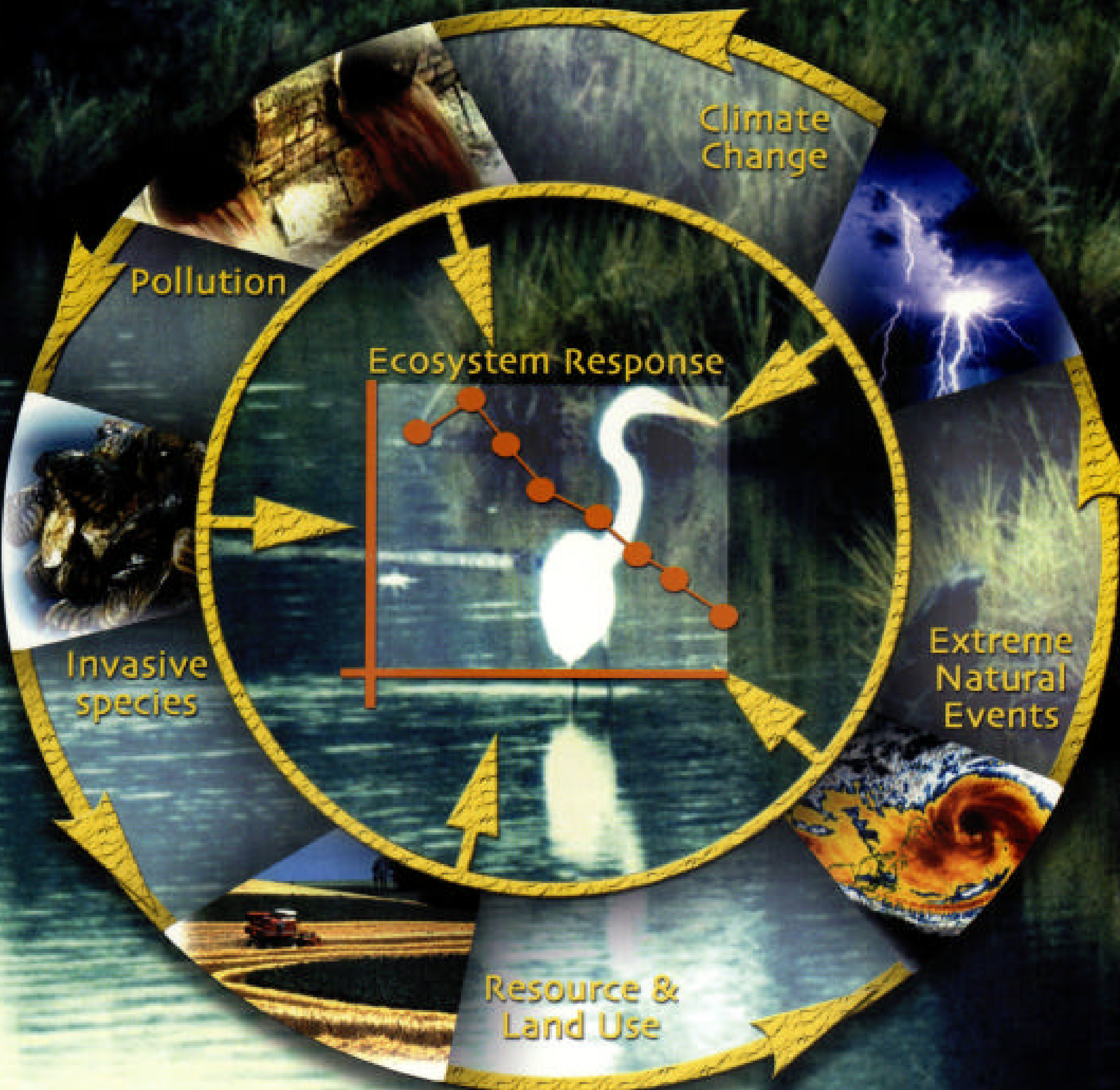
A New Outlook from NOAA



Ecological Forecasting

Expanding NOAA's Assessment & Prediction Capabilities to Support Proactive Ecosystem Management

NOAA

The notion of developing an ecological forecasting service for coastal managers grew out of a desire to focus the new science enterprise in NOAA's National Ocean Service around a prediction theme. The more we discussed this idea with managers and scientists, the more we were convinced that this concept would not only help converge wide-ranging research and observation programs around a new and challenging science, but that it would also help enrich the science-policy interface. Such forecasts will help answer managers' "what if" questions, while at the same time challenge scientists to move beyond measuring and understanding coastal ecosystems to building a capacity to assess impacts of future change.

Initial workshops and planning sessions with the NOS's National Centers for Coastal Ocean Science led to interactions across all of NOAA's line offices and coincided with similar developments in other agencies and in the academic ecological sciences community. While some rudimentary forecasts are being made now, the potential for this idea to move the field forward and connect it to public policy development is unlimited.

I encourage you to look over this brochure, explore the potentials it offers, and join NOAA, other agencies, and the coastal science and management communities to shape its future.

Donald Scavia
NOS Chief Scientist

Donald L. Evans
Secretary of Commerce

Scott B. Gudes
Acting Under Secretary for Oceans and Atmosphere
Administrator and Deputy Under Secretary

Margaret Davidson
Acting Assistant Administrator for
Ocean and Coastal Zone Management

Gary Matlock
Acting Director for National Centers for
Coastal Ocean Science

Ecological forecasts:

"Predict the impacts of chemical, biological, and physical changes on ecosystems, ecosystem components, and people."

America's ocean and coastal environments provide a wealth of resources, a home for many marine species, and opportunities for business and recreation. Sustaining productive ecosystems, and restoring damaged ones, depends on our ability to understand and predict the impacts of human activities and natural processes on those systems — in other words, to forecast change. Forecasts are part of our every day lives. We rely on weather forecasts to plan the day's events or prepare for a severe storm. Economic forecasts help individuals and businesses navigate the uncertainties of the financial world. Ecological forecasts will predict the impacts of chemical, biological, and physical changes on ecosystems, ecosystem components, and people.

There are three key benefits to focusing on ecological forecasts: they will lead to better decisions, they will improve communication between science and management, and they will help set science priorities.

Improving decisions

Effective coastal stewardship requires an understanding of how today's decisions will affect the delivery of ecosystem goods and services in the future. Ecological forecasts can provide local, state, regional, and Federal decision-makers with those assessments and predictions so that strategies to sustain productivity and mitigate impacts from natural events and human activities can be developed. In other words, "knowing" the future will produce better informed decisions.

Communication among scientists and managers

Bringing scientists and decision makers together to define what forecasts are needed, what time and space scales are most relevant, and what form they should take helps translate both management needs and science capabilities across traditional communication gaps. Focusing discussions around forecasts ensures relevance for coastal managers and provides challenges for coastal scientists.

Setting science priorities

Developing and improving ecological forecasts that coastal decision makers want can help focus the science agenda. Setting goals around forecasts can help define what to monitor, what models to build, and what ecosystem processes need to be better understood to reduce uncertainty in the forecasts. In this way, from the enormous range of potential scientific efforts, one can choose those that are both challenging intellectually and serve the more applied needs of the forecasts.

Forecasting ecosystem responses

The five key categories of ecosystem stress — pollution, land and resource use, invasive species, extreme natural events, and climate change — can challenge the integrity of ecosystems and impede the delivery of their goods and services. These stresses can act alone, but they often occur together, and their cumulative affects are poorly understood.

Pollution – While the past three decades have brought most chemical point sources under control, non-point sources, particularly excess nitrogen from agricultural and suburban runoff and automobile and industrial emissions, have become increasingly significant stresses on coastal ecosystems.

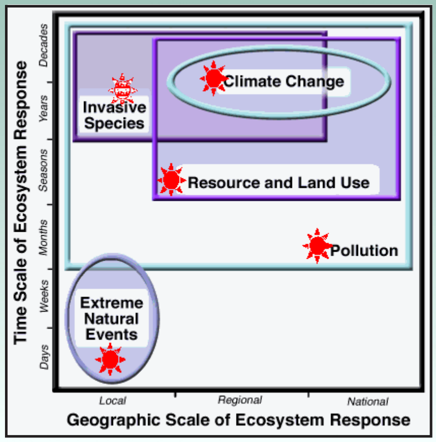
Climate Change – Changes in sea level, temperature, currents and stratification, storm frequency and intensity, and precipitation will change delivery of freshwater, sediments, and pollution; while salinity, tidal ranges, erosion, and coastal flooding increase the vulnerability of coastal ecosystems and communities.

Land and Resource Use – Increasing domestic and international demands for food, fiber, and space are accelerating changes in land and resource use, resulting in over harvested fisheries, lost habitat, degraded water quality, and increased chemical and sediment runoff.

Invasive Species – Exotic plants and animals, brought to the U.S. from other countries or moved to new areas from within the U.S., can damage native plants and animals, change native community structure, and produce enormous economic impacts.

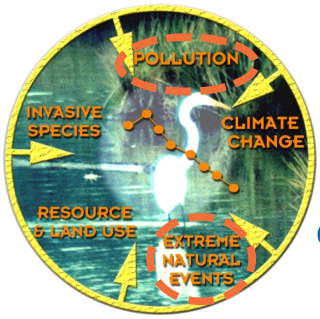
Extreme Natural Events – Hurricanes, coastal storms, floods, and droughts produce profound ecosystem changes both directly, and indirectly through their influence on other stressors. Predicting theses impacts is useful in both emergency response and long-term planning.

Ecosystem responses are as varied as the inputs that strain them, playing out on scales from hours to decades and from local to global.

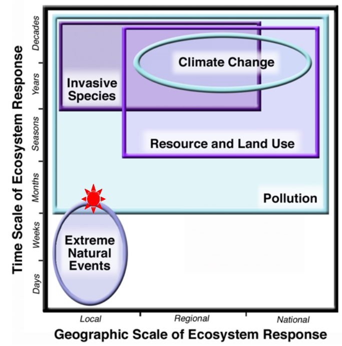


The following five examples in this document illustrate ecological forecasts across broad time and spatial scales. They demonstrate the value of forecasts, the capabilities needed to produce them, and the range of time and space scales of ecosystem responses.

Landfall of Harmful Algal Blooms



A short term regional forecast:
Florida and Gulf of Maine Red Tides



The Issue:

Harmful algal blooms (HABs) occur in every coastal state, with cumulative economic costs exceeding $1 billion. They represent a scientifically complex and nationally relevant coastal issue. The movement of an HAB from ocean waters to shore can cause human illness and death, fish kills, and marine mammal mortalities. The following examples illustrate emerging capabilities to detect and predict when and where such blooms will impact coastal resources and communities.

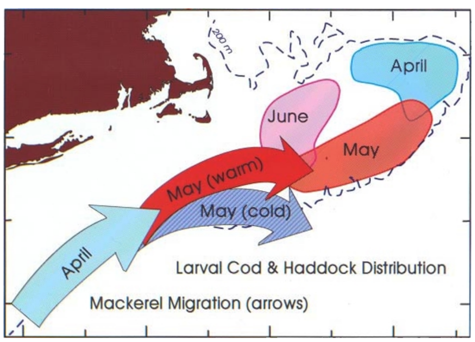


Figure 1

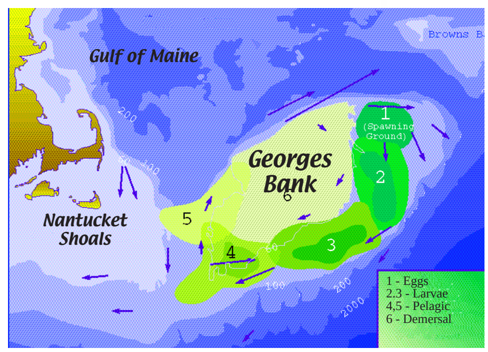


Figure 2

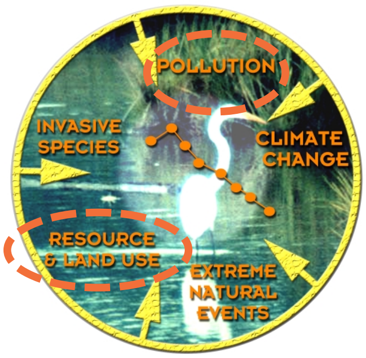
The Forecast:

Florida Red Tides - Florida red tides release neurotoxins that have killed fish and marine mammals, and can cause respiratory impairments for people along the shore. This HAB can be detected using surface chlorophyll concentrations derived by satellite imagery (see Figure 1). Coupling this imagery with field data from ships can provide scientists with the information needed to alert local, state, and Federal officials of the location and movement of the bloom. These "nowcasts" and near term forecasts are guiding monitoring and management actions by responsible officials.

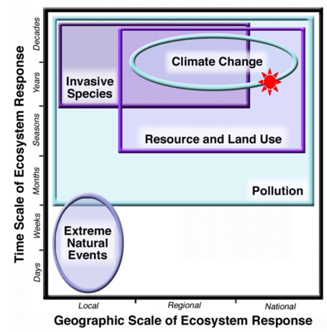
Gulf of Maine PSP - HAB blooms in the Gulf of Maine release toxins that produce Paralytic Shellfish Poisoning (PSP) which can lead to closures of important fisheries and aquaculture operations. Computer models of the algae movement, growth, and death can simulate the distribution of the toxin-producing algal cells (see Figure 2). When fully developed and verified, models like these will provide early warning systems for coastal and marine resource managers and the public.

The ultimate goal of HAB forecasting is to predict bloom development, persistence, and toxicity. With improved understanding of how physical and biological processes interact to promote HAB development, reliable models can support rapid response by monitoring agencies and health departments to safeguard public health, local economies, and fisheries.

Water use Under a Changing Climate



A long-term regional forecast:
Apalachicola Bay Oysters



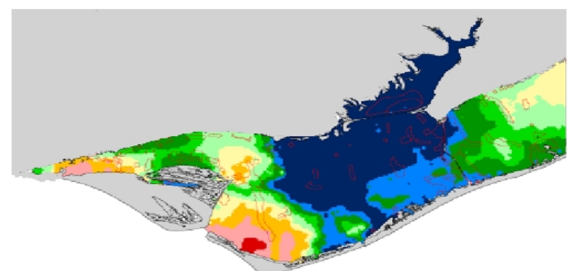
The Issue:

Meeting human demands for water can impact the sustainability of key fisheries. The reduction of freshwater flow to estuaries can increase salinity and modify circulation patterns, resulting in impacts on the viability of estuarine-dependent fisheries. This increased demand for water must also be evaluated in the context of a potentially changing climate. The following forecast predicts the impact of reducing inflow of freshwater on oyster abundance under different climatic conditions.

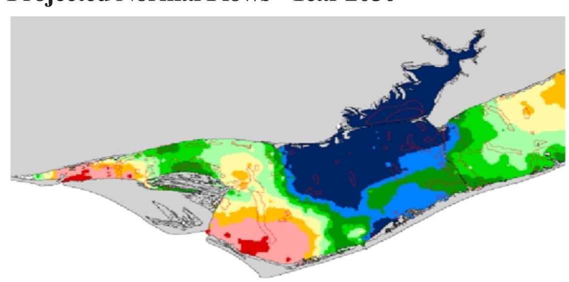
The Forecast:

Abundance of the oyster drill, a major oyster predator, depends on salinity and the physical stability of the water column. Computer models, based on alterations in freshwater inflow, can simulate changes in salinity and stability and relate those changes to the oyster drill. These models were used to estimate oyster mortality under two future scenarios: 1) meeting human demands for water in the year 2050 under current climate conditions and, 2) meeting those same demands under a potentially dryer climate. The outcome from the models, when compared to current rates of oyster mortality, show that changes in timing and magnitude of freshwater inflow increases the abundance of the oyster drill and consequently, oyster mortality increases. The forecasts indicate that overall oyster mortality would almost double from the current 9% to 16% when meeting the 2050 human needs under normal conditions and overall mortality would increase 5-fold when meeting those same needs under a dryer climate (see figure).

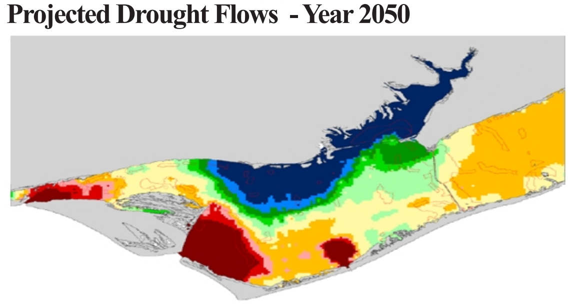
Normal Flow Conditions - Present Year



Projected Normal Flows - Year 2050

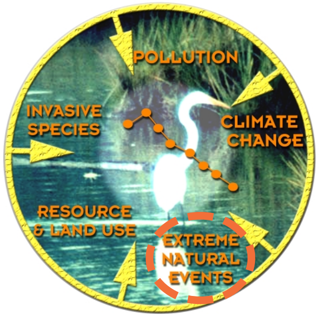


Projected Drought Flows - Year 2050



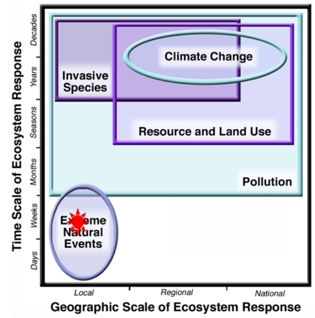
Dark red indicates 81-100% oyster mortality

Habitat Recovery



A long-term local forecast:

Integrating Sea Grass Recovery Rates and Environmental Suitability



The Issue:

Sea grass beds are valuable ecosystems that provide refuge and forage opportunities for wildlife, fishes, and invertebrates. To reestablish these important habitats, successful restoration efforts should be based on selecting suitable sites for sea-grass growth and estimating recovery rates. In fact, these approaches have been used in recent successful court cases related to sea-grass damage assessment.

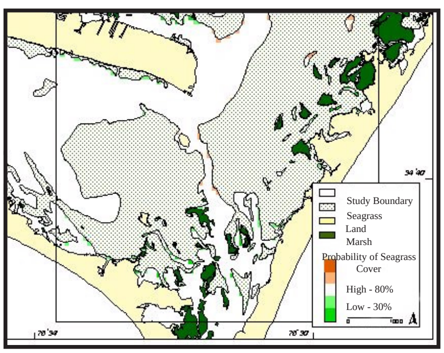


Figure 1

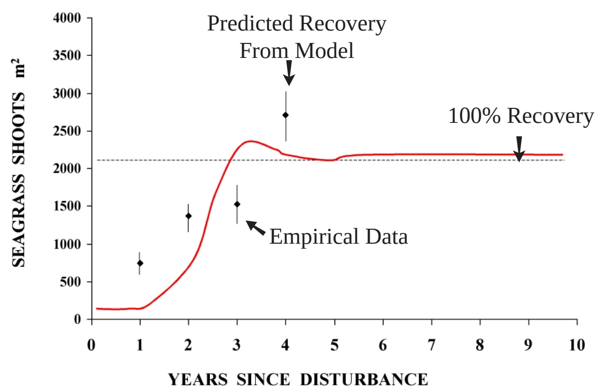


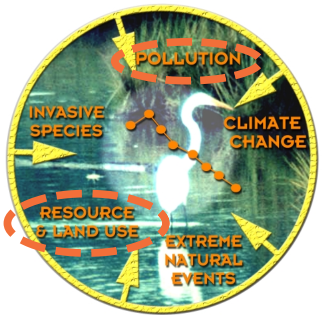
Figure 2

The Forecast:

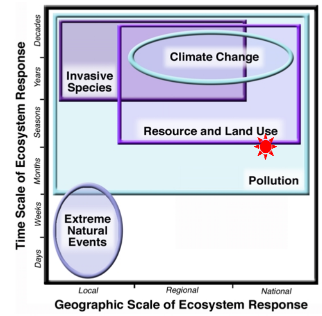
A model of the influence of wave disturbance, the primary physical detriment to growth, was integrated with maps of sea-grass coverage and bathymetry off the coast of Beaufort, North Carolina, to forecast the probability of sea-grass cover. The model provides forecasts of the probability of habitat cover within the study area (see Figure 1), indicating the best areas for sea-grass restoration, and the probabilities of where habitat cover will be lost to acute storm events.

Coupling the identification of suitable environments for recovery with forecasts of the rate of recovery (see Figure 2), provides milestones for measuring the effectiveness of restoration efforts and a basis for assessing damages in habitat restoration cases.

Land Use & Coastal Ecosystems



A long-term national forecast:
Estuarine and Gulf of Mexico Hypoxia



The Issue:

According to recent reports from the National Academy of Sciences, excess nitrogen inputs and the resulting symptoms of coastal eutrophication — algal blooms, loss of submerged aquatic vegetation, and depletion of dissolved oxygen (hypoxia) — is the most serious coastal pollution problem. Based on estimates of population growth and estuarine susceptibility, a recent NOAA report also predicted that 86 estuaries are likely to show increased eutrophication symptoms by the year 2020 (see Figure 1). Because most impacts are caused by the discharge of nutrients from point and non-point sources, forecasts of potential changes in eutrophic and hypoxic conditions under various load scenarios are needed.

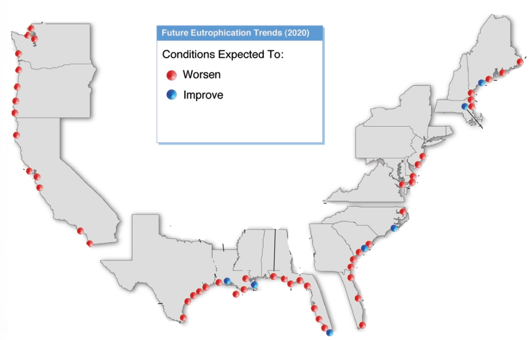


Figure 1

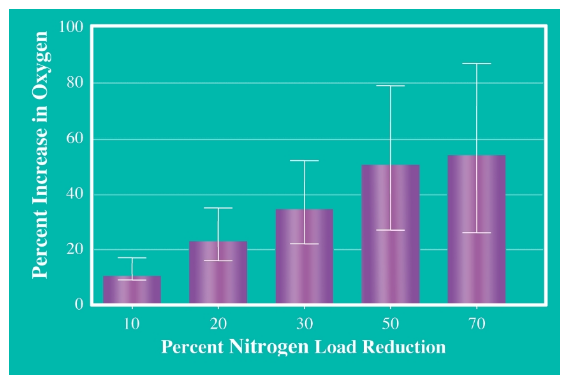
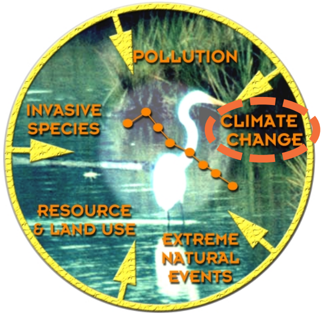


Figure 2

The Forecast:

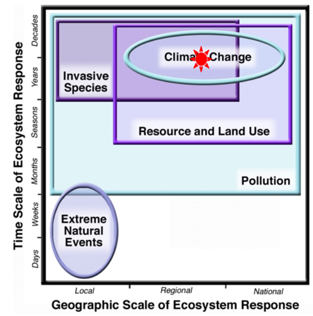
The Gulf of Mexico contains almost half of the nation's coastal wetlands and supports approximately 20% of the dollar value of its commercial fishery landings. Annually, 1.6 million metric tons of nitrogen is flushed into the Gulf of Mexico via the Mississippi River system, stimulating algal growth in surface waters. Recent studies have provided overwhelming evidence that this increased nitrogen input into the Mississippi River system has caused severe oxygen depletion and other related nutrient over-enrichment problems. NOAA-supported models, simulating nutrient cycling, algal growth and death, physical ocean dynamics, and processes contributing to changes in oxygen concentration, were used to forecast the effects of various nitrogen load reduction scenarios. The forecasts indicate that decreasing loads by 20-40 percent would increase bottom-water oxygen concentrations by 15-50 percent (see Figure 2). These findings were a key element in reaching a Federal/state/tribal agreement on an action plan for reducing nitrogen loads and decreasing Gulf hypoxia.

Resource Use & Climate Change



A long-term regional forecast:

Recovery of the Georges Bank Ecosystem



The Issue:

Oceanographic and fishery science has provided key insights into how climate change may affect the dynamics of fish ecosystems. Current research focused on the potential role that climate variability has on the success of particular year-classes of key species will provide a backdrop of natural variability for harvest and habitat decisions of fisheries managers. Understanding the linkages among resource distribution, climate variation, and management actions can potentially aid in the conservation and recovery of species.

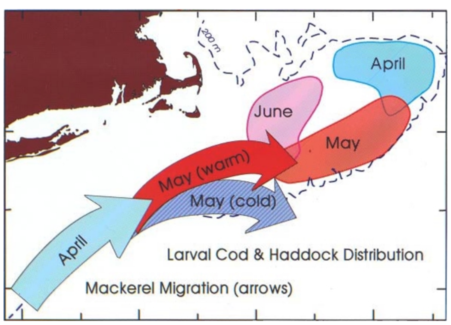


Figure 1

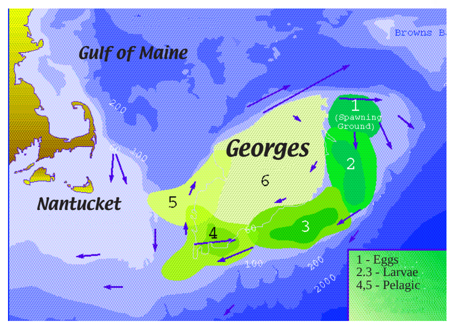


Figure 2

The Forecast

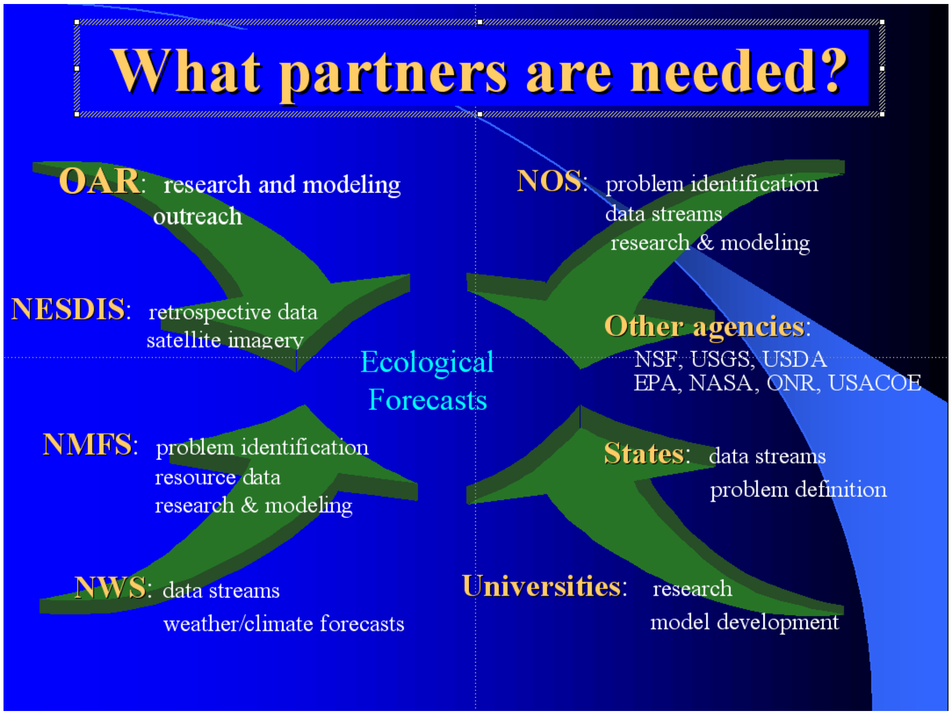
Increased fishing on Georges Bank, one of the most biologically productive areas in the temperate coastal ocean, has resulted in massive ecological shifts and significant declines in fisheries. Valuable species, such as cod and haddock, have been dramatically reduced and replaced by lower valued species, decreasing, for example, the value of the Georges Bank cod fishery from $45 million in 1993 to $24.5 million in 1998. Even though large areas of Georges Bank have been closed to fishing for cod, haddock, and shellfish, their recovery is also regulated by environmental variation. A predictive understanding of these interactions will help support management actions affecting recovery.

A conceptual model, based on physical and biological observations, shows that in warm years, mackerel, a key predator on larval cod and haddock, moves on to Georges Bank in May (see Figure 1), which coincides with the annual clockwise migration of cod and haddock larvae (see Figure 2). This can significantly reduce the potential population size of adult cod and haddock. In contrast, in colder years, mackerel do not migrate onto the Bank and predation is much lower. Models and monitoring systems are being developed to provide short and medium range forecasts to the National Marine Fisheries Service, allowing managers, such as the New England Fishery Management Council, to have better information on the role of environmental variability and climate change in determining abundance of living marine resources.

Partnerships for implementation

NOAA, through the National Ocean Service's National Centers for Coastal Ocean Science, is focusing coastal science toward building and improving ecological forecasts. However, success depends on partnerships at all levels, from universities and local and state governments to other Federal agencies.

With strong partnerships in place, NOAA will work with decision makers inside and outside government to identify forecast needs, and support the internal and extramural capability to respond to those needs.



Ecological forecasting will:

- **Lead to better-informed decisions**

- **Improve communication between science and management**

- **Help set science priorities**

Our goal is to build an assemblage of ecological forecasts over the next 5-10 years so that scientists and resource managers can use them to guide management of our Nation's coastal resources.

For more information, e-mail us at:
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