve as catalysts to operationalize and expand the nascent climate-fisheries programs within NOAA. The FACSS Core Teams are new groups of dedicated experts at each of the NMFS Science Centers that will serve as the critical bridge between CFI's transformative ocean and climate information, ongoing research and development for LMR applications, and the operational, actionable information needed for climate-informed decision making. The FACSS Core Teams will be small interdisciplinary groups of experts who work with existing NOAA programs and partners to advance the application of climate and ocean information in the delivery of the key products and services listed above to operationalize climate-informed resource management. As appropriate for individual regions, these FACSS will consistently provide ecosystem-based assessments and management advice including but not limited to:

- Advice on climate-informed harvest rates (annual)
- Climate-informed species distribution maps (simulations - seasonal - annual - multi-decadal)
- Climate-informed habitat distributions (simulations - seasonal - annual - multi-decadal)
- Climate-informed recovery targets (projections)
- Skill testing of management tool performance (simulations - hindcasts)
- Indicators for Ecosystem Status Reports (seasonal - annual)
- Risk assessment and adaptation plans (annual, short-term forecasts, projections)
- Emergency response tools (nowcasts, forecasts)
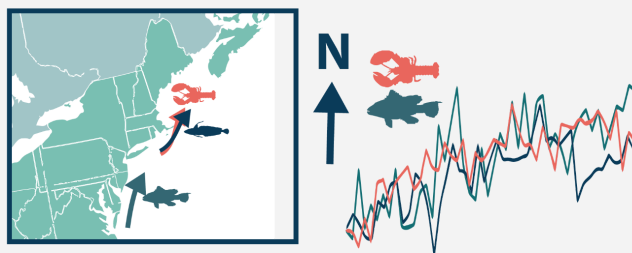- Bycatch and entanglement avoidance (nowcasts, seasonal-to-annual forecasts)

Ecosystem Prediction

The FACSS—in concert with cross-NOAA and external experts—will provide a variety of products and services for use in LMR management advice and decision making including regular, dependable, standardized information on projected future ecosystem conditions. The FACSS Core Teams will facilitate the delivery of products and services that will be curated (queryable, downloadable, and includes metadata) and shared publicly via the CFI Information Hub. Examples of anticipated climate-informed outputs are listed below.

Climate Enhanced Habitat and Species Distribution Maps

The FACSS will provide information on past, current, and expected future changes in the distribution of habitats and species for use in survey designs, stock assessments, allocation, and other management decisions.

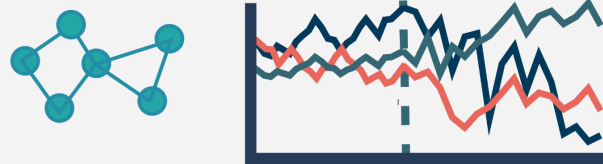**Climate Enhanced Population Forecasts and Projections**

The FACSS will provide information on past, current, and projected future population levels of key target species under expected future ocean conditions for use in management advice and

decision making. These findings will be periodically synthesized in reports containing climate scenarios for management, adaptation, risks, and tradeoffs representing the best scientific information available on climate change for science-based planning and adaptation.

Climate Enhanced Ecosystem-wide Forecasts and Projections
The FACSS will provide information on past, current, and projected future marine ecosystem conditions—including human dimensions—under expected future ocean conditions for use in management advice and decision making.

Early Warning of Tipping Points and Thresholds for Action
The FACSS will provide information on possible ecosystem tipping points and thresholds for use in developing early warnings and responses.

How do these components inform Climate Ready Decision making?
A FACSS will be established within each of the NMFS regions to translate ocean and climate information—including the comprehensive regional model outputs produced by the Regional Ocean Modeling Teams—and turn it into the actionable information that decision makers and communities need to reduce impacts and increase resilience. Each FACSS Core Team is composed of interdisciplinary experts (e.g., ecosystem and human dimension modelers) dedicated to using the climate/ocean projections to produce a suite of products including projections of the ecosystem and species conditions, risk assessments, and evaluations of best management strategies for changing oceans. The FACSS Core Teams work closely with the existing NOAA science and management community to leverage existing expertise, translate and operationalize information developed through ongoing research, and continuously improve the production and delivery of climate-related products and services based on engagement with decision makers. The regional FACSS Core Teams will be part of a coordinated, nationwide network to share information and advance efforts based on shared experiences.

Climate Ready Decision Making

Overview

Through CFI, NOAA and partners will provide the infrastructure and dedicated resources to co-develop an end-to-end operational system that provides decision makers with the reliable, regionally-tailored products and services needed for climate-informed LMR management. The system includes rigorous feedback loops for continuous innovation and improvement based upon input between product makers and users following the NOAA Service Delivery Framework. Driven by the needs of the end-users in both the science and management communities, the CFI products and services include but are not limited to, ecosystem assessments, ecosystem-linked stock assessments, climate-informed harvest rates and recovery targets, climate-informed species distribution and habitat maps, bycatch management, scientific risk assessments, emergency response tools, climate-informed management strategies, climate ready survey designs, and adaptation options.

Key Decision Makers

The CFI is designed to provide critical information on past, current, and future conditions of the Nation's marine and coastal ecosystems to a broad group of decision makers involved in LMR management (fisheries, protected resources, protected areas, habitats), safe navigation, coastal zone management (ports and working waterfronts), energy development, and other sectors. All of these sectors urgently need reliable information on past, current, and projected future changes in climate, ocean, and ecosystem conditions to assess risks and respond to changing ocean ecosystems.

The CFI system is also designed to meet the specific needs of NOAA, State, Tribal, and other decision makers involved in the management and use of the Nation's valuable LMRs. This includes addressing NOAA's requirements for climate-related information to fulfill living marine mandates for fisheries management (e.g., Magnuson-Stevens Fishery Conservation and Management Act), protected resource conservation (e.g., Endangered Species Act, Marine Mammal Protection Act), and others (e.g., National Marine Sanctuaries Act, Coastal Zone Management Act and Harmful Algal Bloom and Hypoxia Research and Control Act). The CFI is specifically designed to support climate-informed decision making through existing science and management bodies and processes at regional, national, and international levels. For example, some of these organizations include Regional Fishery Management Councils, Protected Area Managers (e.g., National Marine Sanctuaries), State Resource Management Agencies, InterState Commissions (e.g., Atlantic States Marine Fisheries Commission, Pacific States Marine Fisheries Commission, Great Lakes Commission), regional planning bodies (e.g Northeast Regional Ocean Council), international entities, and other groups.

System Requirements

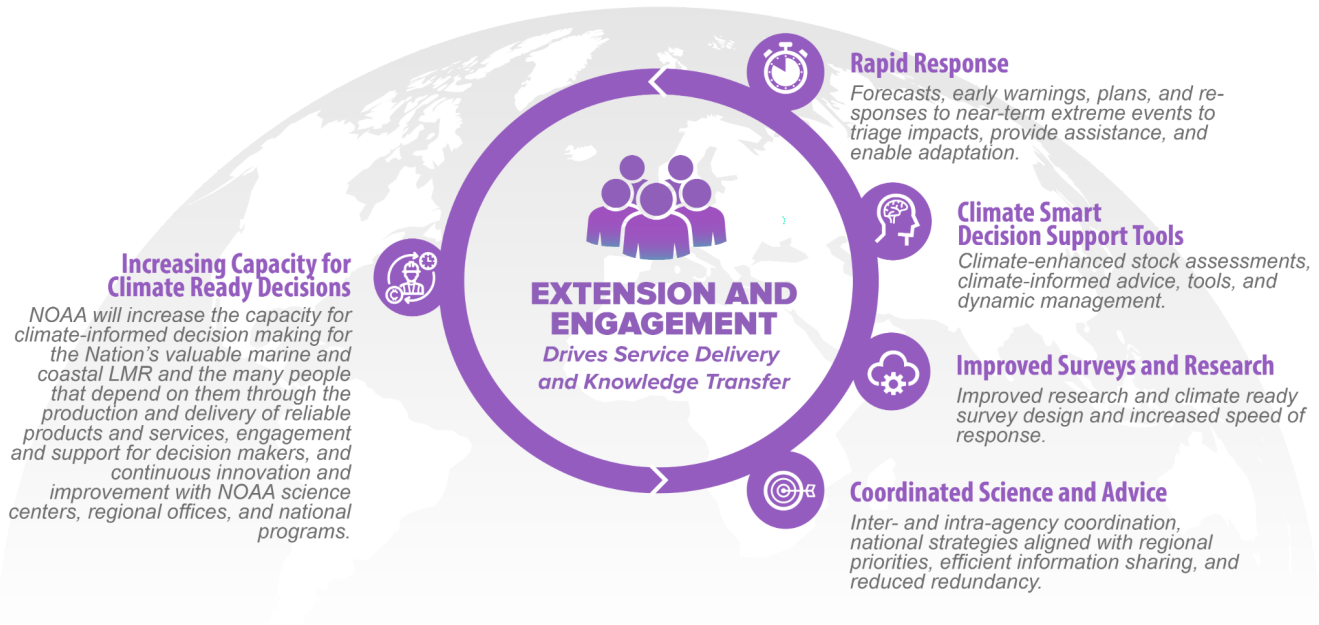*Actionable Information //* LMR managers and decision makers need actionable information informed by the best-available climate and ocean information.

Climate-informed management strategies // Communities and decision makers need proactive, climate-informed LMR management and adaptation strategies to sustain marine resources and the coastal communities that depend on them in the face of climate change.

Key Components

For NOAA to inform climate ready decision making, the following investments will be required:

Rapid Response
Forecasts, early warnings, plans, and responses to near-term extreme events to triage impacts, provide assistance, and enable adaptation.

Climate Smart Decision Support Tools
Climate-enhanced stock assessments, climate-informed advice, tools, and dynamic management.

Improved Surveys and Research
Improved research and climate ready survey design and increased speed of response.

Coordinated Science and Advice
Inter- and intra-agency coordination, national strategies aligned with regional priorities, efficient information sharing, and reduced redundancy.

Increasing Capacity for Climate Ready Decisions
NOAA will increase the capacity for climate-informed decision making for the Nation's valuable marine and coastal LMR and the many people that depend on them through the production and delivery of reliable products and services, engagement and support for decision makers, and continuous innovation and improvement with NOAA science centers, regional offices, and national programs.

EXTENSION AND ENGAGEMENT
Drives Service Delivery and Knowledge Transfer

How do these components connect?

NOAA will evaluate its existing capacity and barriers to using and applying climate information to guide management decisions and invest where needed in additional personnel, training, and educational opportunities for LMR managers and decision makers. This capacity will allow NOAA to make use of the ecosystem predictions delivered by the FACSS and other NOAA-developed, climate-informed LMR tools to rapidly respond and adapt, develop additional climate-smart decision-support tools, improve surveys and research, and provide coordinated science advice across the Federal Government.

Increased capacity for climate ready decisions
NOAA will increase the capacity for climate-informed decision making for the Nation's valuable marine and coastal LMR and the many people that depend on them through the production and delivery of reliable products and services, engagement and support for decision makers, and continuous innovation and improvement with NOAA science centers, regional offices, and national programs.

High Priority Activities.
- Improve process for sharing observational data (e.g., environmental and LMR) in a timely manner to support management decision making.
- Assessment of existing management capacity within NMFS to understand and use climate information for decision making.
- Sustained, iterative engagement with resource managers and related communities

Indicators of Positive Progress.
- Delivery of C-SMART to managers.
- Delivery of climate-informed advice including management scenarios and adaptation options informs resource management decisions.
- Transformative change exists in the use of climate-informed advice in management of marine resources within an Ecosystem-Based Fishery Management

to identify high-priority information needs and climate-smart decision-support tools and to refine products according to evolving needs.

- Increase trainings, best practices, staffing, and other means to expand capacity for climate-related information and management advice in decision making for fisheries, protected resources, and habitat conservation.
- Develop management scenarios and adaptation options using an iterative cycle of input, review, and synthesis with science and management communities. For example, climate-enhanced strategic planning outcomes (integrated climate-harvest-adaptation projections) can be summarized in reports on a periodic basis in response to evolving science and/or global model updates (CMIPs). For fisheries management uses, these reports of Climate Scenarios for evaluation of Management, Adaptation, Risks, and Trade-offs (C-SMART) can be reviewed by relevant Councils and sub-bodies (e.g., SSCs) to assess whether changes to current management are necessary.
- Develop management strategy evaluations in collaboration with managers and stakeholders to evaluate performance and trade-offs associated with alternative climate-informed management strategies and to inform potential changes to current management. For example, understanding the impacts, risks, and tradeoffs of current and future management strategies will be informed by the projected ecological, social, cultural, and economic implications of the coupled socio-ecological system delivered by the FACSS.
- Build an inclusive, collaborative process that protects intellectual property and facilitates the exchange of information across multiple knowledge holders.
- Use co-production of knowledge approaches to build scenarios and evaluate the risk and tradeoffs of adaptation and management actions.

framework.

Organizational Outcomes/Metrics.

- Ecosystem-linked stock assessment advice incorporates seasonal-to-annual indices tailored to the specific ontogenetic processes of assessed species derived from high-resolution regional ocean models.
- Identification of climate-informed management measures and thresholds for action is informed by MSEs.
- Fishery-dependent and engaged communities are informed of the risks of future climate scenarios.

Delivering Management Advice

What follows are examples of the products, tools, and information that decision makers will have access to based upon investments in the Climate and Fisheries Initiative that will allow them to make climate ready decisions.

Rapid Response
Forecasts, early warnings, plans, and responses to near-term extreme events to triage impacts, provide assistance, and enable adaptation.

Climate-Smart Decision-Support Tools
Climate-enhanced stock assessments, climate-informed advice, tools, and dynamic management.

Improve Surveys and Research
Improved research and climate ready survey design and increased speed of response.

Coordinated Science and Advice
Inter- and intra-agency coordination, national strategies aligned with regional priorities, efficient information sharing, and reduced redundancy.

Takeaway

Working across NOAA and with external partners, the CFI will provide the foundational ocean, coastal, and ecosystem information needed to help scientists, managers, industries, and communities identify risks, options, and best management and adaptation strategies for rapidly changing climate and ocean conditions.

NOAA is uniquely positioned to address these complex challenges by building on its existing capacity through new opportunities in climate and marine sciences. Finally, the outcomes described in the CFI will require the support of Congress.

Appendix A: Steering Committee and Implementation Team Membership

Steering Committee Co-Chairs	• David Detlor (NMFS) Deputy Director, Science and Technology • Wayne Higgins (OAR) Director, Climate Program Office
Steering Committee Members	• John Cortinas (OAR) Director, Atlantic Oceanographic and Meteorological Laboratory • Robert Foy (NMFS) Director, Alaska Fisheries Science Center • Jon Hare (NMFS) Director, Northeast Fisheries Science Center • Libby Jewett (OAR) Director, NOAA Ocean Acidification Program • Keelin Kuipers (NOS) Deputy Director, Office for Coastal Management • Deborah Lee (OAR) Director, Great Lakes Environmental Research Laboratory • Catherine Marzin (NMFS) Director, Acting, Office of Protected Resources • Michelle McClure (OAR) Director, Pacific Marine Environmental Laboratory • John Murphy (NWS) Chief Operating Officer, National Weather Service • Jeff Privette (NESDIS) Deputy Director, NOAA Center for Weather and Climate • Venkatachalam Ramaswamy (OAR) Director, Geophysical Fluid Dynamics Laboratory • Jenni Wallace (NMFS) Director, Acting, Office of Sustainable Fisheries • Robert Webb (OAR) Director, Earth System Research Laboratory, Physical Sciences Division • Kevin Werner (NMFS) Director, Northwest Fisheries Science Center
Implementation Team Co-Chairs	• Mike Jacox (NMFS and OAR) • Desiree Tommasi (NMFS) • Charlie Stock (OAR) • Anne Hollowed (NMFS)
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Appendix B: Glossary of Acronyms

C-SMART	Climate Scenarios for evaluation of Management, Adaptation, Risks, and Trade-offs
CFI	Climate and fisheries Initiative
CMIP	Coupled Model Intercomparison Project
COCA	Coastal and Ocean Climate Applications
COMT	Coastal and Ocean Modeling Testbed
CORDEX	Coordinated Regional Downscaling Experiment
CPO	Climate Program Office
DAC	Data Assembly Center
DMAC	Data Management and Cyberinfrastructure
EMC	Environmental Modeling Center
eDNA	Environmental DNA
EPIC	Earth Prediction Innovation Center
FACSS	Fisheries and Climate Decision Support System
FAO	Food and Agriculture Organization
FTEs	Full Time Equivalents
HPC	High-Performance Computing
ICES	International Center for the Exploration of the Sea
IEA	Integrated Ecosystem Assessments
IOOS	Integrated Ocean Observing System
IPCC	Intergovernmental Panel on Climate Change
LOSI	Loss of Sea Ice
MAPP	Modeling, Analysis, Predictions, and Projections
MOM	Modular Ocean Model
MPA	Marine Protected Area
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSEs	Management Strategy Evaluations
NCA	National Climate Assessment
NCSS	NMFS Climate Science Strategy
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
OFS	Operational Forecasts System
OSE/OSSEs	Observing System [Simulation] Experiments
PICES	North Pacific Marine Science Organization
QOSAP	Quantitative Observing System Assessment Program
RAPs	Regional Action Plans
RFMOs	Regional Fisheries Management Organizations