



A STRATEGIC VISION FOR NOAA'S ECOLOGICAL FORECASTING ROADMAP

2015-2019

FOREWORD

Ecological forecasts are used to predict likely changes in ecosystems and ecosystem components in response to environmental drivers (e.g., climate variability, extreme events and hazards, and land and resource use) and resulting impacts on people, economies and communities that depend on ecosystem services. Ecological forecasts provide early warnings of the possible effects of ecosystem changes on coastal systems, and on human health and local and regional economies with sufficient lead time to allow mitigation strategies to be developed and corrective actions to be taken.

Ecological forecasts are products derived from the successful transition of research and development into societally useful applications. NOAA is uniquely positioned to provide ecological forecasting services at the national level. The agency is mandated to forecast weather, water, climate, tides, fish stocks, and status and recovery of protected species, and has a long history of forecasting dating back to the beginning of NOAA's Ocean, Weather, and Fisheries Services. Over the past several decades NOAA has been developing and advancing forecasts and products to address its stewardship, hazard reduction, and fishery **mandates**. NOAA and its partners (e.g. IOOS Regional Associations, Cooperative Institutes) have extensive observational assets in place that can be utilized as the foundation for ecological forecasts. For example, they collect huge amounts of weather, water, climate, oceanographic, coastal, and biological data that can be readily assimilated into predictive systems to support these forecasts. NOAA also has exceptional modeling, computing, and forecasting capacities/expertise, and is at the forefront of development and deployment of new environmental sensors and sampling technology.

To this end, NOAA has developed an operational framework – a **roadmap** – for a NOAA-wide ecological forecasting capability to effectively and efficiently provide dependable, higher quality forecast products on a broader scale with consistent delivery. This agency-wide effort builds upon and unites the numerous but previously disjointed ecological forecast (EF) activities and connects these with related efforts in other federal, state, and local agencies, and the external academic community and private sector to deliver consistent, timely, and reliable

Legislation and Executive Mandates Pertinent to the Ecological Forecasting Roadmap:

- NOAA Administrative Order 216-108 “Requirements Management”
- Harmful Algal Bloom and Hypoxia Research and Control Amendments Act of 2014 (Public Law 113-124)
- Chesapeake Bay Executive Order (#13508)
- The Coastal Zone Management Act
- Coral Reef Protection Executive Order/Coral Reef Conservation Act
- Magnuson-Stevens Fishery Conservation and Management Reauthorization Act
- Clean Water Act
- National Marine Sanctuaries Act
- Marine Mammal Protection Act

Ecological Forecasting Priority Areas

HARMFUL ALGAL BLOOMS

HYPOXIA

PATHOGENS

HABITAT

The Ecological Forecasting Roadmap offers a coordinated and systematic approach to ecological forecasts needed by the nation. These priorities were selected based on three criteria:

- 1 needs expressed by stakeholders,
- 2 how mature NOAA's capacity is in a particular area, and
- 3 national significance.

For further information on the scope of each priority team, see Appendix 2.

ecological forecasts to the American public. It establishes priorities for coordinating NOAA's and its partner programs' existing monitoring capabilities, to developing scientific foundation, operational environmental prediction, and service delivery infrastructures. This strategy offers management solutions for ensuring the protection, monitoring, maintenance and restoration of the health and productivity of ocean, coastal and Great Lakes ecosystems, including natural resources and human communities.

For the period from 2015 to 2019, NOAA's priority through this **Ecological Forecasting Roadmap** is to develop **ecological forecasts for harmful algal blooms, hypoxia, pathogens, and habitat**, in regions of the country where these are issues of major concern. Identification of these cross-NOAA priorities provides focus to this emerging effort to establish momentum in developing and transitioning critical user-driven ecological forecasts to operations. It is intended that the underlying infrastructure and programmatic constructs established under this framework can then be applied to additional forecasting parameters once the approach is validated. This plan provides programmatic guidance to NOAA's Ecological Forecasting Roadmap for 2015-2019.

MISSION

NOAA protects and promotes the health and well-being of humans and our environment by providing timely, reliable and user-valued ecological forecast products and services.

VISION

People are protected from ecological threats while enjoying and sustaining nature's benefits.

VALUE PROPOSITION

NOAA is uniquely positioned to deliver ecological forecasts in near-real time through its existing environmental intelligence, modeling, observing system and dissemination assets.

GUIDING PRINCIPLES OF THE ECOLOGICAL FORECASTING ROADMAP

1. Partnerships are essential.
2. Customer and stakeholder needs, values, and uses should drive ecological forecasting product and service priorities.
3. Successful implementation requires a cross-NOAA approach, integrated across disciplinary and institutional boundaries and employing assets of the entire agency (particularly foundational environmental forecast capabilities).
4. NOAA's Ecological Forecasting Roadmap establishes the framework to support a full continuum of ecological forecasts from imminent events to scenario-based projections.
5. NOAA's approach to ecological forecasting is currently national in scope but regional in application and delivery.
6. NOAA ecological forecasts should emphasize ecological rather than physical outputs, and include impacts on humans and human communities.

What does success look like for the Ecological Forecasting Roadmap?

NOAA’s Ecological Forecasting Roadmap is designed to mainstream and institutionalize NOAA’s roles in ecological forecasting science, service and stewardship while optimizing sustainability of outcomes of societal benefit. Successful implementation of this strategy will be realized when existing ecological forecasts have been transitioned to operations; foundational infrastructure, observations, modeling, dissemination, and data management elements are institutionally supported; strategies are underway to address gaps in capacity; and users regularly and effectively utilize the forecasts and provide feedback for improvement. Policies and mechanisms will be in place to allow cross-NOAA ecological forecasting to effectively transcend Line Office and budgetary barriers to plan and execute efforts seamlessly. Extramural success will mean adoption by partners and actors including water resource and emergency managers, farmers, fishers, health officials, academics, and commercial partners.

NOAA ECOLOGICAL FORECASTING STRATEGIC GOALS FOR 2015-2019



1.0 CONSTITUENT PRIORITIES

Identify evolving forecast priorities driven by constituency needs and requirements.

- 1.1 Identify forecast products that will best address the key constituent needs, *focusing on the identified priorities for FY15-19.*
 - 1.1.1 Conduct market research and work closely with constituents to infuse emerging cross-cutting themes (e.g. climate, human health and well-being) into Action Plan.
 - 1.1.2 Identify research that is sufficiently mature to produce a forecast to meet key constituent needs.
 - 1.1.3 Educate constituents and policy makers on the uses and value of existing and emerging forecast products and services.
 - 1.1.4 Institute streamlined feedback mechanisms to capture and assess customer satisfaction and effectiveness of forecast products and services as well as opportunities for improvements
 - 1.1.5 Sustain interactive engagement with constituents for understanding and documenting needs, and assessing and adjusting priorities.
 - 1.1.6 Identify gaps in NOAA forecasting plans and approaches based on constituent needs.
 - 1.1.7 Incorporate social science into all aspects of ecological forecasting, from initial needs assessments to development, product generation, and delivery.
 - 1.1.8 Deliver products and services in flexible, widely accepted industry standard methodologies that meet user needs and can be used to build value added products.
 - 1.1.9 Implement a transparent process for priority setting and outcomes to provide clear communication and manage expectations. Utilize web and email mechanisms to distribute plans and priorities on an annual basis.
 - 1.1.10 Periodically reassess elements of the work plans developed for each priority area (also known as the EF Roadmap Action Plan), and revise priorities based on constituent feedback, NOAA priorities, available resources, and strong cost benefit analysis of the potential impacts of forecasts.
- 1.2 Implement strategic partnerships that capitalize on strengths and resources to pursue shared goals with key sectors:
 - 1.2.1 **NOAA:** Align complementary cross-NOAA capacity (e.g. foundational environmental capabilities) with identified needs to ensure NOAA's most effective strategy to maximize public service provided by the EF Roadmap.
 - 1.2.1.1 Seek efficiencies in implementing the EF Roadmap Action Plan and associated milestones in order to most cost-effectively expand the footprint of NOAA ecological forecasts.
 - 1.2.1.2 Identify areas for collaboration specifically among existing cross-Line Office (LO) efforts, e.g. Integrated Ecosystem Assessment, NOAA Ecosystem Services Team, NOAA Habitat Conservation Team, etc.
 - 1.2.2 **Federal:** For federal agencies, document intersecting interests, opportunities, and needs among Federal agencies for ecological forecasting to most effectively meet respective missions and mandates through collective action.
 - 1.2.3 **Academia:** Work closely with the academic sector to identify and support research that will address forecast priorities, and continuously infuse NOAA's forecasting products and services with cutting edge biophysical and social science.

- 1.2.4 **Private sector:** Per existing policies, provide free and open access to products and services through a variety of mechanisms in order to support development of an ecological forecasting business sector.
 - 1.2.5 **States, localities, and territories:** Deliver operational ecological forecasts to be applied to management action and continually engage with these primary customers to guide the scope and direction of the Roadmap effort.
 - 1.2.6 **Tribes:** Building on the engagement with states, localities, and territories, meet the unique needs of tribal communities for EF products and services and incorporate culturally-based natural and social science information, requirements and approaches to product development and delivery.
 - 1.2.7 **Non-Governmental Organizations NGOs:** Employ a range of approaches based on the specific nature of the organization, including partnerships to allow for additional scientific support, identify regionally-based needs, and serve as a bridge to management action. NGOs serve as both providers of requirements, data, and services, as well as customers for NOAA forecasts.
 - 1.2.7.1 **IOOS Regional Associations:** Work closely with IOOS Regional Associations to support observing, modeling and new sensor technologies.
 - 1.2.8 **International:** NOAA will Work with international entities, including engagement in intergovernmental forums (e.g. U.S. Group on Earth Observations) as appropriate, to apply approaches to ecological forecasting to bilateral efforts and global early warning systems.
- 1.3 Educate constituents on the uses and values of existing and emerging ecological forecast products and services and quantify and document successful application for forecast products and services.

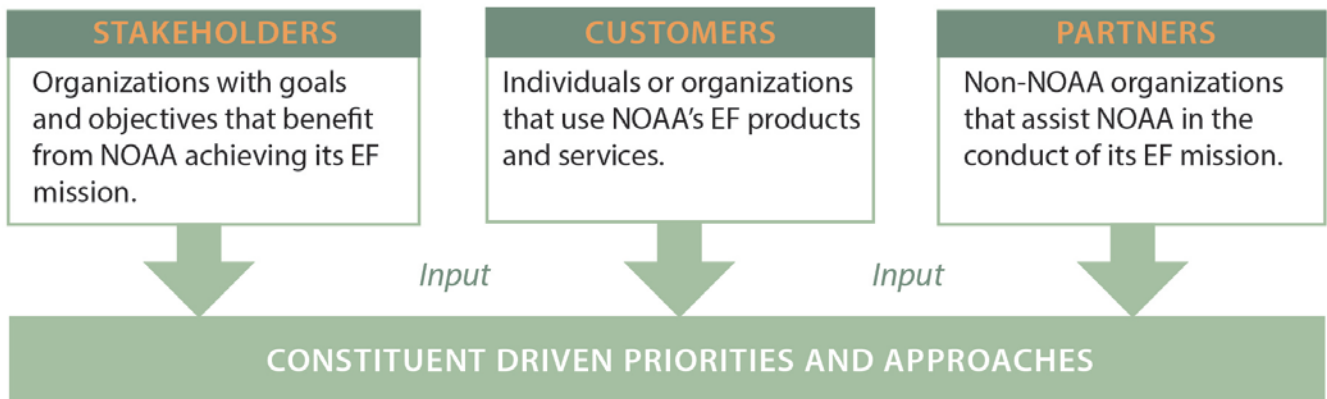


Figure 1. Input from constituents is used to derive priorities and approaches. Constituents include: stakeholders, customers, and partners.

2.0 NOAA'S ECOLOGICAL FORECAST PRODUCTS AND SERVICES

Deliver a targeted ecological forecast portfolio aligned with national, regional and local needs.

2.1 Develop, maintain, and improve upon NOAA's suite of ecological forecasts, products, and services across multiple time and space scales and delivery platforms.

2.1.1 Improve research that is sufficiently mature, to support operational forecasts, within a consistent national strategy to build guidance capacity.

2.1.2 Improve existing EF forecast products and services, with particular focus on:

- *Increasing spatial resolution and timeliness (e.g. via enhanced detection) of existing ecological forecasts;*
- *Broadening temporal coverage of existing ecological forecasts to meet a wider range of applications and management needs;*
- *Improving accuracy and specificity;*
- *Quantifying and providing information on forecast uncertainty; and*
- *Enhancing delivery of existing ecological forecasts.*

2.1.3 Use a consolidated national approach to initiate new product development and delivery aligned with agency and constituent priorities, including:

- *Extension of Roadmap forecast portfolio to additional regions and topics (ecological phenomena outside the initial 4 priority areas);*
- *Integration of new models to existing forecast systems (multiple model approach);*
and
- *Augmentation of existing forecast models.*

2.2 Conduct peer review and evaluation of forecast methodology and accuracy as part of development.

2.3 Deliver products through a wide range of state of the art media (e.g. smart phone accessible, interactive user experience), as appropriate to meet constituent needs.

2.3.1 Establish a long-term strategy to utilize NOAA's mechanisms for discovery, access, dissemination, and archival of data and products as possible.

2.3.2 Employ social media to widely communicate forecast outputs and outcomes/benefits.

2.3.3 Develop diverse dissemination mechanisms and automated product integration as applicable to more effectively reach constituents.

2.2.3.1 Expand integration of ecological information within National Weather Service weather forecast products where appropriate and operationally supported.

3.0 RESEARCH TO APPLICATIONS (R2A)

Streamline processes to successfully transition at least five forecasts from research to applications by 2019.

- 3.1 Utilize best R2A practices and apply existing transition processes and structures in alignment with associated NOAA Administrative Orders to advance NOAA's ecological forecasts through technical readiness levels to sustained operations.
 - 3.1.1 Ensure full communication among key users, stakeholders and developers, including non-NOAA partners, throughout the development cycle to provide feedback, change requirements, and coordinate user testing as appropriate.
 - 3.1.2 Coordinate funding for the product through the applicable LOs, with agreements signed by LO management (or management of external partners), that encompasses the product's/service's needs over its lifecycle.
 - 3.1.3 Capture the life cycle of the product or service, responsible entities, performance reporting, and document funding expectations, as recommended in the NAO 216-105
- 3.2 Develop a multi-year strategy and secure adequate resources to successfully transition research to applications and improve existing ecological forecasting products and services. Resources to support transition and then continued operational production of forecasts are essential.
- 3.3 Continually evaluate state of the art research and technology to impart into new and existing ecological forecasts, products, and services.
 - 3.3.1 Establish and/or use Test Beds to evaluate and assess new approaches. Work with the US IOOS Coastal and Ocean Modeling Testbed (COMT) to facilitate R2A.
- 3.4 Conduct forecast validation and skill assessment of all ecological products and services on a routine basis to quantify forecast accuracy and utility, and to therefore identify gaps and prioritize continuous improvements.
- 3.5 Promote the continuous advancement of research through feedback from constituents on ecological forecasting products and services.

What is Research to Applications?

NOAA has a policy on transition of research to applications, with which the EF Roadmap is fully compliant. Per NOAA's Administrative Order 216-105, "applications" is defined as the use of research results in furthering NOAA's mission. Application of the best available science and technology is essential to meeting NOAA's mission.

"This demands an operations enterprise that is able to quickly recognize and apply significant new research products and methods; a research and development enterprise focused on the ultimate application of emerging science and technology to user needs; and a formalized management structure that ensures that both the research and development enterprise encourage and support the transfer of research to operational status or information services to meet mission responsibilities."

-NAO, 2008

For the purposes of ecological forecasting, transition from research to applications includes transition of a forecast to operations.

For NOAA's EF Roadmap, "operational" activities are sustained, systematic, reliable, and robust mission activities with an institutional commitment to deliver specified products and services

The feedback mechanism of Applications to Research is considered as important as Research to Applications.

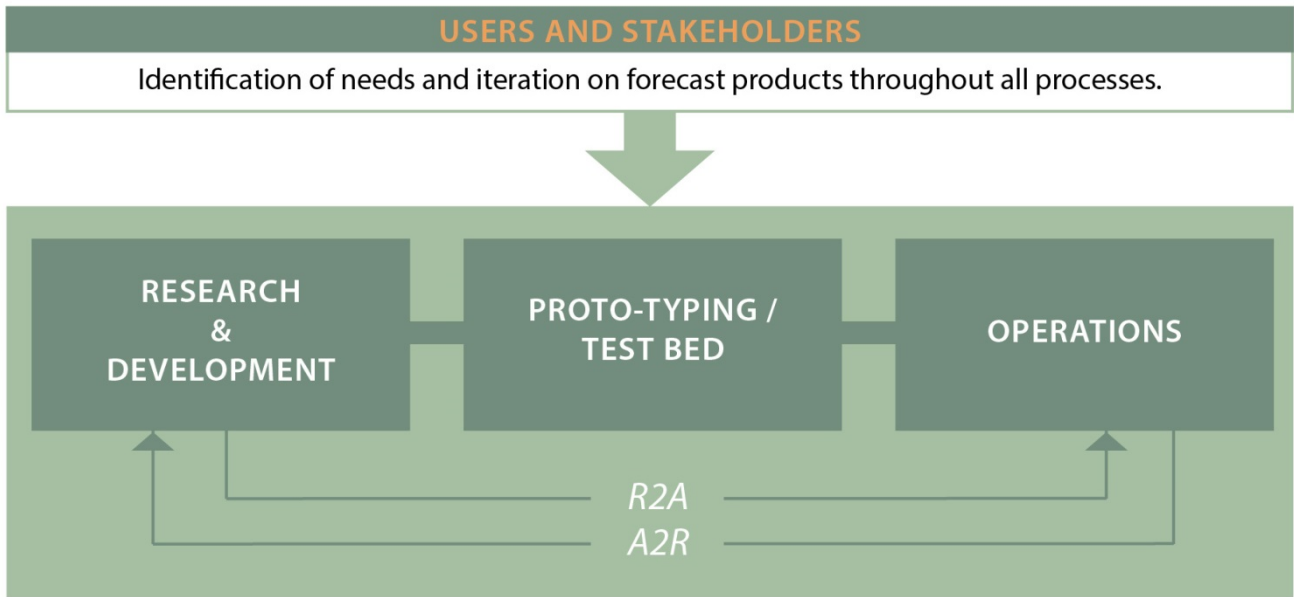


Figure 2. Operational forecasts are continuously improved by incorporating feedback back into research and development.

4.0 NATIONAL INFRASTRUCTURE

Evolve NOAA's infrastructure, technology, people, processes and systems to support ecological forecasting at a national scale, applied and delivered regionally.

- 4.1 Establish a corporate enterprise framework that builds on NOAA's existing systems and capacities to support an ecological forecasting infrastructure.
 - 4.1.1 **Observations:** Maintain and/or fully leverage existing observations in support of operational ecological forecasts through both Federal (including NOAA) and non-Federal partners. Utilize data sharing agreements and other means to support an operational framework.
 - 4.1.2 **Models:** Implement a robust earth system modeling framework, building on existing and new efforts within and external to NOAA. Integrate socio-economic data and models as available and appropriate.
 - 4.1.3 **Data integration and analysis:** Develop and enhance the infrastructure for timely and reliable data integration, data synthesis, and analysis to generate ecological forecasts.
 - 4.1.4 **Product generation:** Develop and enhance the infrastructure for generating, analyzing, packaging and delivering NOAA's ecological forecast products and services in a variety of constituent-defined formats, incorporating social science techniques and principles.
 - 4.1.5 **Dissemination:** Exploit and enhance NOAA's and its partners' existing infrastructure for EF product and service dissemination. Utilize diverse dissemination mechanisms (internal and external to NOAA) to reach constituents.
 - 4.1.6 **Archival:** Maintain repository of source data, models and ecological forecasts and products, and, as available, customer use and response to forecasts, to support validation, assessment, and research.
- 4.2 Develop and advance a strategy to improve *and operationalize* observational and modeling capabilities for ecological forecasting, with a focus on incorporating ecological forecasting requirements and time frames into existing products and capabilities (e.g., National Ocean Service Operational Forecast System and US IOOS coastal modeling strategy under development by the Interagency Ocean Observing Committee).
- 4.3 Ensure ecological forecasting research and model development are aligned with service delivery needs and actively support the transition of new products and services to applications
- 4.4 Incorporate NOAA and partner regional assets (e.g. IOOS Regional Associations) into the operational framework for forecasting to create an efficient business model for forecast development and delivery.
- 4.5 Formalize agreements required for sustained operational forecast production and delivery.
- 4.6 Mobilize and sustain a highly skilled and motivated workforce across all Line Offices to meet EF mission objectives.
- 4.7 Establish mechanisms for information technology (IT) support of cross-Line Office products and data streams.

5.0 GOVERNANCE AND MANAGEMENT

Institutionalize ecological forecasting as a sustainable cross-NOAA Program and priority.

- 5.1 Establish a Program structure and mechanisms to produce and deliver “one-NOAA” ecological forecasting products and services.
 - 5.1.1 Ensure multidisciplinary and cross-Line Office engagement, including establishment of ecological forecasting Test Beds.
 - 5.1.2 Ensure coordinating Line Office policies permit an unfettered collective NOAA ecological forecasting capability.
 - 5.1.3 Codify roles, responsibilities and commitments in performance plans and Annual Operating Plans (AOPs).
- 5.2 Develop and seek broad NOAA, Department of Commerce and Congressional support for a formal, long-term EF Roadmap funding stream.
- 5.3 Influence NOAA’s budget formulation process to secure funds for the development, transition and operation of ecological products and services.
- 5.4 Seek efficiencies in existing programmatic activities and find new opportunities for resource growth in support of ecological forecasting.
- 5.5 Employ a consistent approach to institutionalize long-term cross-NOAA commitments to operational forecasting through agreements where appropriate, strategic plans, annual operating plans, and other planning and execution mechanisms at the Line and Program Office levels.
- 5.6 Conduct periodic portfolio reviews to identify any gaps or weaknesses in the program structure or governance.

NEXT STEPS

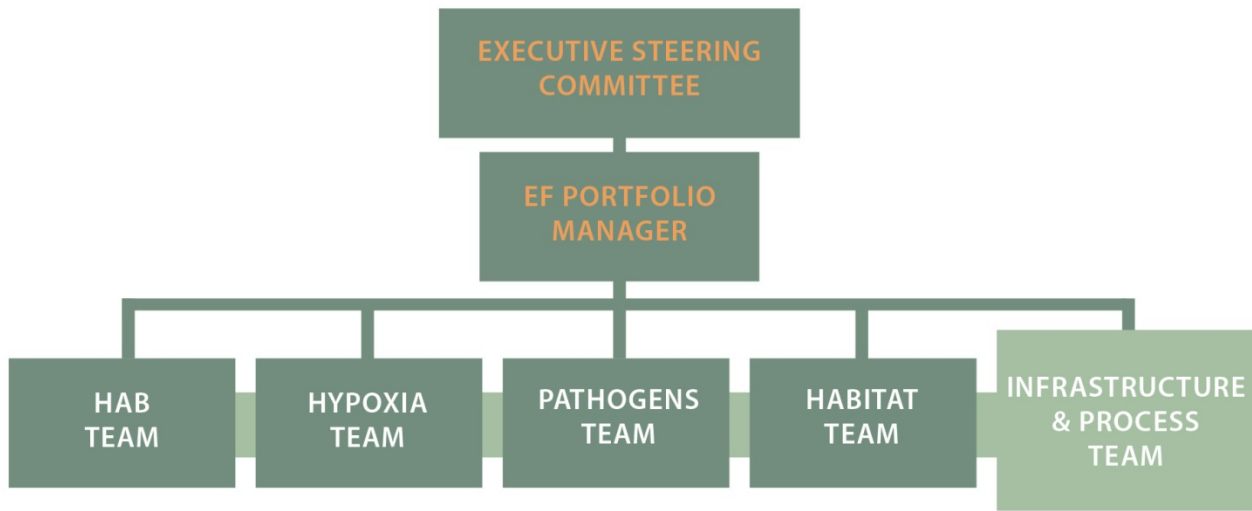
The Ecological Forecasting Roadmap brings structure and focus to NOAA’s disparate ecological forecasting effort in order to concentrate execution on priority Cross-NOAA objectives. This document will be used to provide programmatic guidance to NOAA’s Ecological Forecasting Roadmap. It will be reviewed approximately once every 2 years with complete updates every 5 years. Accompanying Action Plans will be updated on an annual basis. Execution of EF Roadmap efforts will be conducted across NOAA Line Offices and institutionalized through Annual Operating Plans, Transition Plans, and Agreements to support an operational framework.

APPENDIX 1. EF ROADMAP GOVERNANCE STRUCTURE

Development of regionally-based but nationally coordinated ecological forecasts will be complex, challenging, and will require harnessing of intellectual, financial, and other resources from all Line Offices within NOAA.

Governance of the EF Roadmap is comprised of three components, each reaching across LOs.

- a. Ecological Forecasting Steering Committee: Composed of one Senior Executive (SES/ST/SL) from each participating Line Office (6 members), provides oversight to the EF Portfolio Manager.
- b. Ecological Forecasting Portfolio Manager: A scientist/manager who, under the general oversight of the EFR Steering Committee, works across Line Offices to develop and implement a coordinated strategy for improving NOAA's products and services in ecological forecasting.
- c. Integrated Cross-NOAA Ecological Forecasting Technical Teams: These teams will be principally responsible for developing and implementing NOAA-wide ecological forecasts. Specific activities of these teams are updated annually in an EF Roadmap Action Plan.



APPENDIX 2. DESCRIPTION OF EF TEAMS

- Harmful Algal Blooms** NOAA identifies harmful algal blooms before they are reported at the coasts, forecasts bloom location, intensity, and landfall, and notifies resource managers and health professionals so that any necessary actions (e.g., beach and shellfish ground closures, public health warnings or notices) can be taken in advance of landfall.
- Hypoxia** NOAA has been working with local academics and many state and other partners for years to understand causative factors of hypoxia, recommend mitigative actions, and forecast seasonal extent and some effects, and is therefore pursuing multiple approaches to hypoxia forecasting techniques and time scales.
- Pathogens** NOAA has begun a range of efforts to monitor and predict potential pathogen occurrences in waters and shellfish in several areas, because bacterial contamination of shellfish is the leading cause of seafood-associated illnesses in humans. Disease-causing strains of *Vibrio* bacteria are the initial focus of this broader team.
- Habitat** NOAA is developing and applying new approaches to forecast, hind-cast, and now-cast major changes in the distribution of important coastal, marine, and Great Lakes habitats and associated species as an initial area of focus within this broader habitat theme.
- Infrastructure and Processes** Core capabilities and cross-cuts are essential for all of the ecological forecasts. These include but are not limited to: ongoing observations and data collection from various platforms and in situ sensors; integration and application of atmospheric, physical oceanographic, chemical, and ecological models; data management and analysis; computational capacity; test beds; capacity to develop and test new algorithms; delivery mechanisms; etc. A holistic view of the infrastructure requirements allows NOAA to be more effective in pursuing and applying resources.