**STATEMENT OF**
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**STRUCTURE AND FUNCTION OF MARINE ECOSYSTEMS**

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Mr. Chairman and members of the Committee, thank you for inviting me to speak about the structure and function of marine ecosystems. I am Dr. Steve Murawski, Director of the Office of Science and Technology in the National Oceanic and Atmospheric Administrations' National Marine Fisheries Service (NMFS).

At the request of the Committee, NMFS has provided a PowerPoint presentation on the structure and function of marine ecosystems and the human interactions with these systems. This testimony will serve as talking points for the attached slides.

**Slide 1 – Structure and Function of Marine Ecosystems**

This testimony provides a brief overview of marine ecosystem science, including the various types of science needed to support decision making when developing policies for the marine environment. The challenges of integrating ecosystem knowledge arise from the fact that many complex and simultaneous processes are ongoing in the marine environment, and human uses affect these systems in many ways. An ecosystem approach to examining marine systems implies that we can examine processes at varying scales of complexity and aggregation (for example, multiple species and their roles in the environment) to understand the essential details of their interactions. The key processes of marine ecosystems are to capture solar energy and transfer that energy among various groups of animals and plants. This energy production then supports virtually all life in the oceans, and on land as well. Understanding these connections is essential to valuing the full range of goods and services supplied by marine ecosystems. Although marine ecosystem science (incorporating the physical sciences, biology, and social sciences) is still relatively young, significant progress has been made in theory, observation, and experimentation. I will summarize a few areas of marine ecosystem science that are relatively well known, some important questions that remain unanswered, and some issues that are essentially unknowable (the topic of a recent workshop at Scripps Institution of Oceanography).

**Slide 2 – Gulf of Mexico**

As this map of the Gulf of Mexico illustrates, marine ecosystems of the nation and the world are the focus of many, sometimes conflicting, human uses. Often we deal with these issues one at a time (e.g., nutrient enrichment of the coastal areas, protected species management, and energy development). However, many of these issues are interconnected. For example, in the Gulf of Mexico, nutrients entering from the Mississippi River into the northern Gulf of Mexico are transported westward, where they contribute to plankton blooms and eventually result in low oxygen conditions in the northwest Gulf. Fisheries, in turn, are affected in these areas, and harmful algal blooms may occur with increasing intensity. Coral reefs and other sensitive habitats are also affected by a range of human activities as well as naturally occurring disturbances. To understand the full ramifications of these issues, an ecosystem approach examines the cumulative impacts of these various activities on biota of the marine environment. An important aspect of implementing an ecosystem approach to science and decision making is to understand the interactions between human activities and naturally occurring physical phenomena, such as hurricanes and coastal current systems. Science supporting the ecosystem approach makes use of observing systems—such as satellites, buoys, and biological sampling systems—to monitor the state of the environment and the various pressures influencing the ecosystem.

**Slide 3 - Definitions**

Marine ecosystems can be defined on many spatial scales, ranging from the entire marine environment of the earth to a small bay or estuary. The defining characteristics of an ecosystem apply no matter how the ecosystem of interest is defined. Marine ecosystems are defined by their geography, the animals and plants within that geographical scope (including humans), as well as aspects of the physical, chemical, and biological environment and the processes that control ecosystem dynamics.

The environment of the ecosystem includes the biological, chemical, physical, and social conditions that influence organisms, and the environment is usually described in terms of the aspects (physical, chemical, and biological) important to a process under discussion.

**Slide 4 – Spatial Scales and Boundaries**

Many of the important physical and biological processes in the marine environment (such as sea surface temperature, illustrated in the top panel of this slide, as monitored by satellite), show gradual changes over large spatial scales. Likewise, while some animals and plants live their entire lives in a very localized area (a few square kilometers), others, including the great whales and migratory fishes such as tunas, use entire ocean basins. How then do we define spatial boundaries in the marine ecosystem to study processes and make decisions at a regional level? These varying spatial scales must be considered, particularly when we consider the interactions between the physical environment and biological processes, including variations in the climate system and its effects on biota. One useful concept is to look at the world’s oceans at an intermediate scale known as Large Marine Ecosystems, or LMEs. Several studies have defined about 45 LMEs in the world’s oceans, with eight of these occurring in U.S. territorial seas and the Exclusive Economic Zone (EEZ). At the scale of LMEs, we can link variations in the physical and chemical environment with biological productivity, the status of various marine populations, and the wide spectrum of human interactions contributing to observed changes. The LMEs in the United States will increasingly be the focus of regional ecosystem science and management activities. It must be recognized, however, that these boundaries will remain somewhat subjective, and for some issues, other narrower or wider boundaries will be necessary.

**Slide 5 – The Trophic Pyramid and Energy Flow**

The marine food chain, or "web," has at its base the production by marine plants of phytoplankton. At successive trophic levels (1 = phytoplankton, 2 = zooplankton, etc.), the amount of mass that can be supported is only about 10 percent of the mass at the lower adjacent level. This is because considerable amounts of energy are required for growth, movement, and reproduction. Nutrients released by these processes are recycled by the ecosystem back to the base of the food chain. Human activities influencing the marine food web include increasing nutrients in the coastal systems, which may stimulate phytoplankton production (which may have a variety of consequences for ecosystems). Harvesting at the top levels of the pyramid may also alter the number of animals in lower levels, resulting in changes in the availability of species for human uses, as well as in the dynamics of the ecosystem.

**Slide 6 - Photosynthesis**

This graphic is a composite satellite image of "ocean color," which is an indication of photosynthesis. Marine phytoplankton (composed primarily of diatoms and dinoflagellates) are responsible for photosynthesis in the ocean, the base of the marine food web. The requirements for photosynthesis are sunlight and nutrients, such as nitrogen and phosphorus, as well as trace amounts of other elements, including iron. All photosynthesis occurs in the upper 200 meters of the ocean, and mostly in the upper 50 meters, because of the inability of sunlight to penetrate the depths. The "photic zone" (less than 200 meters) represents only about 7 percent of the volume of the oceans, whose average depth is about 2.3 miles. Unused phytoplankton eventually dies and sinks through the photic zone, so most nutrients in the ocean occur deeper than photosynthesis can occur. Therefore, to support the living system nutrients must be transported from ocean depths to the photic zone. This occurs in upwelling zones and by other current systems. Upwelling zones, such as those off the west coasts of the United States, South America, and Africa, are among the most productive ecosystems in the world. Understanding marine productivity thus involves not only looking at the photic zone but understanding current and upwelling systems and nutrients supporting biological systems.

**Slide 7 – Scales and Observations**

To understand how various species and their physical and chemical environments interact, we must make a variety of observations. Sea surface observations of ocean color reveal complex eddies and "hot spots" of productivity resulting from the interaction of marine currents, the geology of the sea floor, and nutrient concentrations. Various other species are influenced by these local differences in marine production, which affect their abundance and distribution. Compared to observing sea surface color and temperature, it is much more difficult to sample the three-dimensional structure of the physical environment, as well as various species, including mobile animals and those attached to the bottom (the "benthos"). Various sampling methods are applied by many organizations to provide an integrated picture of variations in marine ecosystems.

**Slide 8 – Regional Climatology Affects Ecosystems**

Long-term variations in climate phenomena, such as the North Atlantic Oscillation (NAO), can result in marine conditions that in turn affect the biological components of ecosystems. A parallel Pacific Decadal Oscillation (PDO) has similar impacts on biota of the North Pacific. The NAO results from variations between a high-pressure system off the Azores and a persistent low-pressure system south of Iceland. The relative positions of these high- and low-pressure systems affect surface winds, and thus storm activity. Changes in the weather-climate system can have important implications for marine ecosystems (see next slide).

**Slide 9 – Interaction between Physical and Biological Components of Ecosystems**

The NAO index is based on the activity of the NAO system—a positive index means cooler and wetter conditions in Europe, a negative index means dryer and hotter conditions. This graph illustrates that changes in the NAO index are correlated with changes in the phytoplankton, zooplankton, and some fish catches. Thus, managing marine populations involves not only accounting for human effects on them, but also noting variations in the biological systems as influenced by regional climate systems.

**Slide 10 – Harvesting Affects Distributions and Abundances of Species**

Ecosystems are influenced not only by variations in the world and regional climate, but by a variety of human activities as well. Most importantly, these human activities include nutrient enrichment of coastal areas (such as Chesapeake Bay), modifications of the coastal zone (dredging, pier construction, mining, and fishing impacts on bottom habitats), as well as direct harvesting effects for some animals. Activities such as harvesting influence both the abundance of important species, such as Atlantic cod, and their geographic distributions. For example, the collapse of cod stocks off Newfoundland resulted in the shrinking of their distribution, as well as changes in the abundance of some of their prey species. In particular, marine invertebrate species such as shrimp and crabs are now more abundant than before the cod—a predator of these species—declined. Observing systems for marine ecosystems thus need to monitor the spatial distribution of important animal populations as well as the factors controlling their abundance.

**Slide 11 – Status of Knowledge of Species**

This graphic illustrates the status of knowledge of species and processes affecting marine ecosystems. Some facts concerning marine ecosystems are well understood, some issues are currently unknown, and other areas are essentially unknowable. We now have a significant understanding of the surface dynamics and production of phytoplankton, based on sampling with instruments such as satellites. Likewise, we have a considerable body of knowledge regarding some major species of animals, including primary fishery targets as well as important animals such as marine mammals and other species. Our knowledge of 3-D dynamics of ocean systems is good for selected areas, and we have mapped some of the ocean habitats well. Less understood are the number of species currently in the ocean and the effects of climate variation on ecosystem dynamics. Also less understood are issues such as the reversibility of human impacts on species and ecosystems, and the appropriate valuation of the full range of ecosystem goods and services. Some issues are either very costly to investigate (e.g., complete mapping of the entire sea floor), or conceptually difficult to resolve (such as predictive models of many-species dynamics). Still other issues may never be fully known, such as the structure and functioning of "pristine" ecosystems (e.g., before human impacts).

This concludes my presentation, Mr. Chairman. I will be happy to respond to any questions that you or members of the Subcommittee may have.